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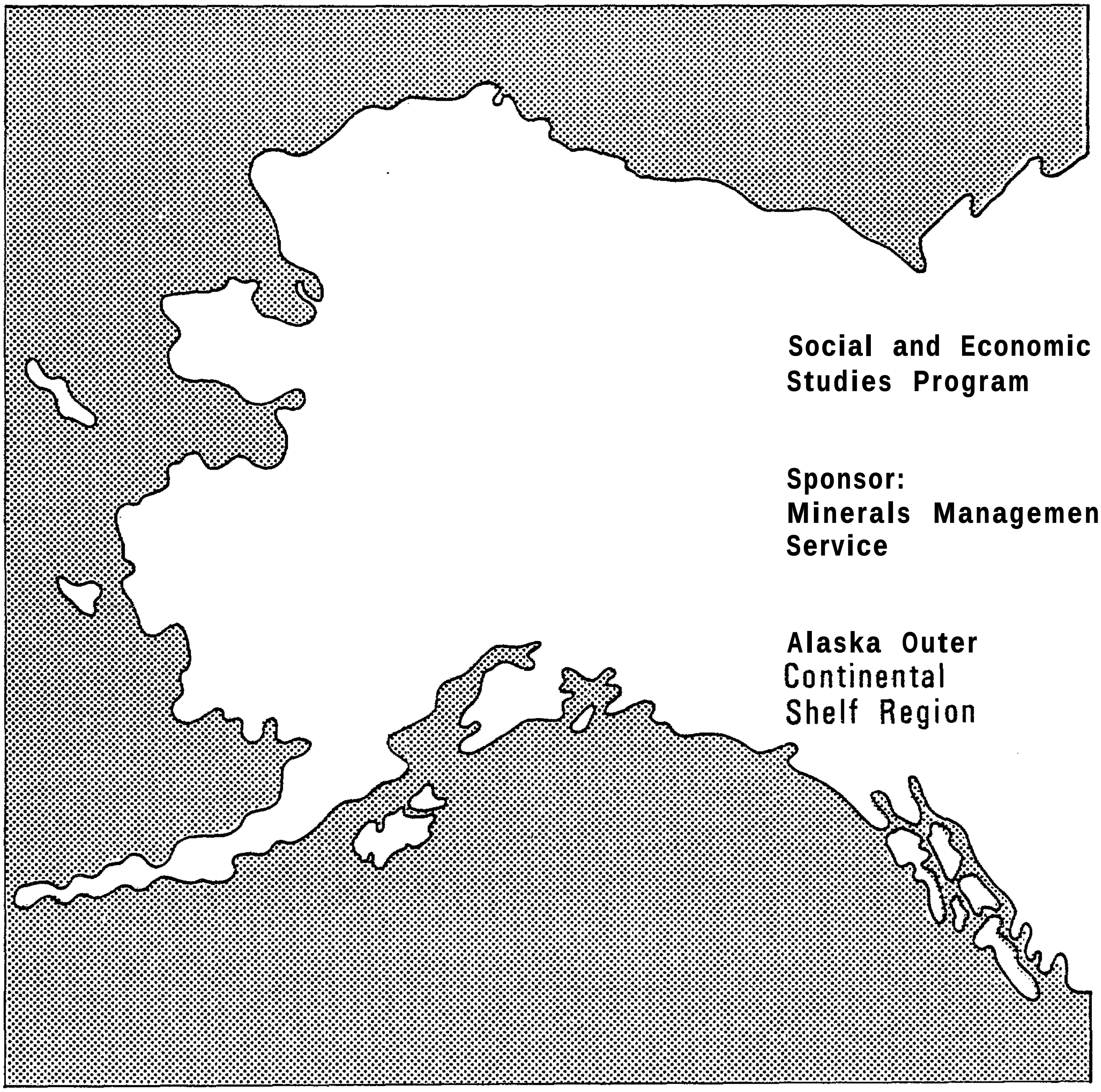

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Alaska Outer Continental Shelf Region

Cultural Resource Compendium

OCS Study MMS 86-0018

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

Final Report

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This report is submitted in fulfillment of the Bureau of Land Management's Mineral Management Service Contract No. 14-12-0001-29008, and this volume, the Alaska Outer Continental Shelf Cultural Resource Compendium, was prepared by the University of Alaska Museum, University of Alaska-Fairbanks, Fairbanks, Alaska. The purpose of this volume is to synthesize a series of analyses of the Bering, Chukchi, and Gulf of Alaska Outer Continental Shelves conducted to determine the potential for the occurrence and preservation of prehistoric archeological sites on them. The results of several Bureau of Land Management funded field research efforts are also included in this volume. These consist of a submarine archeological survey undertaken in the area of the Pribilof Islands in 1976, an archeological survey of St. Matthew Island in 1976, an archeological survey and geologic assessment of Chinitna Bay in 1978, an archeological reconnaissance of caves in the vicinity of the Porcupine River in 1978, and an analysis of sediment cores and sub-bottom profile data collected by NOAA research vessels in the vicinity of Kodiak Island and Shelikof Strait.

The effort to synthesize these data was originally begun in 1978 and the research was completed by 1980. However, due to a series of unavoidable circumstances, the preparation of the final report was delayed until 1984. Since the time of the original research and analysis, several studies pertinent to the potential occurrence and preservation of archeological sites on Alaska's Outer Continental Shelves have been published. Important among these works is the Archaeology of Beringia authored by Frederick Hadleigh West (1981). In this major work, West identifies central Beringia as the Outer Continental Shelf stretching between Siberia and Alaska. He postulates that this region exhibited greater ecological productivity than either eastern Beringia (that portion lying in North America) or western Beringia (that portion lying in Asia). He suggests that during late Pleistocene times central Beringia was analogous to the savannas of Africa in productivity and that this region may have supported a comparatively dense human population. Following the environmental crash in central Beringia resulting from inundation of the Land Bridge by rising sea level and massive climatic change at the end of the Pleistocene, the human "survivors" moved into eastern Beringia (Alaska and adjacent parts of ice-free Canada) which was a refugium for the remaining Pleistocene fauna (West 1981:155-181). He explains the regional variation observed in the earliest Alaskan archeological assemblages as a result of increased isolation and adaptation to regionally different environmental settings in eastern Beringia. If West's mode? for explaining the first human colonization of the Americas is correct, then abundant remains resulting from human occupation of the Alaskan Continental Shelves during the late Pleistocene should exist.

A second major and essential reference pertinent to the assessment of the potential for occurrence of prehistoric archeological remains on Alaska's Outer Continental Shelves is the Paleoecology of Beringia (198?) edited by David M. Hopkins, John V. Matthews, Jr., harles E. Schweger, and Steven B. Young. This volume contains a series of contributions by a wide spectrum of international researchers from a variety of disciplines including paleontology, geology, palynology, paleoclimatology, and anthropology. A major contribution of this volume is a section entitled "Man in Ancient Beringia" in which the contributing authors, Muller-Beck, Morlan and Cinq-Mars, Haynes, and Martin, all accept the hypothesis that man entered the Americas during the late Pleistocene via the Bering Land Bridge. Thus, it logically follows that if these perspectives by eminent archeologists are true, that prehistoric archeological sites dating to Land Bridge times should be located on Alaska's Outer Continental Shelves.

While West (1981) and the archeological contributors to the Paleoecology of Beringia all, in varying degrees, adopt a perspective which favors a productive environment in Beringia which would be conducive to human colonization of the region during the late Pleistocene, several contributors to the Paleoecology of Beringia suggest that during the Duvanny Yar Interval (30,000 - 14,000 B.P) the Beringian environment was dry, hostile and supported a comparatively impoverished biota. This difference in interpretation results from conflicting interpretations of the late Wisconsin pollen data which suggest to Ritchie and Cwynar (1982) an impoverished biota. This further leads them to speculate that the abundant Pleistocene fossil mammal remains may be attributed to earlier interstadials and not to the Duvanny Yar Interval (30,000-14,000), the time during which most anthropologists believe man first entered North America via the Bering Land Bridge. Additionally, Hopkins (1982) concludes that the Duvanny Yar Interval was a time of maximal activity of sand dune formation over vast areas of Beringia, indicating that this interval was characterized by high winds and little vegetation cover. Archeologists are challenged by the suggestions of Ritchie and Cwynar and Hopkins that the Beringian environment may have dry and hostile and supported a comparatively impoverished biota during the Duvanny Yar Interval. If this scenario should ultimately be demonstrated, it would tend to undermine current anthropological theory which relies on a comparatively rich biota to attract human expansion from Asia into eastern Beringia during late Pleistocene times.

The Paleoecology of Beringia ends with a synthesis authored by the editors, Schweger, Matthews, Hopkins, and Young. The summary focuses on what is perhaps the most important contribution of the volume: "The Productivity Paradox". This is the term applied to the two conflicting interpretations of the paleoecology of Beringia - at one extreme late Wisconsin Beringia is described as bleak, barren, wind swept, and biotically impoverished (most strongly advanced by Ritchie and Cwynar) and at the other extreme it is conceptualized as a lush savanna which supported species diversity and greater biomass than modern times (a concept most avidly supported by Guthrie:1982). Anderson (1980) defines the continuing quest for archeological documentation of early (pre-11,000 B.P.) human occupation of Alaska as one of the most pressing archeological problems. After more than fifty years of controlled scientific investigation, the role, of the Bering Land Bridge as a route for human colonization of the New World remains unclear.

However, the occurrence of prehistoric archeological sites on Alaska's Outer Continental Shelves is not entirely linked to the problem of whether or not central Beringia supported human populations during the late Pleistocene. The fact that firmly documented archeological remains occur on mainland Alaska by 11,000 B.P. demonstrates that human populations were resident in eastern Beringia by that time. It is reasonable to assume that biotically rich coastal environments were inhabited by human populations. The earliest evidence for coastal settlement is ca. 8500 B.P. documented by Laughlin (1975) at the Anangula Blade Site on an islet of Umnak Island in the Aleutians where archeological remains have been preserved because tectonic uplift has occurred at a rate greater than rising sea level. The date for the Anangula Blade Site should be regarded as a minimum limiting date littoral adaptation, and such subsistence strategies predate the recorded occupation at Anangula. Any portion of Alaska's Continental Shelves which was exposed to subaerial conditions between 11,000 B.P. and the end of the post-Wisconsin sea level rise holds potential for the occurrence of prehistoric archeological remains. The important question is whether or not sites of former human occupation can survive marine transgressions.

Although a great deal of attention has been devoted to shipwreck archeology, primarily by treasure seekers, the field of marine archeology has only in recent years devoted serious attention to submerged terrestrial sites on the continental shelves. In the Gulf-of Mexico pioneering research has been undertaken off-shore from Venice, Florida with the discovery and analysis of a submerged terrestrial site. The result of this work has led Ruppé (1980:43) to conclude that "...we can state unequivocally that drowned terrestrial sites can be excavated in a stratigraphic manner and will produce evidence important to archaeologists." A comprehensive volume entitled Quarternary Coastlines and Marine Archaeology (Masters and Flemming, eds. 1983) contains numerous contributions which not only clearly document the occurrence of prehistoric habitation sites in submarine contexts which were occupied at times of lower sea level (Ronen 1983:122-134; Flemming 1983:135-173; Geddes et al. 1983:175-187; Masters 1983:189-213; Raban 1983:215-232; and others), but also demonstrate their ability to survive marine transgressions. Perhaps the most succinct conclusions have been drawn by Flemming (1983:166) following the analysis of a vast body of data documenting the survival of numerous submerged prehistoric archeological sites which were occupied at times of lower sea level. He states:

(a) Lithic site structures and artifacts, uncemented walls, burials, hearths, middens, food remains, and tools and other artifacts can survive in stratigraphic context in the sea or below the coastal groundwater table after a marine transgression.

(b) Such remains are protected either because the environment is low energy (ria, lagoon, estuary, karstic cave, archipelago), or because the beach gradient provides a protective cover of sediment.

Numerous contributors to Quaternary Coastlines and Marine Archaeology recognize and emphasize the scientific Importance of prehistoric archeological sites surviving in marine environments. The archeological record is largely derived and interpreted from sites preserved in terrestrial environments. Sites occurring on the continental shelves not only provide insights into human movements and colonization of former land bridges and coastal environments, but are critical to our understanding of the role of coastal environments in human cultural development and hominid evolution prior to the end of the post-Pleistocene eustatic sea level rise. The possibility that such sites occur and are preserved on Alaska's Continental Shelves is extremely high. The discovery and investigation of such sites may provide the only source of information which can explain the origins and development of northern marine oriented subsistence strategies before they are discernible in the terrestrial archeological record.

Based on results of field research and evaluation of published and unpublished data, a paleoenvironmental history of Alaska's Continental Shelves is presented in this volume for the late Wisconsin and early Holocene marine transgression. Major factors considered include: (1) climatic history, (2) rate of sea-level rise, (3) possible still stands, (4) extent of glaciation, (5) marine circulation patterns, (6) productivity and distribution of faunal resources, (7) terrestrial ecology, (8) transgressive and post-transgressive physical perturbation of the continental shelf, and (9) the potential for site survival. Through integration of these, albeit scanty, data a paleoecological history was developed for the last marine transgression and the potential for prehistoric archeological site occurrence on Alaska's Outer Continental Shelves is assessed.

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SUMMARY

The study area encompasses all of the U.S. portions of the continental shelves of the Beaufort, Chukchi and Bering Seas, and that of the North Pacific from Umnak Island in the Aleutians to Cape Suckling east of Prince William Sound. The range of present ecological conditions encountered over this region is diverse. During the marine transgression following the Late Wisconsin glacial maximum conditions over this shelf were different than today but were probably ecologically diverse.

Based on bathymetric and geologic data, Sharma documents 6 possible stillstands, or significant temporal pauses in sea level rise (from -125 m to present sea level) during the last major marine transgression. He correlates these to. global and North Pacific temperature curves for the same interval. Within this time Alaska's continental shelves were exposed to subaerial conditions.

The most drastic ecological changes, probably occurred on the Alaskan North Slope (including the continental shelves of the Beaufort, Bering and Chukchi seas). The coast and continental shelf of the North Pacific also experienced ecological fluctuations during this period, with the primary variables being species composition and resource distribution determined by temperature, precipitation, and extent of glaciation.

During and shortly following the culmination of the final Wisconsin glaciation, Northern and central Beringia was probably dryer than today. Abiotic factors resulted in vegetation which has been referred to as "tundra-steppe" which supported grazing mammals such as mammoth, horse and bison. Sometime after the Late Wisconsin glacial maximum this ecological community declined, and became extinct probably shortly after about 15,000 B.P. A transition in vegetation occurred from tundra steppe to mesic herb-tundra, and moose and caribou became the predominant large mammals.

Following the paleographic and paleoenvironmental reconstructions, a model of human settlement patterns is presented based on a synthesis of anthropological literature defining the ecological basis for settlement patterns of northern hunters and gathers. The literature indicates that settlements are largely dependent on faunal resource distributions. Based on the ecological criteria identified as responsible for contemporary distributions of modern land mammals, sea mammals, and fish; areas of past high faunal productivity are identified from paleoenvironmental and paleogeographic reconstructions. These areas are identified as locales of high potential for the occurrence of prehistoric archeological sites occurring on Alaska's Outer Continental Shelves. In its basic form the axiom is simple: nonagricultural hunters and gathers must settle where faunal resources are concentrated. This model is applied to northern and central Beringia and its littoral margins during land bridge times as well as the sequence of successive stillstands. These locales are transferred to a series of U.S.G.S. protraction diagrams for the study area, and are defined as areas of high, moderate, and low potential for the occurrences of prehistoric archeological sites.

ACKNOWLEDGEMENTS

Funding for this research was provided by the Bureau of Land Management, Outer Continental Shelf Office (now the Minerals Management Service), U. S. Department of the Interior. Special thanks are due the BLM staff for their patience during the process of completing this report in the midst of difficult circumstances. The researchers express our appreciation to Mr. William Civish, Dr. Dean Yoesting, Mr. Thomas Warren, and Ms. Marsha Bennett whose patience and support are responsible for the completion of this report. Our special thanks is extended to Mr. David C. Plaskett for assistance during the field work and Mssers. Dixon Sims and Robert Sattler who assisted with editing and graphics preparation.

CHAPTER I
OCCURRENCE AND CHRONOLOGICAL PLACEMENT OF STILLSTANDS ON THE ALASKAN CONTINENTAL SHELVES

G. D. Sharma

Investigations for Locating Submerged Human Habitat on Alaskan Shelf

ABSTRACT .

The Beaufort, Bering and Chukchi shelves are large, smooth and shallow. The Alaskan Pacific Shelf on the other hand is rugged and consists of fiords, sea valleys, enclosed basins, banks and plateaus. The shelf, termed Beringia, was approximately nine million square kilometers in area which intermittently formed a land bridge between Asian and North American continents. Thus , submerged Beringia must have vestiges of the early migrations during lower sea level stands.

The bottom geomorphic features on the Alaskan Shelf provided evidences for earlier lower sea level stands of this region. Even considering the destructive processes of inundation and marine sedimentation, some bottom features have retained their original relationship to the present bottom topography. The most diagnostic and persistent features of the earlier sea level stands on the Alaskan Shelf included sills, terraces and basin enclosures. Based on these features six former sea level stands on the Alaskan Shelf have been identified and respective paleogeographic maps presented. These past sea level stands occurred at -125 m, -82 m, -66 m, -55 m, -38 m, and -28 m below present sea level.

Paleogeographic maps of earlier sea level stands provided information as to the likely places one might find seasonal resource concentration or migration paths. A combination of topographic features and ecological factors providing sustained subsistence should render some areas more suitable for human habitat than others. Using these techniques, areas with high potentiality for presence and preservation of vestiges of early man can be delineated on the submerged shelf.

A. Study Area

The area described here includes the continental shelves of the Beaufort, Chukchi, and Bering seas, and of the Gulf of Alaska and lower Cook Inlet, including Prince William Sound. Based on erogenic and morphologic evolution, the shelf surrounding Alaska can be broadly subdivided into four areas: northern, northwestern, western, and southern. The northern or Beaufort Shelf is the submerged part of the North Slope, which extends from the foothills of the Brooks Range north to the continental slope in the Arctic Ocean. The geologic evolution of this shelf is intricately related to the arctic tectonic regime.

The northwestern shores of Alaska are bordered by a broad shallow platform extending westwards into the Leptev Sea, the eastern part of which is the Chukchi Shelf. The eastern Chukchi Shelf described here lies between 66°-740 N. latitudes and 156°-1770 W. longitudes. Although the geologic evolution of the Beaufort and Chukchi shelves were controlled by the same tectonic elements, the physiography and the contemporary characteristics of these shelves are significantly different.

The Bering Shelf is underlain by a series of prominent arches and deep basins which were formed in relation to an earlier subduction zone along the base of the present Bering Slope. One of these prominent arches, part of which is exposed as St. Lawrence Island, forms a series of shallow sills between the Bering and Chukchi seas and has played an important role during Pleistocene times. The depth of these sills controlled the flow of Bering Sea water into the Chuckchi or vice versa in the recent past, thus these sills were significant controlling physiographic elements. There is little evidence for glaciation on the Bering and Chukchi shelves, although some evidence of recent ice gouging has been observed in shallow regions of the shelves. Both the Bering and Chukchi shelves are extremely wide and, except for a few drowned valleys, have relatively smooth floors.

The Gulf of Alaska and Cook Inlet regions are part of the continental plate resting on the subsiding Pacific Plate to the south. In contrast to those to the north, the Gulf of Alaska Shelf has been extensively glaciated and is dissected by numerous fiords and sea valleys. Unusually large plateaus and shallow banks are unique to this region.

B. Past Climate and Climatic Changes

Periodically, the earth has undergone long periods of continual glaciation. Paleontologic and stratigraphic evidence indicates that during the last billion years the earth has had three major periods of glaciation, during which the polar regions were covered with thick ice sheets subject to rhythmic expansions and contractions.

The precise reasons for these global fluctuations between glacial and interglacial conditions are not known, but it is assumed that the relative distribution of continents in the northern and southern hemispheres as a result of continental drift may be one of the causes. Beyond a certain critical mass of continents, the continued accretion of land in the northern hemisphere may have set up astral movements of the earth which led to subtle climatic changes in the polar regions, triggering glaciation in the higher latitudes of the northern land masses.

Evidence for recent glaciation in Alaska is recorded in the Yakataga Formation of Miocene age in Southeastern Alaska. These glacial tills suggest that the last glacial age in the Northern Hemisphere began about 10 million years ago. Continental cooling extended the glaciers towards lower latitudes until, by about three million years ago, a large part of the higher latitudes of the northern hemisphere was covered with ice sheets.

The extent of this ice sheet varied regionally, and underwent worldwide periodic extensions and recessions. Worldwide studies of glacial deposits on land, and deep sea cores from various oceans, indicate that fluctuations in ice cover can be correlated to global climatic cycles of 100,000, 41,000, and 22,000 years, perhaps caused by the astronomical configurations of the earth's tilt and eccentricity.

Almost one and one-half centuries ago, Charles Maclaren (1842) of Scotland argued that the sea surface during an ice age must have been lower than during interglacial ages. The shores of all continents bear the evidence of past lower sea level stands. The precise correlation between ice age cycles and sea level fluctuations has been difficult, however, due to isostatic rebound and regional tectonics.

Glaciation and sea level stands in Alaska during the last glacial age have been sparsely studied. The paleoecology of the Bering and Chukchi seas, including ice cover and transgressions, has been described by Hopkins (1967, 1972), who observed seven episodes of major cold and warm climates. During periods of cooler climate the sea regressed toward the shelf edge, while during interglacial periods sea level rose to transgress the relatively smooth and flat continental shelf. Sediments deposited during each transgression have been observed along the shores of Alaska. According to Hopkins (1972), the earliest transgression, the Beringian, occurred during the late Tertiary or early Pleistocene ca. 2,200,000 yr B.P. The next transgression, the Anvilian, invaded the shelf sometime between 700,000 and 1,900,000 yr B.P., when shorelines were between 20 and 100 m above present sea level. The succeeding Einahnuhtan and Kotzebuan transgressions occurred about 300,000 and 175,000 yr B.P. respectively. Sea level during these transgressions stood about 20 m above present. Beach deposits at Nome, between 7 and 10 m above the present shoreline, are about 100,000 years old and were deposited during the Pelukian Transgression. The following Woronzofian Transgression occurred between 25,000 and 48,000 yr B.P., when the shoreline was lower than at present. The last major transgression in Alaska took place between 5,000 and 10,000 yr B.P. and rose to within two meters of present sea level.

Various episodes of glaciation on land have been examined, but such studies have been confined to a few localities and invariably describe only recent advances and recessions of mountain glaciers. The Late Wisconsin glacial maximum in northern latitudes is estimated as occurring between 25,000 and 20,000 yr B.P. (Frenzel 1973). This was followed by warmer weather which resulted in a recession of glaciers in the Brooks Range (Hamilton and Porter 1975). At about 13,000 yr B.P. the glaciers began to readvance and a colder climate prevailed until around 11,000 yr B.P. Between 11,000 and 8,000 yr B.P. the climate again became warmer, with glacial recession to higher altitudes. Between 8,000 and 7,000 yr B.P. there was another minor readvance of glaciers in the Brooks Range, indicating a colder climate. A third warm period began at about 7,000 yr B.P.

Similar glacial chronology has been observed in Southeastern Alaska by Goldthwait (1966), who documented a rapid retreat of glaciers between 25,000 and 10,500 yr B,P., followed by a minor readvance between 10,500 and 9,500 yr B.P. Miller and Anderson (1974) reported glacial advance in the vicinity of Juneau between 10,000 and 9,000 yr B.P., and glacial advance on Prince of Wales Island was dated between 10,000 and 8,000 yr B.P. by Swanston (1969). A subsequent reversal in climate has been dated by various investigators between 7,200 and 2,900 yr B.P. (Goldthwait 1966), between 8,500 and 4,500 yr B.P. (Heusser 1966b), and 9,000 and 2,500 yr B.P. (Miller and Anderson 1974). Since 4,200 yr B.P., glaciers in this region have been pulsating, with minor advances and retreats.

A warm interval of the early Holocene, generally termed the "climatic optimum", has been dated in southeastern Alaska between 5,500 and 3,250 yr B.P. by Miller and Anderson (1974); between 7,050 and 4,150 yr B.P. by McKenzie and Goldthwait (1971); and about 3,500 yr B.P. by Heusser (1953). Following this "climatic optimum", the climate in southeastern Alaska, except for minor fluctuations, has gradually become colder.

Glacial deposits in Cook Inlet and southcentral Alaska have been studied by Karlstrom (1955, 1957, 1966), who observed eight major retreats of glaciers between 26,000 and 22,500 yr B.P., 19,000 and 15,500 yr B.P., 12,500 and 9,000 yr B.P., and 5,500 and 1,500 yr B.P.

Although a general trend in climatic variations can be observed from glacial histories, it is rather difficult to correlate minor fluctuations from one region to another. It should also be noted that variation in temperature is not the sole agent affecting the size of a glacier. In view of the variable terrain and large latitudinal extent of Alaska, the chronology of climatic changes and resultant fluctuations of sea level can perhaps best be considered on the basis of continental ice sheet extensions.

Extensions and recessions of continental ice in North America have been studied since the last century. Goldthwait et al. (1965) have compiled the chronology of the geographic position of the ice sheet margin between Indiana and Quebec (Fig. I-1). Except for the latest advance (18,000 yr B.P.), fluctuations of the ice sheet do not correspond to the warming and cooling of earth predicted by the Milankovich theory. Therefore, it appears that fluctuations of glaciers and continental ice sheets, although influenced by climate, are not the sole indicators of global cooling and warming cycles.

The accretion of an ice sheet is, to some extent, dependent on atmospheric circulation, since glaciers and ice sheets need a supply of moisture to maintain their position and to expand. If sufficient moisture is not available, some regions do not undergo glaciation in spite of low temperatures during glacials. For example, there is no evidence for glaciation during Wisconsin times in the Tanana Valley of Alaska. Regions 'further south, with relatively cool and moist climate had, on the other hand, thick sheets of ice with large areal extent. In contrast to continents, the oceans tend to respond only to long-term cooling and warming trends. Based on faunal fluctuations and variations in oxygen isotope ratios in sediments from various oceans, fluctuations in temperature during the past have been determined. The temperature variation curve shows periodic major climatic cycles which prevailed during the Pleistocene, the last of which is shown in Figure I-2. A detailed curve of temperature variations during the recent past (10,000 yr B.P.) is presented in Figure 1-3. This curve shows a climatic optimum around 7,000 yr B.P. and other fluctuations which perhaps correspond to the advance and retreat of glaciers discussed above.

Variations in global climate, as is well known, cause changes in sea level . In studies of paleoclimates there have been significant efforts devoted to identifying paleosealevel stands (also referred to as "stillstands"), and sediments deposited during various stillstands have been dated. Radiometric data for stillstands have been collected from various

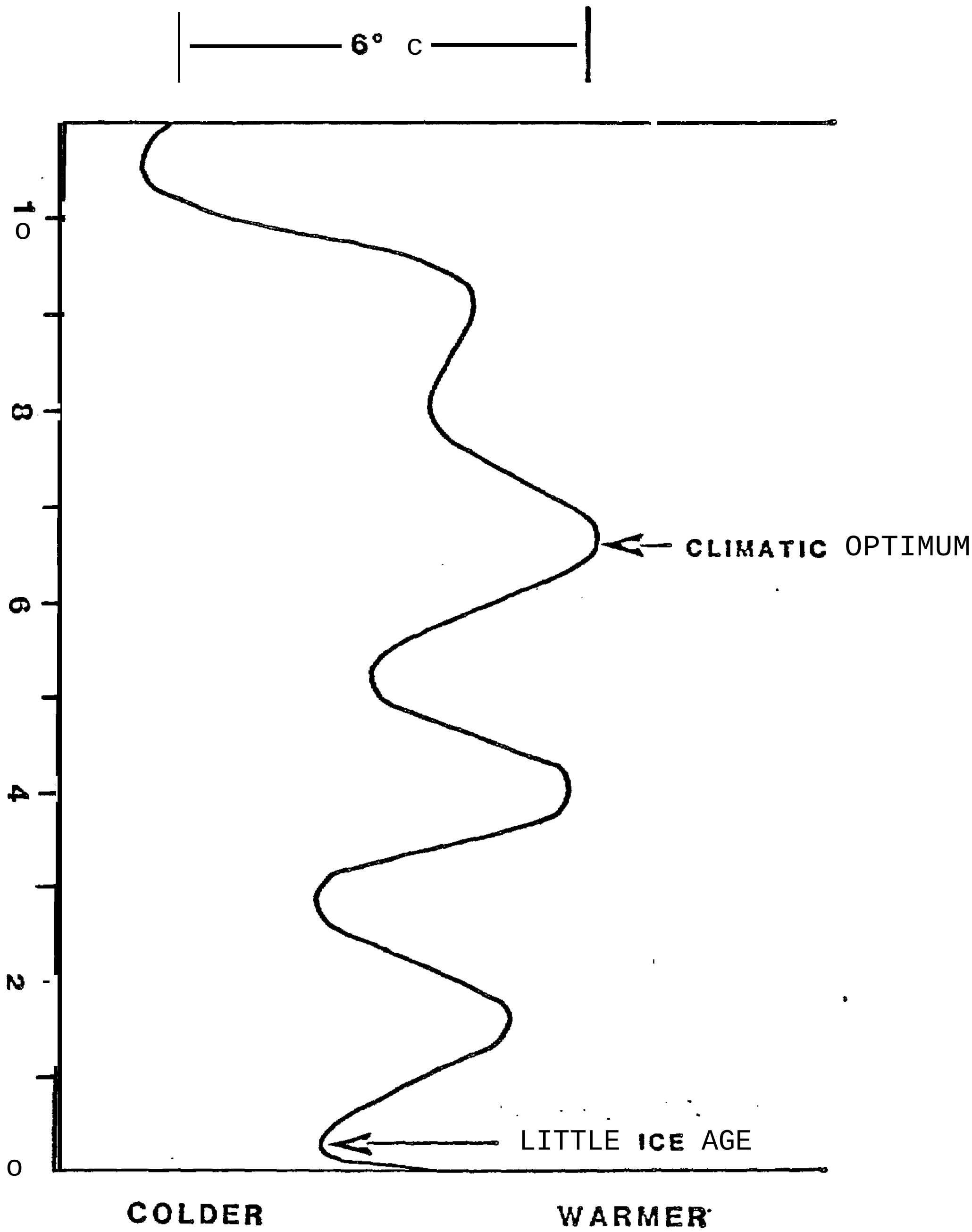


Figure I-3: Global temperature fluctuations over the past 10,000 years.

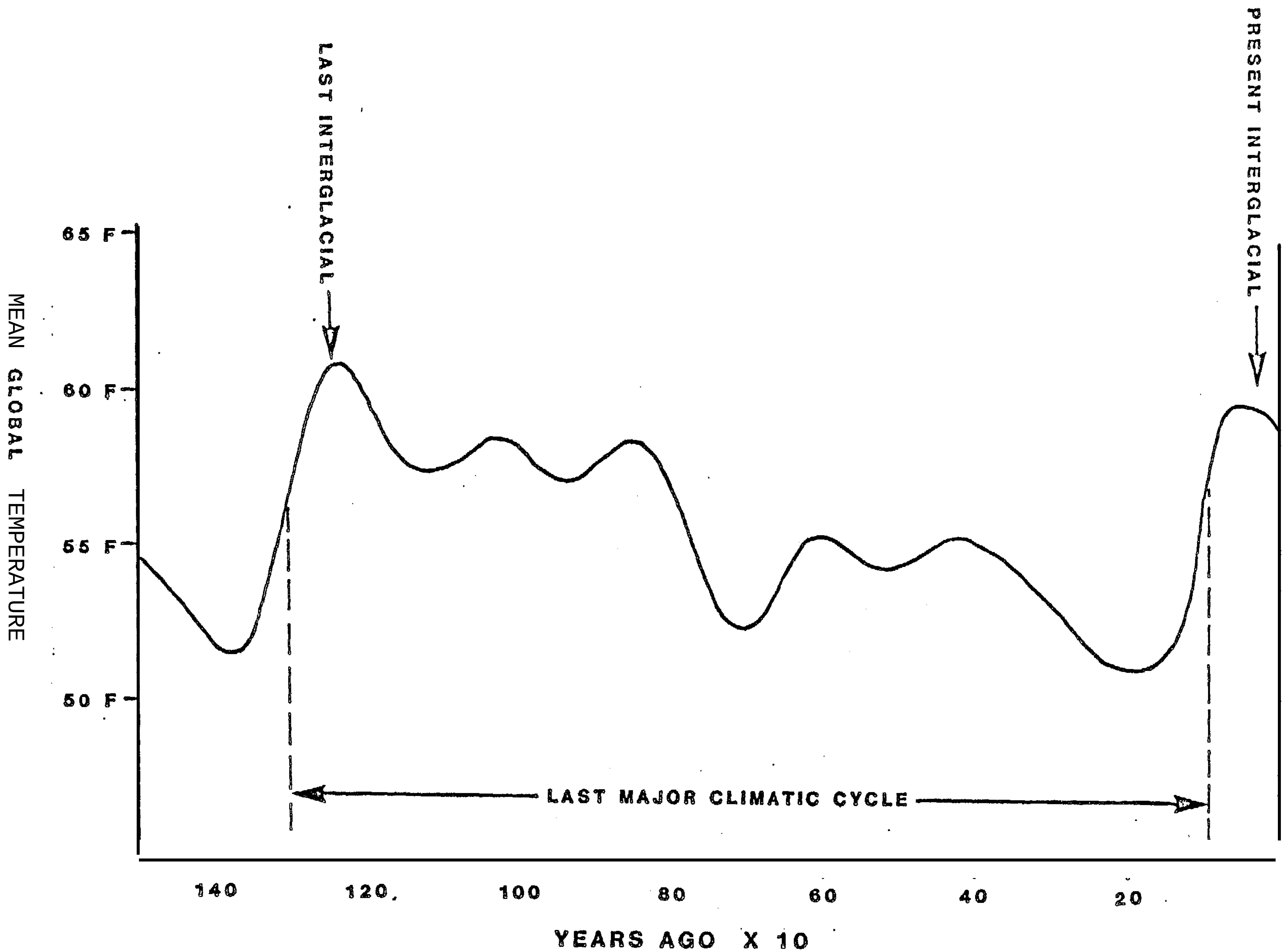


Figure I-2: Global temperature fluctuations during the late Pleistocene.

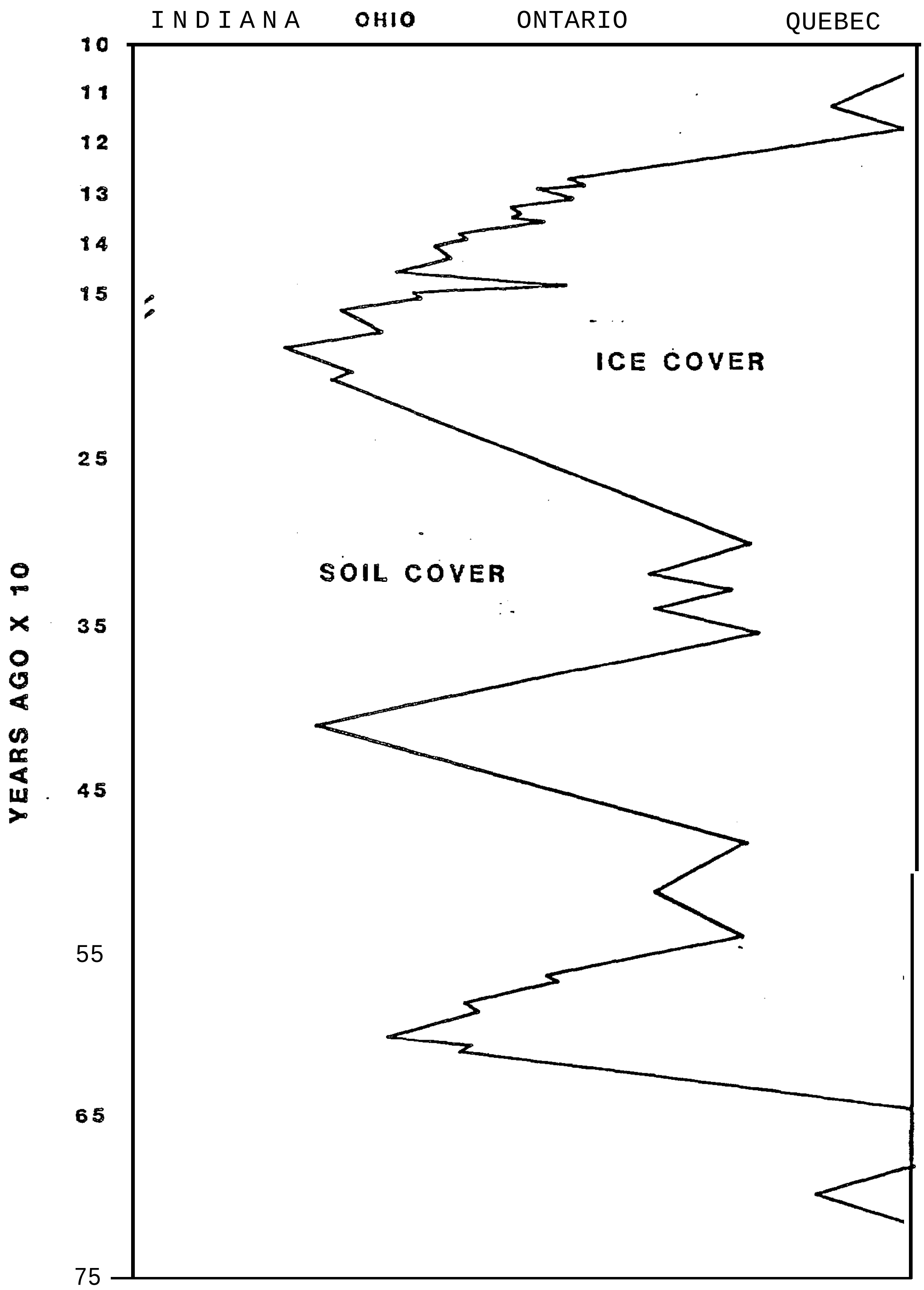


Figure I-1: Chronology of the geographic position of the ice sheet margin between Indiana and Quebec (from Goldthwait et al., 1965).

parts of the world, and a curve for past sea level stands has been plotted (Fig. I-4). It is notable that the chronology of temperature reversals is identical to the chronology of sea level stands. It must, however, be pointed out that the extent of sea level fluctuation does not correspond to the degree of temperature fluctuation. Once again, it appears that the amount of water stored in the form of ice during ice ages does not necessarily correspond to the degree of cooling. Nevertheless, without exception, sea level stands are higher during warmer periods (interglacial) than during cooler periods. Paleoclimatic curves and paleosealevel curves have been derived through independent approaches, yet both show identical chronology for each reversal. It is not only appropriate but essential to attempt to relate these to sea level stands observed on the Alaskan Shelf.

Bathymetry and bottom morphology of the Alaskan Shelf provide evidence for six stillstands. These horizons, in spite of differences in regard to the geologic evolution and tectonism of various sectors, are common throughout the Alaskan Shelf. The faceted sectors of the Alaskan Shelf understandably have a maximum variety of fluvio-glacial features which typify characteristic stillstands. These are notably well preserved. The various horizons of submerged features along the Aleutian Shelf, because of tectonic and seismic activities, should occur in a random fashion. However, frequent these stillstand features not only occur at the same water depths throughout the Aleutian Shelf, but they match precisely with those which occur on the more stable Bering Shelf.

c. Beaufort Shelf

1. Introduction:

The Beaufort Shelf during the past decade has been the focus of environmental studies by oil companies as well as federal and state agencies. Much of the research is directed towards understanding the delicate arctic environment so as to cause minimum perturbation in the natural ecosystems during exploration and exploitation of resources from the shelf and nearshore region.

The bathymetry of the Beaufort Shelf was first explored during the Canadian Arctic Expedition of 1913 on board the KARLUK (Stefansson 1944). Topography of the Arctic Basin and the adjacent shelf, including the nature of the sediment cover, was described by Emery (1949). The first comprehensive geological investigation of the Beaufort Sea was carried out by Carsola (1954). Recent studies include distribution of subshelf permafrost (Hopkins 1978), ice gouging (Reimnitz and Barnes 1974) and sediment dynamics (Naidu 1978).

Information relating to sea level history of the Beaufort Sea is almost non-existent. The need for such information was emphasized during a "synthesis meeting" sponsored by NOAA and BLM at Barrow, Alaska, 24-27 January 1978. Attendees noted, "Knowledge of sea level history is needed for estimation of long-term sedimentation rates, for coastal stability studies, for geothermal modeling to predict distribution of offshore permafrost, and for determining the areas most likely to contain submerged archeological

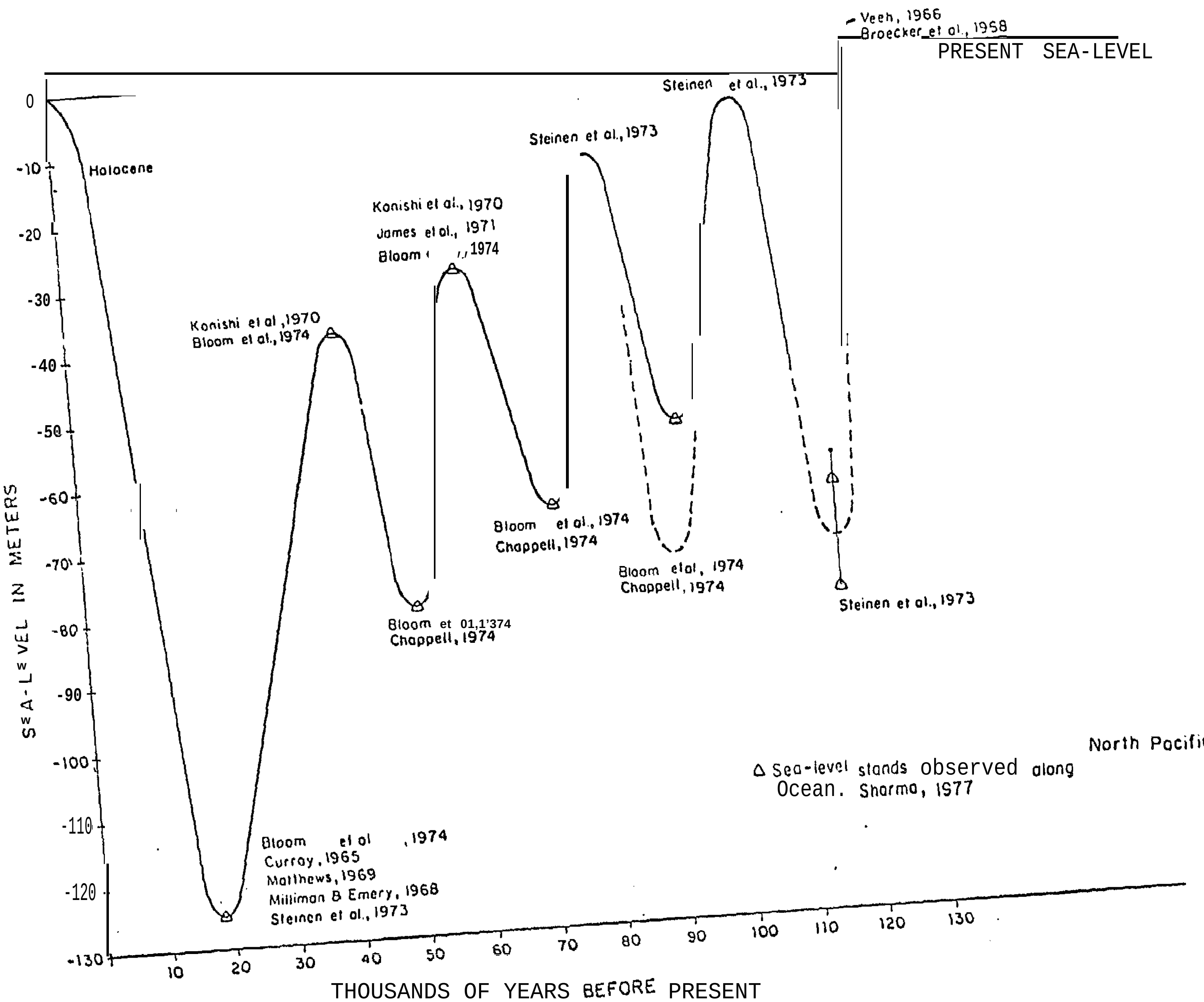


Figure I-4: Late Pleistocene sea level fluctuations (data compiled by G.D. Sharma).

sites." Past variations in sea level, therefore, have contributed significantly to the present physiography and the ecosystem of the Beaufort Shelf.

2. Geologic Evolution:

The geological evolution of northern Alaska and the adjacent Beaufort Shelf includes five stratigraphic sequences, each of which is related to an orogeny which preceded the sequence. The earliest known Paleozoic feature of northern Alaska is the east-west oriented Colville Geosyncline. The major stratigraphic sequence of the Colville Geosyncline are facies deposited during the Cambrian and Devonian. Between Cambrian and Devonian time, the geosyncline was filled with both eugeosynclinal and miogeosynclinal facies, which have since been metamorphosed. Sometime during the Devonian, the entire region was uplifted and a broad, stable Arctic Platform extended along northern Alaska. Marine sediments are comprised of elastic and carbonate rocks deposited on the platform between late Devonian or early Mississippian times" through early Cretaceus times. These marine sediments are the second sequence of rocks in the region, which near Prudhoe Bay contain giant oil and gas reserves. At the close of Jurassic or beginning of Cretaceus times, an intense orogeny compressed the southern part of this platform and thrust the Paleozoic and early Mesozoic rock sequence northward onto the central part of the platform. The compression perhaps occurred concurrently with, and was probably caused by, the opening of various rift valleys in the Atlantic, Pacific, and Arctic oceans. This resulted in uplifting of the Brooks Range-Herald Arch structure, which subsequently supplied sediment detritus to the northern part of the platform. These elastic deposits formed the third stratigraphic sequence in the region.

Cretaceus orogeny also formed the major geologic feature of the shelf, the Barrow Arch. This arch is a broad subsurface regional structure. The axis of the arch follows the Beaufort Coast from the foothills of the Brooks Range (near the U.S./Canadian boundary) to Point Barrow and extends westward under the Chukchi Shelf. The arch divides the northern portion of the Arctic Platform into a southward-sloping plain and a narrow northward-sloping continental margin to the north. Late Cretaceus and Tertiary sedimentation north of the arch subsequently prograded the Beaufort Shelf seawards to the present continental margin. The area submerged briefly as a result of crustal warping during the Tertiary era, resulting in deposition of a fourth stratigraphic sequence.

At the beginning of the Pleistocene Epoch, crustal downwarping of the shelf again caused marine flooding and the final sequence of Beaufort Shelf deposits. These Pleistocene sediments covered the Tertiary topography to form a smooth plain, the Gubik Formation, which consists of an unconsolidated mixture of silt and fine-grained sand with clay and gravel and is the youngest stratigraphic sequence on the Beaufort Shelf.

The present coastline and the adjacent nearshore area or the Beaufort Sea are greatly influenced by rivers. The entire 450 km coast, extending from Harrison Bay to the Canadian border in the west, can be classified as deltaic, built by numerous rivers originating in the Brooks Range and draining the broad coastal plain.

Landward, the Beaufort Shelf is joined to an extensive plain with tundra soils, patterned ground, lakes, ponds, streams, and braided rivers. Plain sediments are mostly fine-grained sand and silt occasionally including clay and gravel, and are the product of frost action and aeolian deposition. The entire onshore region is underlain by permafrost, which acts to cement these sediments together. However, annual freezing and thawing of exposed layers forms a thin veneer of unconsolidated sediments which are modified by alluvial, lacustrine and aeolian reworking and tundra soil development. Along the shore, thermal, fluvial, and marine processes erode the coast and rework nearshore sediments to produce sandy and gravelly barrier islands and beaches.

Morphologically, the entire coastal belt between Point Barrow and the Alaska-Canadian border at Demarcation Point can be divided into three groups: barrier islands, tundra bluffs, and river deltas. Four irregular, discontinuous barrier island chains occupy 53% of the coast and are composed of coarse sand and gravel. Tundra bluffs with gravelly beaches form 32% of the coast, and deltas make up the remaining 15%. The latter consist of a mixture of sand, silt, and clay (Short _et al_. 1974).

3. Bathymetry:

Detailed bathymetric charts for the eastern and western portions of the Beaufort Shelf (Figs. I-5 and I-6) were prepared using data from various sources. The most recent and reliable data were bathymetric charts and depth profiles obtained by Geophysical Corporation of Alaska, Marine Seismic Survey, Beaufort Sea Area, Alaska, 7 September 1975. Latest editions of NOAA charts of the Beaufort Sea were also used to fill data gaps. A few U.S. Geological Survey bathymetric charts and old boat sheets released by the U.S. Navy were also used as a data base, and bathymetric data for some areas were retrieved from U.S. Geological Survey charts. The water depths of these charts were compiled from various unspecified cruises, so the reliability of this data is uncertain. Various cruise reports published by the U.S. Coast Guard were also included for regions where other data were not available.

The NOAA bathymetric charts used for compilation of Figures I-5 and I-6 were as follows:

U.S. Department of Commerce,
U.S. Alaska-Arctic Coast,
NOAA Chart Numbers

16042 - 1974	16061 - 1977	16066 - 1974
16043 - 1974	16062 - 1977	16067 - 1977
16044 - 1974	16063 - 1977	16081 - 1974
16045 - 1774	16064 - 1974	16082 - 1976
16046 - 1977	16065 - 1975	

Transfer of bathymetric data from the various charts was difficult, since almost all source charts were of different projections. Even NOAA

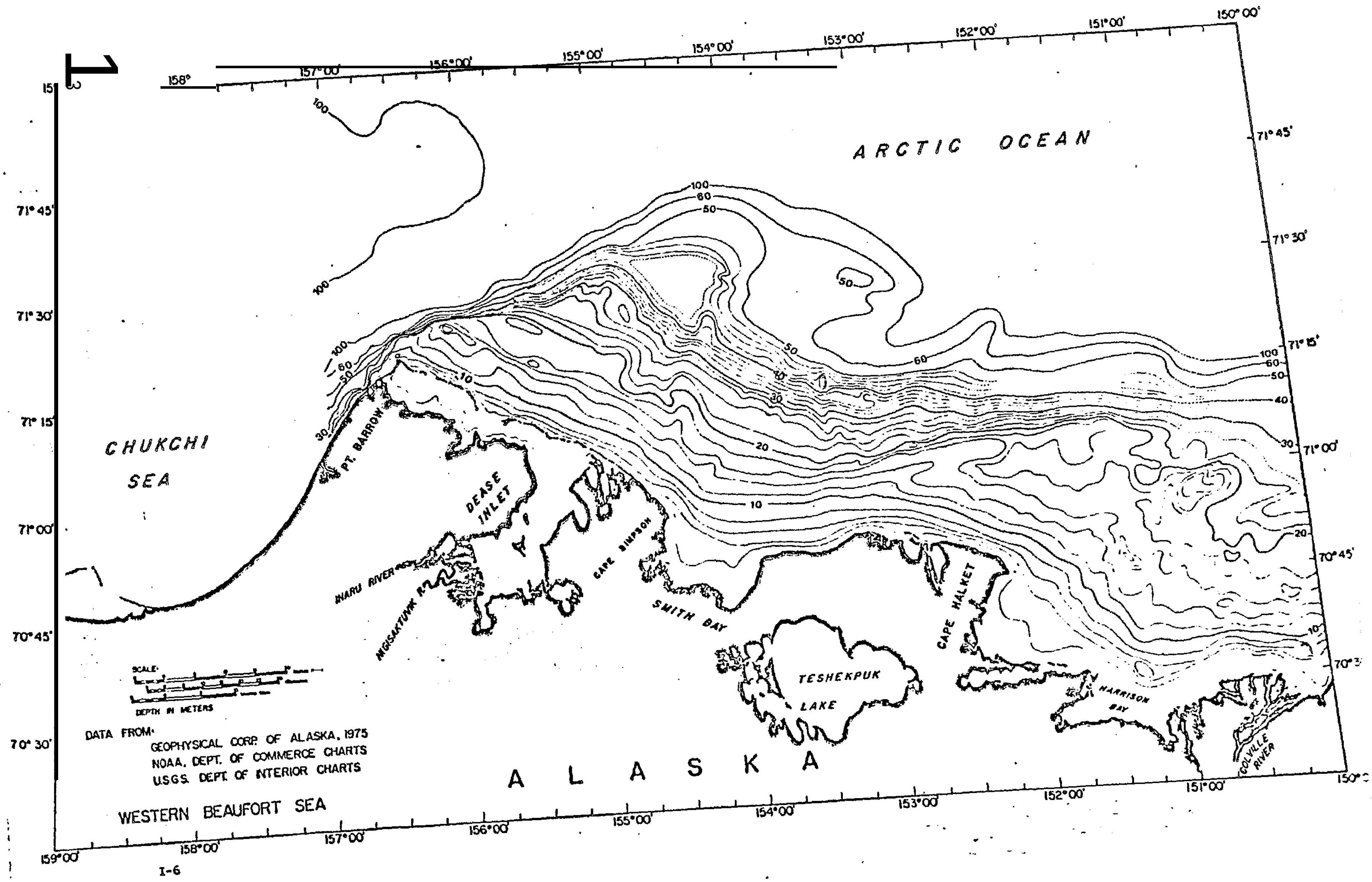
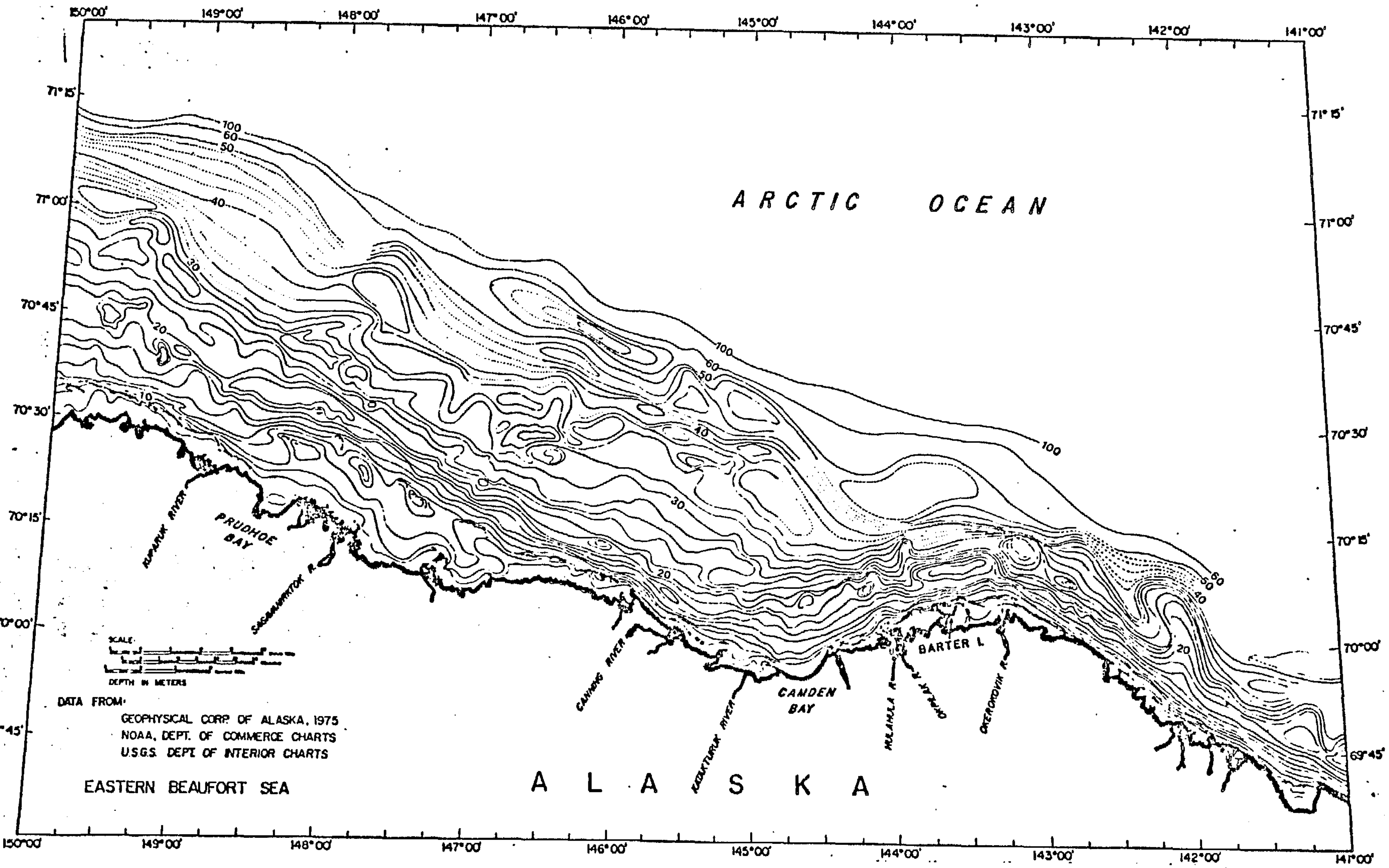


Figure -6: Bathymetry of western Beaufort Shelf.



I-5

Fig. I-5: Bathymetry of ea tern Beaufort Shelf.

charts with similar projection had different scales. Because of the difference in projections and scales, it was necessary to transfer each data point individually by reading coordinates. Thus, the longitude and latitude of each point was read and transposed on an Equal Area Projection 1:250,000 scale chart provided by the BLM. Over five thousand points were read and transposed to the BLM Charts in order to develop bathymetric contours for the Beaufort Shelf.

The 1:250,000 scale and low shelf gradient permitted isobath lines at intervals of -2 m along the inner and middle shelves. Slightly thicker isobath lines were drawn at -10 m and multiples of -10 m. The shelf gradient beyond the -50 m depth, however, was too steep to permit inclusion of -2 m contour intervals. Similarly, beyond -60 m isobaths, only the -100 m isobath line could be projected due to lack of data points and steeper gradient.

The bathymetry of the Beaufort Shelf is very complex. The eastern part of the shelf, between longitudes 141° and 155°W., is relatively steep and narrow (about 30 km in width), and includes three protruding headlands and three major topographic highs. The relief of these topographic highs varies from one or two meters to 10 m.

The central shelf, between 144° and 151°W. longitude, is about 70 km broad and of more gentle gradient. The prominent feature of this region is a complex bathymetry resulting from numerous islands and submerged topographic highs, some of which are large enough to be shoals or small banks. The longitudinal axes of these topographic highs are invariably aligned to the present coastline, with normal relief of 2-4 m, though a few are higher (up to 10 m). These higher features are round, with a rather steep gradient, and are probably the result of permafrost which underlies most of the shelf.

The western section of the shelf, between 151° and 157°W. longitude, is also fairly wide, with two major headlands. Between 153° and 155°W. relatively smooth step-like banks are the major features on the shelf. These banks appear to be submerged shoals between the -44 m and -46 m isobaths, perhaps formed as hypothesized below.

Based on the bathymetry, the opening of Bering Strait occurred during the -55 m (sill depth of the strait) sea level stand, permitting inflow of Pacific Water into the Chukchi Sea. Initially, most of this water was channeled through Hope Valley northwest into the Arctic Ocean. Subsequently, as sea level rose, Bering Sea Water began to flow north and east of Harold Shoal. After reaching the -38 m isobath, this Bering Water began flowing parallel to the Alaskan Coast and entering the Arctic Ocean through Barrow Canyon. This -38 m sea level stand coincided with inundation of most of the Bering Shelf and the opening of Shpanberg Strait, thus permitting Yukon River discharge to flow northwards through the Bering Strait to the Chukchi Sea. Following flooding at the -38 m isobath, Bering Sea Water and entrained Yukon sediments then began to flow northward along the Chukchi Coast to Point Barrow and beyond, with resultant deposition of large quantities of sediments to form the shoal between the -44 m and -46 m isobaths. Prince of Wales Shoal is currently forming north of Bering Strait under similar conditions.

There are a series of large, submerged, step-like flat areas northeast of Point Barrow, which may be called small banks. It is suggested that these were formed during periods of sea level stabilization, and may represent extensions of the shoals discussed above.

There are no major submarine valleys located on the Beaufort Shelf, though shelf bathymetry has a few conspicuous features which suggest a former subaerial environment. Those features include a series of depressions which are discontinuous and do not show consistent seaward grading. A lack of apparent submerged deltas and valleys generally prohibits delineation of sea level still stands on the Beaufort Shelf, however, and the absence of bottom features diagnostic of paleodrainage prohibits offshore extension of present rivers onto the shelf. In comparison with continental shelves to the south, the Beaufort Shelf exhibits a very meager number of paleoshoreline features.

Causes of such scanty occurrence of common shoreline features on the Beaufort Shelf may be due to ice-related processes, which dominate the nearshore area. The magnitude and the intensity of these processes, such as prevail at present, should shed some light on the types of shoreline and bottom features which might have developed earlier.

Along its gradient, the Beaufort Shelf exhibits distinct zoning. Landward, the coast is adjoined by an extensive plain with tundra soils, patterned ground, lakes, ponds, streams, and braided rivers. From shore to -10 m water depth, the slope of the shelf is gentle (see Figs. I-5 and I-6), with islands, bars, and numerous small deltas. Downslope, between -10 m and -20 m, the gradient of the shelf is slightly steeper. Seaward, between -20 m and -50 m, the gradient of the shelf once again flattens somewhat, but becomes quite steep beyond -50 m.

4. Nearshore Processes:

Development of the nearshore gradient of the shelf may be the result of ice related processes. Generally, during winter, the shore ice extends to -10 m, while the area between -10 and -20 m is a zone of interaction between stationary coastal ice and the moving polar ice pack. This region is a zone of intense ice-gouging as reported by Reimnitz and Barnes (1974), where deep-keeled pressure ridges and grounded ice islands, driven by winds and currents, plow the shelf bottom. Ice-gouge features on the sea floor range from V-shaped to U-shaped furrows, commonly more than a meter deep and up to 10 m wide. Some furrows are up to 5.5 m deep. The majority of furrows are oriented east-west, parallel to the coastline, and reflect the westward drift of the polar ice pack.

Ploughing by ice-gouging disturbs and causes vertical mixing of surficial sediments. In some shallow areas, with water depths to -3o m, ice-gouging is frequent enough to rework sediments at least once every half century (Reimnitz and Barnes 1974). Also because of the prevalent westward drift of the ice, ice-ploughing causes a net displacement of sediment to the west. Movement of sediments occurs either as a result of "ice-bulldozing" or through subsequent reworking of sediment by currents along the furrows. Submerged topographic highs and islands must have been ideal regions for frequent grounding of ice floes, and were thus particularly vulnerable to extensive ice-gouging during earlier sea level stands. Repeated ice-gouging of these features undoubtedly results in alteration of their surficial sediment structure, migration of sediments, and their ultimate destruction.

Most exposed as well as submerged features of the U.S. inner Beaufort Shelf are quite mobile and impermanent, including both constructional and erosional remnant islands. Constructional offshore islands, for example, are migrating westward at rates ranging from 19 to 30 m per year and landward between 3 to 7 m a year (Lewellen 1970; Wiseman et al. 1973). Erosional remnant islands that have been isolated from the mainland by thermokarst collapse and rapid thermal erosion have likewise been considerably modified. These islands lie far offshore, near the shear zone between shorefast ice and the arctic ice pack, with their seaward slopes subjected to ice-push. Often the ice-push virtually bulldozes the seaward beach sediments to the landward side, thus causing landward migration of the islands while adding new material to the seaward beaches.

The coast of the Beaufort Sea is extremely dynamic. Coastal retreat along the Beaufort Sea is rapid (Leffingwell 1919; McCarthy 1953; Hume and Schalk 1967; Lewellen 1970; Dygas et al. 1972; Hume et al. 1972; Wiseman et al. 1973; Lewis and Forbes 1975; Barnes et al. 1977; Reimnitz et al. 1977; Cannon 1978; Hopkins 1978), caused by the distinctive arctic processes of thermokarst collapse and thermal erosion. Thawing of ground ice in onshore lakes leads to subsidence, which ultimately permits invasion of the sea so that the lake becomes part of the shoreline. Shoreline features are thus largely controlled by rates of thermokarst erosion.

5. Surficial Sediments:

Surficial sediments on the Beaufort Shelf mainly consist of 5 to 10 m of marine mud underlain by 1-2 m of" thick, well rounded gravel and coarse sand beach sediments. Osterkamp and Harrison (1976) dated the sand and gravel underlying the marine clays at approximately 22,000 yr B.P. Dates for marine clays obtained by Hopkins (1977) ranged from 18,000 to 22,000yr B.P., and were considered to be anomalous. Barnes and Reimnitz (1974) reported that these clays are pre-Holocene, or more than 7,000 to 10,000 years old.

6. Paleoshorelines:

The few geomorphic features diagnostic of paleosealevel which have survived destructive ice processes cannot be correlated with certainty, since their vertical position in relation to present sea level may have changed due to subsidence of the shelf during and subsequent to the last transgression. The area was subjected to extremely cold air temperatures during the last glacial, during which time extensive permafrost undoubtedly formed under the exposed shelf, as recent investigations (Hunter et al. 1976; Osterkamp and Harrison 1976; Lewellen 1976; Hopkins and Hartz 1978) have revealed. Subsequent to transgression, some of this permafrost has reached equilibrium with the present temperature regime, though much of the deep relic permafrost still exists. Melting of surface permafrost may, therefore, have resulted in subsidence of the shelf floor. Another potential clifficulty in correlating earlier sea level stillstands in the Beaufort Sea with stillstands documented from other Alaskan continental shelves is that subsidence of the shelf due to subsurface permafrost thaw may not be uniform throughout its extent.

The sparse occurrence of paleoshoreline features, in conjunction with inadequate knowledge of post transgressive subsidence of the shelf floor, prohibits detailed reconstruction of Beaufort Shelf paleogeography. Evidence for major events of middle and late Wisconsin glacial and interglacial episodes can, however, be extrapolated from the growth and ablation of terrestrial glaciers and from shelf sediment dating.

During the Pleistocene, the Brooks Range was high enough to accumulate year-round snow which generated valley glaciers. The thickness of ice in some places exceeded 600 m, though glaciers in the Brooks Range coalesced only along the flanks of the Range, with their northern termini short of the Arctic Coastal Plain (Hamilton and Porter 1975). Al though the shelf may have been glaciated in early Pleistocene or Tertiary times, during Wisconsinan times the Alaskan Beaufort Shelf remained free of glacial ice.

The shoreline features characteristic of sea level stillstands and ensuing transgressions are, for reasons described above, ambiguous for the Beaufort Shelf. A few shelf features are, however, diagnostic of sea level stillstands, particularly the submerged terraces off Point Barrow described "earlier.

Fortunately, sea level changes are global and, except for local isostatic change, can be superimposed from one part of the globe to another. It is, therefore, safe to assume that the transgressive sequence in the Beaufort Sea followed a pattern similar to that observed in the Gulf of Alaska and the Bering Sea. where diagnostic stillstand features have been preserved (see Sharma 1977). The submerged terraces off Point Barrow support such a view. With this in mind, we have produced six paleogeographic maps showing sea-land distributions corresponding to the -28 m, -38 m, -55 m, -66 m, -82 m and -125 m stillstands (Figs. I-7 through 1-12).

D. Beringia

1. Geologic Evolution:

The earliest known Paleozoic features of Beringia are the east-west oriented Colville Geosyncline in the north Chukchi Sea and the Kobuk Trough in the south, which are separated by a geanticline the eastern extension of which is the Brooks Range. The entire region of Beringia during the Paleozoic and Mesozoic eras, remained as a geosyncline and was progressively filled with marine sediments. At the close of the Mesozoic Era the region was uplifted. During the Tertiary, the emergent Chukchi Sea floor was intermittently submerged as a result of crustal warping (Hopkins 1959).

Paleozoic rocks surrounding the northern Bering Shelf, when extrapolated to subsurface, presumably form the basement of the Norton and Chirikov basins. Southwards, beneath the offshore region between the Yukon and Kuskokwim rivers, the shelf is probably underlain by Mesozoic rocks of the Koyukuk Geosyncline (Gates and Gryc, 1963), probably extends offshore

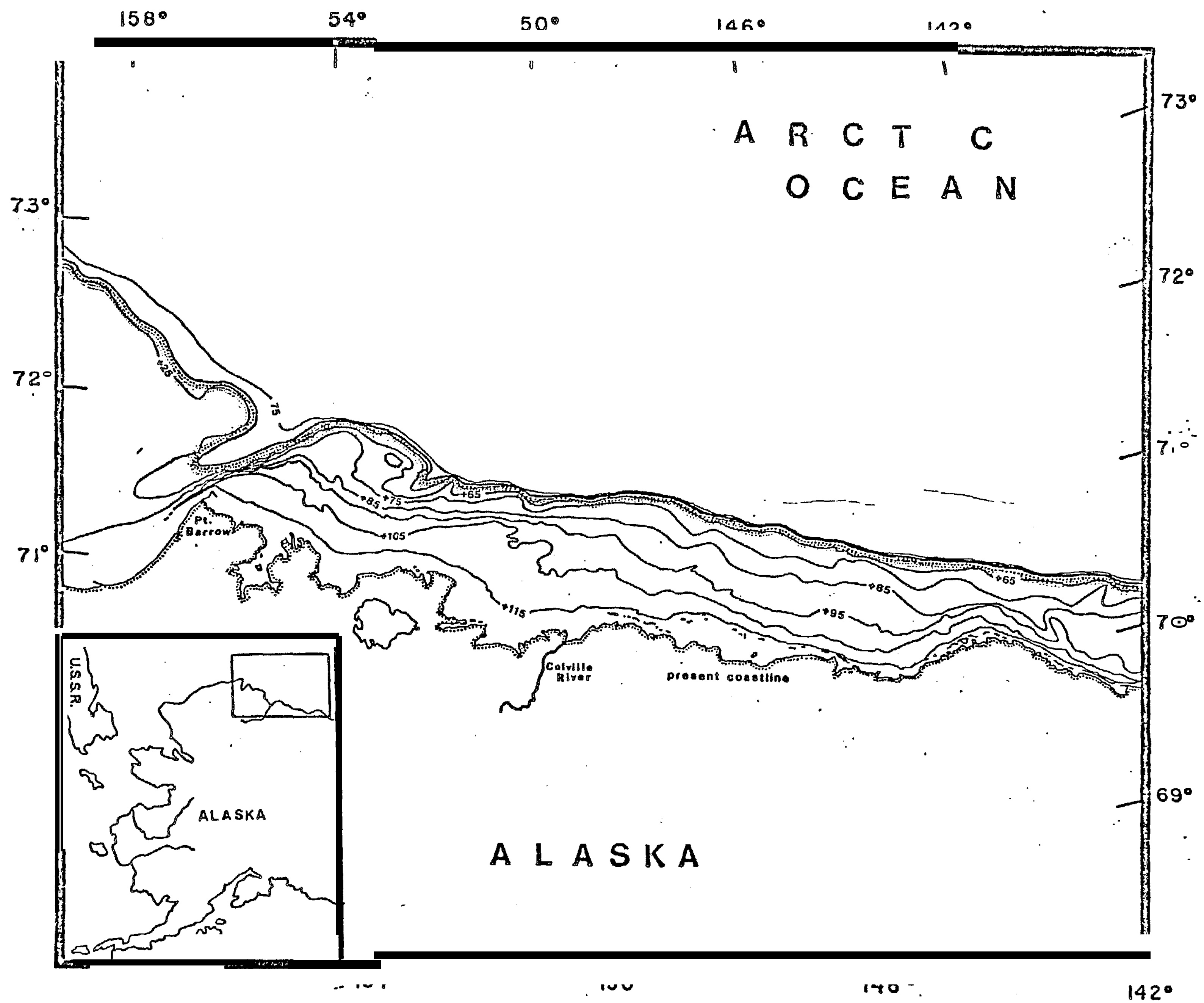


Figure I-12: Beaufort Shelf, -125 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

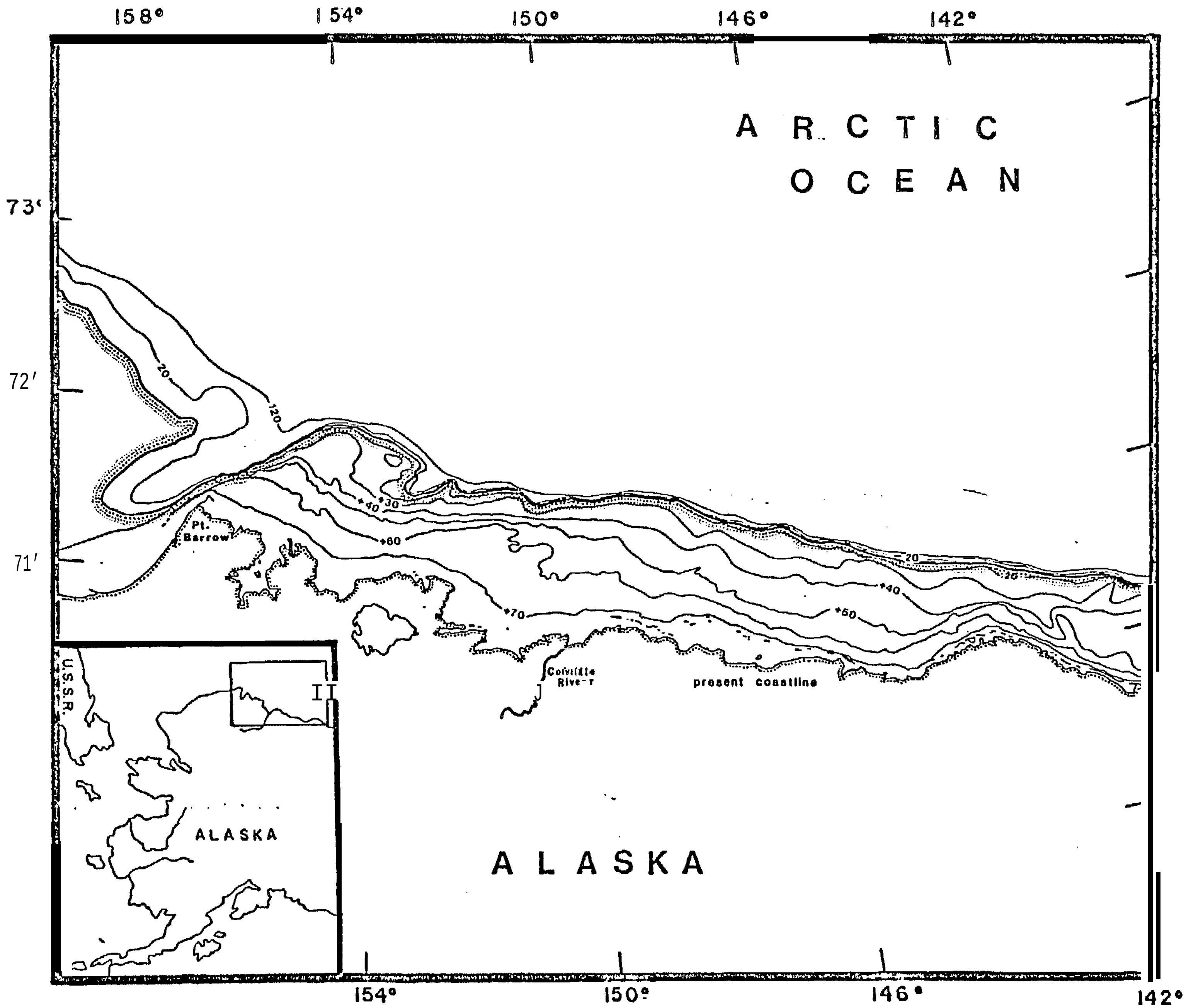


Figure 1-11: Beaufort Shelf, -82 m still stand. Former isobaths and land elevations (indicated by "+") given in meters.

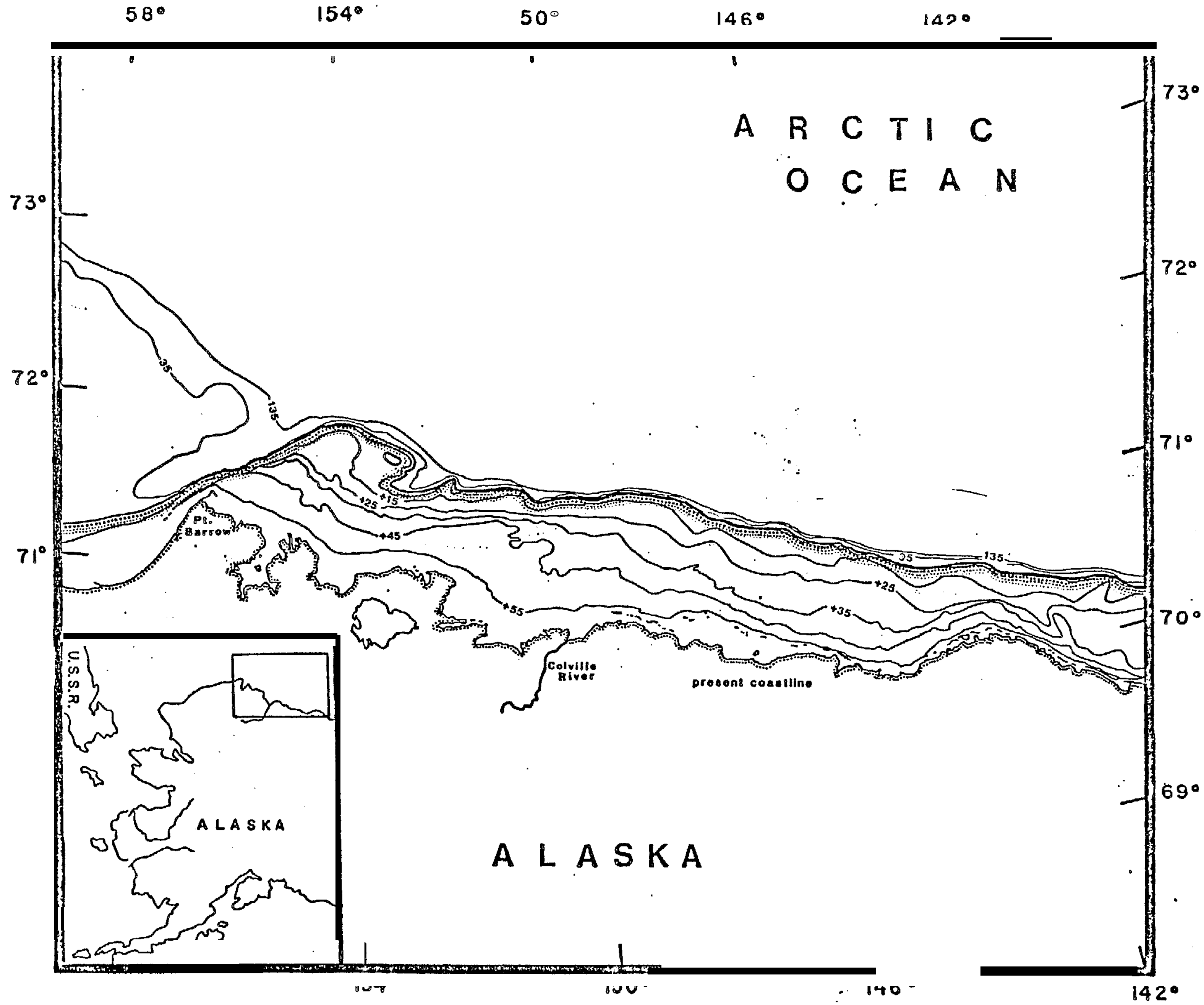


Figure I-10: Beaufort Shelf, -66 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

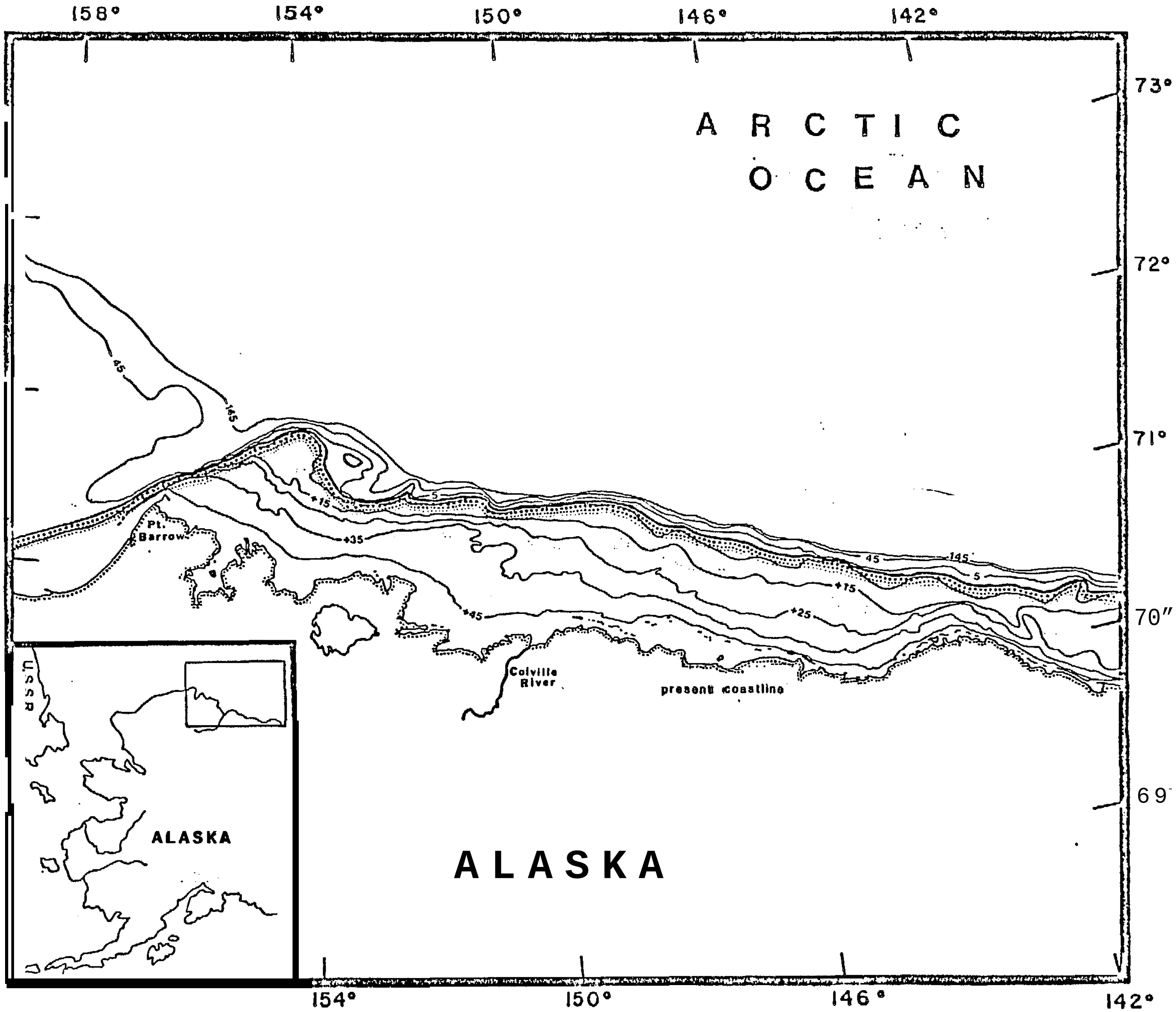


Figure I-9: Beaufort Shelf, -55 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

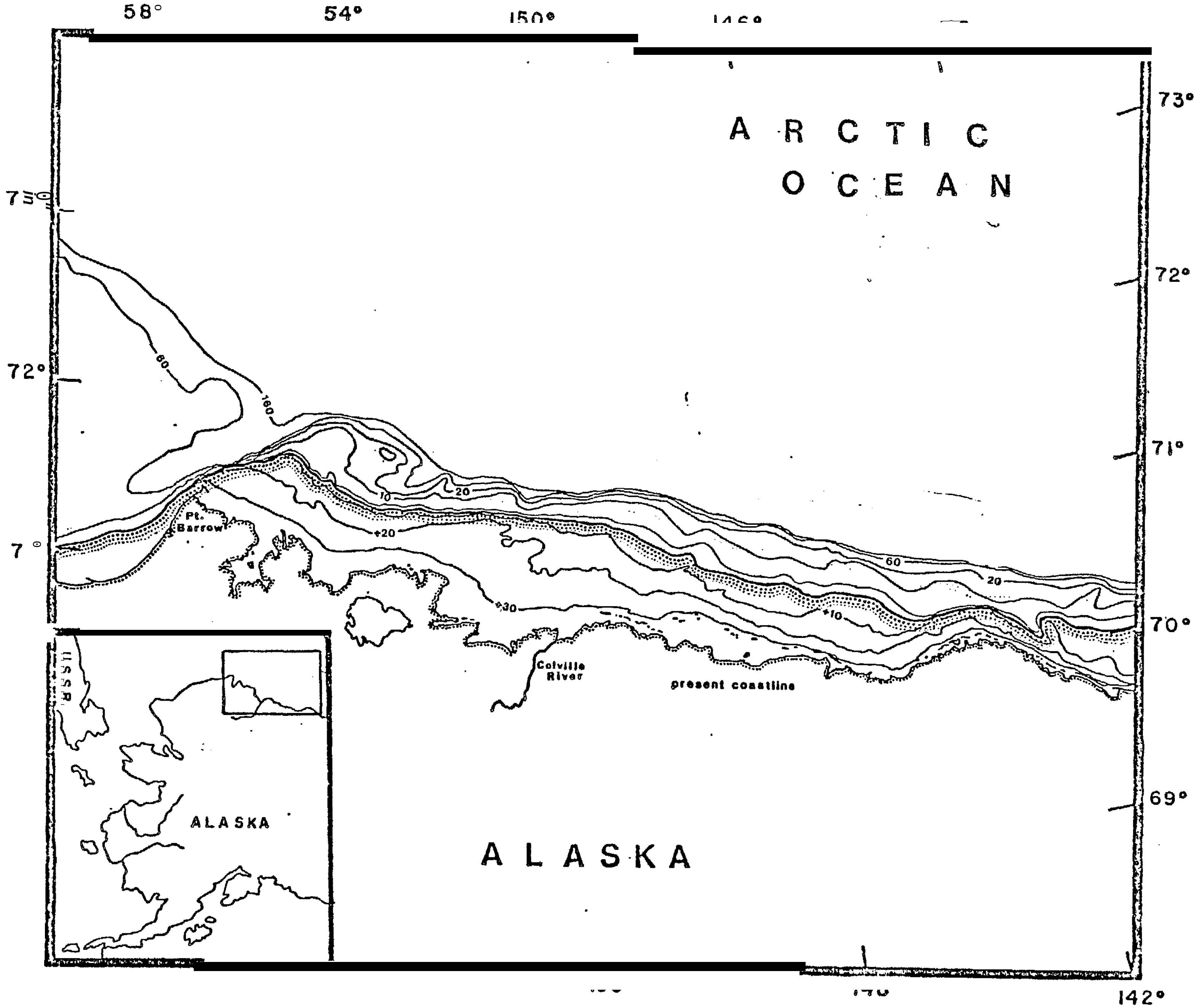


Figure I-8: B ufort Shel , -38 m sti lstand. F er sobat s and land

b. Anvilian Transgression:

This marine transgression was first designated by Hopkins (1965) and is based on a marine sequence deposited near Nome which is distinctly 'different from those of the preceding Beringian and following Einahnuhtan transgressions. Typical sediments deposited during the Anvilian Transgression are found on the coastal plain near Nome, contain marine fossils, and have been exploited for their rich gold content. These sandy and gravelly beach and littoral sediments form a 2-3 m thick discontinuous sheet. Transgressive sediments were also deposited during 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), when sea level was about 20 m higher than present. Sea water temperature was moderate during this period, and circulation on the shelf was similar to that of present, with northward flow through Bering Strait. ·

c. Einahnuhtan-Kotzebuan Transgressions:

In 1967, Hopkins identified two major transgressions between 100,000 - 300,000 and 170,000 - 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.

Typical sediments deposited during the middle Quarternary 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 which are overlain by basaltic lava flows and bedded tuffs, suggesting that at its end the transgression was followed by volcanic eruptions on the island. In some sections of the bluffs, the Einahnuhtan marine sequence and overlying volcanic beds are truncated by shelly gravels deposited during a later submergence. These sediments represent the Kotzebuan Transgression and are, in turn, overlain by a later volcanic sequence. Fortunately, the volcanic sediments provide excellent material for dating glacial and interglacial events of the Einahnuhtan-Kotzebuan stages. The best estimate of potassium-argon age for the lower lava flow is 320,000 ± 70,000 yr B.P., and for the younger beds, 120,000 ± 70,000yr B.P. (Hopkins 1973).

The type locality for 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 the Baldwin Peninsula (Hopkins, 1965). This 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 transgressive sediments are exposed along the Kukpowruk and Epizetka rivers (McCulloch 1967).

The Beringian Sea during the Einahnuhtan Transgression was slightly warmer than at present, with sea level approximately 20 m above present.

d. 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 and extended, as piedmont glaciers, several hundred kilometers in length and width across the lowlands to within 15 km of the coast near Kivalina (McCulloch, 1967). Although most rivers (such as the Kobuk and Noatak) were filled with valley glaciers, the ice probably did not extend seaward beyond the shoreline. The Hope Seavalley in the southern Chukchi Sea, for instance, indicates subaerial, non-glacial erosion (Creager and McManus, 1965) during various glacial episodes. The Yukon and Kuskokwim lowlands probably remained ice-free.

The Seward and Chukotka peninsulas were covered by ice caps during this period, and glaciers extended onto the continental shelf. Glaciers from the Chukotka Peninsula extended southward as far as 100 km into the Chirikov Basin (Nelson and Hopkins, 1969; Grim and McManus, 1970; Kummer and Creager, 1971). In southern Beringia mountains and highlands were covered with snow and valleys were filled with interconnected glaciers and ice fields which spilled over the lowland and spread onto the adjoining continental shelf due to increased atmospheric moisture from the south and southwest, and to lowered snow line as the result of depressed" summer temperatures.

At the height of the Illinoian Glaciation, shoreline receded seaward to the -135 m isobath and exposed about 80% of the Beringian continental shelf. Anomalous reflective sub-bottom features at 2-5 m along the -135 m isobath observed by Moore (1964) were initially interpreted as lava flows. Hopkins (1973), however, has 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. The overlying sediments represent detritus deposited during the Wisconsin Transgression, indicating that these beaches remained submerged during later regressions.

e. Sangamon (Pelukian) Transgression:

Following the Illinoian Glaciation the climate became warmer, triggering a marine transgression which climaxed approximately 100,000 years ago (Hopkins, 1967). Sangamon marine terraces and nearshore deposits are well preserved and are generally found landward of Holocene coastal deposits in areas which remained ice-free during Wisconsin Glaciation. These Sangamon deposits suggest two episodes of transgression separated by an intervening regression of several thousand years (Hopkins, 1973).

Evidence of the Sangamon Transgression is widely distributed in the form of terraces, generally found 5 to 10 m above 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 from Barrow, the Sangamon Transgression is commonly represented by narrow wave-cut terraces on steep, rocky shores, as described by Sainsbury _et al._ (1965) near Cape Thompson. 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 the transgression, in this area, was about 10-12 m higher than present sea level. The presence of ice wedge casts in deposits suggests that the rise of sea level was irregular and was interrupted by colder periods (McCulloch, 1967).

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

Major Sangamon deposits lie 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 sea level stood at about 10 m above present. The marine fauna suggests slightly warmer water temperatures than at present, and that considerable Pacific Water was contained in a northward flow similar to present circulation across the shelf.

f. Early Wisconsin Glaciation:

The events occurring in Beringia between the end of the Sangamon Transgression (approximately 70,000yr B.P.) and about 30,000 years ago are poorly documented and not well understood. The climate during this period was generally cold, though punctuated 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 remain obscure, though 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 sea level over Beringia during interstades did not normally rise above present sea level, sediments deposited during these stages remain submerged except in areas of uplift.

The lowering of sea level during the last glaciation caused the shoreline of Beringia to regress to the -90 m to -125 m isobath, thus exposing most of the shelf to subaerial erosion. On the Chukchi Shelf, the Hope Seavalley received the drainage of westward flowing rivers and extended westward and northward to 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 Creager and McManus (1967), who postulate that these features developed as a result of irregular sea level rise during Wisconsin Glaciation.

Drainage from the northeastern Chukchi Shore was carried north into the Arctic Ocean through Barrow Submarine Canyon. Interestingly, the watershed divide between the Chukchi and Bering drainages was located along St. Lawrence Island rather than at Bering Strait at that time. Therefore, part of the northern Bering Sea drainage flowed northward and was also carried into the Hope Seavalley.

On the Bering Shelf, the Kvichak and Kuskokwim rivers maintained a course illustrated by interconnecting 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 may have entered the Bering Sea through the Pribilof Submarine Canyon.

g. Mid-Wisconsin Transgression:

The Mid-Wisconsin Transgression, which flooded Beringia to within 15 m of present sea level, occurred about 25,000 to 40,000 years ago (Hopkins, 1973). The sea floor of Norton Sound, in the northeastern Bering Sea, consists of two topographic depressions, the major of which is a large east-west trending basin 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 these beds and channels 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 such deltaic sediments were probably deposited during the Mid-Wisconsin Transgression. .

In spite of its size, it appears that the Yukon River has frequently changed its course during glacial and interglacial stages, in ways that may not be reconstructible given our present level of information.

h. Late Wisconsin Glaciation:

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. Since this regression did not persist over an extended period, there is little evidence from which to reconstruct the geography of Beringia during this time.

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 (1975). 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, 1975). The radiocarbon date determinations of 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, 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, all of which suggest that the major drainage from the Alaska Mainland was carried southward. The Yukon River probably flowed along the eastern shores of Nunivak Island and into Pribilof Canyon, while the Kuskokwim and Kvichak rivers drained to the south and southwest, respectively.

i. 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 this Late Wisconsin Transgression are reconstructed primarily from 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, 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 -70 m; (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 submerged Po River valley extends 250 km and terminates at -100 m; and finally, (5) on the Sunda Shelf, between Borneo 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. Rising sea level during interglacial conditions resulted in the subsequent drowning of these river mouths and valleys. Changes in glacial regimen also resulted in changes of stream regimen, 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, 1711 N-17B, 1711 N-18M, 1714 -11B, 1714 N-12B, 1814-10B and unpublished data of the University of Washington, reveals that the shelf consists of three broad benches. 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 morphology 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 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 forefronts. Two prominent indentations in the -70 m isobath east of the Pribilof Islands, when traced shoreward, were unaccompanied by 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 northeast 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 Late Wisconsin Glaciation (22,000 yr B.P.), carried its discharge just south of the Pribilof Islands and debouched into the Bering Sea through Pribilof Canyon (Fig. 1-13).

Evidence for northward migration of the Yukon River during the Late Wisconsin Transgression has been presented by Knebel and Creager (1973), 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 Creager (1973), who suggest that the Yukon River flowed between St. Lawrence and St. Matthew islands between 11,000 and 16,000 years ago. Based on radioactive date determinations and foraminiferal assemblages, 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), sea level rose steadily from a low of about -70 m to -50 m. At this time Bering Strait and Anadyr Strait were flooded, separating the Asian and American land masses and admitting 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, slowing sea level rise and forming a prominent shoreline between the -60 m and -50 m isobaths on 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), indicating climatic warming. A modest glacial retreat about 13,000 or 14,000 years ago, likewise reflecting this trend, was followed by an advance in Beringia (Porter, 1964b, 1967; Ferrians and Nichols, 1965). The major shoreline along the -60 m and -50 m isobath was probably formed 14,000 to 13,000 years ago, with minor fluctuations during

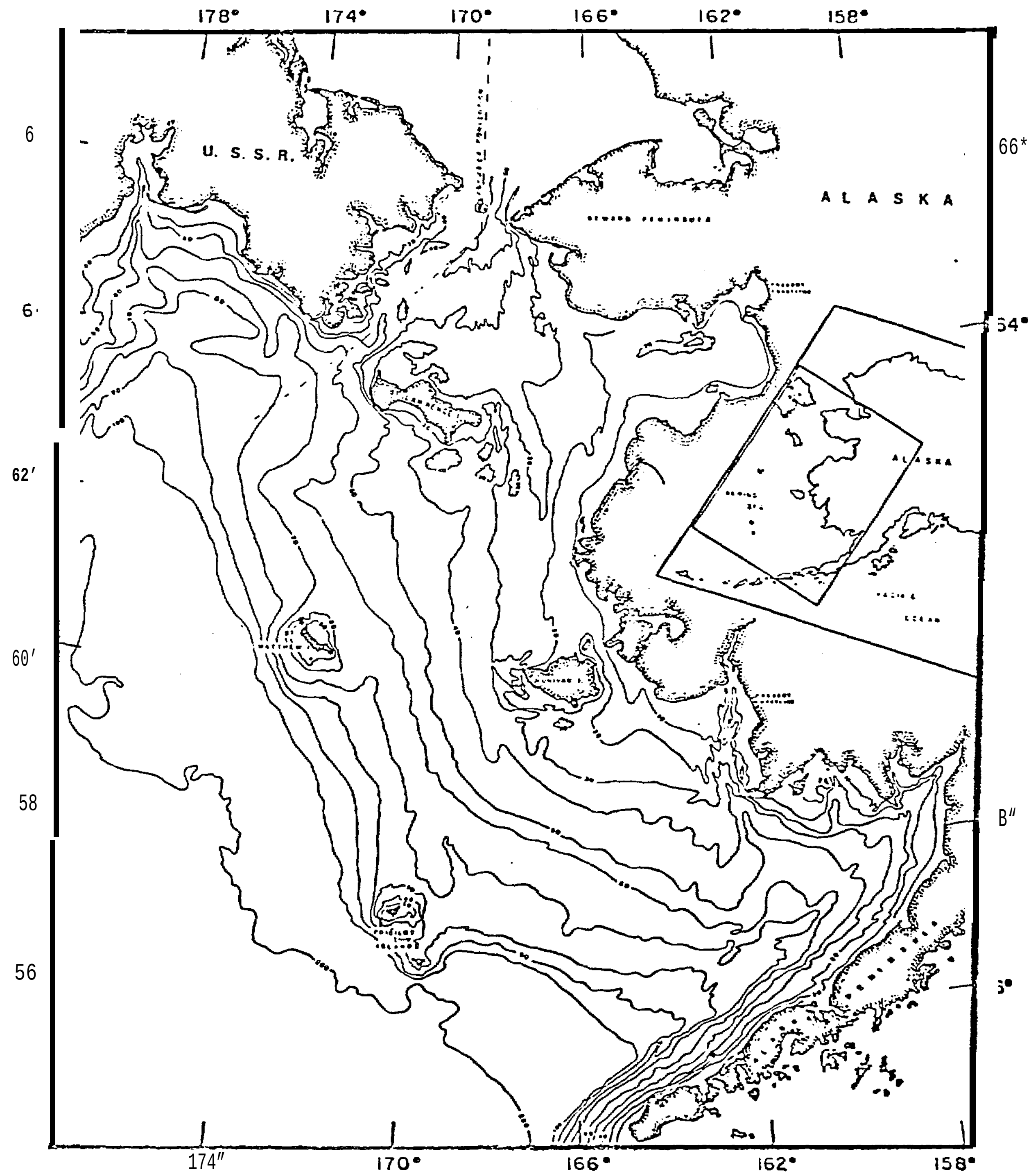


Figure I-13: Bathymetry of the Bering Shelf.

the period of 13,000 to 10,000 years ago. Sediments and fauna from deep-sea cores indicate that climate on a world-wide scale remained somewhat severe until an abrupt warming trend 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 (Shpanberg Strait) was 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 Shpanberg Strait, the northward-flowing water set up a strong current along the mainland which diverted the Yukon River discharge into the Chukchi Sea through Shpanberg 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.

After this minor interruption. sea level began to rise again 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. 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 Plain, with Mid-Wisconsin beach ridges near Point Barrow uplifted by tens of meters. The rebound in this area further complicates the reconstruction of paleogeography in the Chukchi Sea. Submerged sedimentary records along the eastern shore of the Chukchi Sea, especially along 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 to about -125 m. The final glaciation began about 22,000 years ago and, according to Kind (1967), lasted until about 12,900 years ago.. Marine sediments obtained from a long core from the southeastern Chukchi Sea and studied by Creager and McManus (1965) indicate that between 14,000 and 18,000 years ago sea level on the Chukchi Shelf stood between -55 m and -60 m. 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.

Creager and McManus (1967) further suggest that sea level in the Chukchi Sea began to rise about 15,000 years ago, with an interruption between 11,500 and 12,500 years ago when sea level stood at the -38 m isobath. Colder climates between 11,000 and 10,000 years ago, and from 11,700 to 8,700 years ago have been reported by McCulloch (1967) and Kind (1967) respectively. Most investigators concur that at 8,700 yr B.P. a warming trend started and continued until present. Concurrent with this warming trend, sea level in the Chukchi Sea rose steadily and culminated at about present level between 3,000 and 4,000 years ago.

2. 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 with rugged sea coasts.

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 which bound Bering Strait.

The Alaska Peninsula, to the south, rises gradually to an altitude of about 1,250 m and is dotted with volcanic cones of 1,500 to 3,000 m elevation. Extensive glaciation occurs, draining to the north through the lowlands. The lowlands contain numerous small and several large lakes, while the littoral zone generally consists of moraines and outwashes, often covered with contemporary sand and silt.

Bristol 'Bay, to the southeast, 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 Ahklum Mountains, which are steep, rugged and heavily glaciated.

Alaska's two largest rivers, the Yukon and the Kuskokwim, form a huge delta of sub-continental magnitude between the Kuskokwim Mountains and the Seward Peninsula. 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, while 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 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 is extensively glaciated. Drainage is provided mainly by two rivers, the Koyuk which flows eastward and south into Norton Bay, and the Kuzitrin which flows westward into Imuruk Basin-Port Clarence.

In the Chukchi Sea, the coastline extends northeast from Bering Strait to Kotzebue Sound, then northwest from Kotzebue Sound to Point Hope and, finally, northeast from Point Hope to Point Barrow. Dominating major coastal physiography is the western flank of the Brooks Range, which forms coastal promontories in the central Chukchi Sea. The eastern shoreline lies along 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 a large, shallow embayment in the southeastern corner, Kotzebue Sound. This 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, an area bordered by sea cliffs, there are numerous coastal lagoons and barrier islands formed by the longshore current which originates in the Bering Strait and hugs the Alaskan Mainland.

North of Point Hope, the coast follows 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 major 35° structural lineaments.

The coastal morphology in the northern Chukchi Sea is controlled by prevailing winds and resulting wave influences, resulting in 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 dominate the southwestern sections. The combined effect of these winds and waves results in a convergence of nearshore transport systems and a resulting accretion of land at capes or points, with divergence in the central part of the system where erosion of the shoreline is common.

3. Environmental Setting:

a. Introduction:

Beringia comprises an extremely large, shallow shelf extending over several 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 the world ocean), it contains approximately 3.7×10^6 km^3 of water. Its northern boundary is marked by a narrow (85 km), shallow passage between the Chukotka and Seward peninsulas, 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 the Aleutian island chain. Hydrographically, the Bering 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 geologic structures: the Alaska Orocline in the east and the Chukotka Orocline in the west.

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 this shallow shelf lies adjacent to Alaska and eastern Siberia. With the exception of several islands (the Diomedes, St. Lawrence, St. Matthew, Nunivak, the Pribilofs, Hagemeister, Round), the shelf floor is featureless, and displays flatness and slope uniformity to a degree that is extremely rare on other shelves of the world oceans.

The unusual features of the shelf are its width and 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 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 Shelf by Bering Strait, and in the north is bordered by an abrupt escarpment leading to the floor of the Arctic Ocean.

b. Bathymetry:

The regional bathymetry of the Bering Shelf has been described by Gershanovich (1963), Grim and McManus (1970), Kummer and Creager (1971), Sharma et al. (1972), Sharma (1972, 1974a, 1974b), Askren (1972), Knebel (1972), McManus et al. (1974). For the most part the shelf is extremely flat, with an average gradient of about 0.2/km (Fig. 1-13). 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, Shpanberg Strait, has two linear depressions separated 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 in part a result of the superimposition of younger Cenozoic rocks on older geological structures.

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 unmeasurable gentle slope (Creager and McManus, 1966). The major topographic features of the Chukchi Shelf are Herald Shoal, Cape Prince of Wales Shoal, and Point Hope Seavalley (Fig. 1-14). 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 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.

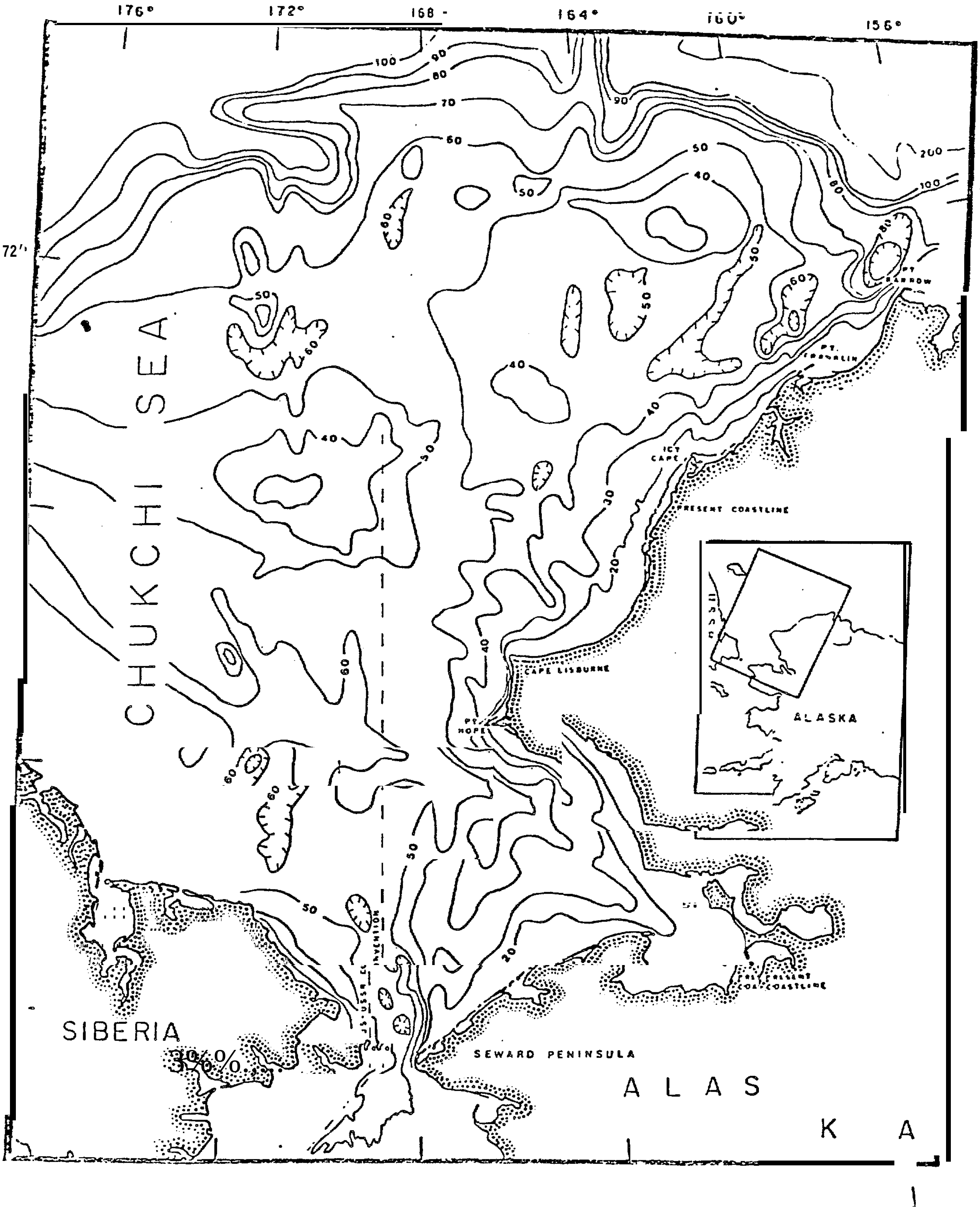


Figure I-14: Bathymetry of the Chukchi Shelf.

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 m to -58 m in the Hope Seavalley has been described as marine and deltaic deposits formed during a period of sea level stabilization (Creager 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 lower sea level stands, these sills must have emerged as large islands with prominent shorelines surrounding them.

c. Hydrology and Hydrography:

Most of the Bering Shelf lies in subarctic latitudes, where eye" onic atmospheric circulation predominates. The annual weather patterns are largely controlled by the Honolulu, Arctic and Siberian highs, and by the Aleutian Low. During summer, the Honolulu High occupies the northern Pacific Ocean and generates southerly and southwesterly winds in the eastern Bering Sea. With the onset of winter, the Honolulu High moves to the southwest and is replaced by a large, intense Aleutian Low. This shift permits movement of the Arctic High farther to southward and results in predominant northeasterly winds on the shelf. These seasonal winds significantly influence currents on the shelf, and influence 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. Storms intensify currents, sometimes reverse the general flow, and often destroy water stratification in shallow regions.

The shelf is influenced by the mild north Pacific Ocean and by the Bering Sea maritime climate to the south and west respectively, as well as by the cold continental subarctic climate to the east. The southern shelf is strongly affected by meteorological conditions prevailing along the Aleutians, with a consequently milder climate than prevails in the north. Cloudy skies, moderately heavy precipitation, and strong surface winds characterize shelf weather. Average summer temperatures vary from 10"C in Bristol Bay to about 8°C in Norton Sound; average winter minimums range from -14° to -18°C (Environmental Data Service, 1968). The annual precipitation is 600 mm on 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 the 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 percent 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 from California, Oregon and Washington combined. The significance of such a large discharge becomes even more apparent when it is considered that most of this discharge occurs 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. Shelf water conditions are highly variable during the summer. 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 downwelling of large volumes of water. Because 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, which is dominated during the summer by cold Gulf of Anadyr Water and during the winter is covered with sea ice; 2) The southern region between St. Matthew Island and the Alaska Peninsula, which is ice-free except when occasional severe winter conditions cause ice to form further south. The waters of both regimes are continually modified near the surface by river discharge and at depth by the shoreward movement of saline waters.

Ice conditions during winter in the northern regime are severe. Observations recorded over 30 years (U.S. Navy Hydrographic Office, 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 prevailing winds (Konishi and Saito, 1974). From January through April, ice in the region north of Nunivak Island covers between 80-90% of the sea surface. The ice begins to recede northward in May, and by early July is generally beyond Bering Strait.

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); and Favorite (1974).

The driving force for water movements on the shelf is a combined effect of wind, tide and surface runoff. The tidal range on the shelf is moderately low, ranging 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, 1973b). Under such meteorological conditions, 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. The 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 Bering Strait by Creager and McManus (1967).

The flow pattern of northward-moving Pacific water on the shelf is somewhat unclear. Many investigators have described the formation of various smaller gyres, particularly in the region 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 documented, no concerted attempts have been made to determine the intensity and the configuration of these currents or to determine whether these currents prevail throughout the year.

Oceanographic studies in the Chukchi Sea have been conducted by Saur et al. (1954), Aagaard (1964), Creager and McManus (1966), Fleming and Heggarty (1966), Coachman and Aagaard (1966, 1974), and Ingham and Rutland (1972). Water characteristics of the Chukchi Sea are dominated by three factors: 1) winter ice cover, 2) influx of Bering Sea Water, and 3) coastal surface runoff. Most of the year, the waters of the Chukchi Sea are covered with seasonal winter ice and polar pack ice. The ice begins to form in early October, with southward growth proceeding rapidly. By late October or early November, ice clogs Bering Strait. Break-up occurs about mid-June in the southern Chukchi Sea, when the 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 stress and extent of winter ice cover. Easterly and southerly winds tend to move the ice off shore.

The formation of annual ice and the extension of polar pack ice into the Chukchi Sea forms water masses typical of arctic regions. Ice cover keeps the water temperature of the near-surface layers close to the freezing point, 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 the Bering Sea Water.

Coachman and Tripp (1970) reported northward-flowing water through the Bering Strait of the order of $1 \times 10^6 m^3$/see, flowing under the impetus of a surface slope. 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 Bering Strait.

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

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

Water circulation in the eastern Chukchi Sea is dominated by Bering Sea Water influx, which sets up an almost permanent northward current, and by the local wind regime. Near surface and bottom currents in the south. eastern Chukchi Sea during August 1959 and 1960 have been described by Creager (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 (Creager, 1963). These current measurements were fairly uniform throughout the water column. Data revealed a general northward flow from Bering Strait which approximately paralleled the coast. Once past Bering Strait, the water flows in a north and northeast direction. One northeast flow proceeds along the northern coast of the Seward Peninsula to near the mouth of Kotzebue Sound, where it is deflected towards Point Hope. Near Point Hope it gains speed (50 cm/see) and merges with the northward-flowing component. After leaving Point Hope, the combined current again bifurcates. A branch of this northward flow continues west of Herald Shoal, while the main component 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 near-surface currents in the northern Chukchi Sea, are influenced more by regional winds than by northerly currents originating in Bering Strait. 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 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 by protruding capes and pcints generally causes separation of currents and formation of eddies past the cape. Evidence of an eddy northwest of Cape Prince of Wales has been reported by McManus and Creager (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 Heggarty (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.

d. Sedimentation:

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 textures different from that observed on the open shelf. Local textural anomalies in nearshore zones may result from river detrital input and exposure of relict glacial deposits.

The shelf deposits of Bristol Bay have been described in detail by Sharma (1972, 1974a, 1974b, 1979a) and Sharma et al. (1972). These studies show that 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. The floors of shore indentations and some bays are covered with yellowish-brown clayey silt and clayey, silty sand, whereas the open shore is generally mantled with pebbly 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 the 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). Sediments in this triangular-shaped region consist of sand, silty sand, sandy silt, and sandy, clayey silt. The eastern shelf, with a depth less than 60 m, is covered with sediments containing 75% or more sand. Westward, a narrow zone 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 isobaths) appear to be related to water depth: 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. Shorewards of this belt the percentage of silt in sediments increases rapidly. Offshore, however, the sand content increases and reaches a maximum (approximately 90%) between the -20 m and -40 m isobaths. Sediments with a predominant sand fraction also cover a large shallow bank south of St. Lawrence Island. The shelf sediments along the western periphery and southern region (north of St. Matthew Island) at depths in excess of 40 m, consist primarily of silt with minor components of sand and clay. Locally isolated patches of gravel and gravelly sand 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. Sand and silt components predominate and complement each other in the sediments.

The sediment mean size and isopleths in the nearshore region run parallel to the isobaths but 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 sediment sources.

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 Bering Strait to the north and by a 46 m deep sill across Shpanberg Strait, between the Alaskan Mainland and St. Lawrence Island. 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 offshore of Nome have been studied in detail by Creager and McManus (1967), McManus et al. (1969), Venkatarathnam (1969), Nelson and Hopkins (1969), McManus et al. (1974), and Sharma (1974a, 1974b, 1979a).

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 Shpanberg 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, 1969 ; Sharma, 1974a, 1974 b).

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 Alaskan Mainland extending from Cape Romanzof to eastern Norton Sound is mantled with silt. 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 near-shore areas and in proximity to major sediment sources, while silts and clays are deposited offshore. Clay content in sediments is generally minor, varying between 5% and 35%.

Sediment distribution in the southeastern Chukchi Sea has been described in detai 1 by Creager (1963). The results of sediment analysis of over 475 samples from the entire Chukchi Sea have been discussed by Creager and McManus (19.66), and McManus et al. (1969).

Sediments in the Chukchi Sea grade offshore from sandy gravel to sandy, clayey silt. Bering Strait, the southern extremity 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, Cape Prince of Wales Shoal (McManus and Creager, 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, while between Cape Lisburne and Point Barrow the entire nearshore area consists of sand with gravelly offshore bars which create numerous coastal lagoons.

Coarse sediments with mostly sand and grave? are also often found on and around Herald Shoal in the central Chukchi Shelf. This northwest oriented shoal lies between Cape Lisburne and Wrangell Island at a depth of less than 40m. 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 does 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, while in shallower regions, silty sand is common.

Sorting of sediments is related primarily to water energy. In areas of intense currents and wave action, 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). These authors suggested that sand deposition along the northern shores of the Seward Peninsula is controlled by wave-sorting, while sand deposition near the mouth of Kotzebue Sound is 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 to be 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 as particles settling from the wash load of the shelf surface and bottom turbid waters.

4. Paleoshorelines:

Though a previous study (Sharma, 1976) delineated only 3 levels of paleosealevel stillstand on the Bering/Chukchi Shelf, it is obvious that the six still stand levels defined from later work in the Gulf of Alaska (-28 m, -38 m, -55 m, -66 m, -82 m, -125 m) would have pertained to this region as well. Figures 1-15 through I-26 depict shorelines of the Bering and Chukchi seas during these various stillstands.

E. Northwestern Gulf of Alaska

1. Introduction:

The Northwestern Gulf of Alaska Shelf lies between 59° - 56° N latitude and 148° - 164° W longitude. The shelf has a series of northeast-southwest oriented islands, the largest of which is the Kodiak-Afognak island group. These islands bisect the shelf, forming the 300 km long and 40-65 km wide Shelikof Strait. Southeast of Kodiak Island, the shelf is bordered by the volcanic arc of the Alaska Peninsula (Fig. I-27).

Characteristically, the shoreline of the shelf is young and rugged, its steep mountainous terrain and a highly irregular coastline indented by bays, inlets, lagoons, and fiords. The shelf is widest in the northeast, about 250 km, narrowing southwestwards to about 50 km near Umnak Island. Throughout its length, the shelf contains troughs and valleys and is dotted with islands of various sizes.

Seawards, the continental margin descends steeply to the Aleutian Trench. A unique feature of the slope is its steep gradient; from the edges of the shelf it drops more than 5,000 m to the trench.

2. Geology:

During the Pleistocene this shelf was repeatedly glaciated by ice which descended from the ad.i.scent mountains and extended on to the lowlands. Substantial glaciation of the region is obvious from the fiord-indented coastline. During major glacial advances the sea level receded towards the shelf margin, with ice covering part of the shelf. Sediments eroded by the glaciers during low sea levels probably were deposited on the shelf and in the trench.

Contemporary sediments on the shelf form a thin, irregular veneer ranging to a maximum of tens of meters in thickness. Shallow banks are generally either devoid of, or have a minimal amount of, contemporary sediments, with maximum thicknesses accumulated in depressions.

3. Bathymetry:

The Northwestern Gulf of Alaska Shelf is characterized by numerous islands, plateau-like surfaces and sea valleys. The islands are generally found in the nearshore zone which forms a narrow belt adjacent to the coastline and ending seaward between the -30 m and -50 m isobaths. Numerous inlets and fiords are also found in this zone. The shallow zone is actively eroded by wave action.

Offshore, the main part of the shelf, between -50 m and -200 m isobaths, contains large, broad, plateau-like surfaces with banks. The plateau-like surfaces have a low gradient of 1 to 5 minutes. These

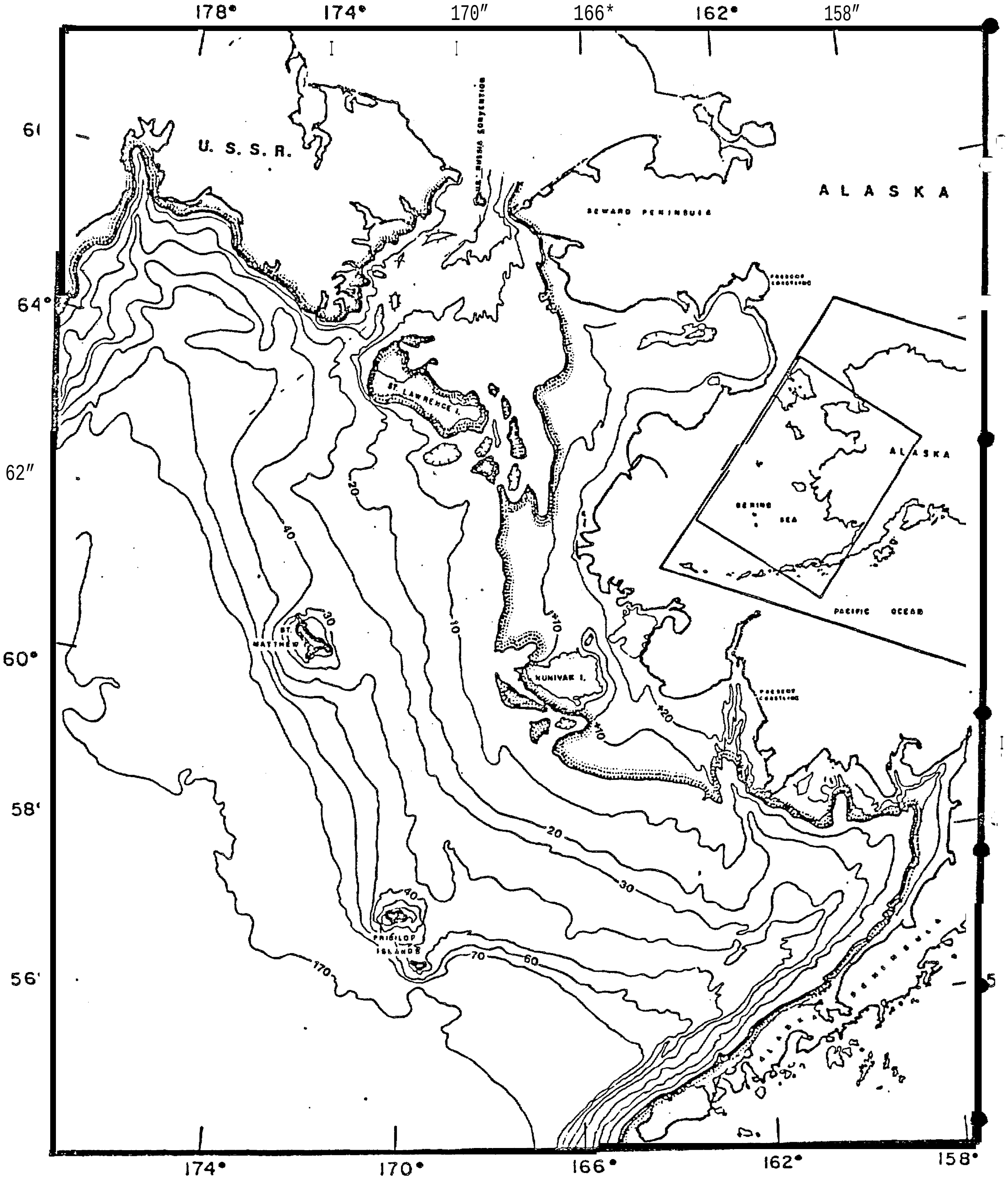


Figure 1-15: Bering Shelf, -28 m still stand. Former isobaths and land elevations (indicated by "+") given in meters.

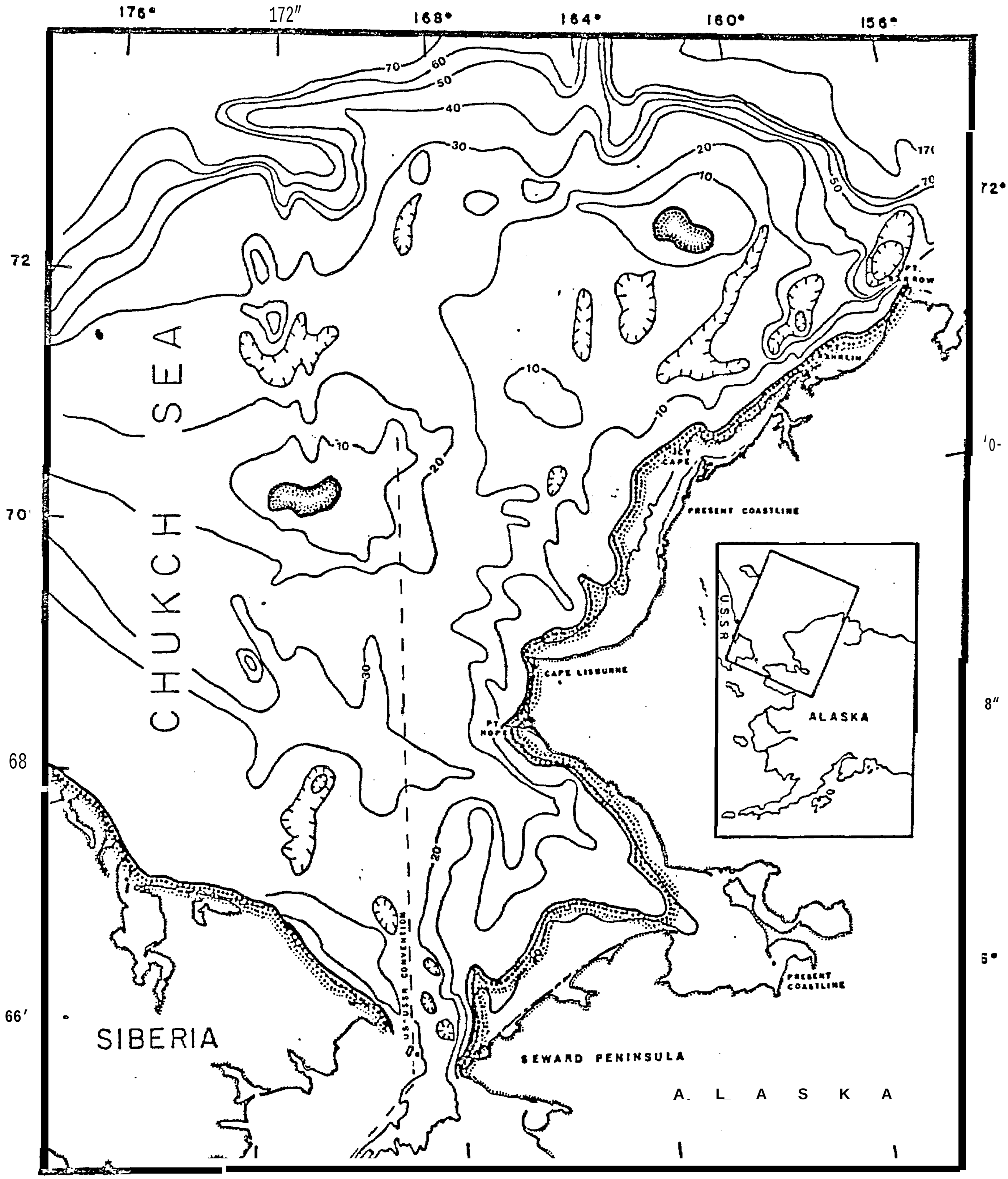


Figure 1-16: Chukchi Shelf, -28 m still stand. Former isobaths and land elevations (indicated by "+") given in meters.

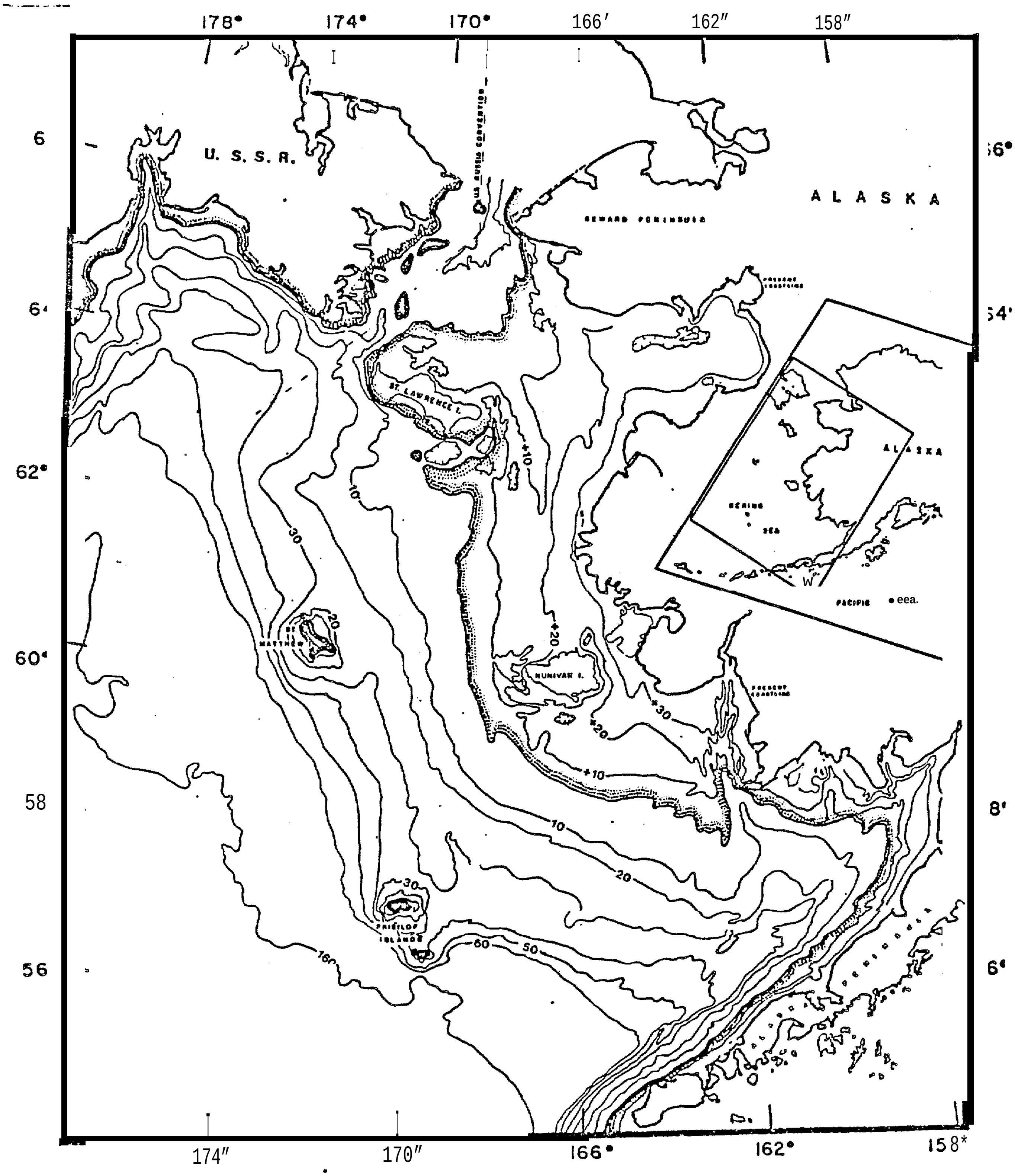


Figure I-17: Bering Shelf, -38 m still stand. Former isobaths and land elevations (indicated by "+") given in meters.

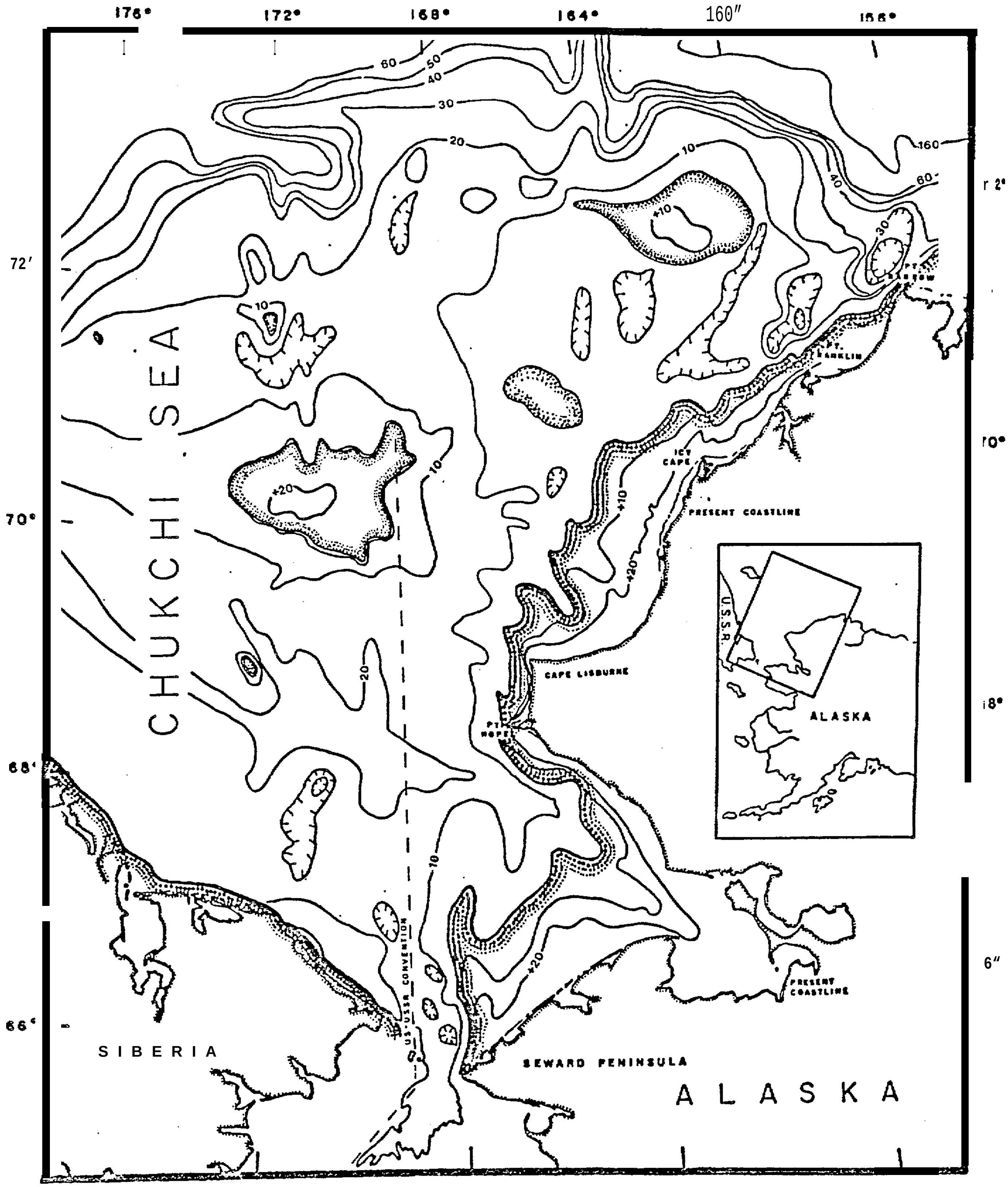


Figure 1-18: Chukchi Shelf, -38 m still stand. Former isobaths and land elevations (indicated by "+") given in meters.

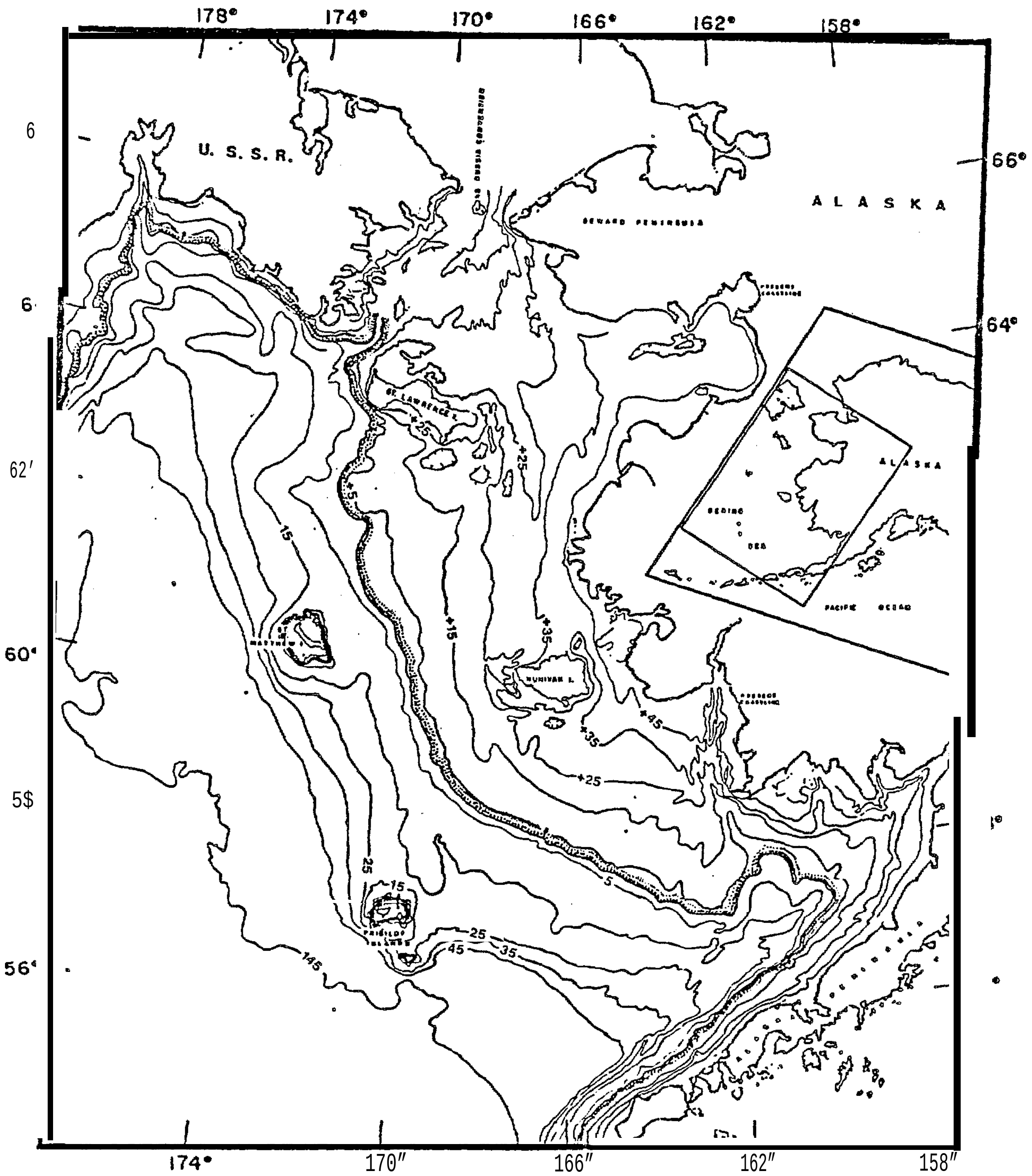


Figure I-19: Bering Shelf, -55 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

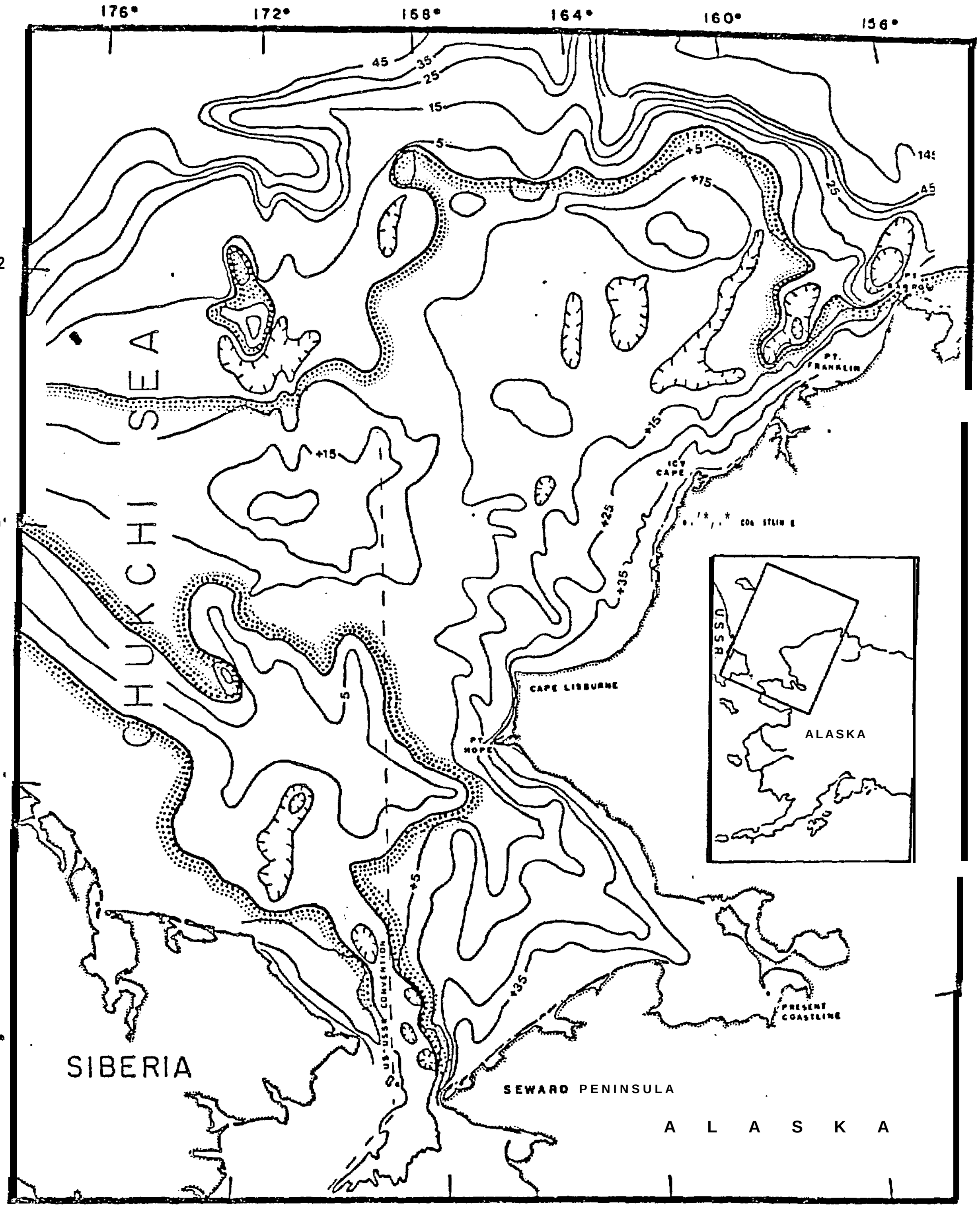


Figure 1-20: Chukchi Shelf, -55 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

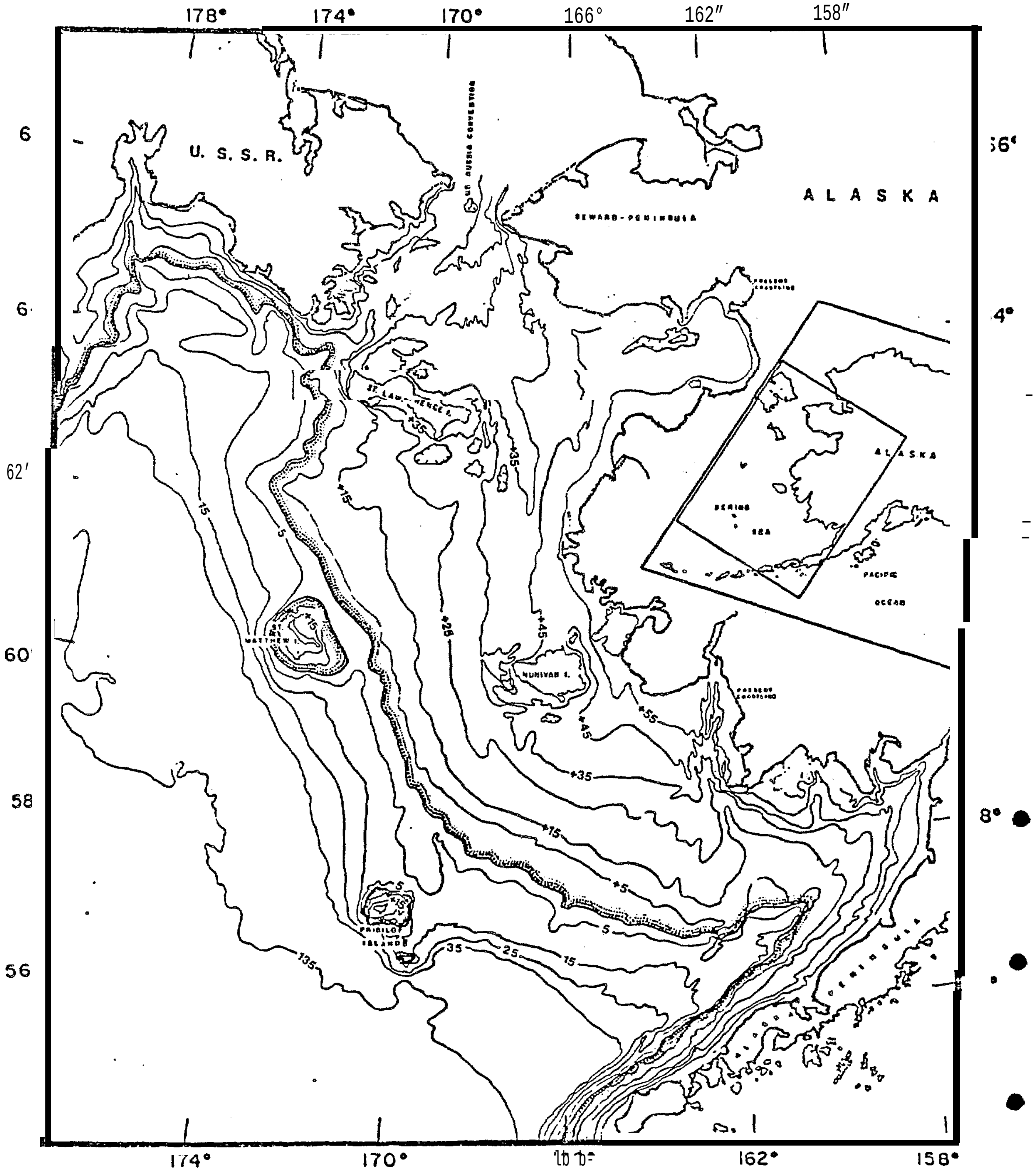


Figure 1-21: Bering Shelf, -66 m still stand. Former isobaths and land elevations (indicated by "+") given in meters.

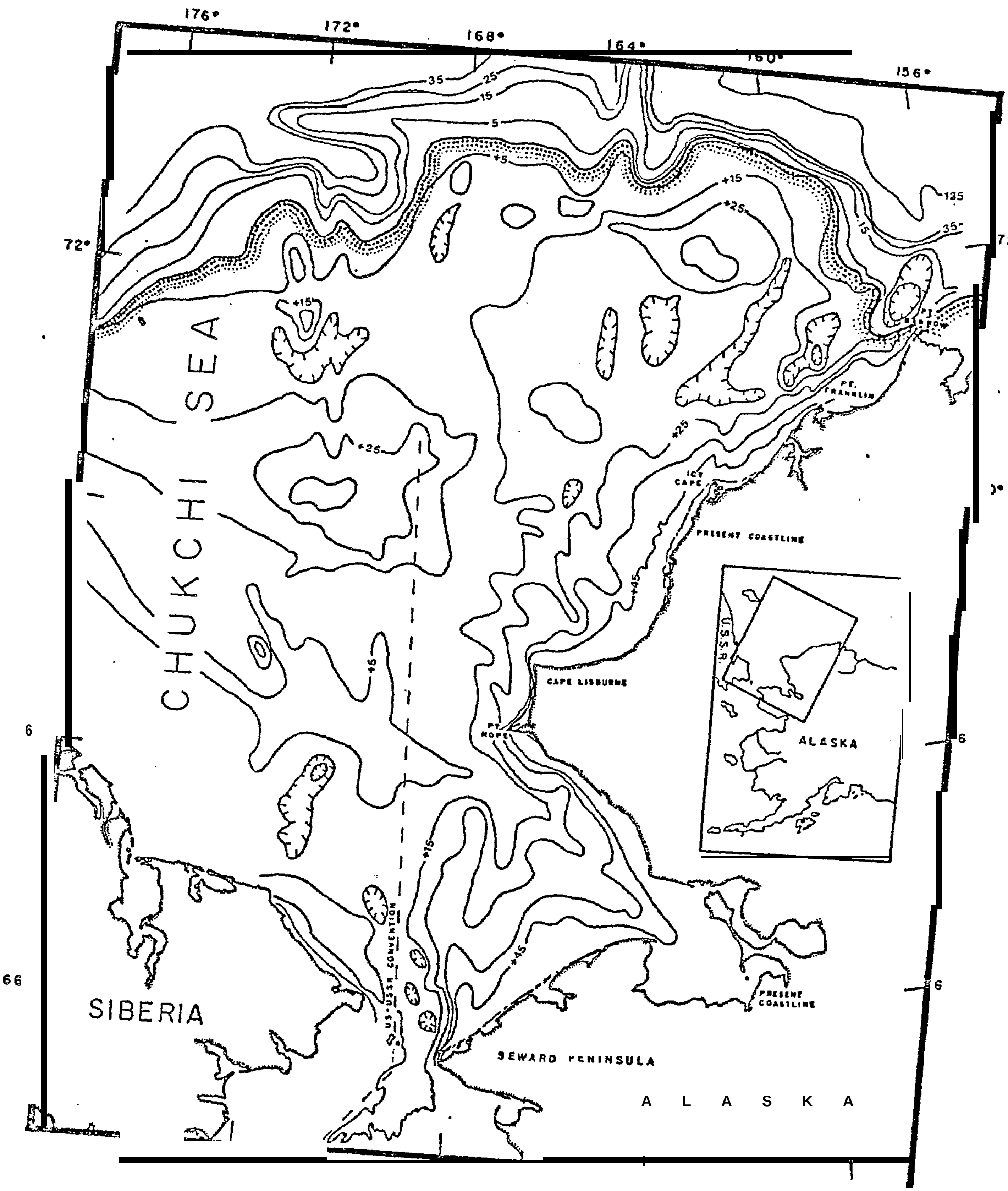


Figure I-22: Chukchi Shelf, 66 m still stand, isobaths and land elevations (indicated by "+") given in meters

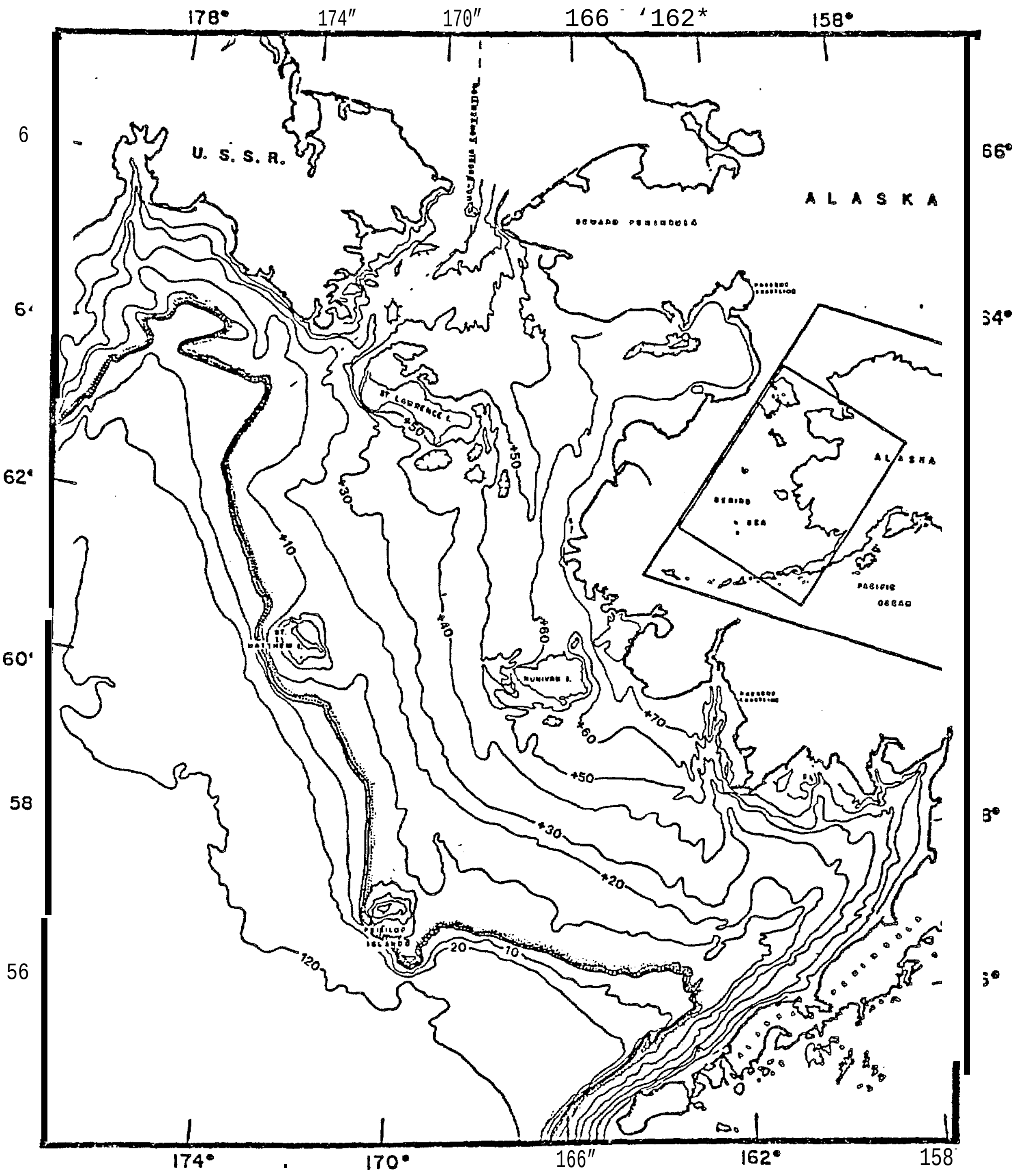


Figure 1-23: Bering Shelf, -82 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

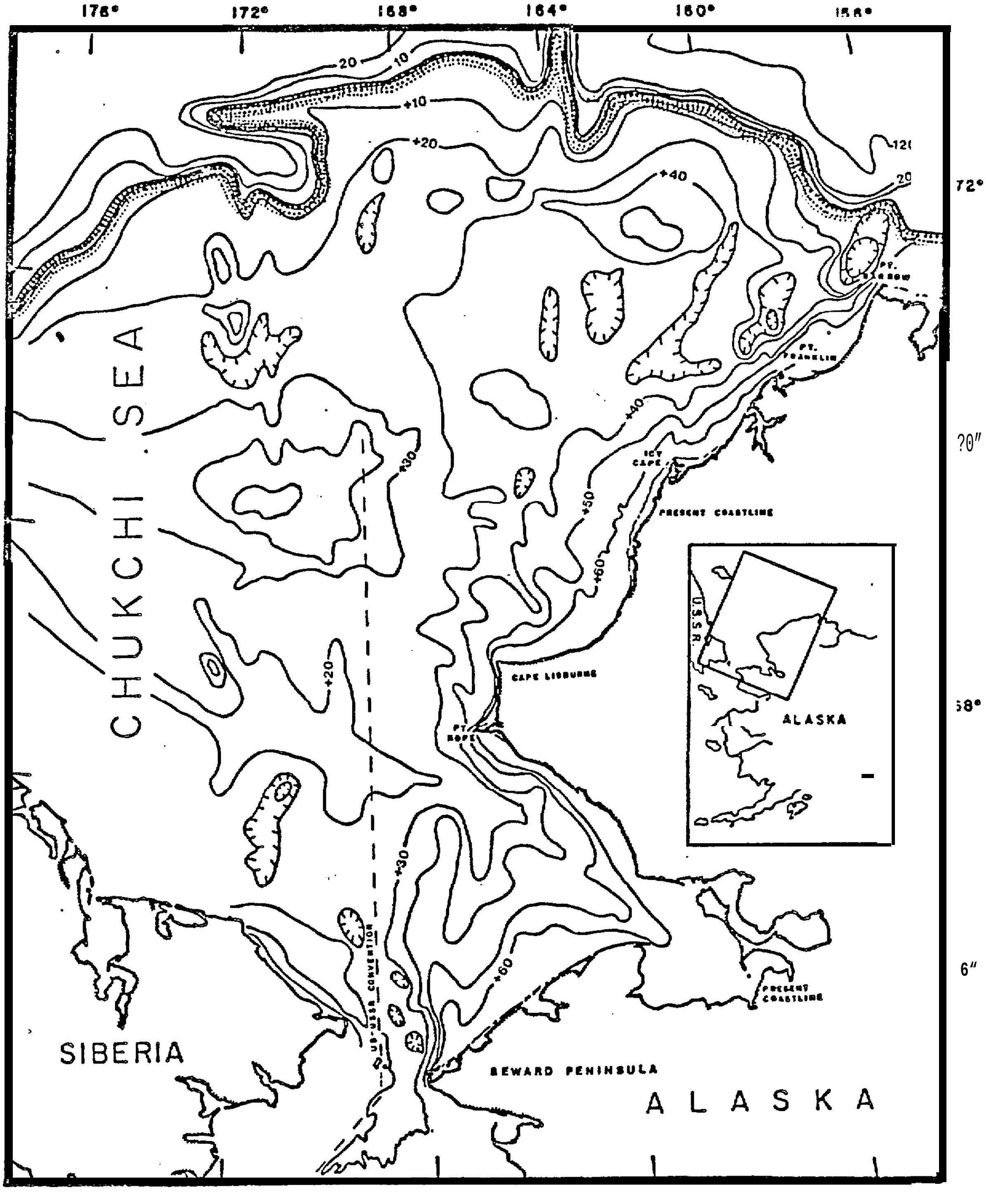


Figure I-24: Chukchi Shelf, -82 m still stand. Former isobaths and land elevations (indicated by "+") given in meters.

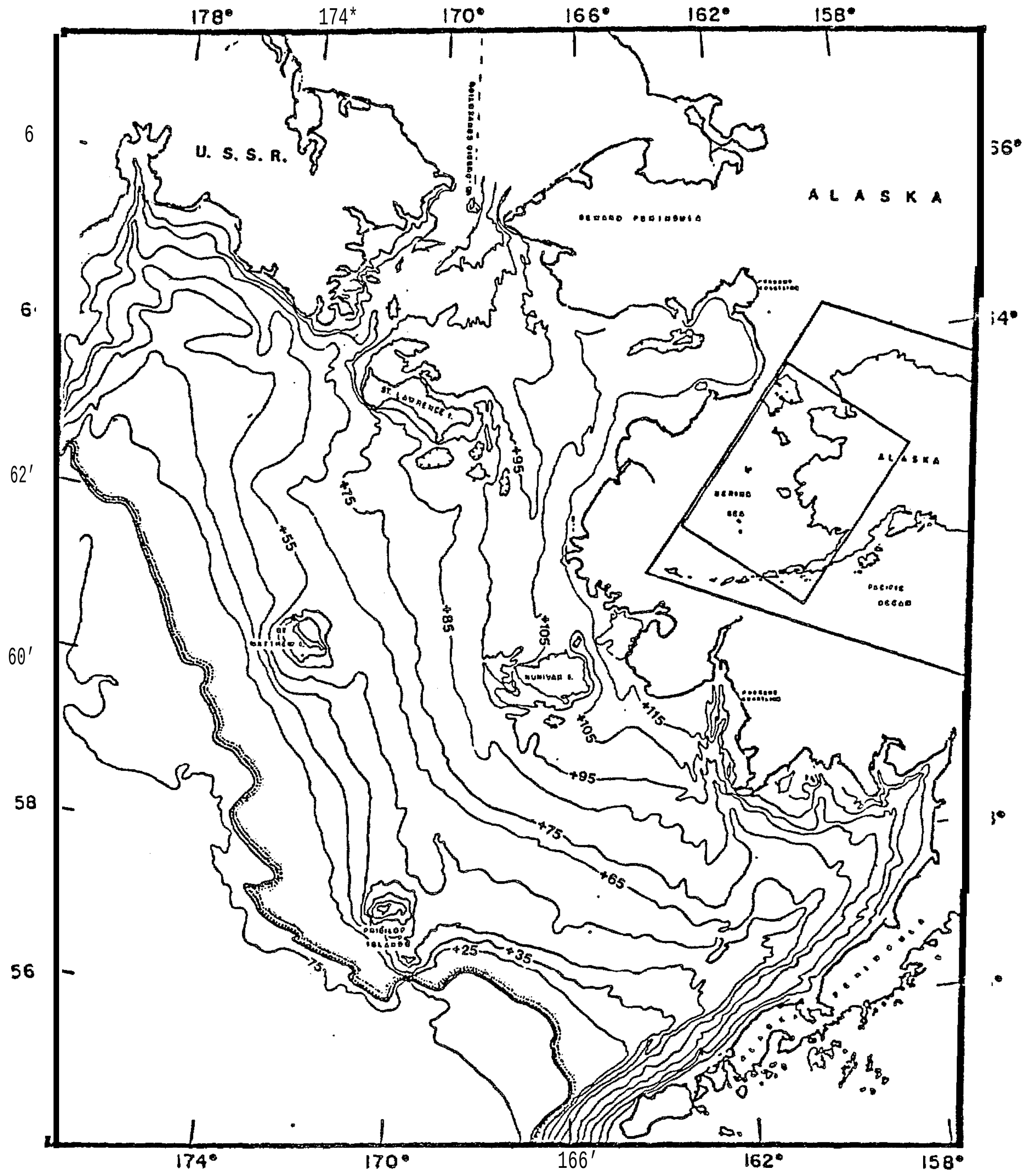


Figure I-25: Bering Shelf, -125 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

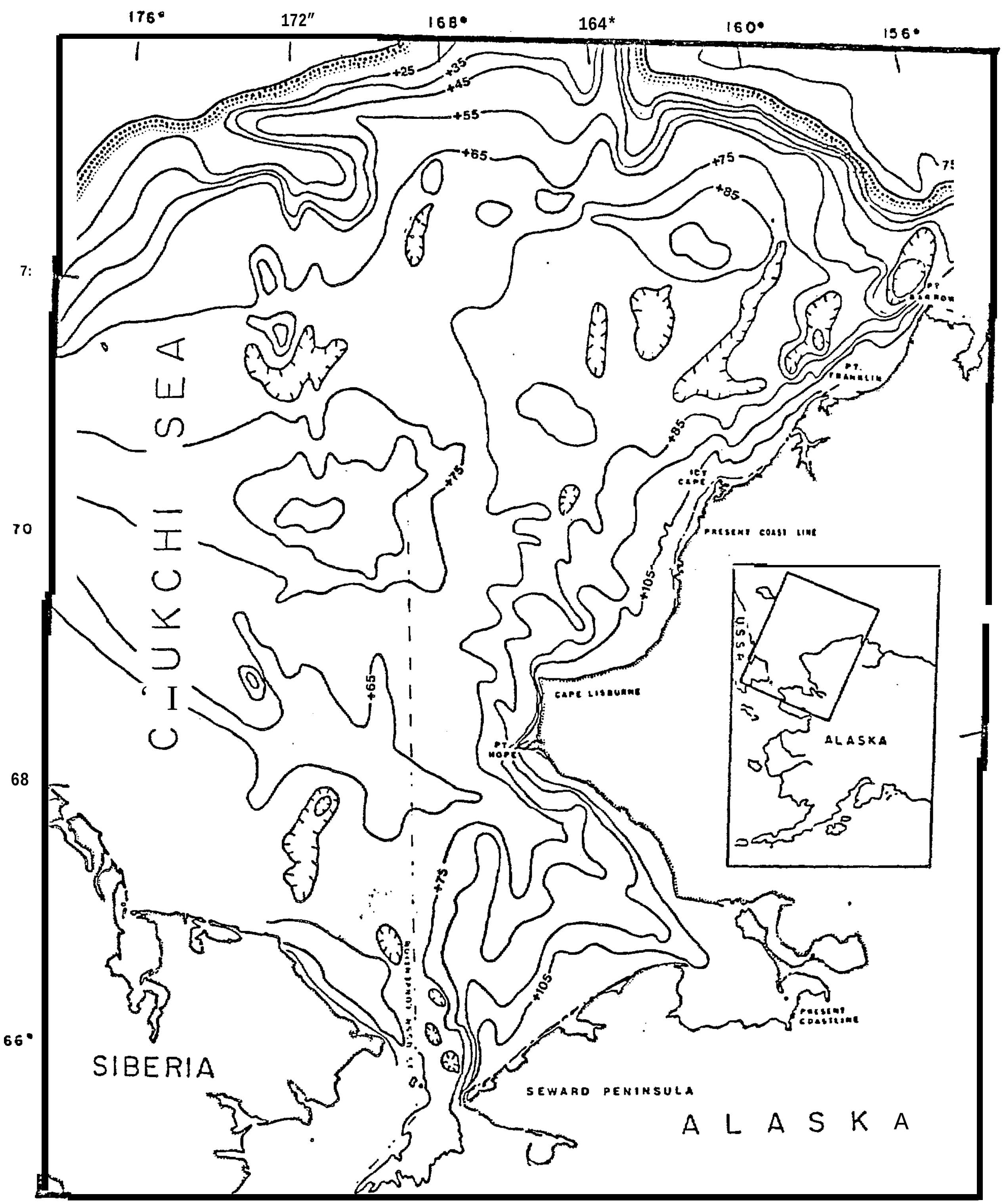


Figure I-26: Chukchi Shelf, -125 m still stand. Former isobaths and land elevations (indicated by "+") given in meters.

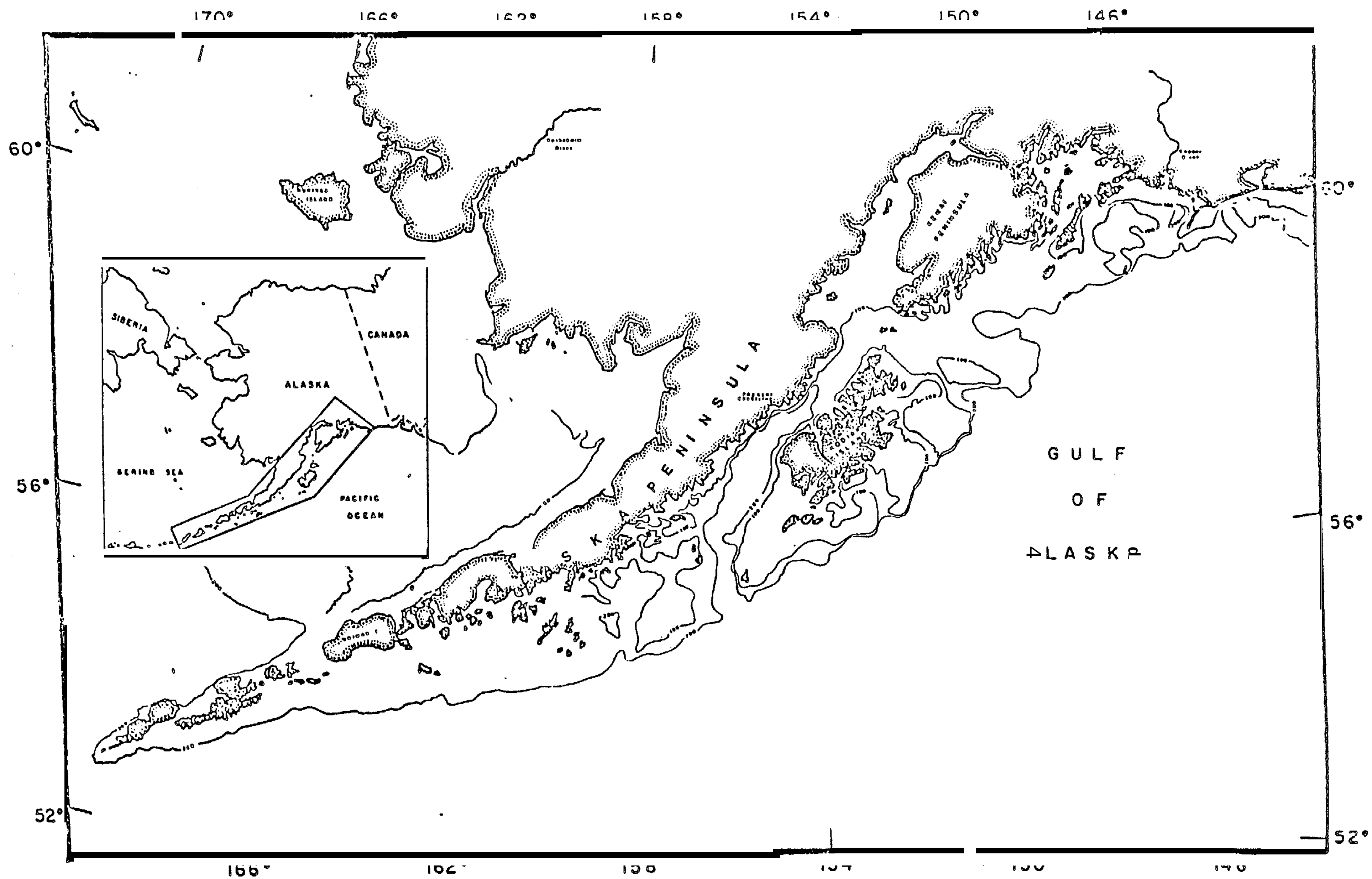


Figure I-27: Gulf of Alaska and North Pacific Shelf bathymetry.

relatively smooth surfaces, however, are interrupted by many banks and shoals that rise, often abruptly, sometimes breaking the surface to form islands. The plateau-like shelf also includes a few depressions which are important clues to paleosealevel stands.

Sea valleys and fiords on the shelf are either aligned essentially parallel to the shelf length or cut across the shelf. Those which run parallel or subparallel to the shelf are generally broad and flat-bottomed, with steep sides. The large size of these valleys suggests that they may have resulted from erogenic plate movements. Fiords generally traverse the shelf width, extending seaward from bays and inlets along the nearshore zone. These U-shaped valleys are only 10 to 50 km wide, and vary greatly in length. The longitudinal profile of such fiords generally shows the deepest part in the middle, as is typical of glacially formed channels.

4. Stillstands:

The rise in sea level accompanying melting of glacial ice generally results in sediment deposition on the shelf. During peak glaciation river influx, though minimal, is stable. During an interstate, the recession of glacial ice results in increased river drainage and increased river flux, overwhelming the carrying capacity of nearshore marine processes.

During an **interstadial,** stabilized sea level establishes a firm shoreline. Depending upon the duration of stable sea level, wave action along the shoreline will erode sediments to form a terrace. The eroded material accumulated in the nearshore region remains an identifiable deposit. In particular, stationary shoreline will invariably actively erode the intervening sill between two basins so as to interconnect the basins and to form a basin enclosure at that level. This process is further enhanced by tides, which often generate swift currents over sills.

Assuming that sea level during post glaciation was intermittently stabilized, the shoreline should be closely fixed in altitude and extend over large areas. These sea level stands should be manifested by their related sedimentary deposits and other bathymetric features. Consistency in the distribution of sedimentary deposits and bathymetric features is extremely important and fundamental to the establishment of the phases of stable shoreline.

The data obtained from the bathymetric charts unequivocally and categorically demonstrate that almost all basin enclosures and nearshore deposits occur along six submerged horizons. These levels are: -125 m (68 fro), -82 m (46 fro), -66 m (-36 fro), -55 m (30 fro), -38 m (21 fro), and -28 m (15 fro).

Clearly, some of the submerged features do not precisely follow these horizons. However, these deviations are relatively few and do not exceed ± 3 m from the norm. These variations are comparatively minor and are probably caused by one of three factors.

Primarily, the bathymetric charts from which data were obtained provided depths in fathoms. Because depths were given in whole numbers (fathoms) the conversion to meters will inevitably result in error of ± 1 m. Depending upon the morphology of the nearshore shelf and coastline, the height of washing by surf during exceptional storms should vary along the coast, Generally, shoreline facing open ocean is subjected to frequent storms and surges, with larger wave length and deeper wave action. In these regions the erosion by wave action is clearly much deeper than along protected shorelines. Location in relation to wave action will undoubtedly cause variation of up to 2 m. Similarly, in regions with tidal amplification the surf zone should be much higher than normal.

Finally, in some regions, accumulation of sediments may be higher than other regions because of local high detritus flux, as undoubtedly occurred in regions covered by volcanic ash. Differences in depositional rate may therefore cause minor deviations in relation to the six horizons listed.

5. Discussion:

Marine geologists have mostly used submerged landforms and deposits as a guide to paleosealevel stand. With the aid of pollen analysis, deep-sea sedimentation, ^{14}C dating and various other isotopic measurements, they have obtained a fairly detailed time-scale for at least the last major ice advance and retreat. A general chronology for sea level stands has been developed and is subject to continual refinement and revision. When no actual dates are available, correlation can be based on relative depths of bathymetric features. Determination of an eustatic curve primarily based on the bottom morphology requires a so called "stable area." But if well-defined shoreline position displacements are consistent over large areas, the problems of tilting and isostasy become minor.

The glaciated shelf off the Alaska Peninsula and Kodiak Island has well preserved paleo-landforms and deposits. These submerged geomorphological features invariably occur at six horizons, with remarkable conformity throughout the shelf, and include erosional as well as depositional features. The most prevalent erosional features are benches and sills. The entire shelf, as a result of glaciation, has numerous fiordal basins separated by sills at various depths. Because of their combined structural and glacial origin, these linear basins are not always graded seaward and usually have reverse slopes. The most important and intrinsic character of the intervening sills is that they crest only at one of the six horizons.

The most significant submerged depositional features for the purposes of this research within the study area are the extensive flat regions, or sills. Large flat areas are widely distributed, and were probably formed by nearshore processes at a time of lower sea levels. These flat areas are mantled with sand, and consistently occur only at water depths which closely correspond to sill depths.

The now-submerged shoreline features of the transition period between late glacial regression and post glacial transgression are well preserved and were easily recorded over the entire area investigated. Certain bathymetric features, such as depressions along the axes of fiords, provide the most reliable evidence for sea level stands.

The basins along the entire shelf exhibit closure uniformly at the same levels: -28 m, -38 m, -55 m, -66 m, -82 m, and -125 m. This suggests that sea level stood stationary for considerable periods of time in order to form these closures. The continuation of each horizon along the entire shelf also indicates that the shelf has been fairly stable. It is, therefore, safe to assume that these horizons represent shorelines dating to periods of glacial advances and subsequent glacial retreats.

The period of Late Wisconsin and Holocene transgression was climatically very erratic, so that the sea level history is complex. Fluctuations of sea level during this epoch have been postulated by numerous investigators, and many of these fluctuations have been chronicled on the basis of radiocarbon dating. We shall attempt to correlate each of the horizons to those dated elsewhere.

The sea level curve of Curray (1960, 1961) showed a low stillstand at -27 m about 8,700 yr B.P. This corresponds well with a -28 m sea level stand indicated by sedimentary features on the shelf in the Gulf of Alaska. Zenkovitch (1969) reported that during the Wurmian regression the Black Sea was isolated from the ocean at about -40 m. The change from lake stage (neoeuxinic state) to marine state (the transgressions of the -40 m level) has been ^{14}C dated at 9,400 ± 220 yr B.P. A period of syngression in Europe, with a eustatic level -38.0 to -38.5 m, has been dated between 9,330 and 9,770 yr B.P. (Morner, 1970). Both -28 m and -38 m sea level stillstands in the Gulf of Alaska represent the Friesland oscillation. Evidence for a stillstand in Laptev Sea at -55 m depth has been obtained by Holmes and Creager (1974). Creager and McManus (1965) similarly found bathymetric evidence for a sea level stand at -53 m in the Chukchi Sea.

About 13,750 yr B.P. according to Morner (1970), sea level stood at -66 m. Soon after, a drastic global climatic change from the Vintapper interstadial to the low Baltic stadial took place at about 13,100 yr B.P. The rate of rise in sea level during this period is estimated to be 1 m/100 years (Morner, 1969), until sea level again stabilized at -55 m at about 12,700 yr B.P. Both of these sea levels left imprints on the Gulf of Alaska Shelf and probably represent climatic change during the Allerod period.

From 14,800 to 15,000 yr B.P. a major glacial regression of global proportions took place. It is postulated that this period represents the -82 m sea level stand in the Gulf of Alaska. A stillstand of sea level during this period has been also shown by Curray (1960, 1961, 1965).

The lowest sea level in the Gulf of Alaska was observed at -125 m, corresponding to the Late Wisconsin peak glaciation between 21,500 and 18,000 years B.P. (Mill iman and Emery, 1968).

The chronology of sea level stands in the Gulf of Alaska as described is tentative. Though the evidence for various sea levels is fairly conclusive, features relating to each of the sea level stands have not been dated, making it impossible to ascertain their sequence. Furthermore, it is not certain that all of these sea level stands occurred during the last glacial ice retreat. Shorelines for the Gulf of Alaska, projected for various stillstand levels (-28 m, -38 m, -55 m, -66 m, -82 m, -125 m), are depicted in Figures I-28 through I-45).

6. Distribution of Ice and Sequence of Glaciation:

Submerged marine geomorphic features interpreted as evidence of previous sea level stands are widespread along the Kodiak and Alaska Peninsula shelves. Most important are the wave cut basin enclosures (sill

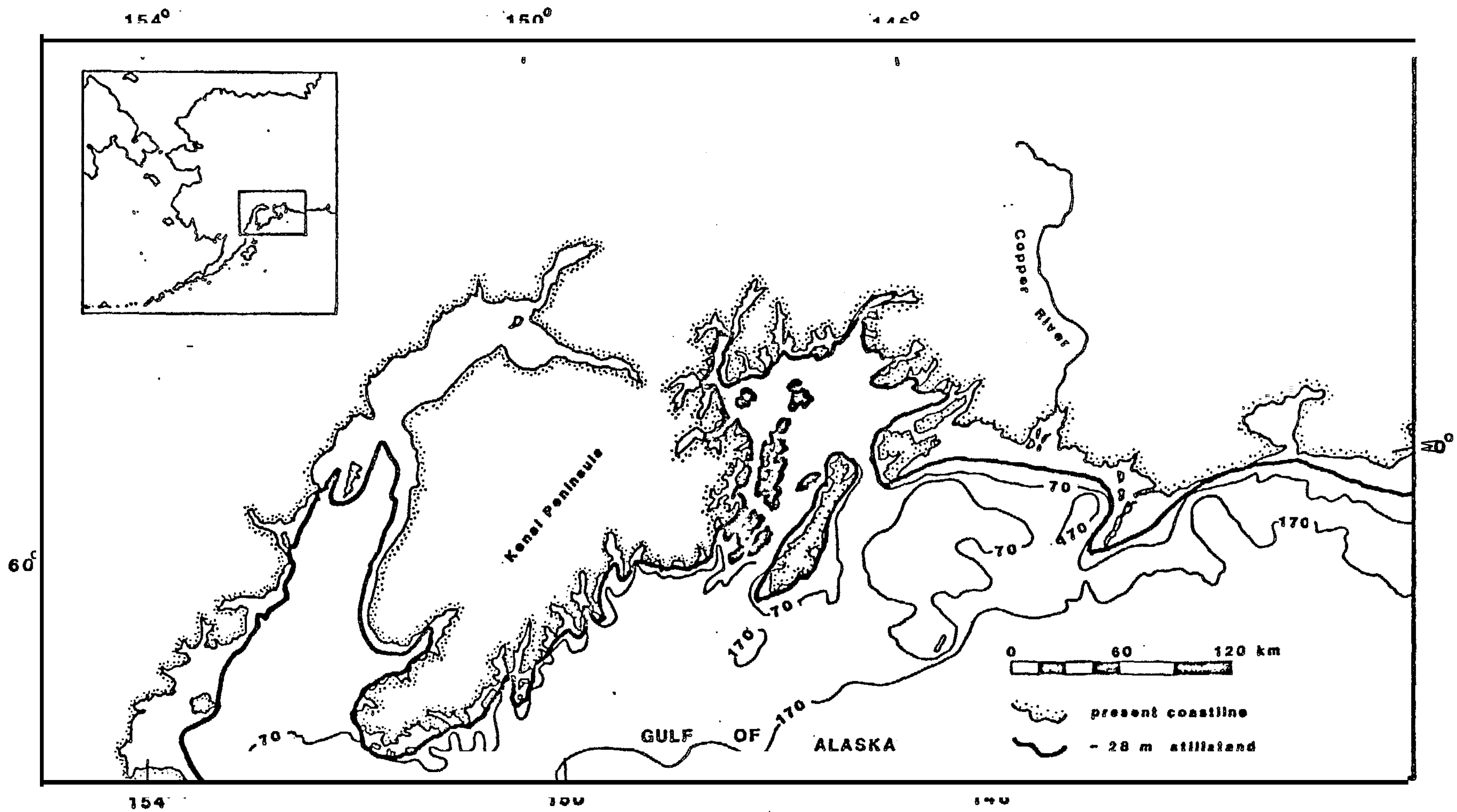


Figure I-28: Gulf of Alaska Shelf, -28 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

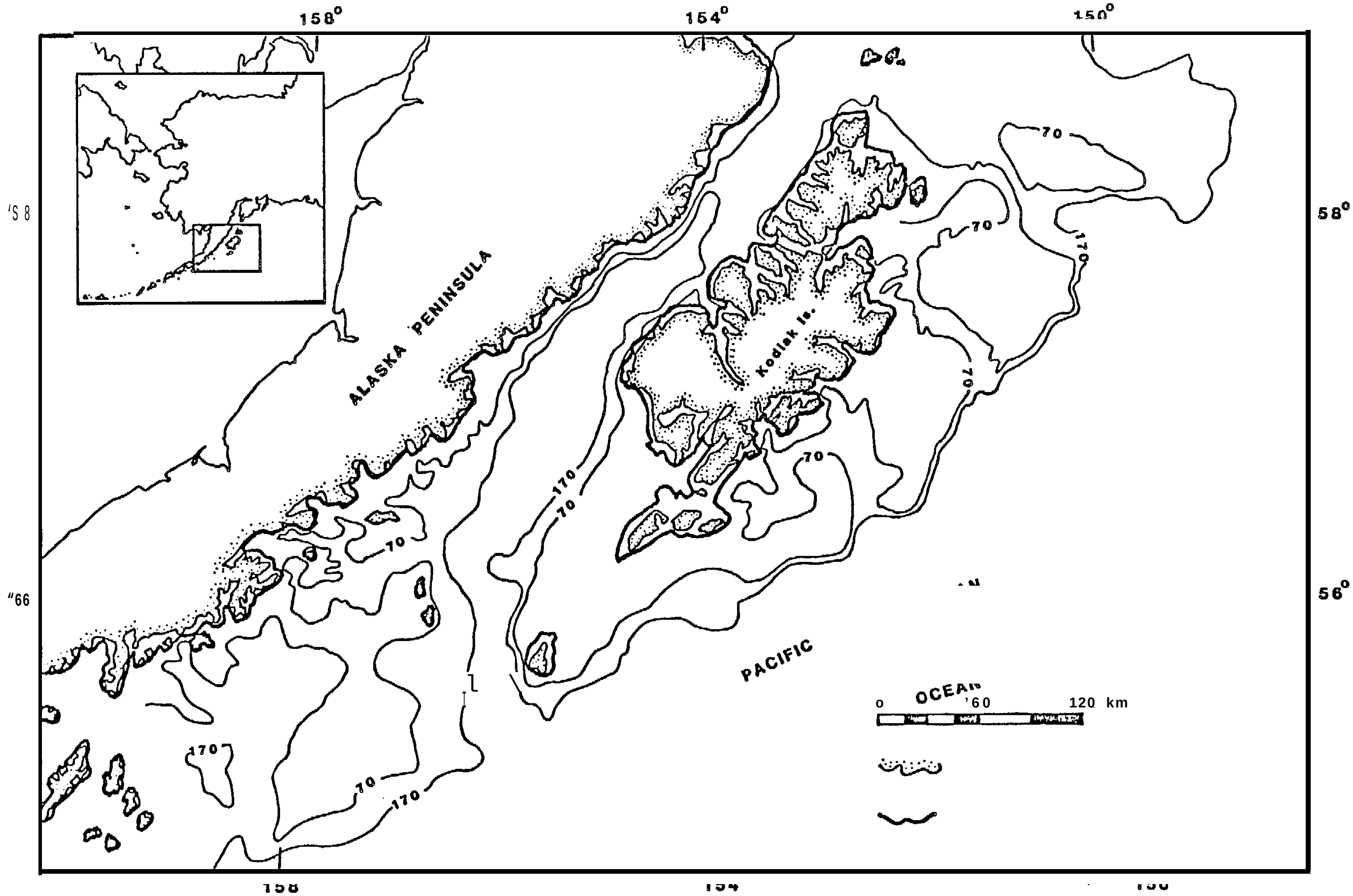


Figure I-29: Kodiak and Alaska Peninsula shelves, -28 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

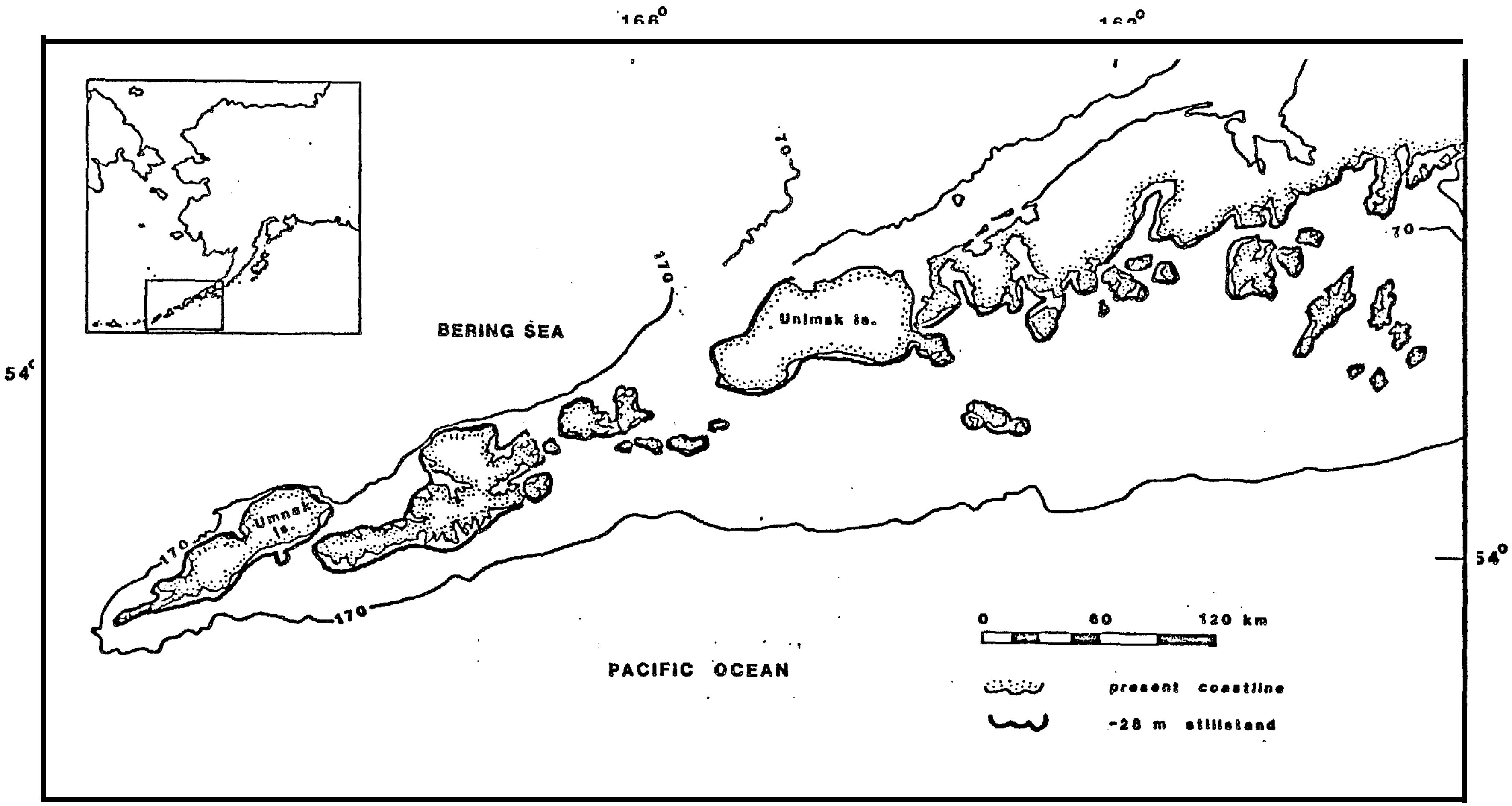


Figure I-30: Aleutian Shelf, -28 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

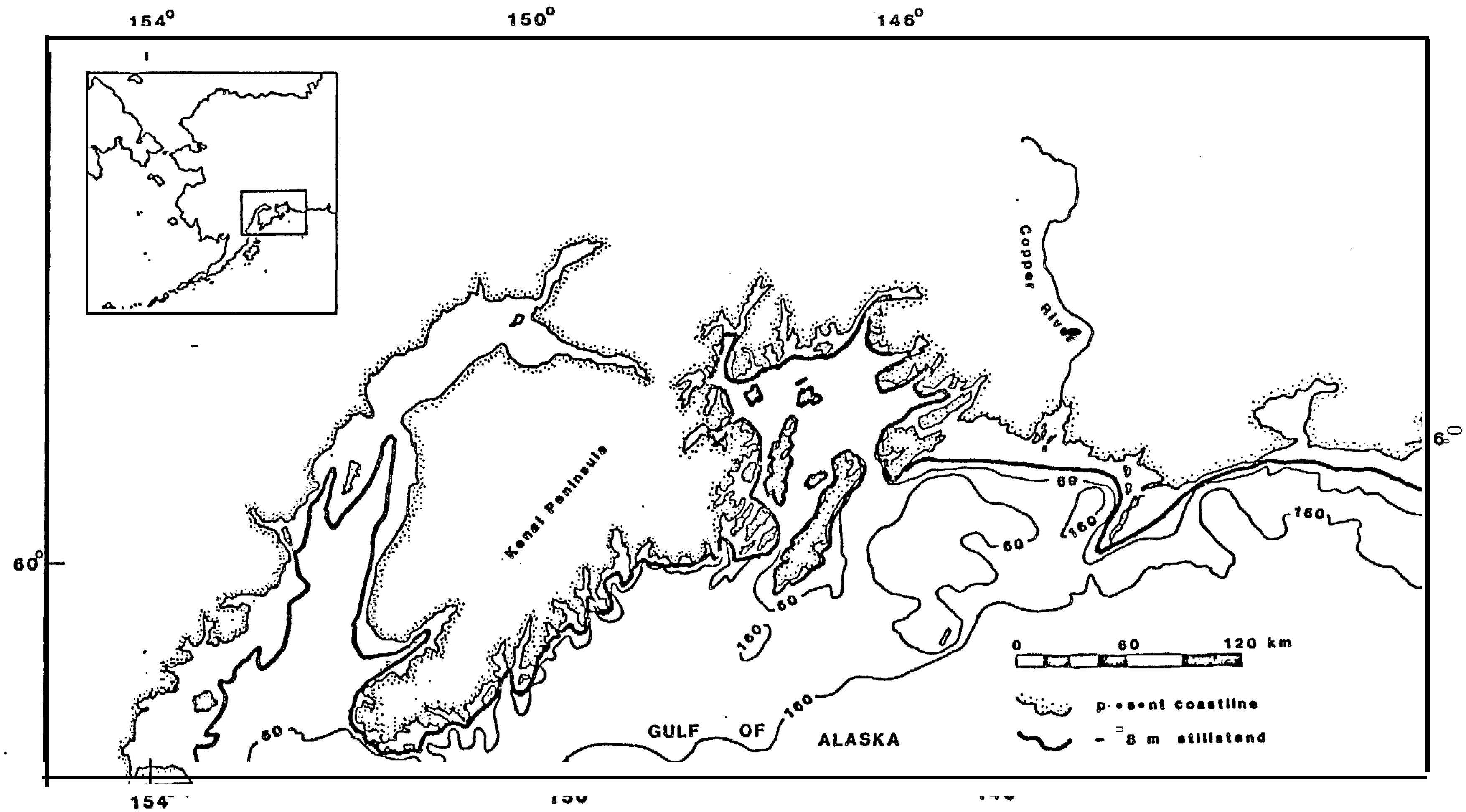


Figure I-31: Gulf of Alaska S elf, -38 m stillstand.

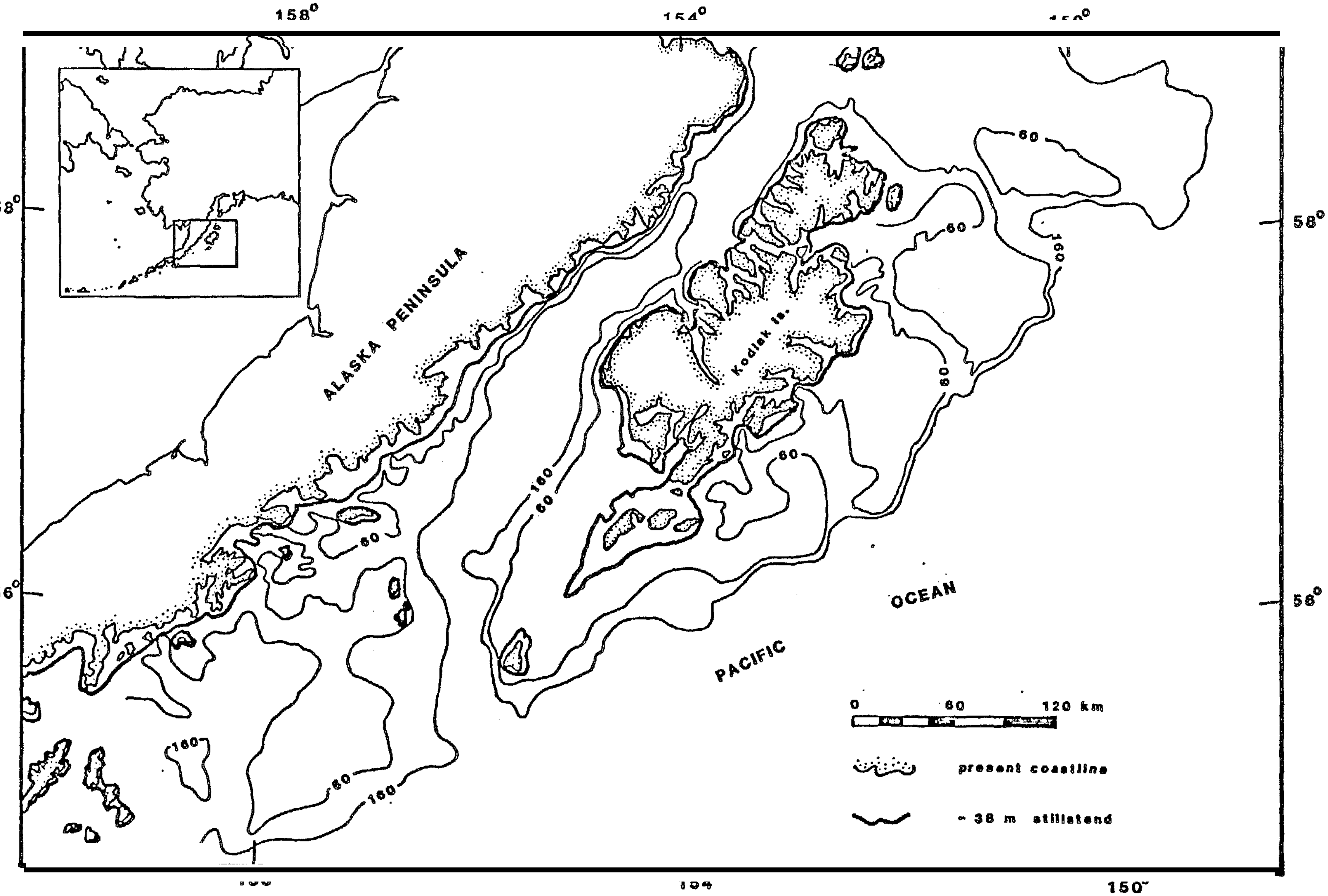


Figure I-32: Kodiak and Alaska Peninsula shelves, -38 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

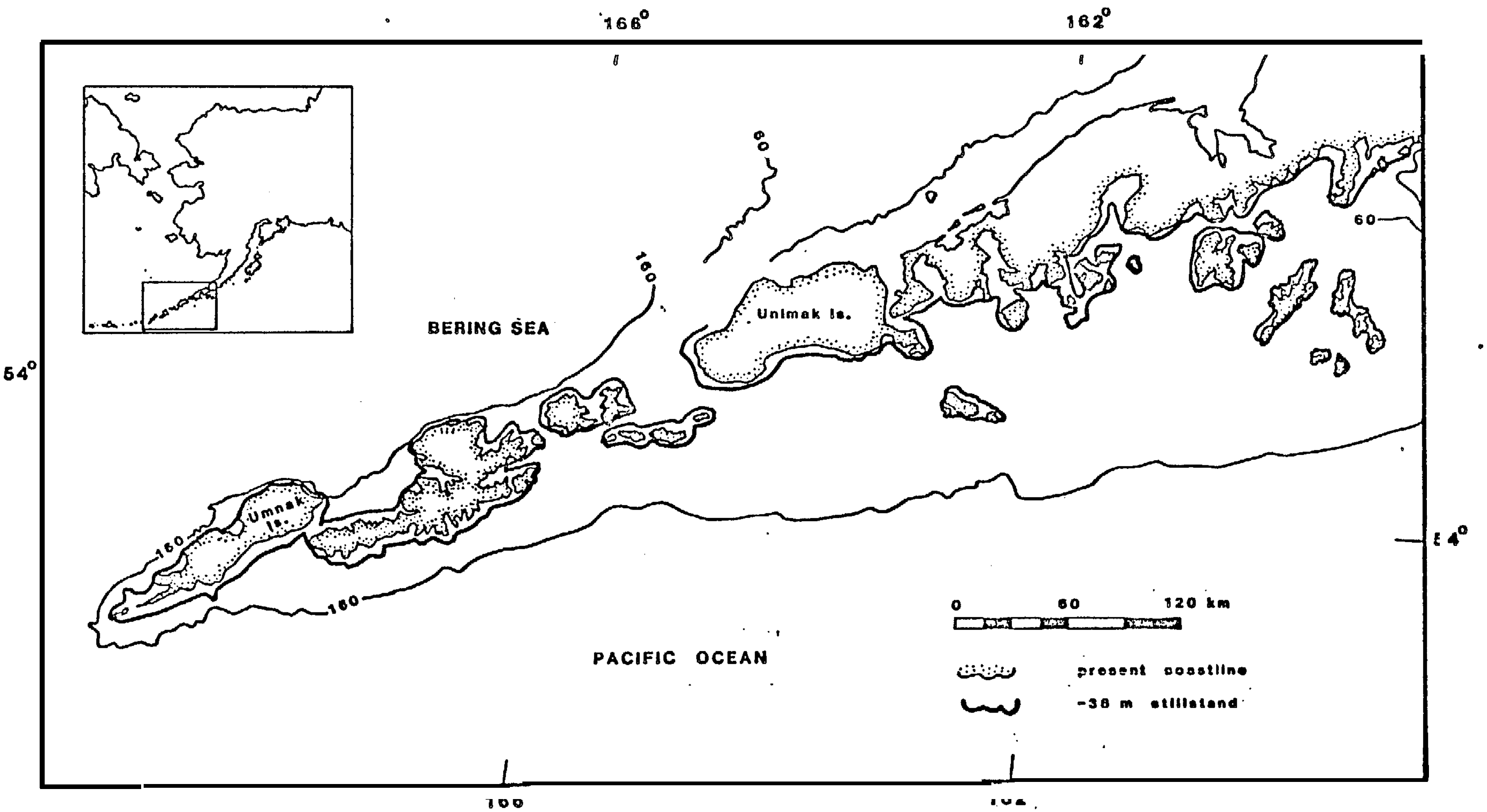


Figure I-33: Aleutian Shelf, -38 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

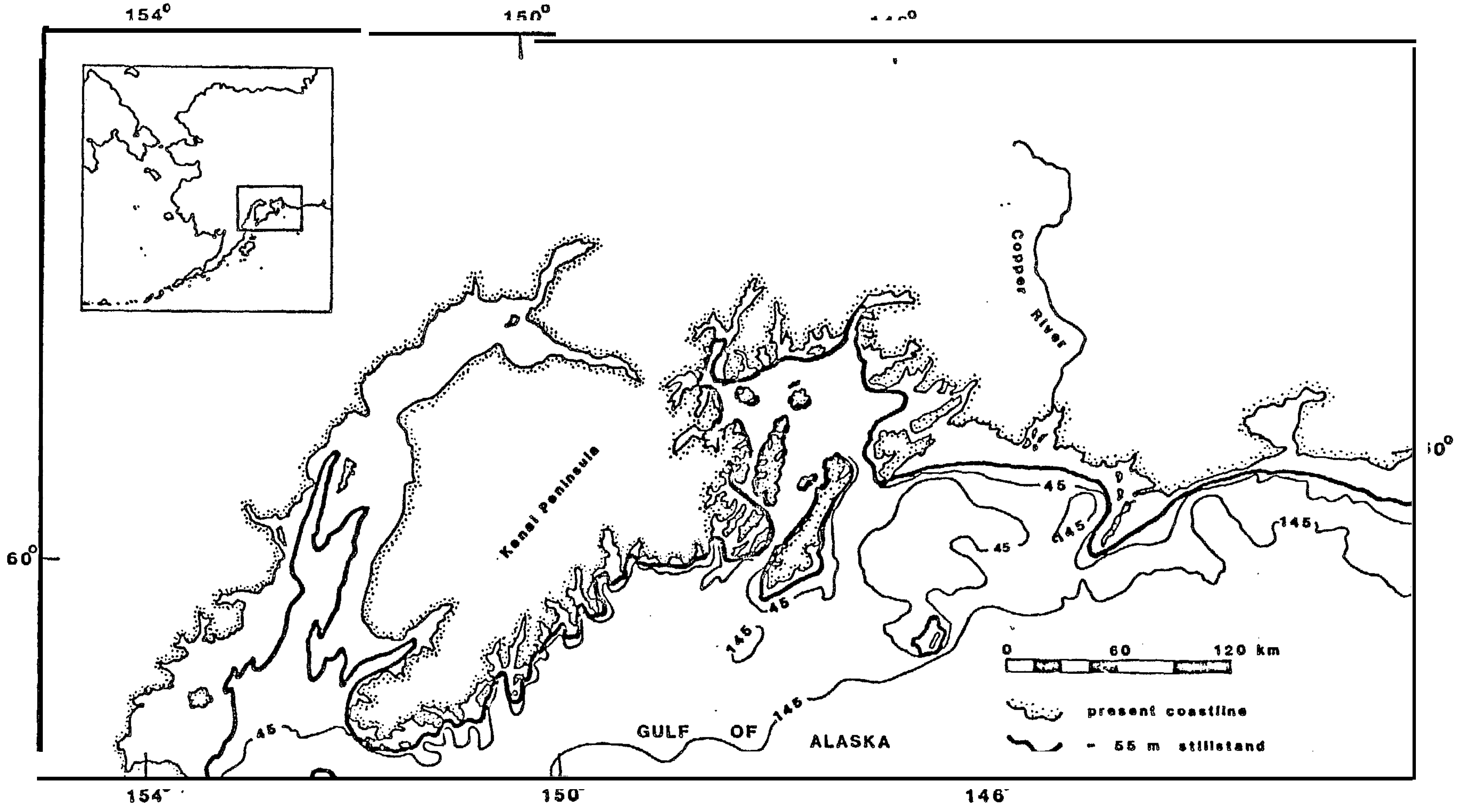


Figure -34: Gulf of Alaska Shelf, -55 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

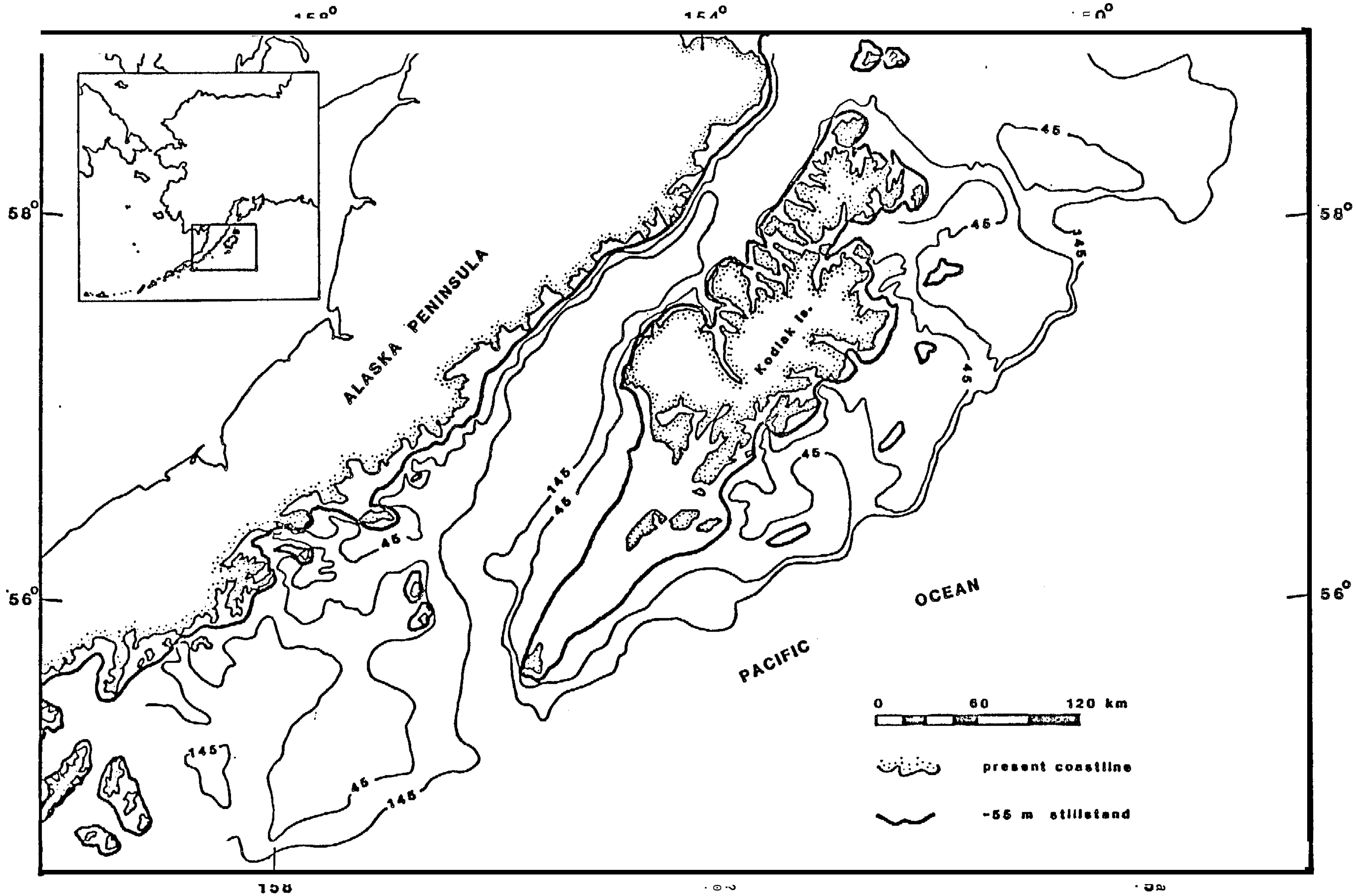


Figure I-35: Kodiak and Alaska Peninsula shelves. -55 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

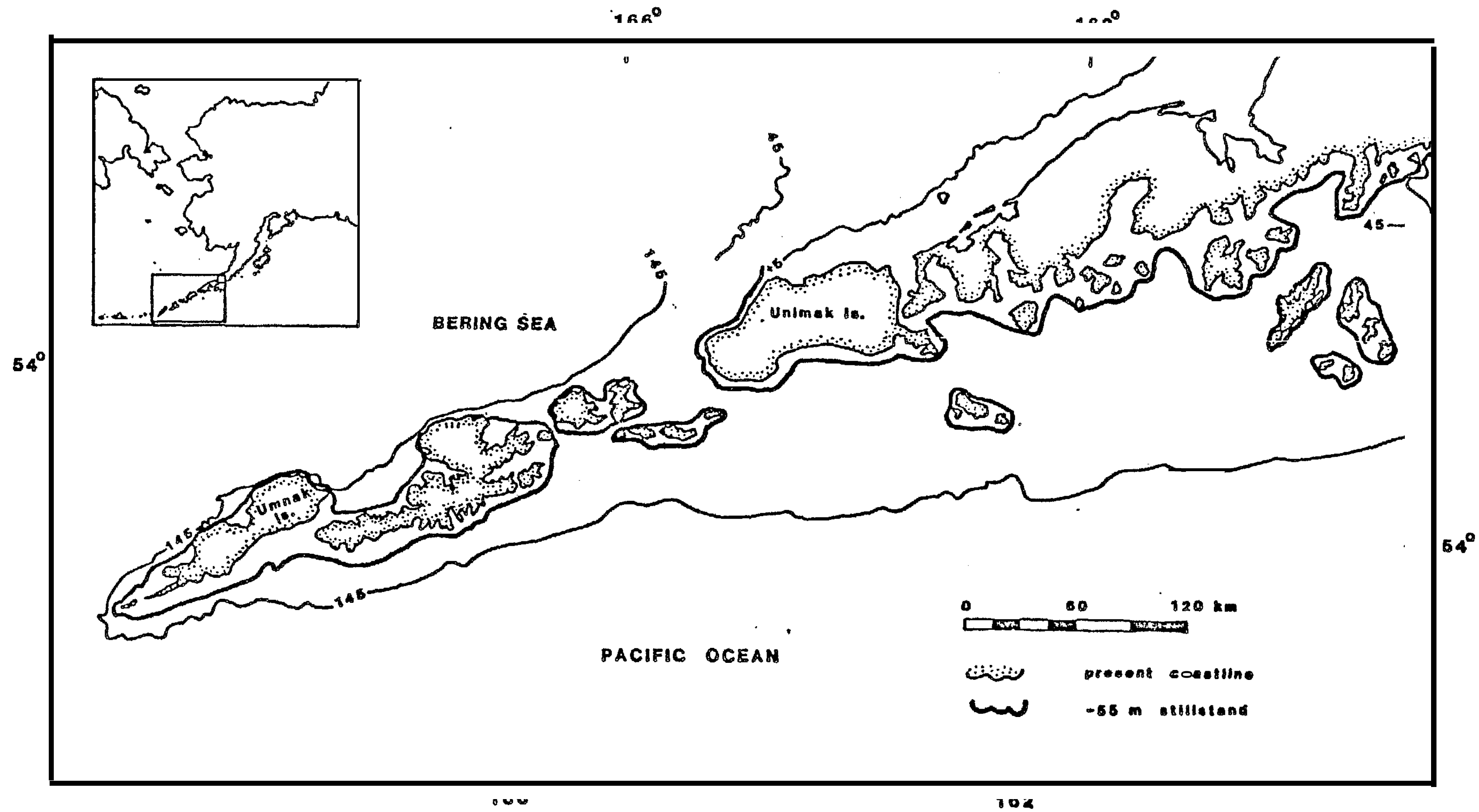


Figure I-36: Aleutian Shelf, -55 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

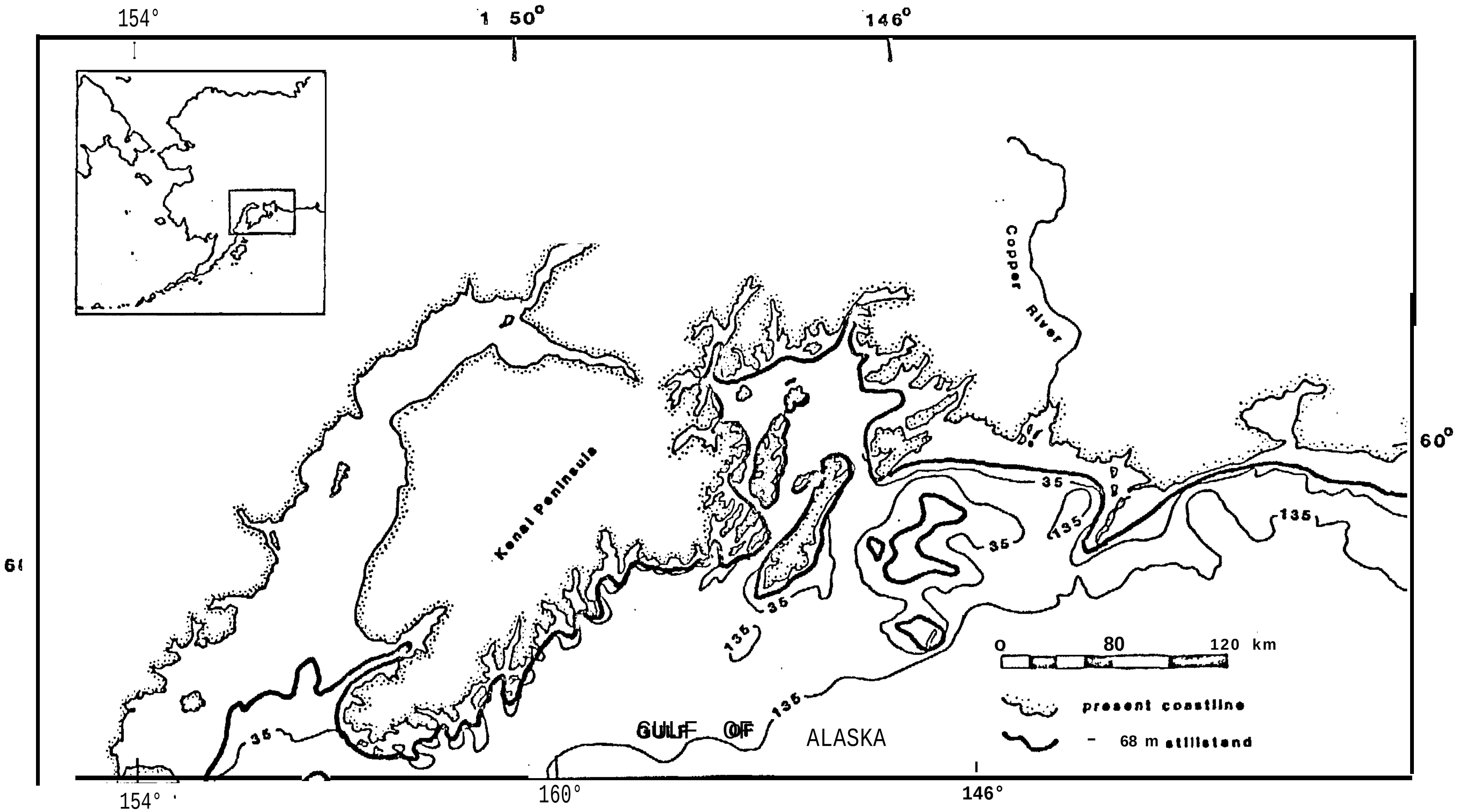


Figure I-37: Gulf of Alaska Shelf, -66 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

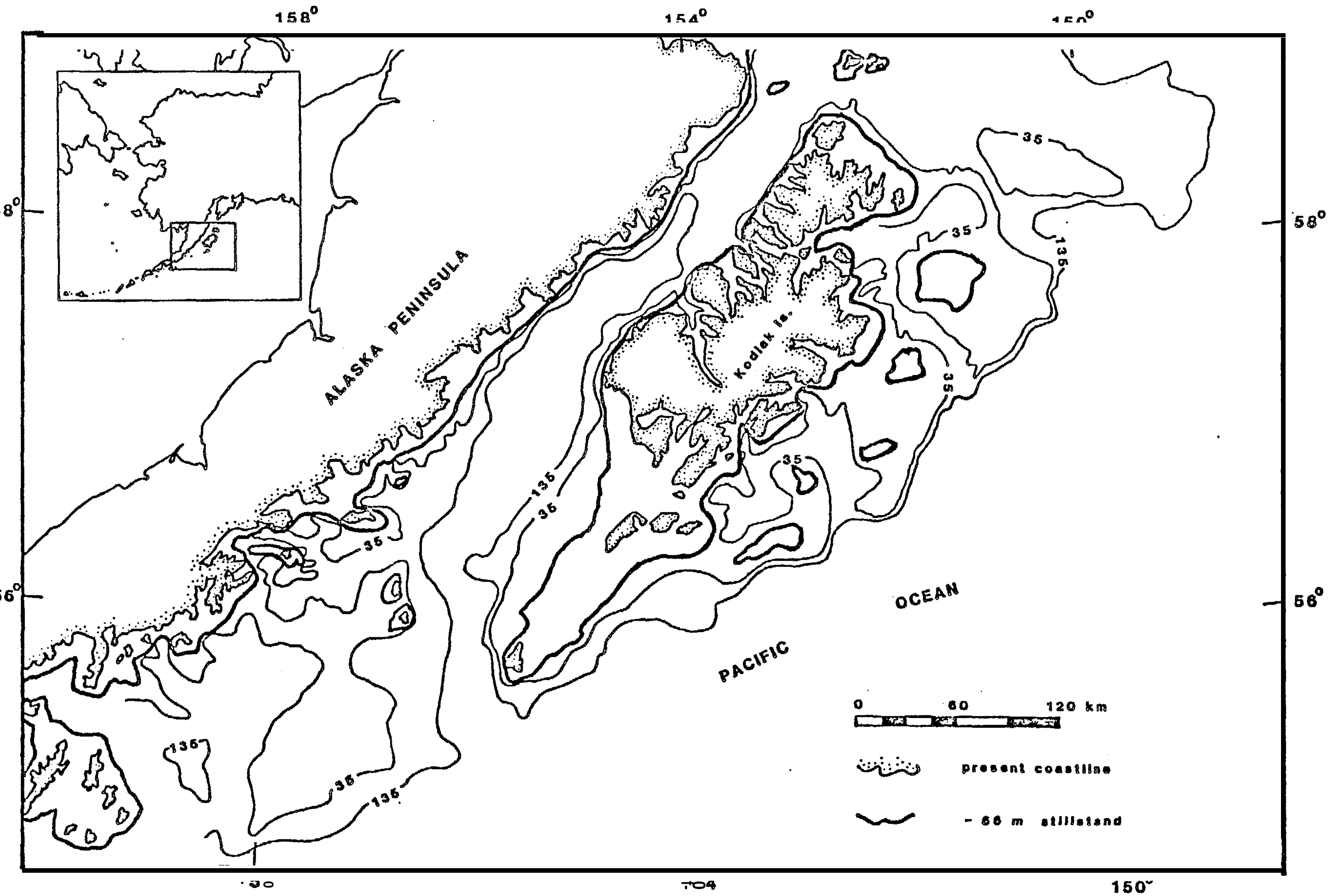


Figure I-38: Kodiak and Alaska Peninsula shelves, -66 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

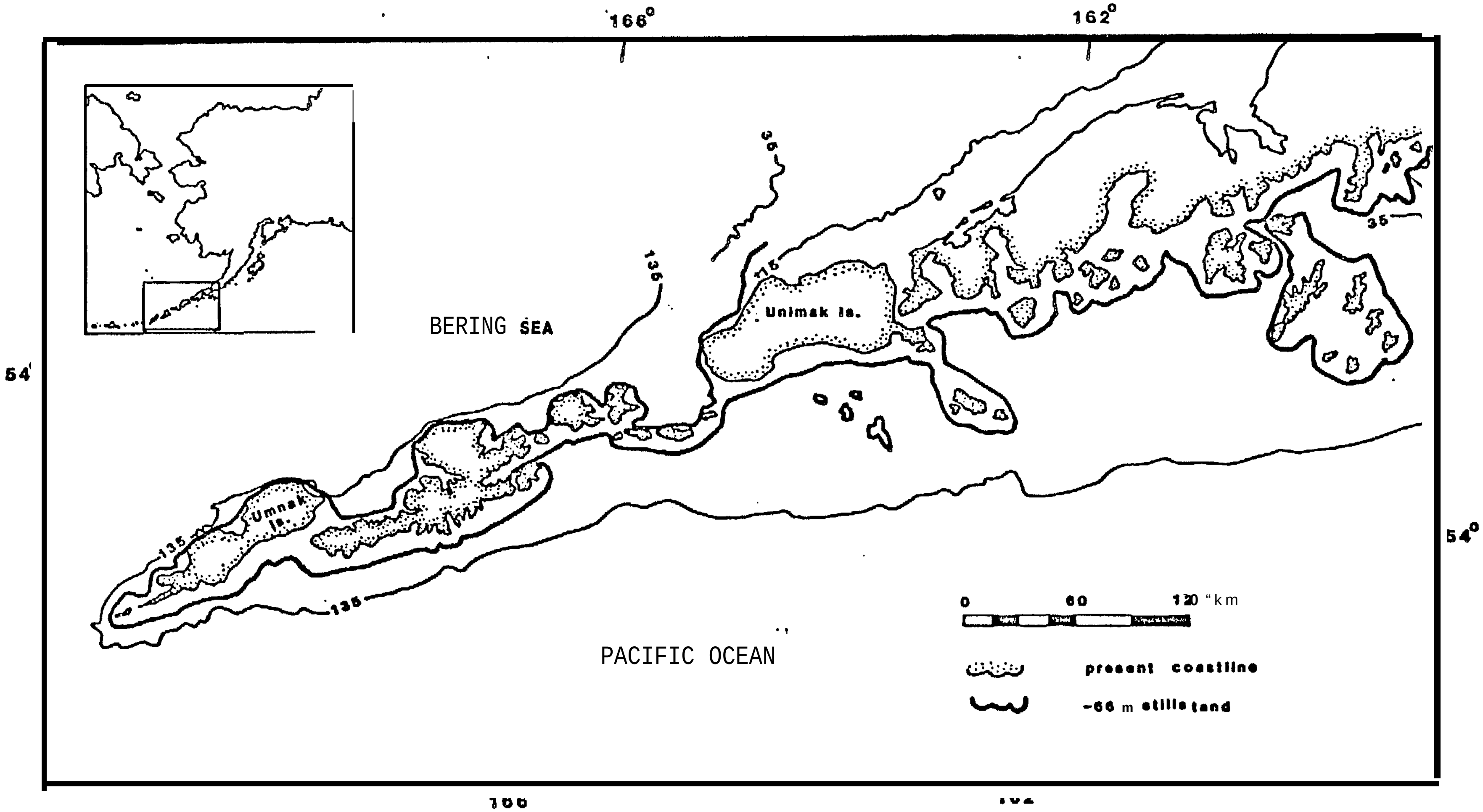


Figure I-39: Aleutian Shelf, -66 m still stand. Former isobaths and land elevations (indicated by "+") given in meters.

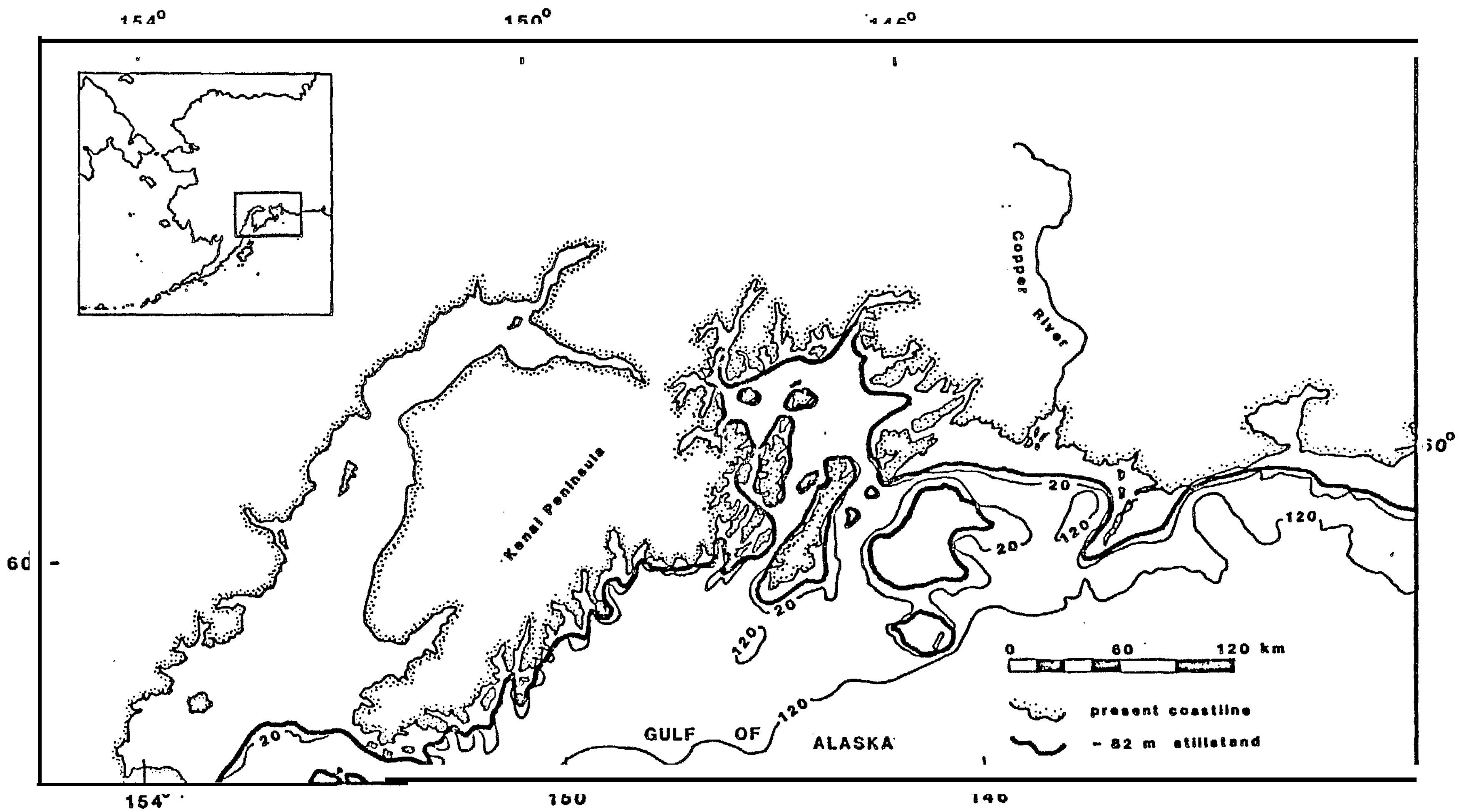


Figure I-40: Gulf of Alaska Shelf, -82 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

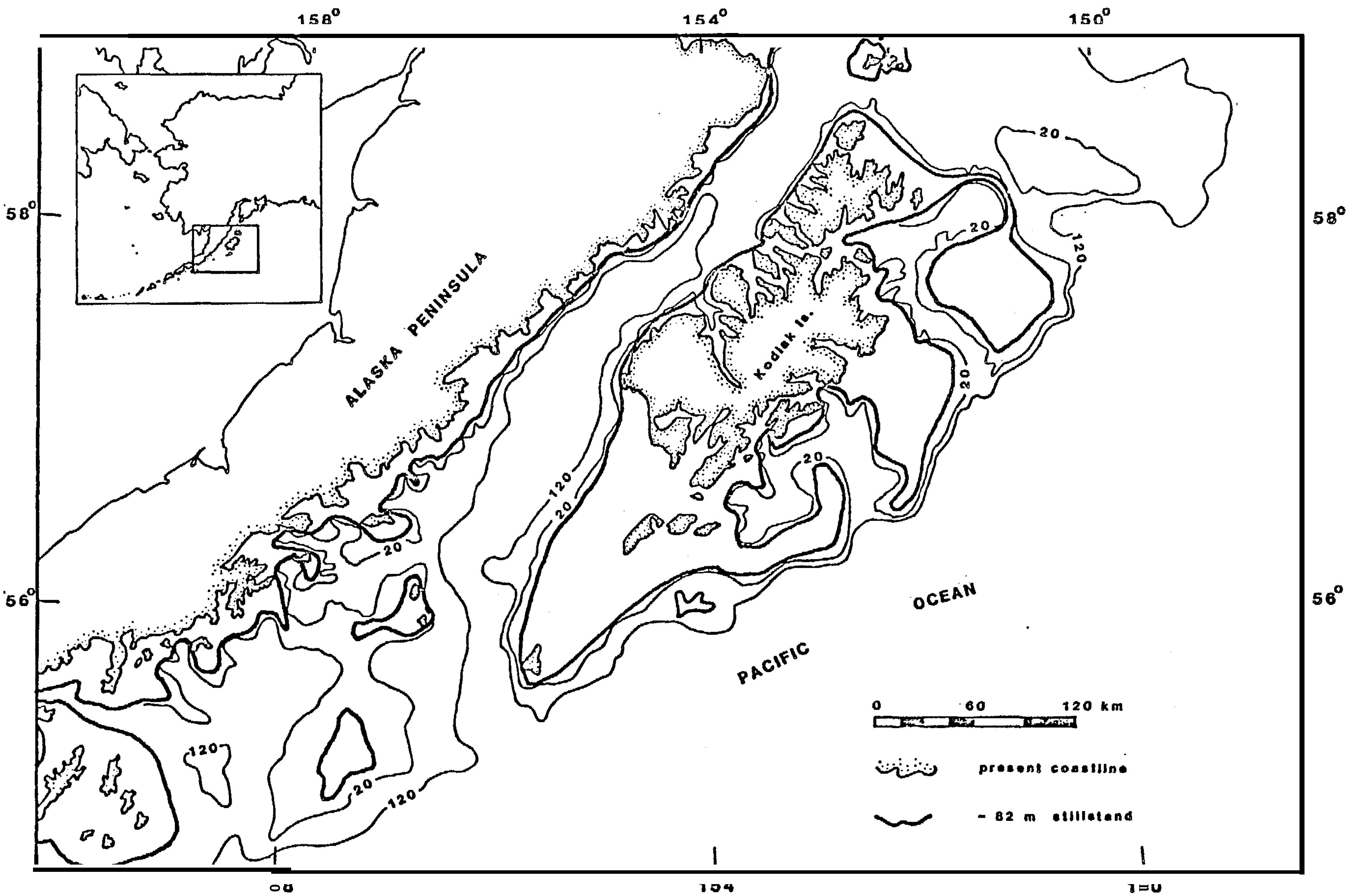


Figure I-41: Kodiak and Alaska Peninsula shelves, -82 m stillstand. Former isobaths and land elevations (indicated by "+") given in meters.

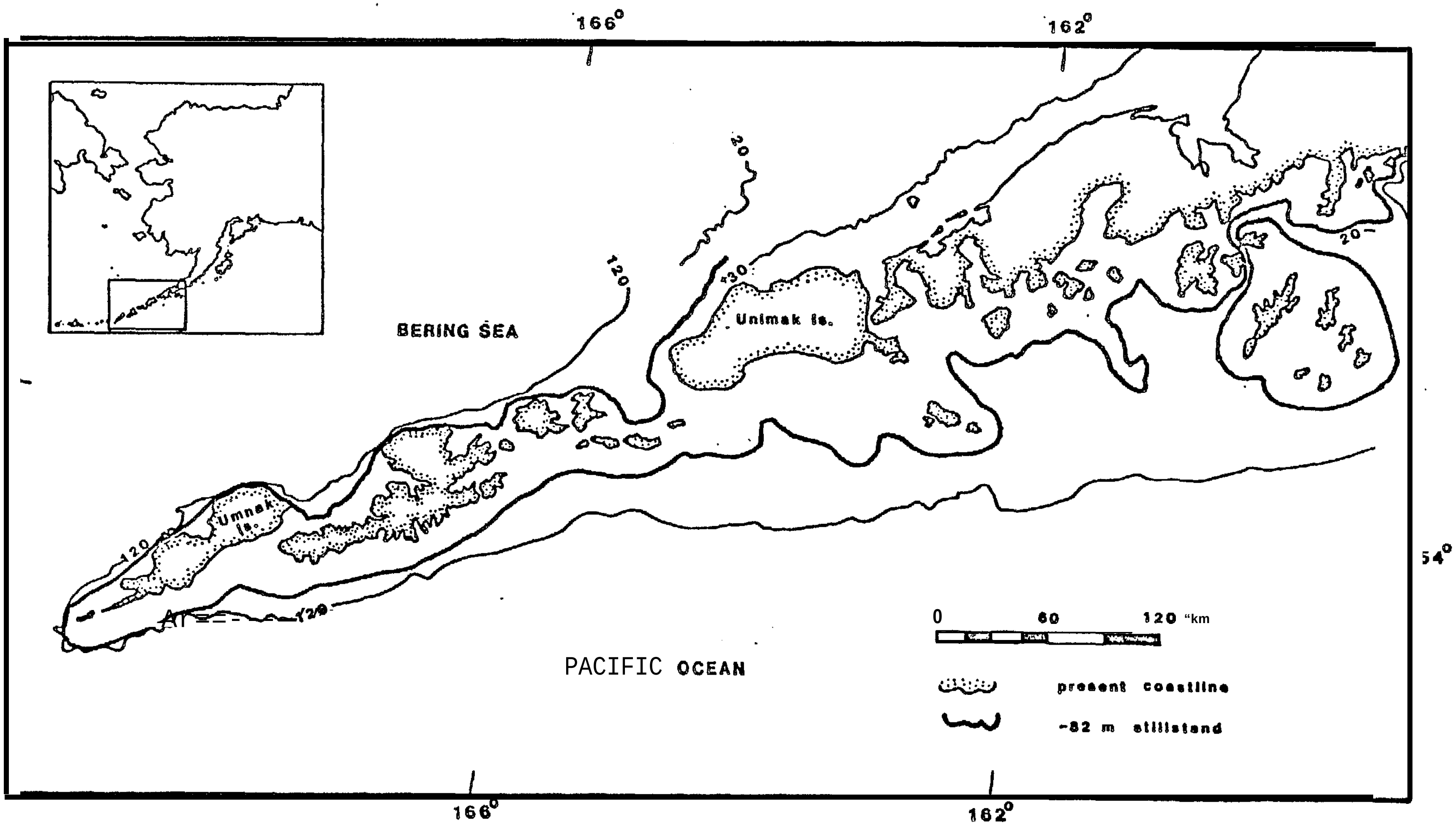


Figure I-42: Aleutian Shelf, -82 m still stand. Former isobaths and land elevations (indicated by "+") given in meters.

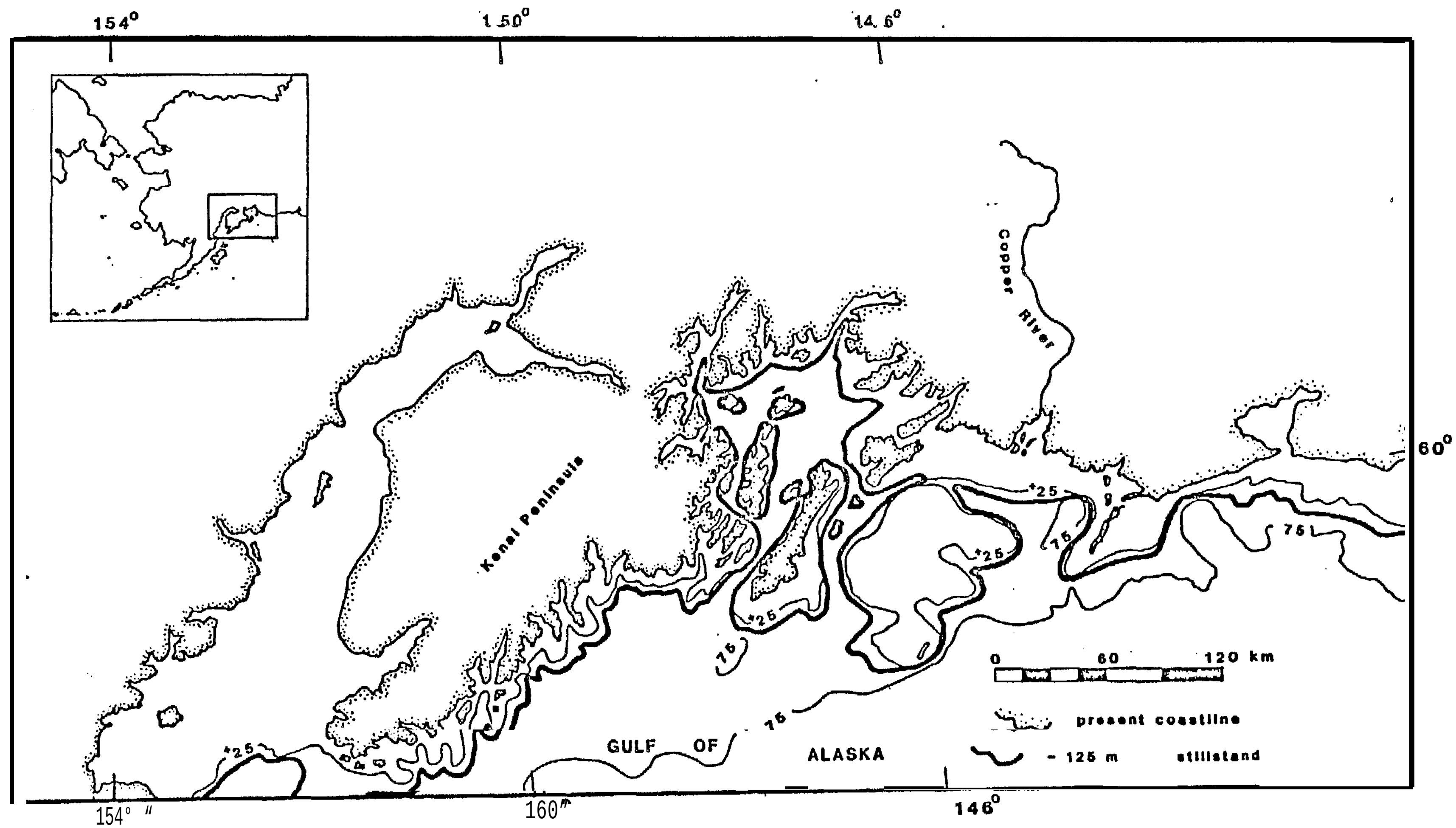


Figure I-43: Gulf of Alaska Shelf, -125 m stillstand. Former isobaths and lard elevations (indicated by "+") given in meters.

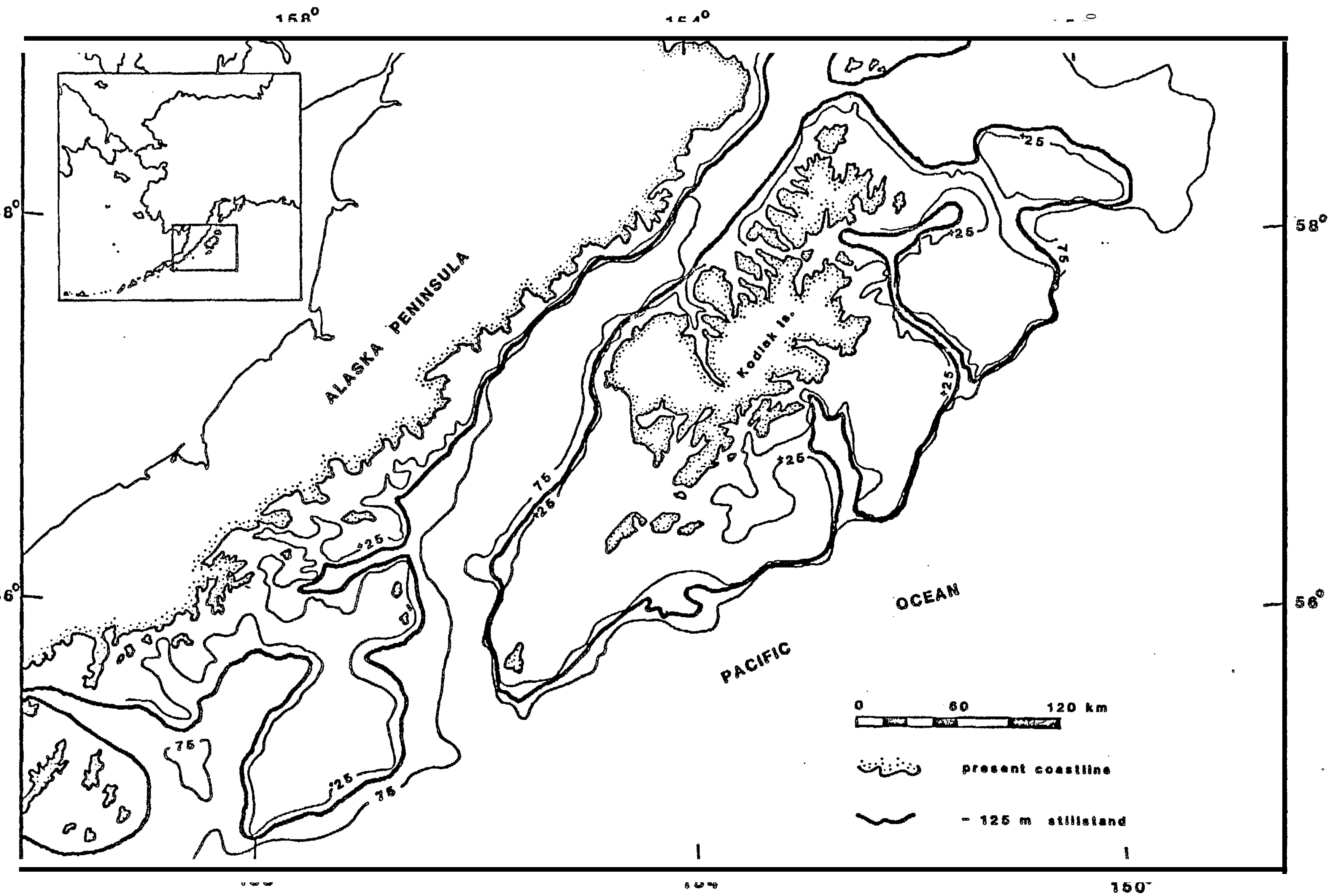


Figure I-44: Kodiak and Alaska Peninsula shelves, -125 m stillstand. For ɴr iso›ths and la ł elevatior (indicate‹ ›y "+") gi› ›n

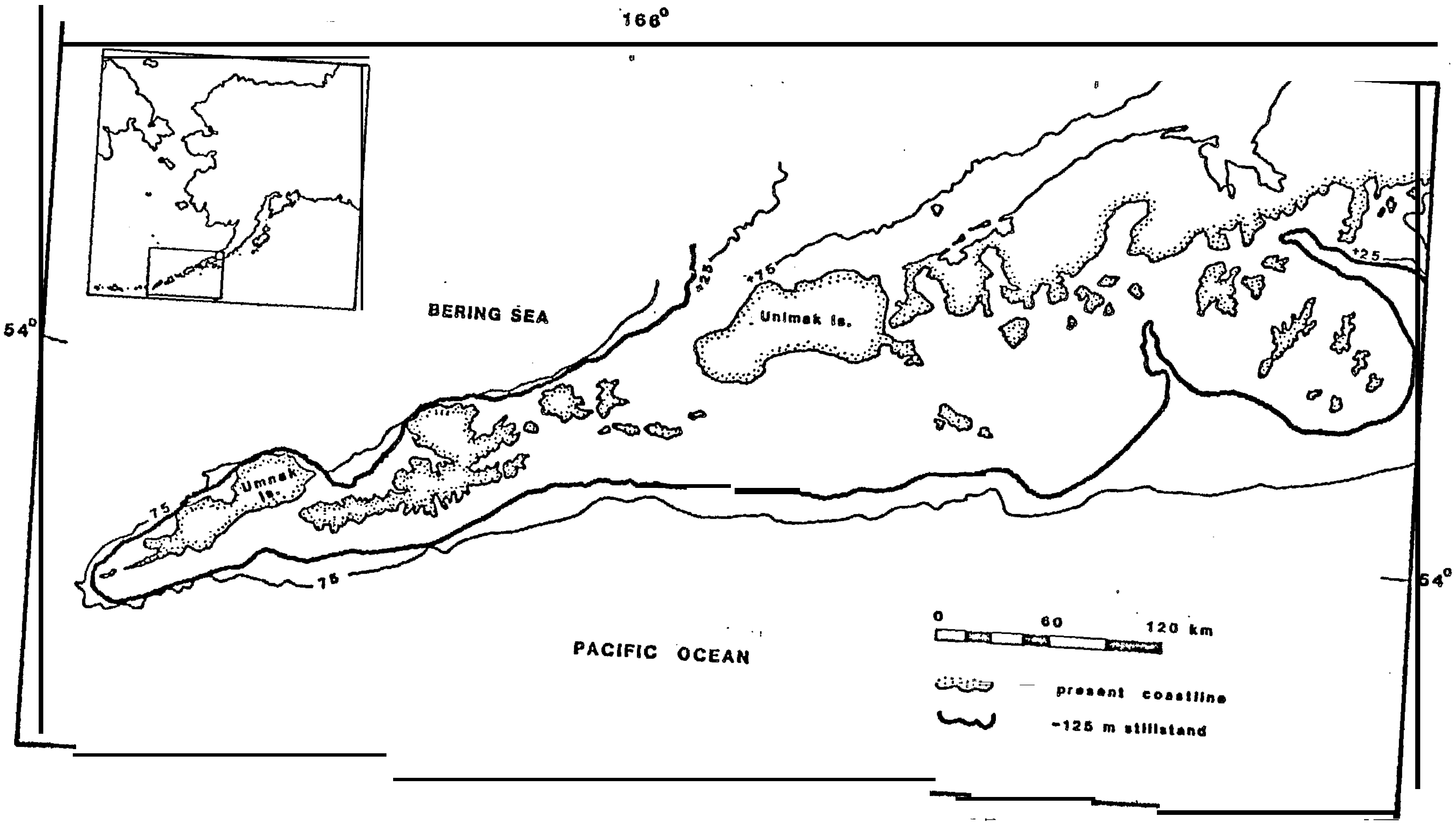


Figure I-45: Aleutian Shelf, -125 m stillstand. Former isobaths and and elevations (indicated by "+") given in meters.

depths) and the terraces or platforms. Sea level fluctuations primarily are dependent on the extension and retreat of continental ice, though it is difficult to assess and measure the ice extension during each sea level stillstand, especially along a coast such as the Alaska Peninsula where snow accumulation and ice flow could be greatly affected by the topography. Moreover, the omnipresent Alaskan Gyre near the shelf edge (100-200 m isobath) could have severely restricted ice extension on the shelf. In order to interrelate each sea level stand with ice extension on the shelf it would be essential to examine the shelf sediments.

Five episodes of onshore glaciation during the Pleistocene Epoch in Cook Inlet and adjoining Kenai Mountains were identified by Karlstrom (1964). The youngest of these glaciation, the Naptowne, reached its maximum approximately 25,000 years ago. Evidence for two post-Naptowne glacial periods have also been reported by Karlstrom (1964). The Tustumena, the older of the two, reached its maximum stage between 3,200 and 5,500 years ago, while the youngest, named Tunnel, advanced between 500 and 1500 years ago.

Along the eastern Gulf of Alaska, an impressive advance of the Malaspina Glacier, reaching a peak between 700 and 1,400 years ago, has been reported by Plafker and Miller (1958). During this advance it is believed that glacial ice probably covered part of the adjacent shelf.

The texture of sediments from various banks of the Alaska Peninsula Shelf suggests that some regions of this shelf have also been glaciated. These glacio-marine sediments have not been dated and may have been deposited during early Pleistocene or Tertiary times. The chronology and extent of ice advance on the Northwestern Gulf of Alaska Shelf has not been studied in any detail as yet, making it difficult to estimate the extent of ice cover on the shelf.

The chronology of sea level stillstands described here is based on the assumption that sea level during late Pleistocene time rose from -125 m to present sea level. This, however, does not preclude minor advances and retreats which probably did not result in significant sea level changes. Although other investigators have dated similar sea level stands during late Pleistocene times, it is not certain that these submerged geomorphic features were formed during the last transgression. This uncertainty is profoundly displayed by the close fit of the sea level stillstands with those observed world-wide during late Illinoian and early Wisconsin glaciations. It is therefore essential that the stillstands be dated in order to accurately reconstruct paleogeographic maps with sea-land-ice distributions along the Alaska Peninsula.

F. Lower Cook Inlet

1. Introduction:

Cook Inlet is located on the northwest edge of the Gulf of Alaska in southcentral Alaska. The inlet, including Knik and Turnagain arms, lies between 59°00'N to 61°30'N latitude and 149°W to 154°W longitude and covers more than 26,000 km^2. This large tidal estuary is a northeast-southwest oriented indentation into the southcentral Alaskan coastline. It differs from other indentations of the Pacific Coast of Alaska in that its head is well behind the coastal ranges and has a broad tributary valley drained by large rivers. The estuary flows into the Gulf of Alaska between the southwestern tip of the Kenai Peninsula and east of the base of the Alaska Peninsula. At its entrance, it is 80 km wide and averages 100 m in depth, extends northeast 280 km, and at the head bifurcates into Turnagain and Knik arms. Cook Inlet is divided into upper and lower sections by a natural constriction near the east and west forelands.

Cook Inlet is bordered by extensive tidal marshes, lowlands with numerous lakes, and glacier-covered mountains. Extensive tidal marshes and mud flats are common along much of the western and northern margins of upper Cook Inlet. Lowland areas to the east extend for more than 110 km to the Kenai Mountains. Along the southern margins, especially to the west, lowlands are very narrow and mountains rise directly from the water.

The estuary is fed by drainage from the surrounding mountains: the Aleutian Range and Alaskan Range to the northwest, the Talkeetna Mountains to the northeast, and the Chugach-Kenai Mountains to the southwest. These mountains are rugged and heavily glaciated. The glacial melt feeds various rivers and streams and is laden with sediments. Major rivers (the Knik, Matanuska, Susitna, Little Susitna, and Beluga) discharge their loads near the head of upper Cook Inlet, while the Kenai and Drift rivers drain into lower Cook Inlet.

2. <u>Geology</u>:

Lower Cook Inlet lies on the southwest flank of the arcuate Matanuska Geosyncline. Structurally, the sedimentary basin--the Matanuska-Wrangell Basin--is bounded by the Talkeetna Geanticline to the northwest and by the Seldovia Geanticline to the southeast (Payne 1955). The basin extends northeast into upper Cook Inlet and southwest down the Alaska Peninsula and Shelikof Strait. The basin is about 320 km long and 110 km wide, and covers an area of about 40,000 km^2. In its simplest form, the basin is a graben bounded by major fault zones to the north, west, and east which have been active since Eocene time. The basin is filled with a 20,000 to 25,000 m thick sequence comprising marine and non-marine sediments as well as volcanic rocks.

Cook Inlet lies in the trans-Pacific seismic zone and is therefore a region of continued tectonic activity. The unique structural, stratigraphic, and tectonic character of the region suggests that Cook Inlet is a remnant of a former arc-trench system. Accordingly, the thick sequence of sediments in Cook Inlet was deposited on an unstable, shallow continental shelf and slope, prone to periodic uplift and subaerial erosion. To the southeast, the deep-water facies of the Kenai Peninsula were deposited and later accreted to the continental margin through northwestern underthrusting of the North Pacific Plate beneath the continental plate. The convergence of the two plates appears to be along the Border Range Fault (MacKevett and Plafker 1974). This fault marks the eastern boundary of the Matanuska-Wrangell Basin, while the Bruin Bay Fault delineates the western edge of the Cook Inlet Basin. The plutonic, extrusive volcanics, volcanoclastic sediments, and metamorphosed sedimentary units which lie west of the Bruin Bay Fault are characteristic of the Alaskan-Aleutian Range.

The stratigraphic sequence in Cook Inlet Basin includes over" 12,000 m of Paleozoic and early Mesozoic marine sediments and about 10,000 m of Tertiary non-marine sediments. Tertiary sediments contain hydrocarbons, which are commercially produced in Cook Inlet and from the Kenai Peninsula.

Structurally, little change has occurred in Cook Inlet since the close of the Tertiary. Morphologically, however, the region has been repeatedly affected by glacial advances and retreats. At least five major Pleistocene glaciation have been observed in this region (Karlstrom 1964). Glacier ice during the first three episodes (Mount Susitna, Caribou Hill, Eklutna) filled Cook Inlet and extended as far as Shelikof Strait. At the peak of the Mount Susitna Glaciation, the ice elevation in the Cook Inlet region was 1,300 m. A contiguous sheet of ice during this time perhaps extended from the Copper River Basin to the northeast into Bristol Bay to the southwest. The Caribou Hill Glaciation was less extensive, with ice elevation between 750 and 1,000 m. At the close of this glacial episode, approximately 155,000 to 190,000 years B.P., the ice began to retreat. The Eklutna Glaciation was less severe than preceding ones, and ended about 90,000 to 111,000 years B.P.

During the succeeding Knik and Naptowne glacial episodes, ice covered only portions of Cook Inlet, with Knik Glaciation ice extending further than Naptowne. Karlstrom (1964) reported that during these two glaciations, upper Cook Inlet and parts of lower Cook Inlet were covered by a large glacial lake which was formed as a result of coalescence of ice lobes from Kachemak Bay in the southwest and the Aleutian Range in the west. Preglacial lake silt of Knik age occurs to 300 m elevation. The final draining and subsequent encroachment of the sea in Cook Inlet began about 7,000 years B.P., at the close of the Naptowne Glaciation. There have been two major ice advances since the last major glaciation; the Tustumena ice advance between 5,500 and 3,200 years B.P., and the Tunnel ice advance between 1,500 and 500 years B.P.

3. Bathymetry:

The bathymetry of lower Cook Inlet is quite complex (Figs. I-46, 1-47). The major exposed features in the inlet are Kalgin Island (near the Narrows), Augustine Island in the southwest, and Barren and Chugach islands near the entrance. A few smaller islands are scattered in various bays and near the entrance.

Three large bays, Kachemak Bay to the east and Tuxedni, Chinitna, and Kamishak bays in the west, indent the coastline of the inlet. The bathymetry of these bays varies from gradual sloping bottoms to highly complex intervening basins. The floor of Kachemak Bay, for example, consists of numerous basins separated by ridges and sills of various depths.

The inlet has two sea valley systems. The major sea valley system connects upper and lower Cook Inlet through the Narrows. In lower Cook Inlet the sea valley bifurcates north of Kalgin Island into two arms. One arm extends southward along the coast while the other arm extends along the

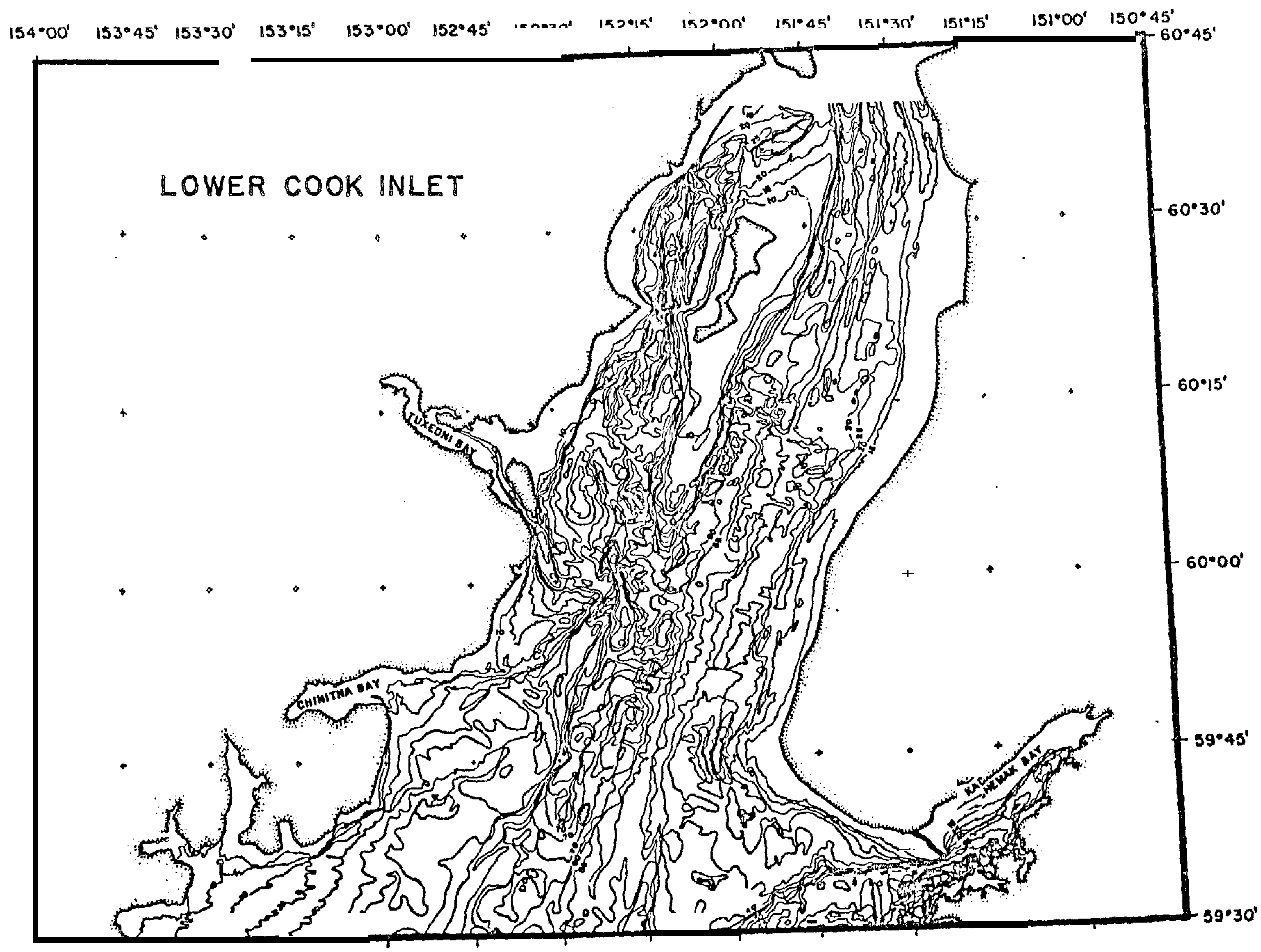
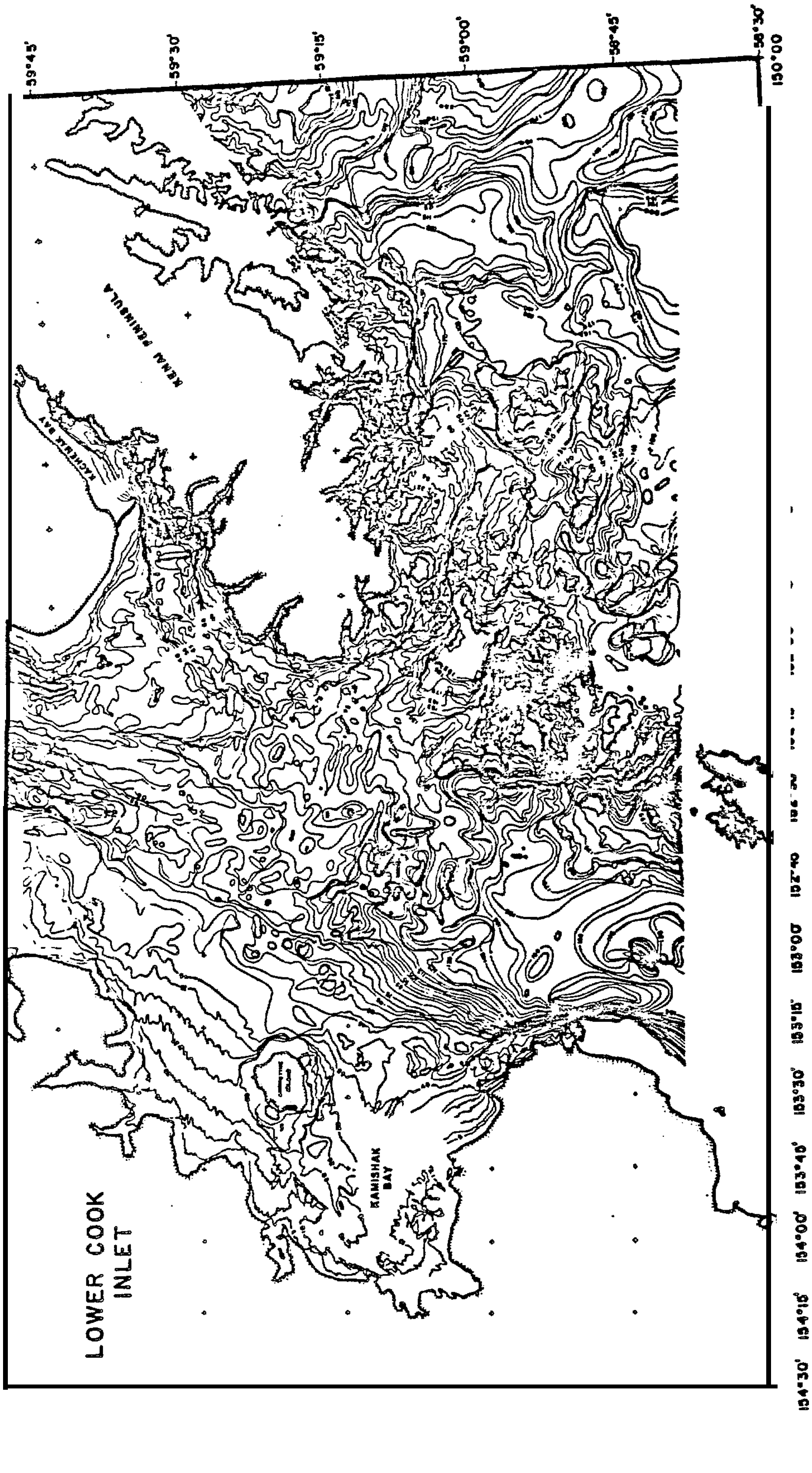


Figure I-46: Bathymetric chart of lower Cook Inlet, northern section.


LOWER COOK INLET
KENAI PENINSULA
KACHEMAK BAY
KAMISHAK BAY
59°45'
59°30'
59°15'
59°00'
58°45'
58°30'
150°00'
153°00'
153°15'
153°30'
154°00'
154°15'
154°30'

west side of Kalgin Island. South of the island, these two arms unite again to form a single valley which extends southwards-and slopes into the trough west of Stevenson Entrance. Throughout the upper reaches of its longitudinal axis, the sea valley has numerous elongated basins.

The northern components of the smaller sea valley system, which apparently carried the drainage from the Kenai Peninsula, runs along the longitudinal section of Kachemak Bay, with a conspicuous valley west of the bay. Southward, these two valleys merge and extend toward the entrance, forming a semicircular course which runs parallel to the eastern shore of the inlet. Near the entrance, the sea valley gradually slopes into the large rectangular trough of Kennedy Entrance, apparently a lake during lower sea-level stands.

Lower Cook Inlet, based on bathymetric features, can be divided into three regions. The inlet floor shallower than -80 m is distinguished by an unusually large number of flat tops and shallow depressions. Most of the flat-top summits reach -55 m depth. The bottom slope of this region is gradual. Beyond the -80 m isobath depth increases rapidly. This steeply inclined semicircular ramp forms the second bathymetric region of the inlet. A few narrow, steeply-walled sea valleys cut across this ramp. At -150 m depth the gradient of the floor once again becomes less inclined and a broad saucer-shaped basin occupies the southern part of lower Cook Inlet. This basin lies west of the entrance and forms the third region of the inlet. The configuration of the deep basin and the landward ramp are indicative of a possible bay during lower sea level stands.

To the south, lower Cook Inlet is connected to an elongated depression, Shelikof Strait, which lies between Kodiak Island and the Alaska Peninsula.

To the southeast there are two passages through which the inlet exchanges water with the Pacific Ocean. The northern passage, lying between the Barren Islands and Chugach Island, is Kennedy Entrance. The entrance has a rectangular basin, Kennedy Trough, with a depth greater than -200 m. The northern and southern rims of this trough are very steep, while to the west and east the bottom rises gradually into the inlet and the Gulf of Alaska, respectively. It should be noted that the basin enclosure of the Kennedy Trough is at -125 m below sea level. In spite of the complex bathymetry, the sill depth connecting Cook Inlet and the Gulf of Alaska consistently lies along the -125 m. isobath. To the east of Kennedy Trough are two east-west oriented ridges separated by a shallow valley with small basins.

The southern passage to the inlet lies between the Barren Islands and Shuyak Island and is called Stevenson Entrance. The entrance has a narrow channel, with a depth exceeding -200 m. To the east of the channel lies a large bank with a smooth surface. Interestingly, the depth of this bank is also -125 m. The floor surrounding the Barren Islands is extremely rugged with basins, ridges, and numerous islands rising abruptly from the sea floor.

The region east of Cook Inlet entrance consists of broad, smooth banks and intervening troughs, with numerous submerged ridges generally extending east to west. Isolated basins are scattered throughout this region.

The shelf of southwestern Kenai Peninsula consists of two broad, U-shaped valleys and two prominent ridges. The ridges and valleys cut across the shelf and slope seawards. The configuration and orientation of these broad valleys is indicative of their glacial origin.

The bathymetric features in lower Cook Inlet suggest that the bottom of the inlet is covered by contemporary sediments. These features are also indicative of the past fluvial, glacial, and marine environments. Many of these features are also indicative of lower sea level.

G. Northern Gulf of Alaska

1. Introduction

The region described here extends from Cape Suckling in the east to the entrance of Cook Inlet to the southwest. This region of the Gulf of Alaska forms the northeastern part of the Pacific Basin and represents the seaward expansion of a bight where the northwest-trending North American Cordillera bends to the southwest at least 90° and merges into the eastern end of the Aleutian Arc and the Aleutian Trench. Physiographically and tectonically, the region is unique. Landward the shelf is bounded by an arcuate structural trend which is the result of the merging of the northwest-southeast trending Chugach-St. Elias Mountains and the northeast-southwest trending Kenai Mountains. Seaward, these structural blocks are separated from the shelf by a broad fault zone which runs parallel to the shelf. Tectonically, the entire region has been active during and since the Tertiary and presently has frequent earthquakes. This tectonic activity is a result of the release of structural stress caused by the strong relative movement between the Pacific and American plates.

The continental shelf which adjoins the North Pacific Basin is semi-circular and varies in width from only 30 km in the east to over 100 km in the southwest. An interesting feature of the shelf is the presence of a small island, Middleton Island, located near the shelf slope. In the northeast, the shelf receives the discharge of the Copper River, one of the largest Alaskan rivers. This river has formed an unusual delta of Holocene sediments. The submerged delta does not prograde seawards but extends parallel to the shore over a distance of 100 km and is separated from the open shelf by a chain of barrier islands.

This shelf also differs tectonically from adjacent eastern and western shelves. Tectonically it is an area where the northwest trending eastern shelf and the northeast trending western shelf merge. This merging of structural trends results in three distinct features which form fundamental regional boundaries on the shelf. Landward, the shelf is bounded by an arcuate broad fault zone which separates the Kenai-Kodiak and St. Elias blocks. Seaward, two large shelves (Prince William Sound and the Gulf of Alaska) are separated by a fault zone. In particular, the sound is a unique large basin with a depth over -400 m. Finally, there is a broad complex anticlinal arch near the shelf break.

2. Geology:

The geologic evolution of the Alaskan Pacific Margin is complex, and the early history of the geosynclinal basin is somewhat obscure. The surficial and structural geology of the region has been described by many investigators, notably Miller et al. (1959), Gates and Gryc (1963), Burk (1965), Moore (1969), and Plafker (1967, 1971). The character of Paleozoic and early Mesozoic rocks of the shelf is not known. The entire shelf and regions adjacent to the gulf, during the Paleozoic, was a geosyncline filled with sedimentary deposits. The Paleozoic era closed without major orogeny and the geosynclinal deposition continued into the Mesozoic era. The absence of Paleozoic strata could suggest that the shelf region is a Mesozoic accretion to the older continental margin (Triassic) which lay farther inland.

During the mid-Jurassic a major orogeny occurred, and as a result the tectonic configuration began to evolve and has continued since. The most important features of this orogeny were folding, faulting, and emplacement of numerous plutonic masses. Clastic sediments comprising graywacke and sandstones were deposited during the Jurassic and Cretaceus periods. This was followed by two relatively minor orogenies during the late Cretaceus and the early Tertiary (Oligocene), succeeded by a major orogeny which began during the late Tertiary (Pliocene) and is presently active in the region (Plafker 1969, 1971).

Late Tertiary orogeny had a profound effect on the evolution of "the shelf along the Alaskan Pacific Margin, including some onshore regions. During the Tertiary Orogeny, a major northeast-southwest trending fault developed along the trend presently occupied by Hinchinbrook, Montague, and Kodiak islands. Due to continual offset along this fault, the seaward shelf in the Gulf of Alaska had significantly different geologic history than the landward shelf in Prince William Sound.

The seaward basin has a broad structural arch near the shelf break, which began rising during Miocene or Pliocene times (von Huene and Shor 1969). The rising of this arch and concurrent sinking of the Tertiary Basin is associated with the sliding of an oceanic plate under the continental mass along the adjacent Aleutian Trench. This sliding caused uplift near the continental margin and tilting of the entire continental shelf to the northwest, resulting in entrapment of shelf sediments. Subsurface sediments and structures at Kodiak have been described by Shor (1965) and von Huene and Shor (1969). There they found the shelf to be filled with 3 to 4 km thick Tertiary sediments. Between Middleton Island and Hinchinbrook Entrance, these sediments are at least 1 km thick. Due to the extreme thickness of sediments deposited, the lower boundary and configuration of the basin remains obscure.

The older rocks were metamorphosed and highly deformed by the middle Jurassic Orogeny, and therefore cannot be easily differentiated. Overlying Tertiary rocks can, however, be divided into three lithologic units, each representing major depositional environments which prevailed on the shelf (Plafker 1971). The lower Tertiary Unit consists of continental pillow lava, tuff, and tuffaceous sandstone and siltstone. The middle Tertiary Unit is a marine sequence with mudstone, siltstone, and occasional sandstone beds. The thick-bedded upper Tertiary Unit (over 5,000 m) is comprised of characteristic shallow-water deposits consisting of mudstone, muddy sandstone, and glacial detritus. Part of-the Tertiary Sequence is exposed in Prince William Sound and on Kodiak Island.

The Pleistocene Epoch, throughout the region, is generally associated with glaciation. Glaciation on the shelf and adjacent land, however, has not been investigated in detail. Although Miocene glacial detritus inter-bedded with marine sediments deposited 10 million years ago have been observed, these are not widespread. Since then, there have been a number of glacial episodes in this region. During the Pleistocene Epoch, extensive icefield and piedmont glaciers repeatedly covered the shelf. The extent of glacial ice cover over the shelf during the Wisconsin is not clear. It is, however, apparent that the entire shelf was extensively glaciated and that there is evidence for glacial sediments on the slope. At the peak of late Wisconsin Glaciation (16,000-12,000 B.P.), much of the continental shelf and part of the slope were covered with glacial ice (Hopkins 1972). Subsequently, a warming trend caused the recession of ice from the shelf, concurrently raising the sea level from -125 m to the present level.

3. Bathymetry:

The bathymetry of the Northeastern Gulf of Alaska Shelf is complex and typical of a glaciated shelf (Figs. I-48, I-49) with numerous broad U-shaped valleys that cut across it. Most" of these valleys are seaward extensions of fiords which form the present coastline. These valleys commonly have intervening basins and occasional sills near the mouths. Large smooth banks are also common.

In the southeast corner, the shelf has a series of troughs and banks, with an oblong deep basin near 58°00'N latitude and 149°35'W longitude. To the northeast, an east-west oriented ridge (58°15'N and 119°50'W) separates this basin into two shallow troughs (58°30'N and 149°50'W; 58°23'N and 149 °30'W). The top of the ridge lies at a depth of -66 m water depth. It should also be noted that the two shallow troughs are separated by a broad bank with a water depth of -125 m. Similarly, the larger trough has a -125 m sill which connects it to the slope. The bank and sill probably were formed during the -125 m sea level stillstand.

Northward, at 59°N latitude, lies an east-west oriented U-shaped valley, bisected by a small ridge. The western part of this valley is an almost circular trough with steep walls to the north and south. The northern flank of this trough has a large terrace at -125 m. This -125 m terrace also separates the trough from a small basin (59°17'N and 19°23'W) to the north. It is apparent that the broad terrace and the sill at -125 m are shoreline features formed during an earlier sea level stillstand.

The bathymetry south and east of Resurrection Bay is extremely complex, with rugged topography resulting from extensive glaciation. The glaciers from Resurrection Bay, and the present Ellsworth and Excelsior glaciers from Day Harbor and the adjacent valley to the east, respectively, descended in the past from the mountains to coalesce on the shelf. This

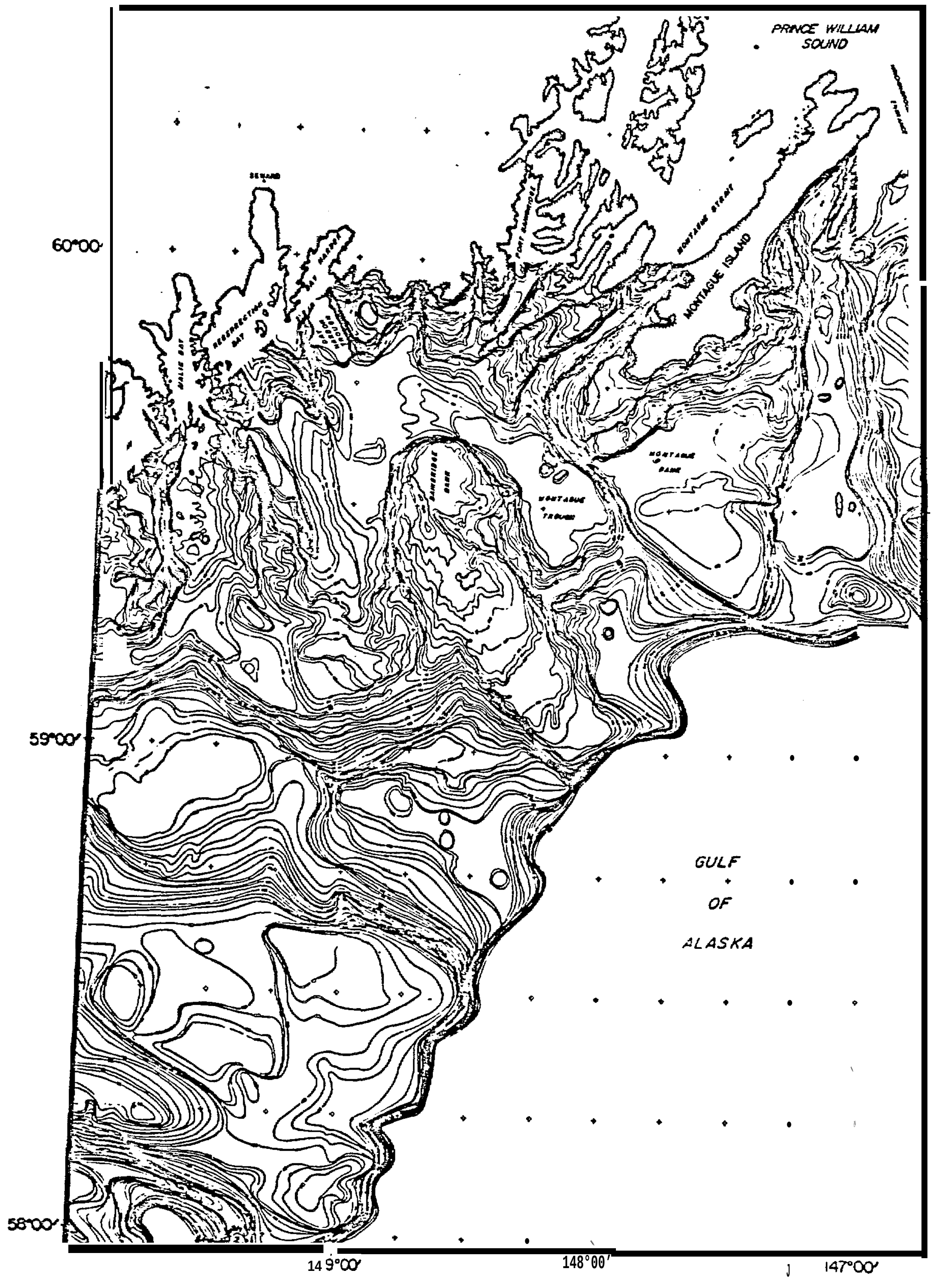
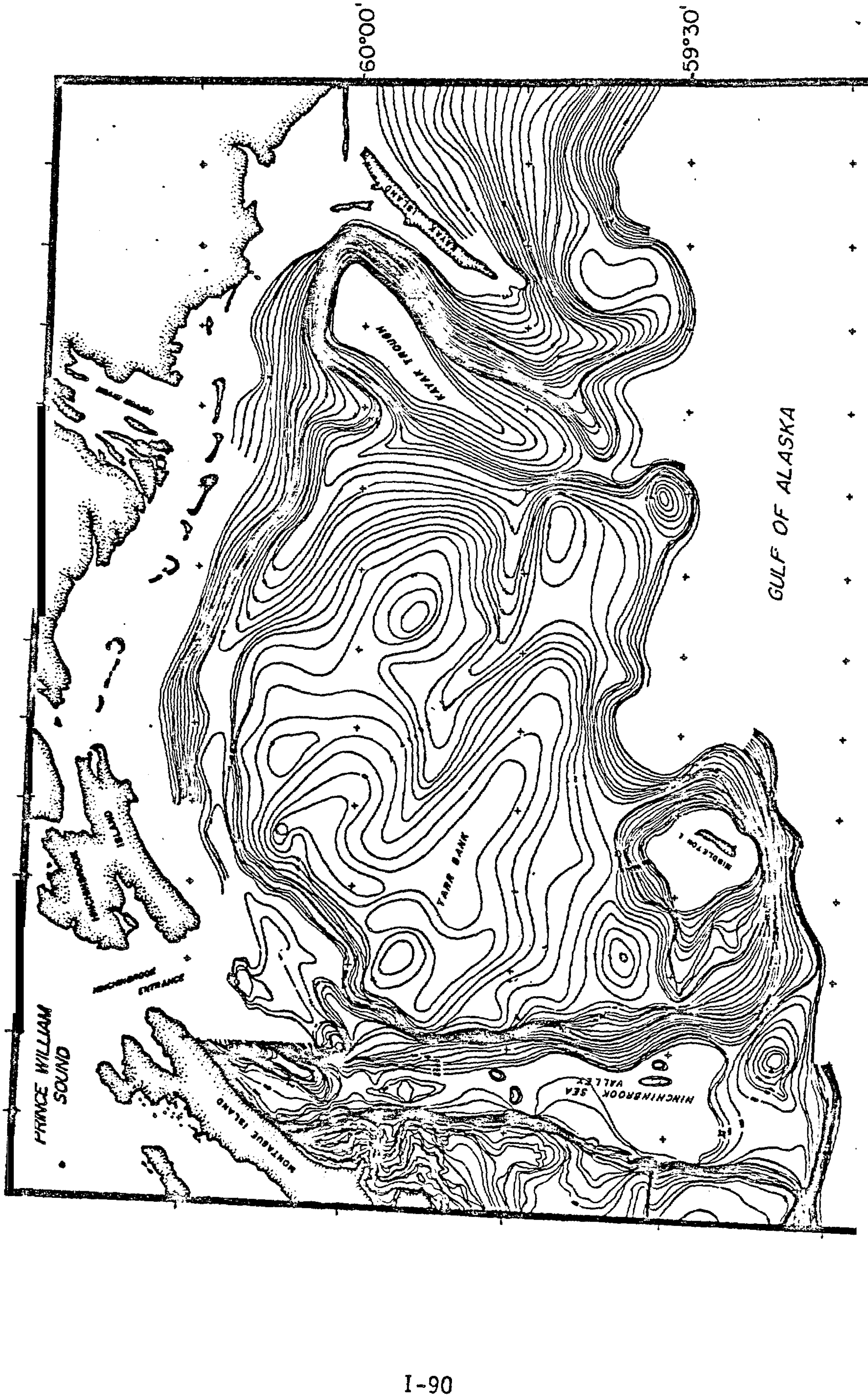


Figure I-48: Bathymetry of northern Gulf of Alaska Shelf, western section.



60°00'
59°30'
147°00'
GULF OF ALASKA
PRINCE WILLIAM SOUND
KAYAK ISLAND
KAYAK TROUGH
TARR BANK
MIDDLETON I.
HINCHINBROOK ENTRANCE
HINCHINBROOK SEA VALLEY
MONTAGUE ISLAND

huge glacier was divided into two lobes by a long broad bank oriented northwest-southeast across the shelf.

One lobe of the glacier turned south and then southeast along the bank. The northern lobe turned east and was joined by glaciers descending from the north through Montague Strait to gouge a broad U-shaped valley along the northeastern margin of the bank. The valley is bisected by a prominent ridge whose origin may be either structural or marginal.

The elongated bank which separates these lobes has two terraces at -125 m and -82 m, respectively. It appears that these features are remnants of earlier sea level stillstands.

South of Montague Island is a large, triangular-shaped bank, with a steep gradient along the side of the bank beyond -125 m. It appears that the smooth surface of Montague Bank is the result of structural factors, glaciation, and marine abrasion. The top of the bank has a -110 m isobath which may be the result of contemporary sediment deposition.

Offshore, the region between Montague and Kayak islands is a shallow region called Tarr Bank, which is circumvented by a moat-like depression. The eastern portion of this moat is called Hinchinbrook Sea Valley, while the north-south basin to the west is known as the Kayak Trough.

Glaciers from Prince William Sound Entrance, the Copper River valley, and part of Bering Glacier apparently occupied the depression surrounding Tarr Bank in the past and carried to the shelf edge.

Numerous bottom features observed in Cook Inlet support past sea level stillstands as observed on other Alaskan shelves. The northwestern shelf has many features which indicate paleosealevel stillstands at -66 m, -82 m, and -125 m. The evidence for shallower paleosealevel stands is perhaps preserved in nearshore areas for which detailed bathymetric data are not available.

4. Bathymetric Data Sources:

Bathymetric charts for lower Cook Inlet and the Northeastern Gulf of Alaska Shelf were prepared using data from various sources. The most recent data for lower Cook Inlet were obtained from the Patty Ray Geophysical Survey, Alaska; the Continental Shelf Data Service, Denver, Colorado; and USGS unpublished charts provided by the BLM Outer Continental Shelf Office, Anchorage, Alaska. Bathymetric data for the Northeastern Gulf of Alaska Shelf were obtained from Continental Shelf Data Service, Denver, Colorado, and earlier Coast and Geodetic Survey charts.

Considerable difficulty arose during preparation of these maps. First, the detailed bathymetric charts for lower Cook Inlet prepared by USGS did not match with the BLM base map of 1:250,000 scale. This necessitated preparation of lower Cook Inlet bathymetric charts through replotting of data collected by USGS and by converting Continental Shelf Data Service information available on different projection, scale, and units.

Similarly, preparation of maps for other parts of the shelf required conversion of data from charts of different projection, scale, and units. These difficulties were overcome by reading thousands of points from earlier charts and replotting them on base charts provided by the BLM office. This led to unforeseen delays in map preparation.

The bathymetric charts prepared for this report are the most up-to-date now available and show bathymetric detail previously found only on scattered charts of various origins.

H. Occurrence and Chronological Placement of Stillstands on the Kodiak-Aleutian Shelf of Alaska

1. Introduction:

During the past decade, investigation of Alaska's Continental Shelf has accelerated. In this period, a general description of the bathymetry, hydrography, sediments, geochemistry and environments of the Alaskan Shelf has been provided by Sharma (1979a), and others. The study of surficial geology, biology and hydrodynamics of shelf areas opened for oil and gas lease sale has also been initiated by the Bureau of Land Management.

The continental shelf under investigation lies between 56°-590 N latitude and 148°-1640 W longitude. The region is designated the Northwestern Gulf of Alaska Shelf and includes Shelikof Strait (Fig. I-27).

This investigation is to study the occurrence and chronology of sea level stillstands on the Kodiak-Aleutian Shelf of Alaska. The stillstands, based on the geomorphic features of the shelf, will be categorized and a sequence of rise in sea level on the shelf during the late Quarternary will be developed. This sequence of rise in sea level will be determined from bathymetric profiles and from analysis of sediment layers surrounding some of the sills on the Kodiak-Aleutian Shelf. The sediment layers, in cores from the vicinity of characteristic sills, should permit assessment of some of the paleoenvironmental characteristics of the shelf during periods of deposition. Chronology of sea level fluctuations, represented by the stratigraphy of sediments in cores, can then be determined by radiometric dating.

Included are "discussions of the bathymetry and various sea-floor geomorphic features indicative of stillstands, and descriptions of bathymetric profiles and core sediments. Characteristics of submerged geomorphic features and results of core sediment analyses are interpreted in order to develop a curve of the sea level fluctuations over the past 20,000 years on the Northwestern Gulf of Alaska Shelf.

2. General Description of Study Area:

This investigation is concerned with the Gulf of Alaska in the vicinity of Kodiak Island, including Shelikof Strait, the Alaska Peninsula and the northeastern Aleutian Islands. The Alaska Peninsula is an extension of the Aleutian Range and consists of a mountainous core with numerous active volcanos. These volcanos form peaks ranging from 1000 m to over 2400 m and display assorted volcanic features (calderas, craters, cones, lava flow and ash deposits). The peninsula is highly glaciated, and cirques and U-shaped valleys abound throughout its entire length. Streams draining the peninsula are short, steep, and swift, often forming waterfalls. The crest of the peninsula is rarely more than a few kilometers from the shoreline. The Aleutian Islands are also formed by volcanoes, and have also been glaciated.

The peninsula and the islands both are characterized by steep, rugged mountains descending to a highly irregular shoreline, with many islands. The serrated coastline is indented with inlets, bays, channels, fiords and lagoons.

3. Geologic Evolution:

The region was a deep basin during the Paleozoic and Mesozoic eras, with widespread deposition of elastics, volcanics and carbonates. During the Jurassic, these sediments were intruded by large amounts of granitic materials, which formed the Alaska Peninsula, while deep water elastics were deposited on the shelf and slope. During the early Tertiary, the shelf region was intruded by granitic materials and the region was uplifted to form the present continental shelf configuration. Major deformations occurred during or after the granitic intrusions. The area has been tectonically active throughout the Cenozoic.

The Pleistocene Epoch brought repeated glaciation of the adjacent mountain ranges and lowlands, as is obvious from the fiord-indented coastline. During major glacial advances the sea receded towards the shelf margin and ice covered much of the continental shelf. Most sediments eroded by the glaciers during low sea levels probably were deposited on the shelf and in the Aleutian Trench. The present geomorphology of the region, therefore, evolved as the result of a combination of tectonic and glacio-fluvial processes.

The shelf has a series of northeast-southwest oriented islands, the largest of which is the Kodiak-Afognak Island Group. These islands bisect the shelf, forming the 300 km long and 40 to 65 km wide Shelikof Strait. Southwest of Kodiak Island, the shelf is bordered by the Alaska Peninsula. This portion of the shelf also has a few clusters of islands such as the Shumigan Group. Several other smaller islands and island groups occur off the southern Alaska Peninsula, most prominent being the Sanak and the Semidi islands. The extreme southwest part of the shelf described here lies off Unalaska and Unimak islands. The latter are the northeastern base of the Aleutian island chain which extends 2250 km to the southwest and forms the boundary between the Bering Sea and the Pacific Ocean.

The continental slope at the edge of the shelf is quite sharp and heavily dissected by numerous valleys. The shelf break occurs at about the -150 m isobath off the Kodiak-Afognak Island Group, and at about the -125 m isobath off Unimak Island. The continental shelf in the study area ranges in width from 250 km north of the Kodiak-Afognak Island Group to less than 50 km off Unimak Island. The area of the shelf investigated is over 175,000 sq. km.

4. Bathymetry:

Detailed bathymetric charts of the Northwestern Gulf of Alaska Shelf were compiled from various sources during an earlier study (Sharma, 1977). A brief summary of these bathymetric data are provided below.

In general, throughout its entire length, the shelf is characterized by numerous islands, archipelagos, plateau-like surfaces (plateaus and banks), and sea valleys. The shelf can be differentiated into three zones; 1) nearshore zone, 2) offshore zone with plateaus and banks and, 3) sea valleys.

The nearshore zone forms a narrow belt between 5 and 8 km wide adjacent to the coastline and extending offshore to the -30 to -50 m isobath. Numerous islands, inlets and fiords are found in this zone.

The offshore zone, the main part of the shelf between -50 and -150 m isobaths, contains large broad plateaus and banks. These flat surfaces have a low gradient of 1 to 5 minutes. The relatively smooth surfaces of the plateaus, however, are often interrupted abruptly by banks and shoals which rise above the plateau surface. Some of these shoals rise close to, or even above sea level and form skerries and islands. All plateaus and banks are characterized by an irregular and dissected relief, suggesting that these surfaces have been eroded by glaciers or subjected to subaerial erosion during periods of lower sea levels. A few of these flat surfaces (Middle Albatross and Southern Albatross banks) occur along the outer edges of the shelf. These shallow surfaces are bounded by the -40 m isobath and at places can rise to -2 m water depth.

Sea valleys and fiords on the shelf are aligned either essentially parallel to the shelf length or cut across the shelf. Those which run parallel or sub-parallel to the shelf are also parallel to the main structural trend of the shelf. Their close alignment with major trends of faults or with the fold systems of the shelf, and their large-scale dimension, suggest tectonic origin. They are probably large subsiding tectonic depressions resulting from erogenic movement. These large sea valleys are broad, with flat bottoms, steep sides and 1-3 degree slopes. Shelikof Strait is typical of such valleys. The presence of sills along their longitudinal axes and reverse slopes forming intervening basins indicate that these valleys have been intermittently eroded by glacio-fluvial processes during lower sea level stands.

The second type includes sea valleys and fiords which generally traverse the shelf width and are of smaller dimensions. They often originate in the nearshore region in bays and inlets and sometimes extend offshore to the shelf break. The broad sea valleys have steep sides and flat bottoms ranging between 10-15 km wide while fiords are considerably narrower with sills and intervening basins common throughout their course. The longitudinal profile of these valleys and fiords generally shows the deepest part in the middle, as is typical of glacially formed channels.

a. Kodiak-Afognak Island Group:

The bathymetry of the Kodiak-Afognak Island Group is rather complex. Northwest of the islands is a deep trough, Shelikof Strait, which is approximately 300 km long, about 40 km wide and almost 300 m deep. At its northeastern and southeastern peripheries the strait is bounded by sills which separate it morphologically from the Pacific Ocean. The northeastern sill lies east of the Barren Islands, while the southwestern sill lies near the shelf edge. A third sill at approximately -100 m divides Shelikof

Strait into two elongated basins. The northeastern basin is deeper than the southwestern depression which extends to the continental margin.

To the north, the Kodiak-Afognak Island Group is separated from the Barren Islands by a narrow -135 m deep channel, Stevenson Entrance. The channel and adjacent shelf has a basin and sill topography with, in particular, a pronounced sill at -125 m near the eastern margin of the channel. This sill is devoid of contemporary sediments, with an exposed basement complex. Structural arches (sills) along the outer shelf were also observed by Hampton, et al. (1979). They reported that the arches are typically devoid of sediments and have been eroded to exposed bedrock.

The channel broadens eastwards, extending to the shelf edge, where it is known as the Stevenson Trough. The trough forms the boundary between the Portlock Bank to the north and the Albatross Bank to the south.

The main features on the shelf southeast of the Kodiak-Afognak Island Group are the shallow Northern, Middle and Southern Albatross banks, separated by the Chiniak and Kiliuda troughs which cut across the shelf. The bottom profiles of these troughs are structurally controlled but modified by repeated glacial and fluvial erosion. Some of the important features of these troughs are described in subsequent sections.

To the southwest, the Kodiak-Afognak Shelf extends beyond Chirikof Island and is separated from the Alaska Peninsula Shelf by the southern extension of Shelikof Strait. The Trinity Islands and Chirikof Island are separated from the Kodiak-Afognak Island Group by a broad shallow sill of -28 m water depth.

b. Alaska Peninsula Shelf:

This portion of the Northwestern Gulf of Alaska Shelf extends from the western edge of Shelikof Strait to Unimak Pass in the west. The major archipelagos are the Shumagin and Sanak islands. There are, of course, numerous islands in the nearshore zone. Other prominent features of the shelf are two deep (greater than -200 m) basins. One small circular depression lies near the southern end of Shelikof Strait, and a larger triangular-shaped basin is located east of the Shumagin Islands. Numerous depressions between -100 m to -200 m isobaths are scattered throughout the shelf.

There are three prominent banks on the outer shelf; the Shumagin Bank between the Shumagin Islands and the shelf edge; the Sanak Bank southeast of the Sanak Islands and extending to the slope; and the Davidson Bank located south of Unimak Island near the outer shelf. An elongated, irregular-shaped depression (greater than -100 m) separates Unimak Island and the Davidson Bank.

The Shumagin Islands consist of 15 sizable islands and many smaller islets and rocks, with a total area of approximately 6,000 sq. km. Smaller island groups are the Sanak and Semidi islands. The coastlines of these islands are irregular and rocky, and similar to the Alaska Peninsula.

c. Aleutian Island Shelf:

The shelf off Unalaska and Umnak islands is relatively featureless. It is narrow, mostly less than 50 km wide, and, except for a few isolated islands, is typically glaciated. The coastline is similar to the Alaska Peninsula. There are few glacially carved valleys traversing the shelf. Lack of an extensive valley system may be due to the absence of large cirques and potential for snow accumulation on the small islands. Some of these valleys have sill and basin topography along their longitudinal axes.

5. Evolution of Shelf Features:

The bathymetry and sediments of the Northwestern Gulf of Alaska Shelf clearly suggest that the contemporary shelf and its sedimentation is significantly affected by tectonics and climate. Past evolution of the shelf and related bottom features were primarily governed by these factors.

The late Miocene-Pliocene "revolution" set the stage for the present Northwestern Gulf of Alaska Shelf, resulting in significant changes in the physiography of the adjacent land, sediment source and hydrography. Concurrent uplift of the arch along the shelf break resulted in tectonic damming of sediments by the shelf ridge. These events were all probably related to the northwest movement of the Pacific Plate.

Subsequently, the shelf was subjected to subaerial glacial and fluvial erosion. The earliest evidence for glaciation in the Gulf of Alaska has been reported by Plafker and Addicott (1976) in Miocene deposits. Although Miocene glacial deposits are not widely distributed, evidence for extensive glaciation of the shelf during subsequent epochs, particularly during the Pleistocene, is overwhelming. Glacial and glacio-fluvial activity was mainly associated with valley cutting on the shelf. Depending upon the size of cirques and the coastal morphology, glaciers descended from the landmass, cutting deep into the shelf and sometimes extending across its entire width to the shelf break. Repeated advances and recessions of ice formed typical fiords and sea valleys throughout the entire shelf. Their longitudinal profiles show basin and sill topography.

Submerged bathymetric features observed on the Gulf of Alaska Shelf are typical of glaciation during lower sea level stands. Frequent occurrences of over-deepened rock basins, fiords, and valleys with reversed slopes are clear testimony for extensive glaciation during the recent past. Deflection of glacial ice by topographic obstructions and flow of glaciers through low-lying areas resulted in differential erosion of the underlying rocks. The vertical erosion by ice is generally maximum on the inner and middle shelf where the channel is narrow. As the channel broadens on the outer shelf, intensity of erosion decreases. This usually results in formation of deepest basins on the inner shelf and relatively shallower but broader basins on the outer shelf, with intermittent sills separating individual basins. The over-deepened basins of the Northwestern Gulf of Alaska Shelf are, therefore, glacial features in that they are a product of erosion by powerful ice during lower sea level stands.

a. Sills:

The topographic highs that often occur at the mouths and along the axes of sea valleys are mostly basement rock, rarely mantled with a thin veneer of sedimentary deposits. Generally, the lack of sediments on sills is in part due to their origin, and in part due to subsequent high energy environments.

The major features on the shelf are clearly indicative of extensive glaciation during lower sea level stands. Each glacial episode and its related sea level stand in turn must have left various sedimentary and topographic imprints. Investigation of such features, therefore, should provide an excellent time frame for past sea level stands on the Northwestern Gulf of Alaska Shelf. Geomorphic features that provide reliable clues for past sea level stands can be categorized as depositional and erosional. The prominent depositional and erosional features which survive over long periods are generally formed during stable sea level stands of glacial and interglacial episodes. The features formed during rising or lowering sea level extend laterally to the point that they ultimately become inconspicuous and the precise time of their genesis becomes vague.

During a glacial cycle, maximum cold is, in general, followed by the extension of ice, lowered sea level, maximum aridity, loss of vegetation, solifluction, stream loading and terrace building. On the other hand, an interglacial period is warm-humid, marked by red and brown types of soils and by vegetational cover which inhibits large-scale erosion and sediment supply to the shelf. Only transitional phases, towards the beginning and end of each glacial cycle, would be marked by increased terrigenous supply to the sea, facilitated by turbidity currents as well as eolian activity, with formation of large scale depositional features.

Depositional features include deltas and bars formed at the mouth of sedimentary pathways. These are mostly formed closest to the stable sea level stands because of increased terrigenous load at the beginning or end of each glacial cycle. The larger influx of detritus generally overwhelms the carrying capacity of the nearshore marine processes, thereby leaving a distinct depositional feature along the shoreline of the sea level stand.

Erosional features formed during stable sea level stands are terraces and sills. During an extended sea level stand, wave erosion near the shoreline will invariably form a conspicuous terrace. Such terraces are common throughout the world and are well accepted as evidence for past sea level stands.

Sills formed by ice erosion during glaciation are termed here as primary sills (Figure 1-50). The combined influence of ice and shoreline erosion, however, can form so-called secondary sills. Secondary sills initially were primary sills whose shoreward faces were subjected to coastal erosion due to changes in sea level. During a stable sea level stand, a broad terrace is cut at the shoreline. Because of the indentation formed by wave erosion into the shoreface, the sill is structurally weakened at the terrace level, particularly if the terrace is cut in the thin, narrow, upper part of the sill. During a subsequent ice advance, it is quite probable that the glacier, prior to overriding the sill, will exert enough force to break the upper part of the sill near the terrace and thus

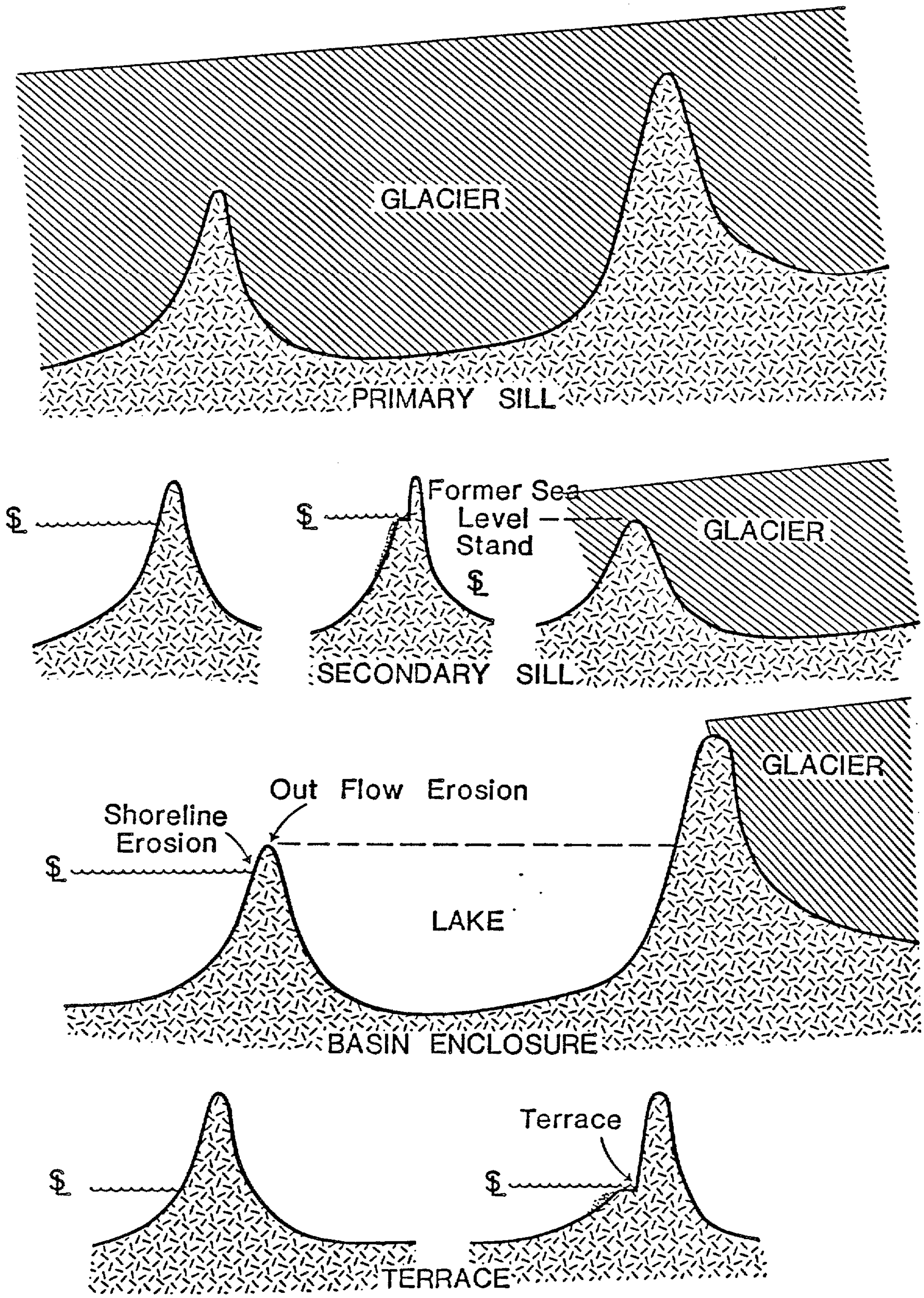


Figure 1-50: Evolution of sills, basin enclosures and terraces along glaciated coasts.

lower the sill depth to the earlier sea level stand. Collapse of sill depth will in turn drastically reduce the erosive power of the overlying ice and sill level will not be lowered further by ice flow.

The basin enclosures (broad sills and structural arches) along the glaciated shelf are formed by the combined actions of glacial, fluvial, and marine processes (Figure 1-50). Fiords and sea valleys with multiple sills have intervening basins between them. During an interstate, the ice should recede upland and the intervening basin, in general, would be filled by the drainage from glaciers as well as surrounding terrain. The basin products (fauna, flora and sediment deposits) prior to eventual marine transgression will typically be of fresh water origin. During this time the seaward edge of the basin serves as a dammed outlet. Contentious outflow over the sill through a narrow constriction would result in intense and accelerated downward erosion of the sill, which would persist until the sill-depth was lowered to sea level.

Initially, the configuration and height of sills are controlled by regional structure, tectonics, bedrock lithology and extent of erosion. Along coastal areas, repeated glacial advances and retreats and intermittent sea level stands would ultimately modify the primary sills. It is apparent that all primary sills would not be transformed to secondary sills or basin enclosures; however, if sea level remained stationary over a considerable period, most coastal primary sills would eventually be reduced to sea level.

b. Paleoshorelines:

Assuming that sea level stands during past glaciation and interstadials were intermittently stabilized, then the respective shorelines should be closely fixed at certain altitudes and should extend over large areas. Additionally, such sea level stands should be manifested by their related sedimentary deposits and bathymetric features. The consistent occurrence of sedimentary deposits and bathymetric features at fixed horizons is extremely important and fundamental to the determination of phases of stable shorelines formed during lower sea level stands.

In spite of excellent clues and evidence observed throughout the world, the nature and extent of eustatic changes are still controversial, especially those of the post-glacial periods, and investigators in different parts of the world have arrived at varying conclusions. The differing opinions mainly stem from the fact that the vertical relationship of geomorphic features formed during paleosealevel stands to present sea level are controlled by various factors. The problem of determining precise eustatic changes is compounded by the complexity of isostatic adjustments in Alaska following the removal of the ice sheet. Important factors, the effect of which must be taken into consideration are: 1) tectonic movement of the shelf (subsidence and uplift), and 2) isostatic adjustment resulting from loading and unloading of ice on the continent and by rising and falling sea level on the shelf.

It is apparent that the northern Pacific Shelf is a tectonically dynamic region and is classified as an island arc collision shelf, where a relatively thin, dense oceanic crust with sedimentary cover (Pacific Plate) is being thrust under a less dense continental plate. Major thrust faults run parallel to the Alaska Peninsula and Aleutian Islands Arc System. Major subsidence and uplift occur along these faults. The entire Gulf of Alaska has been the scene of considerable seismic activity. It is evident that tectonics have played a major role in positioning of shorelines, both in long-term geologic evolution and during the much shorter period of Pleistocene Glaciation.

Rates of relative sea level changes around Juneau, in the southeastern section of the Gulf of Alaska, have been evaluated by various investigators from tide-gauge observations. These observations indicate vertical movement of the mainland, part of which is covered by the Juneau Ice Field. The rebound is offcourse, taking place in the vicinity of a mountainous region close to where ice thickness was maximum. It is also suggested that beaches along the Alaska Peninsula have been lifted. The chronology of raised beaches in Alaska has not been well documented.

Although detailed studies are lacking, nonetheless it is believed that the Alaskan Mainland and Alaska Peninsula have, to some extent, risen relative to the sea during post-glacial times. The outer shelf, on the other hand, may have suffered submergence. Isostatic changes in the Gulf as a result of the 1964 major earthquake are a typical example of such readjustment. While glacial rebound should be limited to areas of thick ice accumulation, the margin of the accumulation should be marked by a huge line of zero vertical movement passing along the shelf. The sinking of the outer shelf may be due to the mass transfer of subcrustal material inwards to compensate for the uplift of the hinterland.

In view of the complexities arising from factors controlling eustatic and isostatic changes, the observed data must be carefully reviewed. It would be essential to compare the data gathered from the Northwestern Gulf of Alaska Shelf with data from a stable area, such as the Bering Shelf.

Once various sea level stands are recognized in a region, an even more difficult task lies in dating each of the stands, reconstructing the history, and determining a paleosealevel curve. To solve these questions it is generally necessary to obtain material indicative of conditions under which the events occurred. In the northwestern Gulf of Alaska, this could be achieved by obtaining cores from strategic locations and then analyzing such core sediments as to age and depositional environments. Material from cores could be used for radiometric dating, and should provide absolute dates for various horizons within the core. With this in mind, landward as well as seaward slopes of various sills were selected for coring. It was hoped that sediment wedges near the sill top would permit retrieval of sediments deposited during mid-Wisconsinan glaciation.

6. Methods:

a. Bathymetric Charts:

In general, the bulk of the information was obtained from National Ocean Survey (Coast and Geodetic Survey) nautical charts. The availability of soundings per unit area varied significantly throughout the region. For example, while detailed bathymetric charts of areas surrounding the Kodiak-

Afognak Island Group provided good control, some areas along the Alaska Peninsula have relatively little or no coverage.

Some detailed bathymetric charts of the area, produced by Continental Shelf Data Systems, Denver, Colorado, were also made available by the Bureau of Land Management. Various investigators who had worked in the area were also contacted for their data.

Although an extensive examination of existing and available nautical charts was conducted to develop new charts, reliability of these charts varied according to the date and extent of the hydrographic survey. Additionally, charts were inconsistent in terms of methods employed for depth measurements, projections, and scales. There is no intention on the part of the author to present these charts as a final, definitive configuration of the Northwestern Gulf of Alaska Shelf floor. Much of the region needs additional survey.

b. Bathymetric Survey:

Sub-bottom profiles from some prominent fiords and sea valleys of the shelf off the Kodiak-Afognak Islands were obtained using Ratheon PRECISION TRANSMITTER and RECEIVER, Serial No. 115, recorded on a Ratheon PRECISION FATHOMETER RECORDER, Serial No. 215. Pulse width used varied between 0.3 to 1.0 ms at power settings of either -6 or -12 db. Generally shorter pulse lengths were used in order to achieve better resolution of the topmost sediment layers.

All sub-bottom profiling was done with vessel speed between 4 and 6 knots. The fathogram traces were annotated every five minutes to correspond with the five minute fixes taken on the ship bridge.

c. Core Sampling:

A few core samples were obtained using a BENTHOS Model 2171 Gravity Corer with an inside diameter of approximately 6.5 cm, in a clear plastic liner. The station location of core samples is included in Table 1. Because of the location (sill and narrow terrace), retrieval of cores was limited. Positioning of ship and onboard winch capability seriously hampered the retrieval of samples crucial for this investigation. Furthermore, the sand and gravel of the sediments severely restricted the penetration of the gravity corer. Other types of corers, such as piston and vibro corer, would have achieved greater penetration and retrieval of sediments needed for dating.

Upon retrieval, the coreliner with core was carefully removed from the core barrel, excess top of the coreliner sawed off and both ends sealed using coreliner caps and electrical tape. Cores with liners were placed in upright position in freezers. The cores were kept sealed and frozen during transportation and storage.

d. Laboratory Analysis:

In the laboratory, each frozen core was placed in an upright position and permitted to thaw. In a few hours the outer portion of the core thawed while the central portion remained frozen. At this stage, the coreliner was laid horizontally on a table and the corecaps from both ends removed. The semi-frozen core was then extruded from the liner with the help of a long rod with a rubber stopper attached to one end. The core was then allowed to thaw completely.

As soon as the core-thawed completely, it was split into two halves along its length using a wet knife. The length of the core was then measured and a visual description recorded. Sample cuts from one half of the core were taken for textural and chemical analyses. These samples were usually representative of the major lithologic units observed throughout the entire length of the core. Calcareous fauna was carefully removed for identification and possible radiometric age determination.

Sample cuts taken from cores were split into two portions. The larger portion was treated with hydrogen peroxide and used for the wet pipette and dry sieve analysis. The smaller portion was dried, powdered and then analyzed for elemental composition.

Elemental analysis of the sediment powder was performed using the Inductive Coupled Argon Plasma Emission Spectrograph, Jerell Ash Model No. 975. One hundred mg of powder sample was incorporated into a 100 gm standard sodium peroxide pellet and fused in carbon crucibles. The fused material was then dissolved in 50 ml solution of 5% nitric acid. In cases where gel formed during dissolution, an additional 50 ml of 5% nitric acid was used. Elemental concentrations were measured with background correction using a computer and attached printer. Standard samples were run periodically for comparison, with standard error determined to be ±5%. The textural parameters, together with elemental concentrations of the core sediments, were then plotted on graphs.

7. Results:

This section describes the results of analyses of the data collected aboard ship. The bathymetric profiles as well as the cores were obtained by NOAA personnel of the R/V DISCOVERER. Although a detailed plan for locations and sampling was provided, onboard decisions were left to those persons in charge of data collection. Only part of the data requested was collected. Moreover, it was felt by NOAA personnel in charge of the field project that ship size and on-board coring equipment was inappropriate for retrieving the long cores requested. Furthermore, precise positioning of the ship along the sill could not be achieved.

Unfortunately, only one fathogram along longitudinal transects of the fiords, sea valleys, terraces and ridges was obtained. Study of these fathograms, in many instances, revealed the necessity for additional survey. Nevertheless, the fathograms provided substantial evidence for paleosealevel stands on the Alaskan Shelf.

The on-board data for sounding lines, fixes, and core locations are summarized in Table I-1. Each Precision Fathometer Record trace, along with bathymetric charts, was examined carefully for sea floor features. Features relevant to past sea level stands were identified and studied in detail. Fathograms displaying sills and terraces formed during earlier sea level stands are described. Only a few sections of fathograms showing typical features of main sea level stands are presented in the text because entire lengths of each trace cannot be easily included. Brief descriptions of each trace, including location and the character of all geomorphic features observed, are provided. These are as follows:

TABLE I-1: Locations of Tracklines and Core Samples Taken on the Kodiak-Afognak Shelf

Trackline	Latitude	Longitude	Fix	Core	Course Change
A	58°07.5′	152°03.5′	A-1		
Pillar Cape	58°08.0′	152°02.8′	A-2		
	58°08.4′	152°02.2′	A-3		
	58°08.7′	152°01.8′	A-4		
	58°08.9′	152°01.3′	A-5		
B	58°20.5′	152°03.3′	B-1		
Tonki Bay	58°20.1′	152°03.0′	B-2		156°
	58°19.9′	152°02.9′	B-3		
	58°19.5′	152°02.8′	B-4		
	58°19.4′	152°02.6′	B-5		
	58°19.2′	152°02.3′	B-6	B1	
	58°19.6′	152°02.8′	B-7	B2	
	58°19.6′	152°02.5′	B-8	B3	
	58°20.4′	152°03.4′	B-9	B4	
C	58°27.8′	151°57.2′	c-1		
	58°27.9′	151°56.3′	c-2		
	58°27.5′	151°″55.7′	c-3		
	58°27.0′	151°55.8′	C-4		
	58°26.5′	151°55.1′	C-5		
	58°26.4′	151°54.5′	C-6		
	58°26.4′	151°54.3′	c-7		
	58°26.4′	151°53.5′	C-8		
	58°26.7′	151°51.8′	C-9		
	58°26.9′	151°51.2′	c-lo		
	58°27.2′	151°50.2′	C-11		
	58°27.4′	151°50.8′	C-13	C5	
	58°28.3′	151°57.2′	C-16		
	58°28,6′	151°56.5′	C-17		072°
	58°28.9′	151°55.4′	C-18		065°
	58°29.0′	151°54.8′	C-19		
D	58°33.8′	152°08.9′	D-7		
	58°34.3′	152°09.8′	D-8		
	58°34.8′	152°10.6′	D-9		
	58°35.2′	152°11.3′	D-10		
	58°35.6′	152°12.2′	D-11		
	58°35.8′	152°12.9′	D-12		
	58°36.1′	152°13.7′	D-13		
	58°36.5′	152°14.2′	D-14		
	58°36.9′	152°14.9′	D-15		

Table I-1 (Continued)

Trackline	Latitude	Longitude	Fix	Core	Course Change
	58°37.1′	152°15.5′	D-16		
	58°37.2′	152°15.8′			020°
	58°37.3′	152°15.8′	D-17		
	58°37.7′	152°14.8′	D-18		
	58°38.2′	152°13.9′	D-19		
E	58°37.7′	152°41.3′	E-1		
	58°37.5′	152°40.6′	E-2		
	58°37.3′	152°39.8′	E-3		
	58°37.1′	152°39.5′	E-4		
F	58°31.4′	152°49.6′	F-1		
Shuyak Strait	58°31.3′	152°46.3′	F-5		
	58°31.7′	152°50.2′	F-8	F6	
	58°31.9′	152°50.5′	F-9	F7	
G	58°23.5′	152°58.5′	G-1		
Foul Bay	58°22.5′	152°55.3′	G-5		
	58°24.1′	152°59.2′	G-9	G8	
H	58°14.8′	153°12.3′	H-1		
"Manila Bay-	58°14.7′	153°08.4′	H-5		
Shelikof Strait	58°14.7′	153°09.0′	H-6	H9	
	58°14.2′	153°15.0′	H-9	H10	
I	57°52.3′	153°13.7′	1-1		
Uganik East	57°51.1′	153°12.8′	I-4		
Passage	57°51.1′	153°12.7′	I-6	I11	
	57°52.0′	153°13.5′	I -7	112	
	57°52.0′	153°13.6′	I-8	113	
J	58°01.6′	153°25.2′	J-1		
Kupreanof Strait	58°01.5′	153°25.7′	J-2		
and Viekoda Bay	58°01.8′	153°26.3′	J-3		
	58°02.1′	153°26.7′			299°
	58°02.2′	153°26.7′	J-4		
	58°02.3′	153°27.1′			102°
	58°02.4′	153°27.0′	J-5		
	58°02.3′	153°26.0′	J-6		
	58°02.2′	153°25.1′	J-7		153°
	58°02.1′	153°24.5′	J-8		
	58°01.7′	153°24.0′	J-9		
	58°01.3′	153°23.5′	J-10		
	58°01.3′	153°23.3′	J-12	J14	
	58°01.1′	153°23.3′	J-13	J 15	

Table I-1 (Continued)

Trackline	Latitude	Longitude	Fix	Core	Course Change
K	58°11.6′	153°17.9′	K-1		
Raspberry Strait	58°11.2′	153°17.8′	K-2		133°
	58°10.9′	153°17.3′	K-3		
	58°10.6′	153°16.7′	K-4		
	58°10.2′	153°16.0′	K-5		
	58°09.9′	153°15.1′	K-6		150″
	58°09.6′	153°14.7′	K-7		
L	58°19.5′	154°06.2′	L-1		
Kukak Bay,	58°19.5′	154°07.0′	L-2		
Alaska Peninsula	58°19.5′	154°07.7′	L-3		
	58°19.5′	154°08.2'	L-4		
	58°19.2′	154°05.8′	L-8	L16	
M	58°21.9′	151°52.0′	M-1		
	58°21.2′	151°52.3′	M-2		
	58°20.5′	151°52.6′	M-3		
	58°18.0′	151°53.8′	M-7		195°
	58°17.3′	151°54.1′	M-8		
	58°13.8′	151°56.1′	M-13		
	58°10.6′	151°58.2′	M-18		
N	56°58.3′	153°28.3′	N-1		
	57°00.0′	153°27.7′	N-7		355°
	57°00.4′	153°27.6′	N-8		
	57°01.3′	153°27.7′	N-n		286°
	57°01.4′	153°28.4′	N-12		295°
	57°01.4′	153°29.1′	N-13		
	57°01.8′	153°30.9′	N-16		
	57°01.8′	153°31.0′			260°
	57°01.9′	153°32.1′	N-18		245°
	57°01.8′	153°32.6′	N-19		
	57°01.6′	153°33.5′	N-21		
	57°01.6′	153°33.7′	N-22	N17	
	57°01.5′	153°33.4′	N-23	N18	
	57°01.9′	153°30.9′	N-24	N19	
	57°01.9′	153°30.9′	N-25	N20	
O	57°18.4′	152°59.0′	o-1		
Kiliuda Bay	57°18.4′	153°00.2′	0-2		
	57°18.6′	153°01.3′	0-3		
	57°18.7′	153°02.1′	0-4		
	57°18.7′	153°03.0′	0-5		
	57°18.8′	153°03.2′	0-6	021	
	57°18.8′	153°03.5′	0-7	022	

Table I-1 (Continued)

Trackline	Latitude	Longitude	Fix	Core	Course Change
P	57°12.5′	152°32.1′	P-1		
Dangerous Cape	57°13.6′	152°33.5′	P-4		
	57°14.8′	152°34.5′	P-7		
	57°15.5′	152°33.2′	P-9		
Q	57°27.7′	152°42.1′	Q-1		
Ugak Bay	57°27.8′	152°42.9′	Q-2		
	57°28.2′	152°44.2′	o-4		
	57°28.5′	152°45.9′	Q-6		
	57°28.5′	152°46.3′			284°
	57°28.7′	152°46.8′	Q-7		
	57°28.9′	152°48.4′	Q-9		
	57°29.0′	152°49.1′	Q-10		
	57°27.9′	152°50.0′	Q-II		
	57°29.1′	152°50.5′	Q-12		
	57°29.4′	152°50.6′	Q-14	Q23	
	57°29.4′	152°50.6′	Q-15	Q24	
R	57°22.0′	152°27.4′	R-1		113°
	57°21.9′	152°26.5′	R-2		
	57°21.4′	152°24.7′	R-4		
	57°21.1′	152°23.0′	R-6		
	57°20.9′	152°22.2′	R-7		
	57°20.5′	152°21.2′	R-8		
S	57°18.3′	152°23.9′	s-1		
Southwest Of	57°18.1′	152°23.0′	s-2		
Ugak Island	57°18.1′	152°22.4′	s-3		
	57°17.8′	152°21.5′	s-4		
	57°17.6′	152°20.5′	s-5		
	57°17.3′	152°19.5′	S-6		
	57°17.1′	152°18.7′	s-7		
	56°40.1′	156°50.9′		GAC 1	
	56°36.8′	157°01.1′		GAC 2	

a. Bathymetric Profiles:

i. Trackline A:

Trackline A transects the terrace off Pillar Cape (58°07.5'N - 152°03.5'W and 58°08.9'N - 152°01.3'W). It should be noted that the most shallow depth on NOS 16604 Chart (formerly C&CS 8533) is 28 fm and deepens to 32 fm to the northeast and southwest. On the contrary, the shallowest depth on the track chart is about 31.5 fm or 57 m. The observed difference of 7 m may have been caused by the great Alaskan Earthquake of 1964.

The terrace is devoid of sedimentary cover, apparently because the area lies in the vicinity of the main channel, where strong tidal currents are generated, and, with the exception of some potholes, consists of basement rock.

ii. Trackline B:

This trackline is a transect between the two northeast-southwest lying elongated basins of Tonki Bay. There are two excellent tracks; one going in and another coming out.

a) Forward Track:

At the base, at about -130 m, there is a noticeable break in the gradient accompanied by stratified sediments forming the floor of the basin. It appears that although this level coincides with the -125 m sea level stand, it is basically the floor of the basin and not the shoreline. The underlying basement structure to the right is also covered with almost horizontal thick layers of sediments.

To the left, the -82 m shoreline is somewhat obscured by slumped sediments; nevertheless, the change in slope and the sediment. accumulation at this horizon is clearly indicative of a paleoshoreline. The sill, of course, lies precisely at -66 m water depth. The lack of sediments in the saddle implies that either these shorelines are relatively recent or that strong currents inhibit sediment deposition.

b) Return Track:

Thick-layered sediments typify the floor of Tonki Bay. As one moves towards the -66 m sill (note that ship track is not through the deepest part of the sill, therefore, the depth at the sill is not 66 m but 63 m), farther to the right there is a broad -104 m deep saucer-shaped basin. At the extreme right along the slope of this basin, a steeply-sloped layer of probably slumped sediments is observed. Although this appears to be a rather broad shoreline, the reverse sloping of the basin and the steep-lying sediment to the right do not indicate that the submerged feature and sedimentation are the result of wave-cutting shoreline processes. This terrace is not visible on the sub-bottom profile recorded on the earlier pass. On the other hand, the -82 m terrace is smooth and covered by less steeply-inclined sediments. The sill itself, of course, is slightly shallower than -66 m, though this is probably because the ship tracks did not pass over the deepest part of the channel.

iii. Trackline C (Fixes C 3-16 to C-19):

This trackline passes over a -55 m terrace which forms the northern sill of the passage to the south. To the southeast (as one moves towards the left on the trace), the bottom rises rather steeply. The first evidence of irregularity or break in the steep slope of the bedrock appears at about -125 m. Unfortunately, there is no evidence for the next higher -82 m shoreline. The area where the -82 m shoreline should have been formed is rather protected by a shallow foreshore protrusion. It is conceivable that, due to this protective foreshore, the cliff was not subjected to wave action sufficient to cut a conspicuous shoreline. It is interesting to note that a wedge of sediment starts at -82 m along the slope, clearly indicating evidence of shoreline at this depth. Furthermore, there is a distinct break in the slope accompanied by the presence of layered sediment. A rather prominently flat and broad terrace at -66 m is quite conspicuous on the bathymetric profile.

iv. Trackline C:

When approaching from the east along the slope, there is a moderate shallowing of the shelf. A slight break in the shelf gradient occurs at -168 m, followed by a convex slope and slightly steeper bottom. At -153 m there is another break in the gradient of the shelf, beyond which the gradient becomes even steeper. A conspicuous break, which is also distinguished by inclined layered sediment and exposed bedrock, occurs at -133 m. This could be the -125 m shoreline, but since it occurs at -133 m it is somewhat suspect.

The next prominent break occurs at -87 m. Here again, this should have been at -82 m. Thus there is some evidence of tilting in this area, with the tilt proportional to the depth.

To the west, there are a few small depressions separated by broad ridges. Between fix C-7 and fix C-6, there is a broad sill. It appears that the eastern and western extreme ends of the depression are the true sills, which have been peneplaned by shoreline processes, while the shallower depression between these two sills has been filled with sediments.

A flat area west of the peak at fix C-3 is indicative of a paleoshoreline. Note the absence of such flat areas around other peaks.

An excellent example of shoreline and basin is observed east of fix C-2. The broad and flat area not only occurs precisely at -82 m, but is also covered with layered sediments. Because the sill depth at the entrance is -82 m, deeper shoreline features could develop in the river basin.

v* Trackline E:

This line transects a submerged northeast-southwest extending broad ridge. Offshore, the floor grades steeply, while landward of the ridge lies a small elongated depression; This depression parallels the ridge and must have been a bay during lower sea level stands.

The broad and somewhat peneplaned ridge lies near 58°37.3'N and 152040.1 W. Although the ridge does not form a sill, it is nevertheless, according to bathymetric charts, a broad flat erosional feature and must have formed during a -55 m sea level stand. The landward depression, however, is deeper and slopes southwestward into the outer shelf. Because of this entrance to the sea, during the -66 m sea level stand this region was a shallow tidal bay. Subsequently, during the -55 m sea level stand, the adjacent ridge was eroded from the seaward as well as the bay side and the ridge top was peneplaned to -55 m sea level.

vi. Trackline F (Shuyak Strait):

The Shuyak and Afognak islands are separated by Shuyak Strait. The eastern part of the strait is an elongated deep basin, while to the west it shallows to about 8 m water depth. Although the western entrance to the strait lies near 152°40.0' W, the basin forming the western portion of the strait extends 10 km further offshore. Between Shuyak Basin and Shelikof Strait lies a shallow sill which protrudes to -58 m water depth.

The sill is about 2 km wide and, throughout its width, very smooth. Bottom gradients on both sides of the sill are quite steep but the top of the sill is flat and almost devoid of bottom features. The remarkably smooth and horizontal top of this sill has a water depth of -58 m and, therefore, is of enigmatic origin. Almost all sills observed in this region occur either at -55 m or -66 m depths. It is apparent that the smooth top of the sill is not a structural feature; such surfaces can only be formed as a result of erosion. The question then arises as to whether this erosional feature was formed during -66 m sea level and subsequent sedimentation raised the sill to -58 m water depth. On the other hand, the top of the sill may have been peneplaned during -55 m and was subsequently eroded further by strong tidal rip currents, which are common. in the eastern, shallow part of the strait. It is conceivable that soon after cresting of the sill, a narrow constriction was formed so that large amounts of water during each tidal cycle must have passed through the narrow gap, eroding the sill deeper than normal. The initial sill depth during this period was probably even deeper than the present -58 m depth. Subsequently, as the sea level rose, the intensity of erosion by the tidal current diminished until water depth on the sill became deep enough to permit deposition of a thin layer of contemporary sediments.

vii . Trackline G (Foul Bay)

Bathymetry near the entrance to Foul Bay is extremely complex. An outer sill at the depth of -82 m, as expected, developed along the eastern shelf of the bay. However, there is no evidence for this sea level stand along the northwestern coasts of Afognak and Kodiak islands in Shelikof Strait. It appears that, due to lower sea levels, minimal tidal flux, and shelter from the large storm waves, the shorelines formed during the -82 m sea level stand are not well developed in this region.

Evidence for subsequent sea level stands at -66 m in this track is also absent though there is a broad terrace at -55 m near the mouth of the bay which extends northeast along the shore of Afognak Island. There are also a few series of basins and sills near the entrance, and the -55 m sea level stand is fairly well recorded along the broad sill near 58°22.5'N latitude and 152°55.3'W longitude.

There are numerous breaks in the shelf gradients of intervening basins which could be easily interpreted as terraces. However, a careful examination of the bottom profile indicates that these are mostly small depressions which have been" filled with contemporary sediments.

viii. Trackline H (Malina Bay - Shelikof Strait):

The entrance to Malina Bay has a small outer basin and a large, elongated, -146 m deep inner basin which occupies most of the bay. There are two pronounced sills; an inner sill which interconnects the basins and an outer sill which lies between the outer basin and Shelikof Strait.

The outer sill lies at -66 m water depth and slopes steeply towards the shelf, while landward it slopes gradually to form an intervening -72 m deep basin. The bottom of this basin is rugged, with numerous shallow depressions and mounds. ,

The outer and inner basins are separated by a sill which protrudes to -66 m water depth. The sill is quite broad, with a shallow depression. A shoreline feature is quite conspicuous at -66 m along the eastern margin of this broad sill.

ix. Trackline I (Uganik East Passage):

The sill height forming the inner basins does not correspond to the water depth recorded on the bathymetric chart. There are no discernible erosional features indicative of sea level stillstands at -66 m and -55 m water depths, perhaps due to the shallow restriction which lies east of Naugolka Point. In other words, the passage was not transgressed until water rose to the -38 m sea level stand. Prior to this transgression, the basin was either a lake or glacial ice prevented development of deeper features.

Cores taken from the river basin of the Uganik East Passage should provide evidence for freshwater deposits under the thin veneer of contemporary marine sediments deposited after the transgression. Although a thick sequence of sedimentary deposits in the basin is indicated by the bottom profile records, the core retrieved was very short (23 cm long). Therefore, it is not possible to confirm the paleogeography of this area.

x. Tracklines J-A and J-B:

Both bottom profiles are taken over the sill which forms the entrance to Kupreanof Strait and Viekoda Bay. Seaward of the entrance lies a -120 m deep circular basin which has an outer (seaward) sill varying between -80 m and -90 m water depths. Near the mouth of the strait, the shelf is slightly broader than to the northeast and southwest. It should be noted that while geomorphic features indicative of the -82 m sea level stand are missing along the adjacent shelf to the northeast, these features are quite conspicuous in this region. The prominent erosional. features observed here are perhaps due to the greater breadth of the shelf, which permitted the development of basin and sill topography at greater depths.

The sill south of Raspberry Cape, interconnecting the outer circular basin with Kupreanof Strait and Viekoda Bay, represents an erosional plain formed by the -82 m sea level stand. This fairly smooth sill is over a kilometer wide. The small hook-shaped southern extension of this sill also has a smooth, peneplaned surface developed during the -82 m sea level stand.

xi. Trackline K:

The entrance to Raspberry Strait is a typical fiord with basin and sill topography. At its northwestern end, the strait has a broad sill connecting an elongated basin to Shelikof Strait. The trackline transects the sill from northwest to southeast.

Near the entrance to Shelikof Strait the bottom rises steeply, almost vertically. The gradient, however, abruptly becomes nearly horizontal at -70 m water depth. This bottom profile is typical of glacial erosion. Farther to the southeast, near the entrance to Raspberry Strait, the bottom rises gradually to a water depth of -66 m. At this point the sill is rather smooth and over a kilometer wide. This sill forms the southeast rim of the fiordal basin of Raspberry Strait, and is rather smooth with no perturbations. Peneplanation of the sill appears to have been the result of nearshore wave action and cresting of the sill during the -66 m sea level stand.

xii. Trackline L (Kukak Bay - Alaska Peninsula):

The entrance of Kukak Bay has a shallow sill of -33 m water depth. The top of the sill is quite sharp and does not have any erosional features. It is, therefore, apparent that this sill was unaffected by both the -38 m and -28 m sea level stands. Offshore, the presence of an extremely smooth terrace at -66 m water depth suggests formation during the -66 m sea level stand.

xiii. TrackTine O (Kiliuda Bay):

Kiliuda Bay is a typical fiord which lies midway along the south-eastern coastline of Kodiak Island. Near the mouth, the bay has a narrow, deep sea valley which extends offshore. Towards the bay head there are two small basins separated by sills. The first sill lies across Coxcomb and Pivot points. Bottom profile O transects the first sill from east to west.

The sill, as usual, has a depression with sharp peaks to the east and a broad smooth surface to the west. This smooth top of the sill is an erosional surface -38 m under sea surface. The broad western part of this sill, although relatively smooth, is not a flat surface. The top is slightly inclined to the east, i.e., toward the open ocean. The gradient, however, becomes negligible towards the west. It appears that during the -38 m sea level stand, the shore processes formed a beach morphology along the eastern side of the sill. Continued rise in sea level finally resulted in cresting of the sill and flooding of the basin. The peneplanation of this sill, however, occurred during the -38 m sea level stand.

xiv. Trackline P:

This transect runs in a northeast direction, over a rise which separates a narrow, elongated depression (-100 m deep) off Dangerous Cape from the sloping shelf to the south. This rise does not appear to be a sill, but is an area of complex bathymetry. There is no evidence for erosional surfaces in this area.

xv. Trackline Q (Ugak Bay):

Ugak Bay is one of the longest indentations along the southwestern coastline of Kodiak Island. The bay is a narrow depression, over -100 m deep, extending onto the shelf. Landward,' the bay exhibits typical basin and sill topography.

Near Saltery Cove, bathymetric chart NOS 16593 shows a broad sill, at -28 rewater depth, separating a series of depressions which lie landward of it. The entrance sill near Saltery Cove has an irregular surface and does not indicate wave-eroded shoreline. Interestingly, the northwestern edge, which forms the central basin, has a well developed broad terrace at -38 m water depth which appears to be a paleoshoreline.

The central basin itself is separated from the large river basin by a sill at -55 m water depth. This sill has a well developed broad, smooth terrace at -55 m, with a narrow peak to the southeast. The peak, because of its narrowness, is perhaps an isolated island on an otherwise smooth sill. Further to the northwest, the river basin also has a well developed, smooth shoreline terrace at -66 m water depth.

The well developed shoreline terraces observed on the landward faces of sills of the outer and inner basins pose an enigma regarding their origin. A prominent outermost sill, as shown on the bottom profile, lies at about -25 m water depth and is quite uneven. The presence of this shallow sill, if it indeed extends across the bay, would not permit flooding of the basin until sea level had risen higher than the outer sill, i.e. -25 m. If such is the case, then there is no possibility for the development of shoreline terraces at -66 m, -55 m and -38 m as observed along the sills of the outer and inner basins.

A possible explanation for these deeper shoreline terraces is that the sill does not form a continuous barrier between the shelf and the basin, and is perhaps broken by faults and crevices to considerable depth. Both sills have irregular topography at the outer edge and show presence of rather sharp peaks. It is, therefore, conceivable that a narrow passage through the sill permitted the flooding of the outer and inner basins in concurrence with sea level on the shelf. Thus, at each sea level stand, shoreline processes in the outer and inner basin formed respective shoreline terraces. The presence of passages connecting these basins with the shelf can only be confirmed by a detailed bathymetric survey of each sill.

xvi. Trackline S:

This transect is taken over the submerged ridge which extends southwest of Ugak Island. To the west, the ridge slopes to form a long, narrow trough extending northwest to Ugak Bay. To the east lies a broad shelf with a low gradient. Because the ridge lies on the open shelf, both sides were exposed to wave action.

Starting from the west, the fathogram shows a significant break in gradient along the slope. The sea floor at 47°18.3'N and 152°23.9'W is horizontal at a depth of -82 m. To the east, the bottom rises rather slowly with a uniform gradient to -66 m. Near -66 m, "though there are no erosional features and no evidence for a terrace, there is a distinct break in the gradient, probably caused by sea level stand.

The top of the ridge is quite smooth and lies at -55 m water depth. The eastern edge of the ridge slopes gradually to the Kodiak Shelf.

b. Sediments:

The core sediments generally consisted of gray to dark gray muds and muddy sands. Invariably, all core sediments included some ice-rafted pebbles which were often scattered throughout the core length. A few cores showed significant textural variation with depth, while-others had only minor variations. In three cores, a distinct layer of light brown volcanic ash was observed.

Calcareous fauna in the cores was not noticed in significant concentration. Sometimes, thin, broken calcareous fragments were observed in some sections of the cores; however, these were often scattered uniformly throughout the section rather than forming a predominant shell layer. Shell material was removed after dry sieve analyses were completed and forwarded to Drs. Stoker and Dixon for identification and radiometric dating.

The fauna in general included brachiopods, bryozoans and a few other taxa. Most of the species were modern, reflecting coarse (sandy) substrate of high energy environments. There were, however, no species which could provide a specific range of water depth during their deposition.

The properties of. sediments obtained from grain size distribution analysis were used to compute textural parameters according to Folk (1965). These parameters are plotted for each core. The corresponding elemental analysis is also included so as to reflect interrelationship of textural and chemical parameters.

Core B4 (Fig. 1-51), 35 cm in length, was obtained from the vicinity of Tonki Bay (58°20.4'N and 152°03.4'W). There are some significant changes in sediment parameters with depth. The top layer consisted of 8 cm of dark gray sandy mud underlain by 1 cm of very dark (almost black) silty clay. The bottom layer, between 10 and 35 cm, consisted of silty sandy mud grading upwards into silty sand. The reverse grading in the bottom layer is suggestive of shallowing of the environment. The presence of calcareous shell fragments observed in the core, particularly in conjunction with abnormal increases in Ca % at the top of the bottom layer (11-12.5 cm core depth) further indicates a shallow water environment at the close, of the bottom layer deposition. This shallow environment must have persisted for some time to permit accumulation of the calcareous shells. Unfortunately, the calcareous material was not in sufficient quantity for a radiometric age determination. The upward thinning of sediment in the top layer reflects the beginning of rise in sea level. The top mud is representative of present sea level.

A 49 cm long core, C5 (Fig. I-52), was obtained from the vicinity of Tonki Bay. It contained three lithologic units. The upper 19 cm layer consisted of greenish gray silty sand with calcareous shell fragments scattered throughout. The 19-27 cm mid-section of the core was dark gray sandy mud. The lower part contained sandy silty mud which became finer with depth. Throughout the core (in all three sections), occasional ice-rafted pebbles were observed.

The lithologic as well as chemical variation in the core do not reflect any significant change, with the exception that sand content increases with depth and is reciprocated by increasing amounts of silt and clay. The sediments throughout the entire depth of this core perhaps reflect a recent depositional environment.

A relatively long core, F-7 (130 cm, Fig. I-53), was retrieved from the western entrance of Shuyak Strait. The entire core consisted of light gray sandy silty clay. A sharp break in sediment grain size occurs at about 105 cm below the surface, from which sediment size decreases rapidly with depth.

One of the most significant sections in this core lies between 9 and 12 cm, consisting of a light brown ash. It is interesting to note that the ash layer has not caused marked changes in either textural or chemical parameters of the core sediment. This is perhaps because the ash layer was relatively thin and somewhat mixed with the overlying and underlying sediments during coring and extrusion of the core from the coreliner.

The lower section of the core, which is distinctly different texturally as well as chemically from the top layer, is difficult to explain. It should be noted that both aluminum and silicon concentrations increase dramatically with increase in sediment grain size. The silicon increase could be related to increases in sand, provided the sand is mostly quartz, but the apparent simultaneous increase in aluminum rules out that possibility. Therefore, it appears that the lower section of the core is enriched with heavy sands, representing a shallow water environment. The shallow

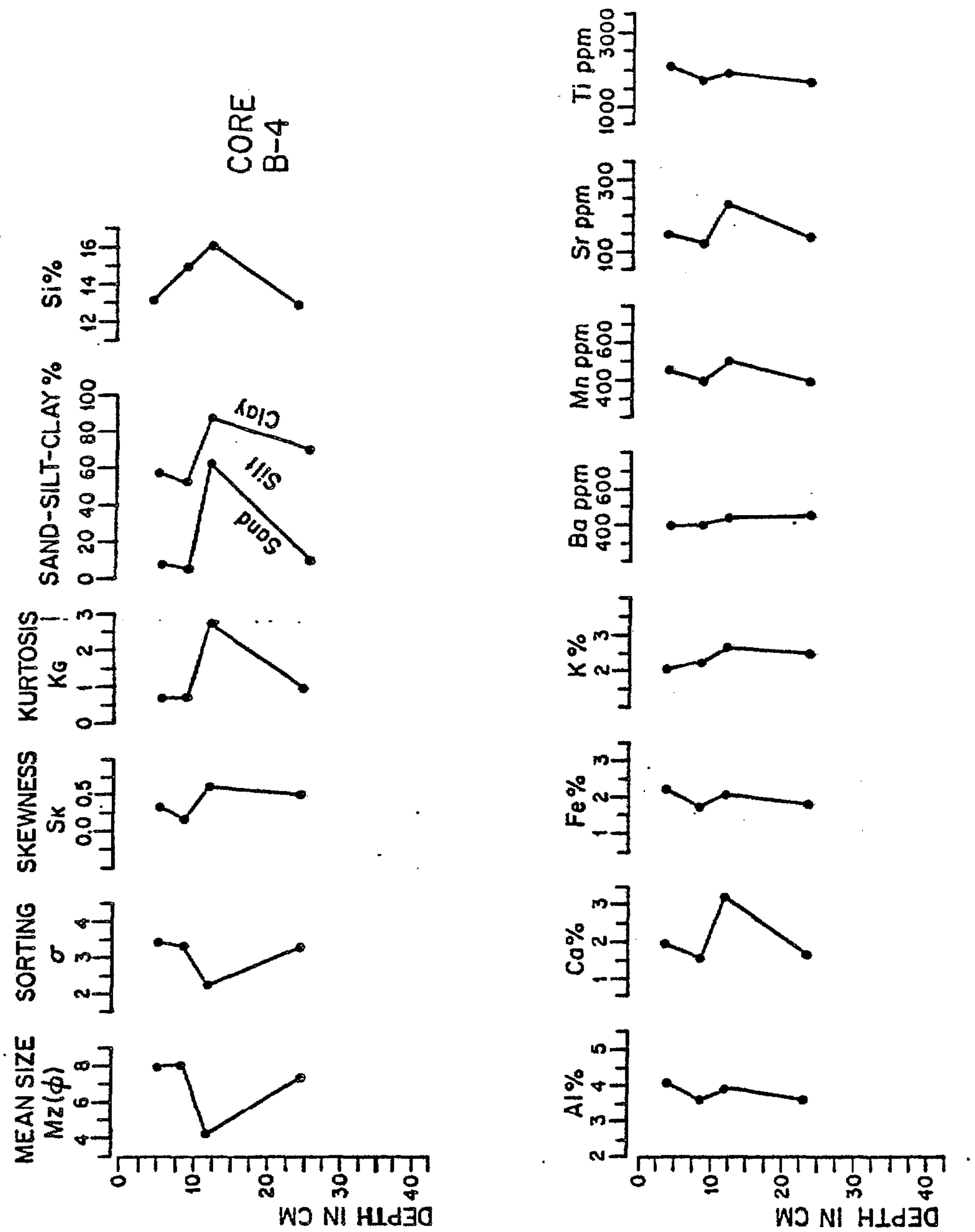


Figure I-51: Core B-4 sediment analysis.

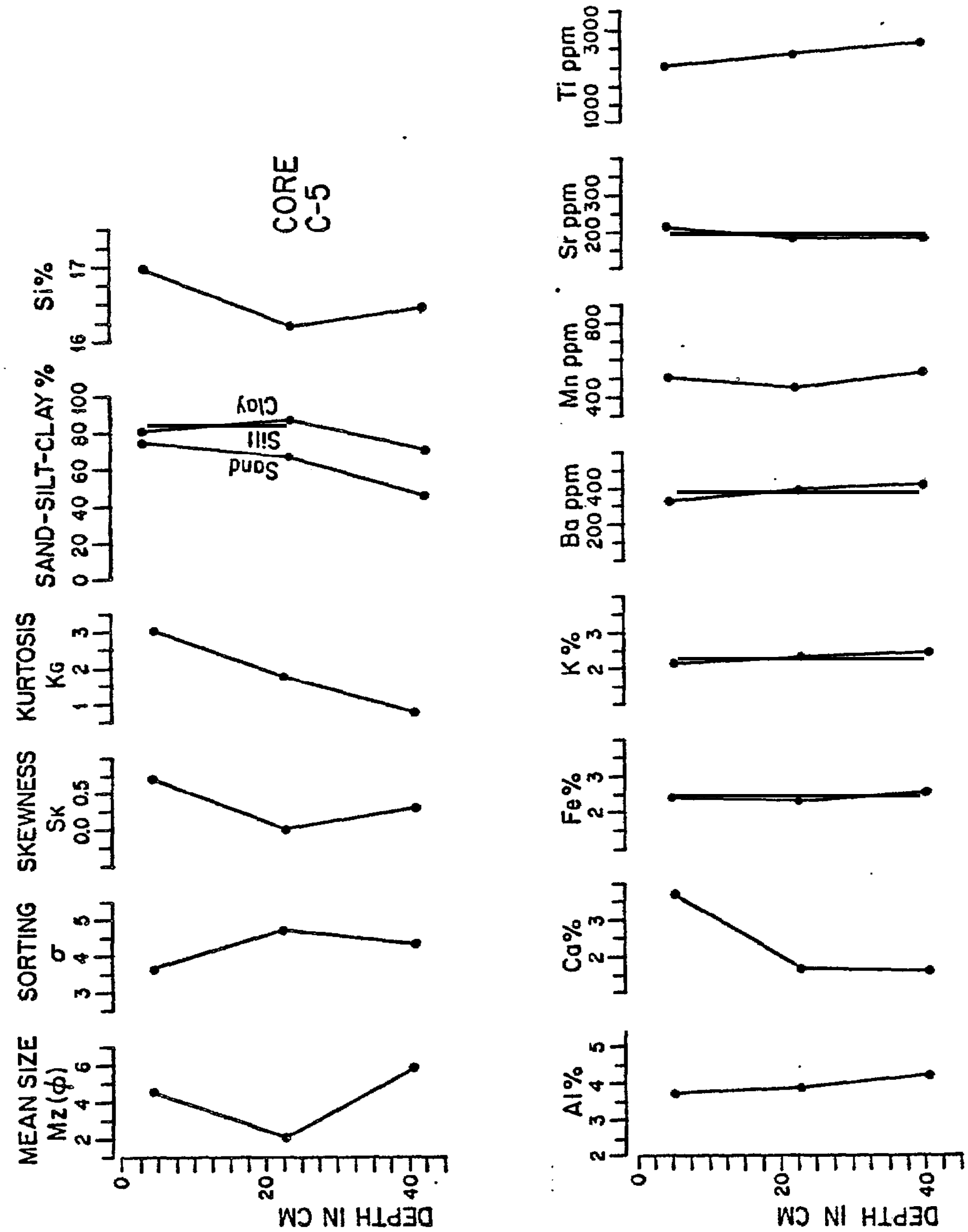


Figure I-52: Core C-5 sediment analysis.

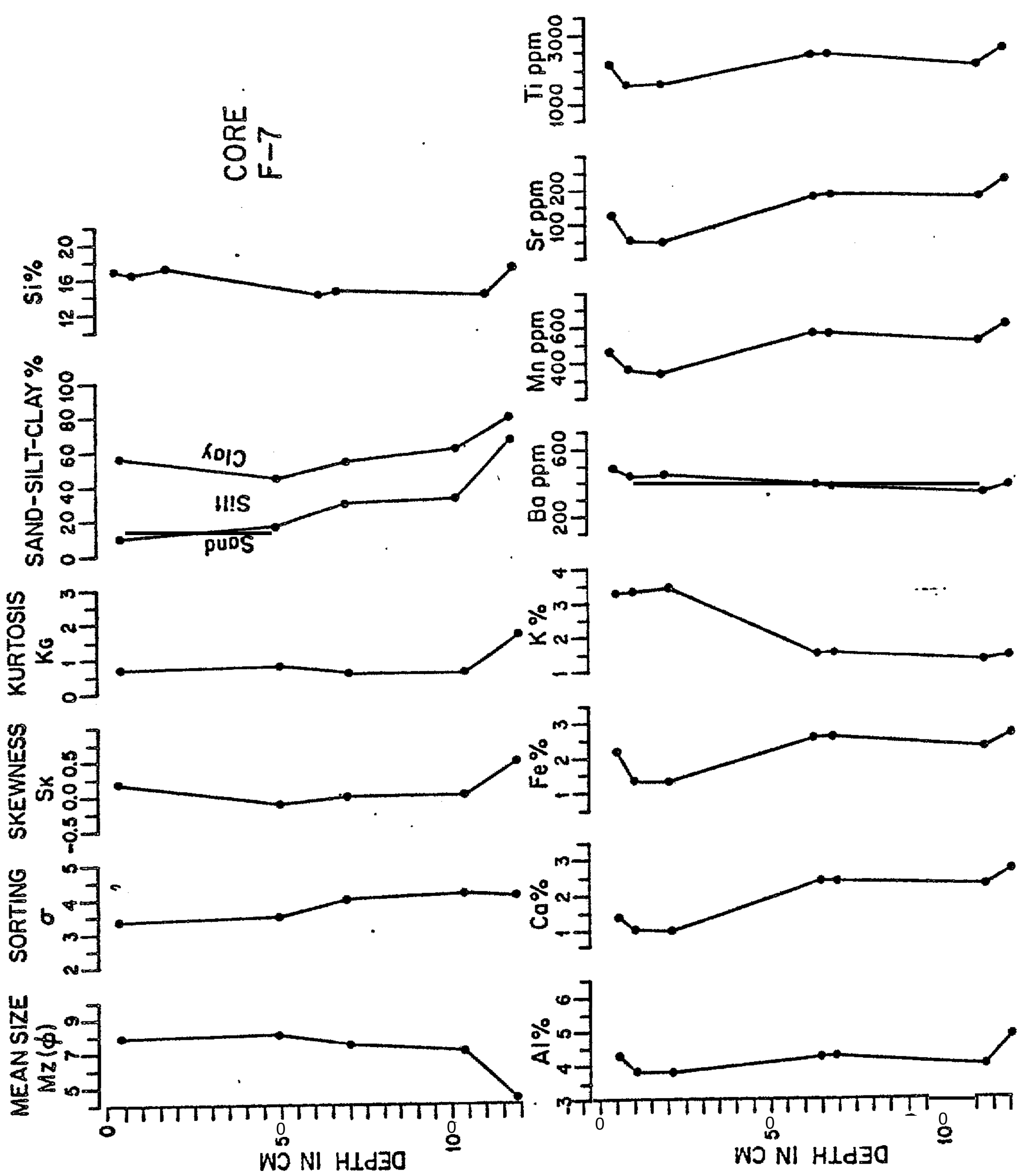


Figure I-53: Core F-7 sediment analysis.

water environment, with its high energy, may have also caused mixing of the ash with bottom sediments and partial removal of fine ash.

There were occasional ice-rafted pebbles scattered throughout the entire length of the core, the largest of which was 3 cm long.

Attempts were made to retrieve a core from the shallow depths of the sill at the entrance of Foul Bay. After repeated attempts, a core (G-8, Fig. I-54) was obtained from -186 m water depth. The core consisted of a thin upper layer (O-2 cm) of greenish-gray sandy mud which was underlain by 1 cm of brownish silty clay of volcanic ash origin. Below the ash layer, the sediments became steadily coarser (note increasing sand) with increasing depth. The upward thinning of sediment in general reflects increasing depth of deposition. Unfortunately, no datable biological material was observed in this core.

Core H-10 (Fig. I-55), obtained from the entrance to Malina Bay, displays extreme variations in the textural parameters of sediments. These fluctuations appear to be the result of turbidity currents and episodal influxes of sediments, possibly the result of landslides along the slopes of the basins, probably triggered by earthquakes.

The surface of the over-one-meter-long core (J-15, Fig. I-56), from the entrance of Kupreanof Strait and Viekoda Bay, consisted of a thin layer of greenish-gray muddy sand. Below the sand was a layer (3-13 cm) of dark gray silty clay. The underlying sediments were mostly sandy silty clay, with silt and clay content increasing with core depth. Ice-rafted pebbles were scattered throughout the core. The core sediments are not indicative of any firm environmental change during their deposition.

Four cores, L-16, N-17, N-19 and Q-23 (Figs. I-57 through 1-60), were taken from the shores of Shelikof Strait and the southwestern shelf of Kodiak Island. These cores consisted of, in general, sandy muds, with composition of sediments quite uniform throughout the cores. The overall texture and composition of these sediments was quite similar to those described earlier. Because of the uniformity of sediments in these cores, it was not considered advisable to draw any inference regarding changes in the depositional environment with depth.

Two additional cores taken from the Alaska Peninsula Shelf, GAC-1 (56°40.1'N and 156°50.9'W, Fig. I-61) and GAC-2 (56°36.8'N and 157°01.1'W, Fig. I-62), showed an overall textural and compositional change with depth. The sediments from core GAC-1 reflected three textural units. The 52 cm top section consisted of silty clayey sand, underlain by a 20 cm thick layer of sandy silty clay. The third section was mostly sand. Depth variations in chemical composition, in general, are to an extent influenced by the sediment texture. The overall trend perhaps signifies general shallowing of the environment as reflected by the deposition of fine sediments overlain by silty sand. The GAC-2 core showed only two types of sediments. The upper 50 cm of the core consisted of sandy silty clay underlain by 65 cm of clay with slightly increased sand and silt. The minor differences in texture and chemical composition do not reflect any significant changes in the depositional environment of these sediments.

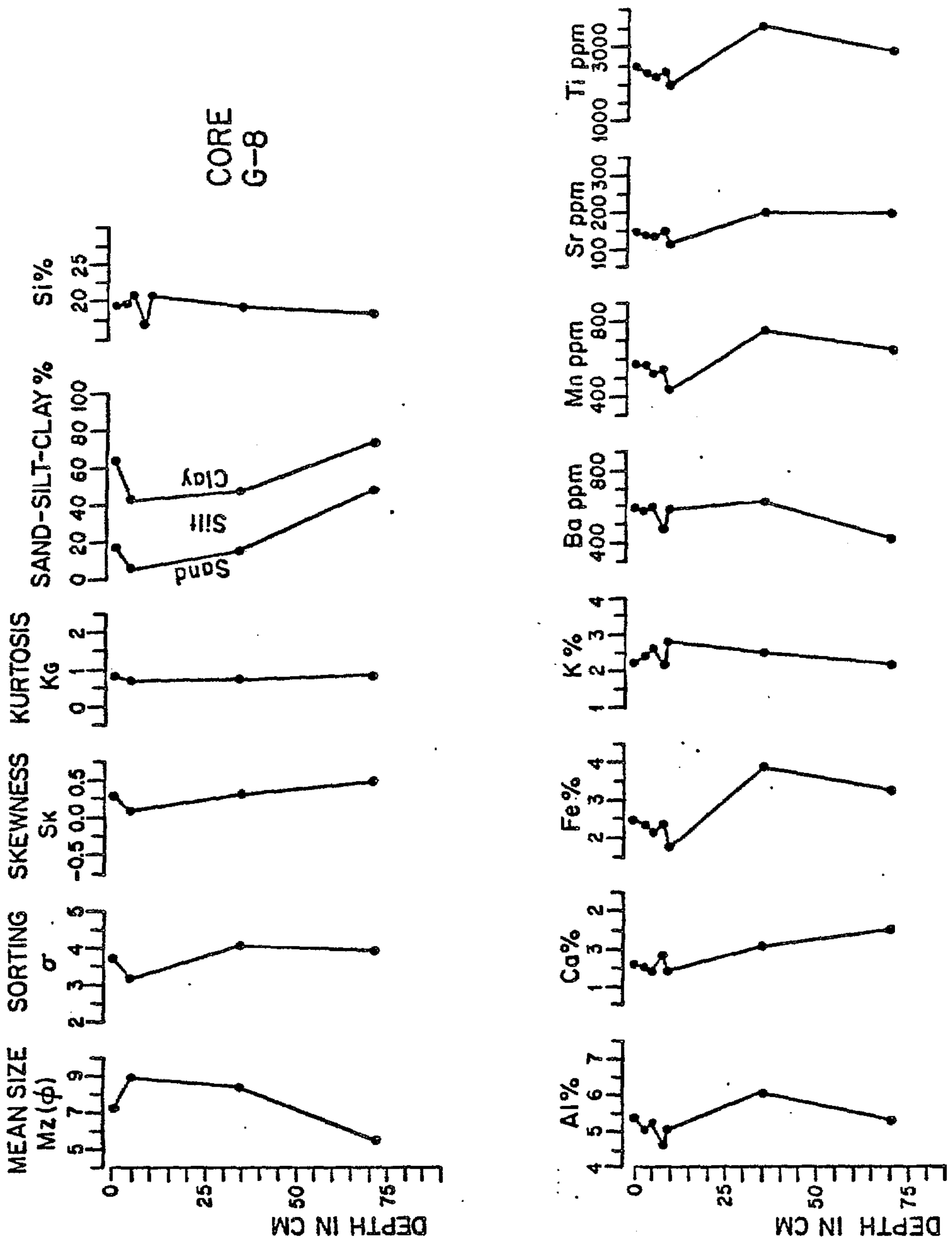


Figure I-54: Core G-8 sediment analysis.

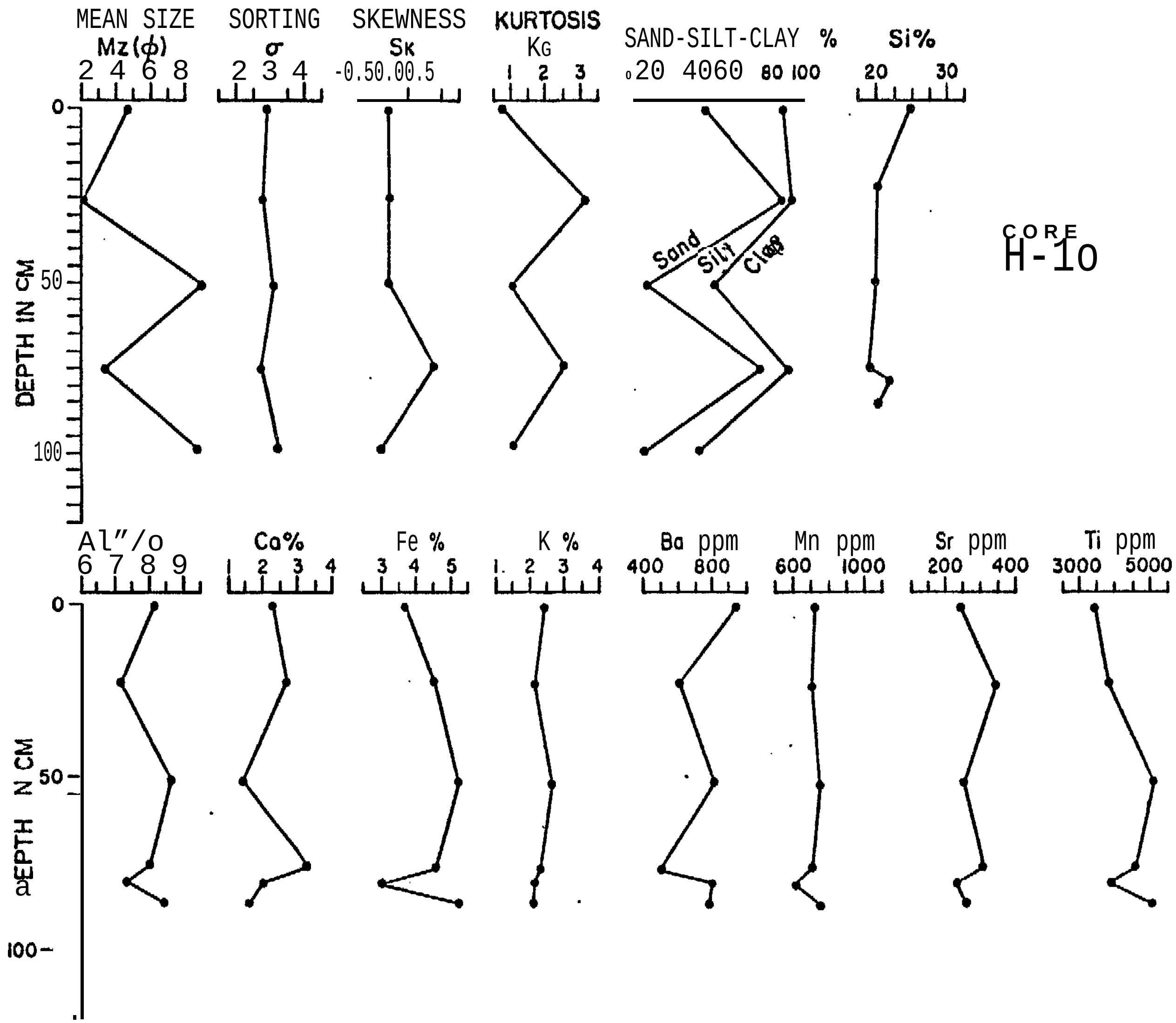


Figure I-55: Core H-10 sediment analys s.

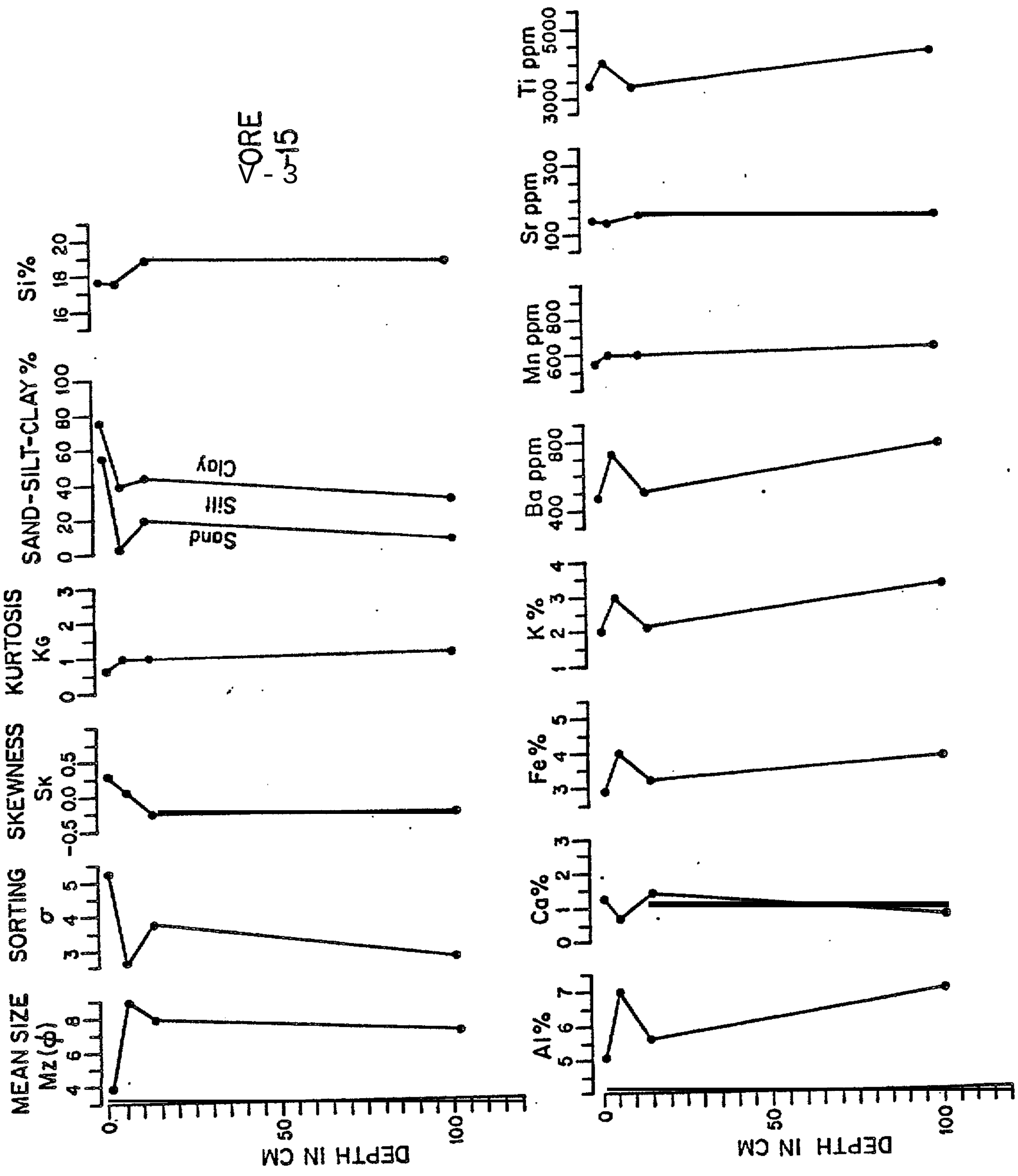


Figure I-56: Core J-15 sediment analysis.

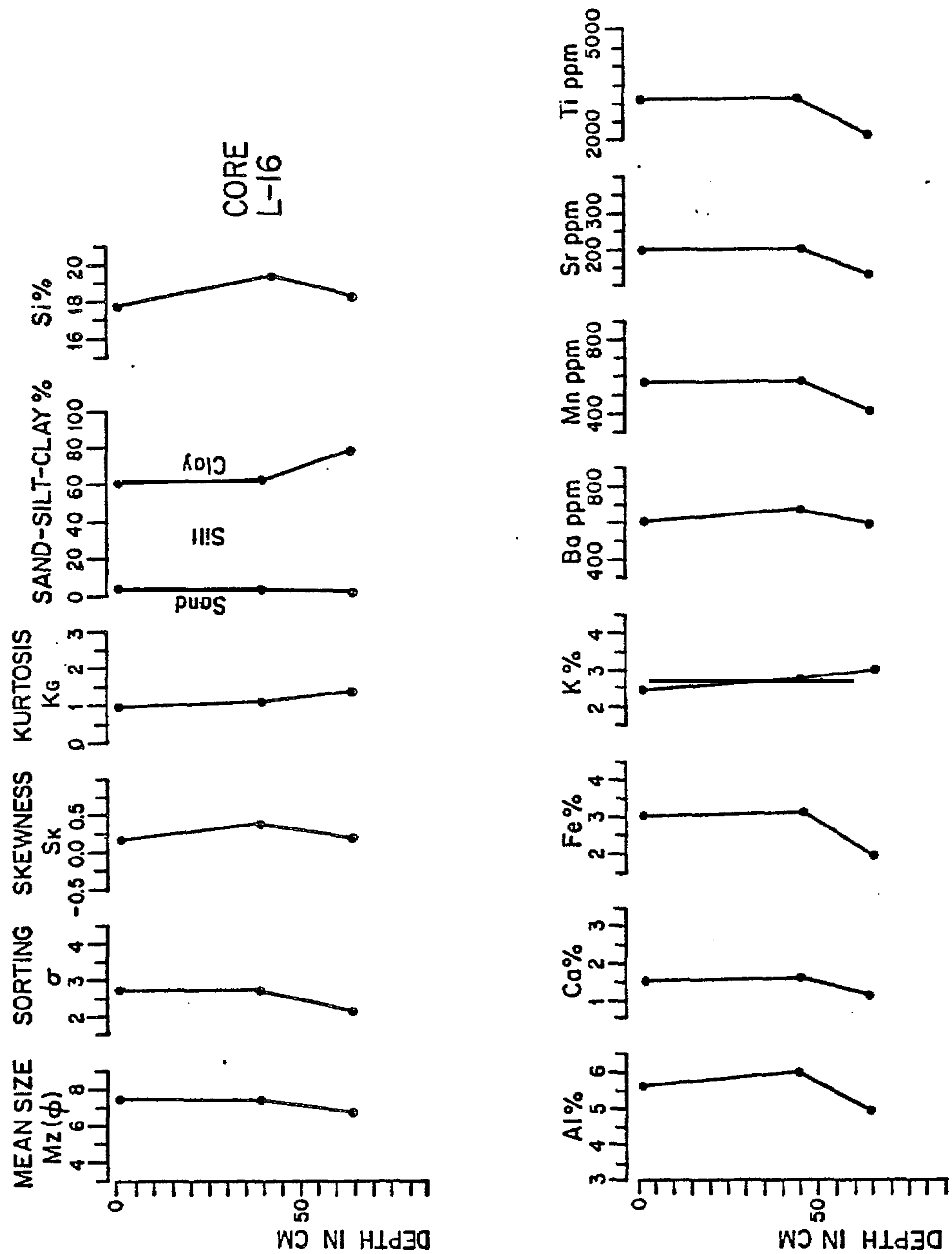


Figure I-57: Core L-16 sediment analysis.

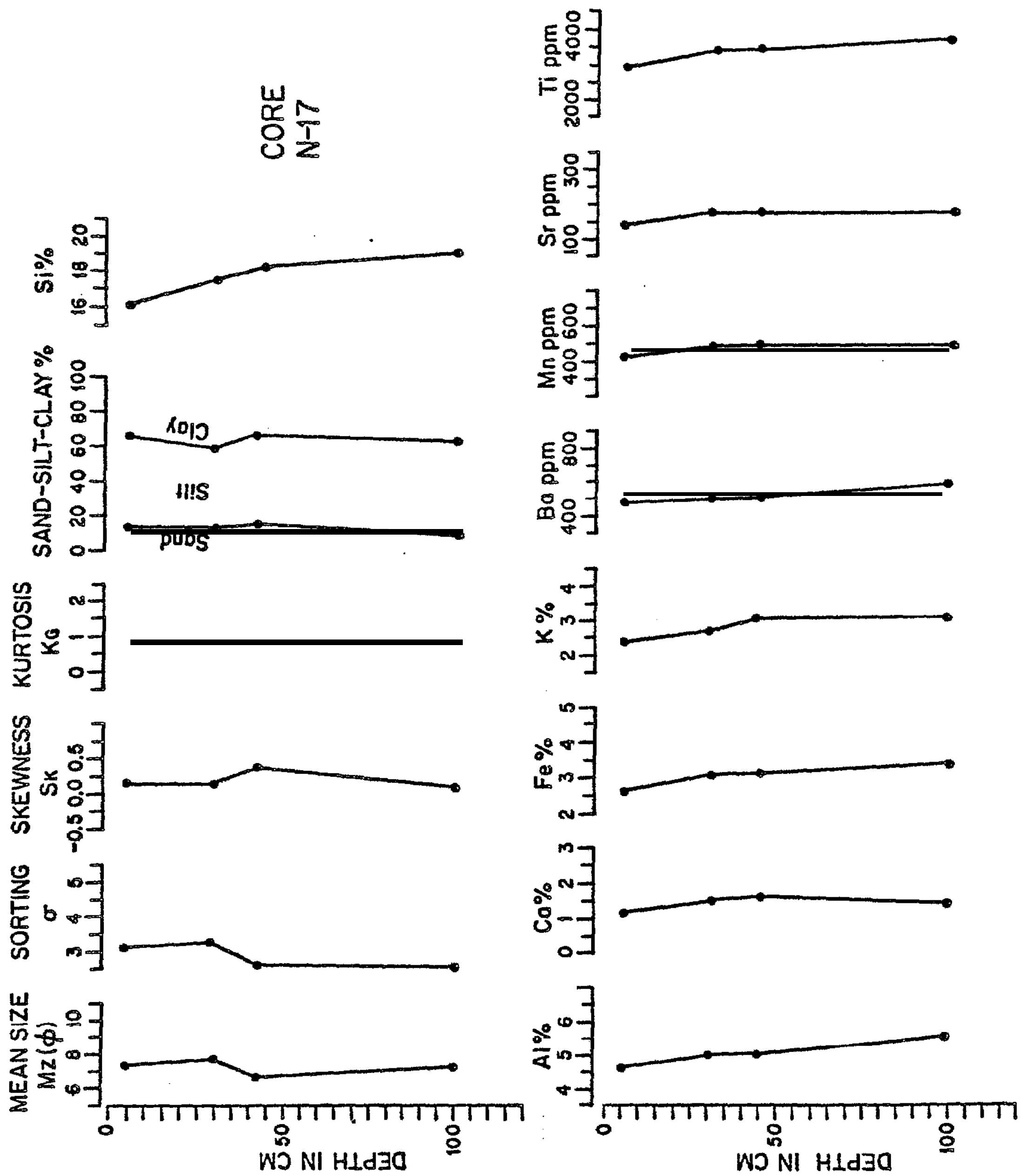


Figure I-58: Core N-17 sediment analysis.

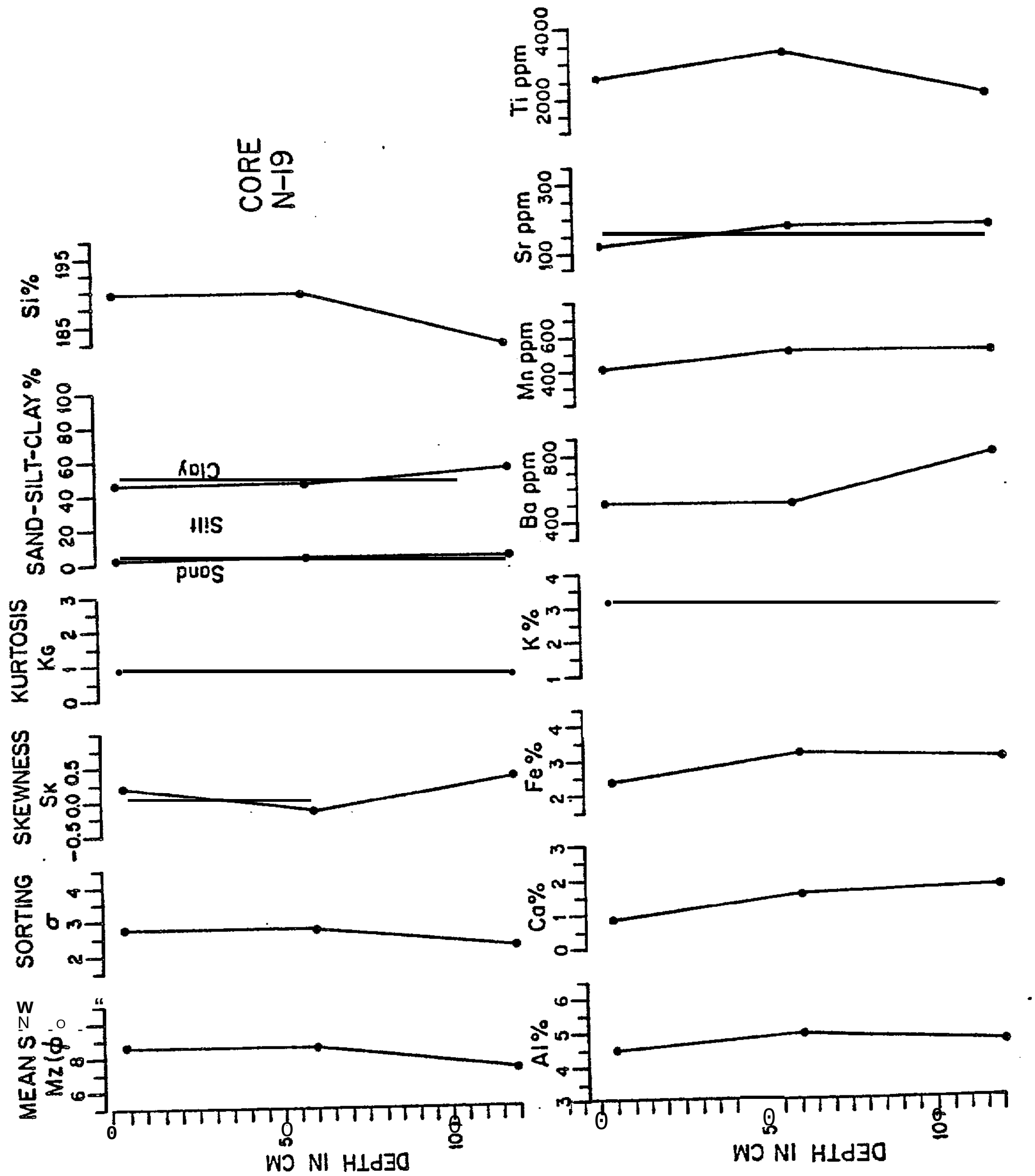


Figure I-59: Core N-19 sediment analysis.

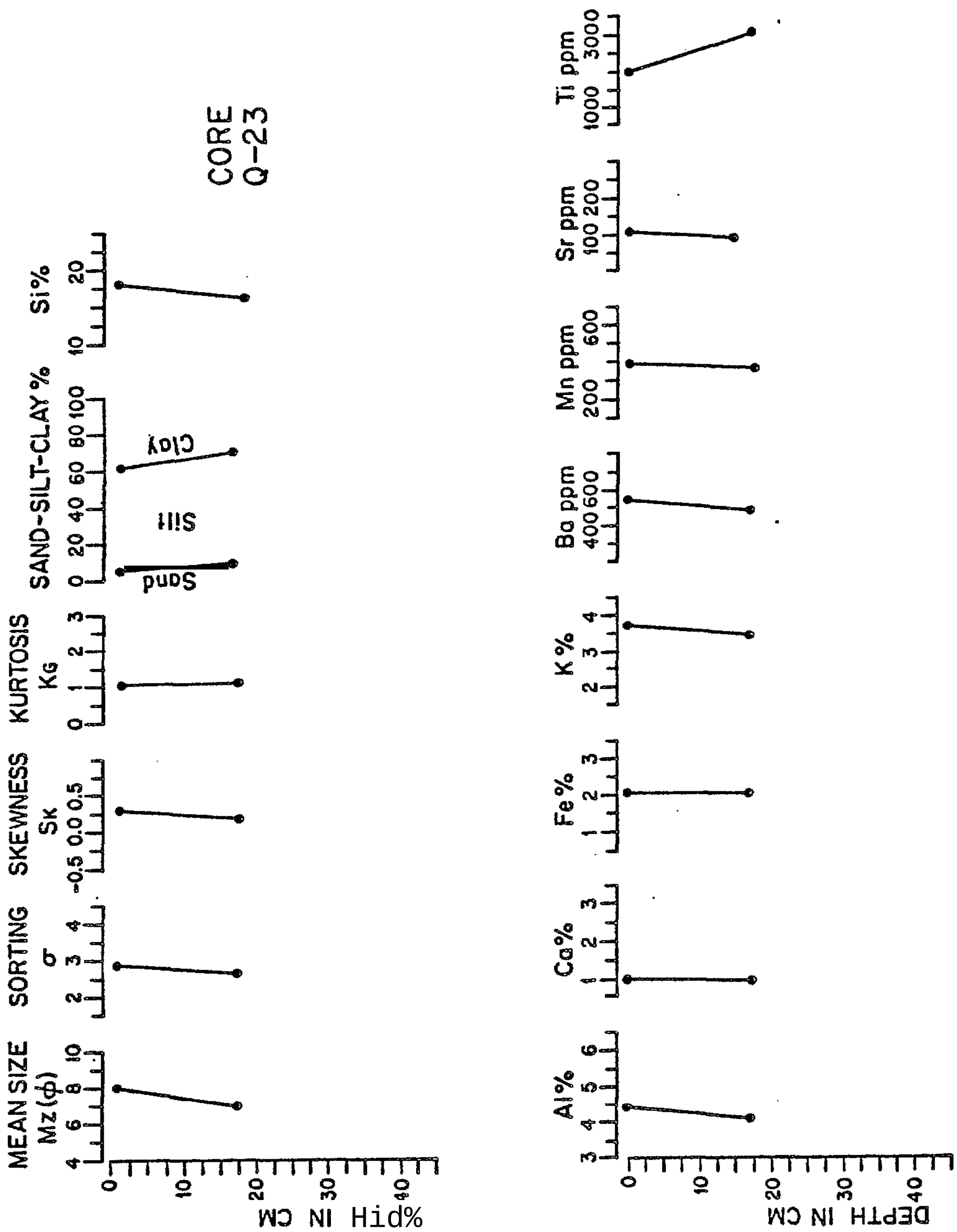
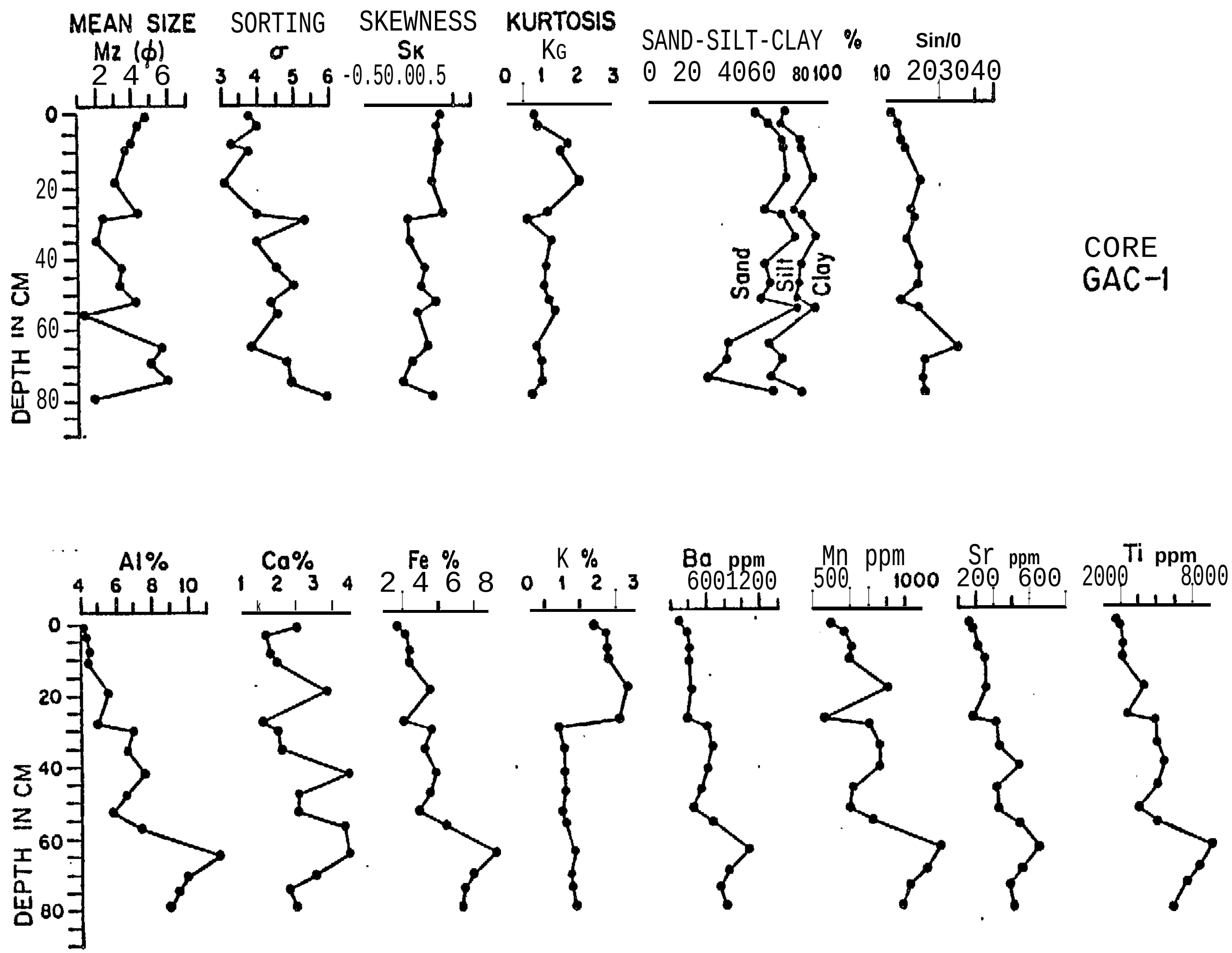


Figure 1-60: Core Q-23 sediment analysis.

Figure I-61: Core GAC- Sediment analysis.



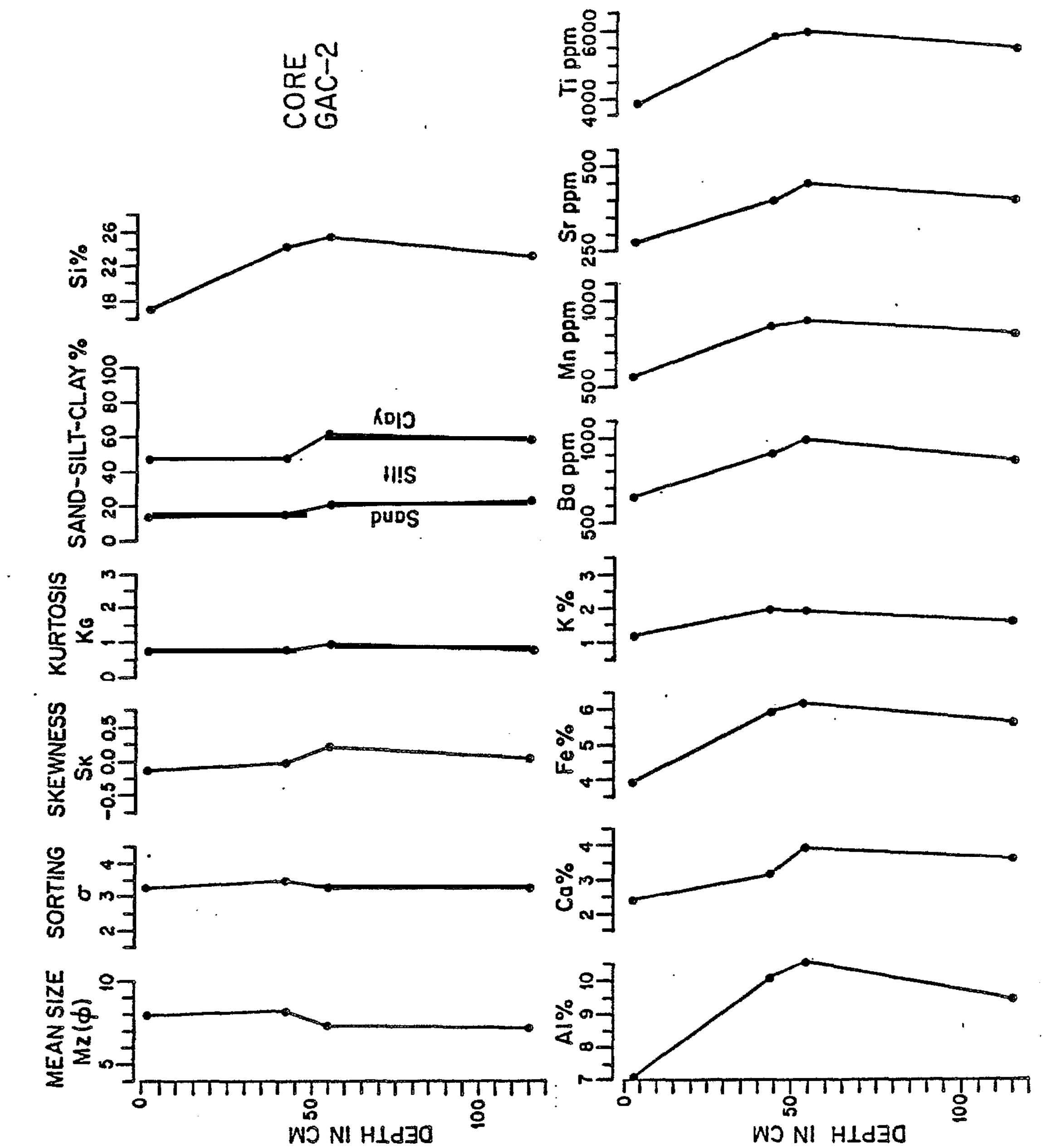


Figure I-62: Core GAC-2 sediment analysis.

8. Discussion:

The sediments observed in these cores are typical of shelf deposits. In general, the sediments show textural as well as chemical variations with depth. Vertical decrease in sediment grain size in core sediments, with few exceptions, reflects increasing water depth of deposition, perhaps resulting from rising sea level and ensuing post-glacial marine transgression. The time-stratigraphy of the core sediments, however, remains unresolved and, therefore, the chronology of the depositional environments representative of marine transgression cannot be established. Sediment characteristics throughout the cores indicate that these sediments were of recent origin, indicating that the core barrels did not penetrate deep enough to retrieve sediments deposited during the late Wisconsinan glaciation and early stages of the ensuing marine transgression.

The primary character reflecting this recent origin was the frequent distribution of ice-rafted pebbles throughout core lengths. These pebbles varied in size, but generally were well-rounded with smooth faces, typical of glacio-marine origin and quite similar to those observed in contemporary sediments deposited on the inner shelf along glaciated southeastern Alaska.

The thin layer of ash observed in a few of the cores also indicated recent deposition. The presence of ash layers in core sediments from the Gulf of Alaska was reported by Nayudu (1964). He observed three distinct layers of volcanic ash with different compositions. The composition and distribution of these layers revealed that the upper layer was Katmai Ash from the eruption of 1912; the middle layer, consisting of andesitic ash, was deposited 12,000 to 15,000 years ago; and the third layer, also andesitic in composition, was deposited between 25,000 and 30,000 years ago.

Various ash layers a'long the Alaska Peninsula have been observed by Laughlin (1975) and Black (1974). Radiometric dating of these ash layers revealed the chronology of deposition as shown in Table I-2.

The distribution of ash in recent sediments on the southeastern Kodiak-Afognak Shelf has been described by Hampton, et al. (1979). The shelf surficial sediments contained various amounts of volcanic ash, the composition and physical properties of which indicated that its origin was the Mount Katmai eruption of 1912. Hampton, et al., (1979) suggest that, due to the lack of contemporary sediment input on some parts of the shelf, the ash layer in these areas remains exposed.

Undoubtedly, the ash layer observed in core sediments was Katmai Ash. The chemical composition as well as the textural properties of the ash from the cores are quite similar to those of Katmai Ash described by Nayudu (1964), Gershanovich (1963), and Hampton, et al., (1979).

The presence of Katmai Ash layers was observed in only three cores (Figs. I-59, 1-60, and 1-61). The depth of the ash layer in these cores varied: in two cores the ash layers were deposited close to the top of the cores, at 9-12 cm (Fig. I-59) and 7-9 cm (Fig. 1-60), while in core H-10 this layer was observed at 78 cm below the surface.

The absence of Katmai Ash in other cores may be due to various factors. Firstly, the core may not have penetrated deep enough to reach

TABLE 1-2. Radiometric Ages of Volcanic Ash Layers Dated from the Alaska Peninsula

Ash IV	3,000 years
Ash III	7,000 years
Key Ash	8,400 years
Ash II	9,000 years
Ash I	10,000 years

C^{14} age determination of various ash layers reported by Laughlin (1975) and Black (1974).

the ash layer. Secondly, cores devoid of ash may have come from areas of high energy environments which prevented its deposition.

Although lack of penetration by the cores into older ash layers prevented the study of sediments deposited during early stages of late Wisconsinan Transgression, the occurrence of Katmai Ash does indicate that vast areas of the shelf are conducive to retention and preservation of depositional material. Most cores were retrieved from the vicinity of sills, over which large amounts of water must pass during each tide. Preservation of ash layers in such high energy environments suggests that chances for the preservation of artifacts on the shelf are equally good.

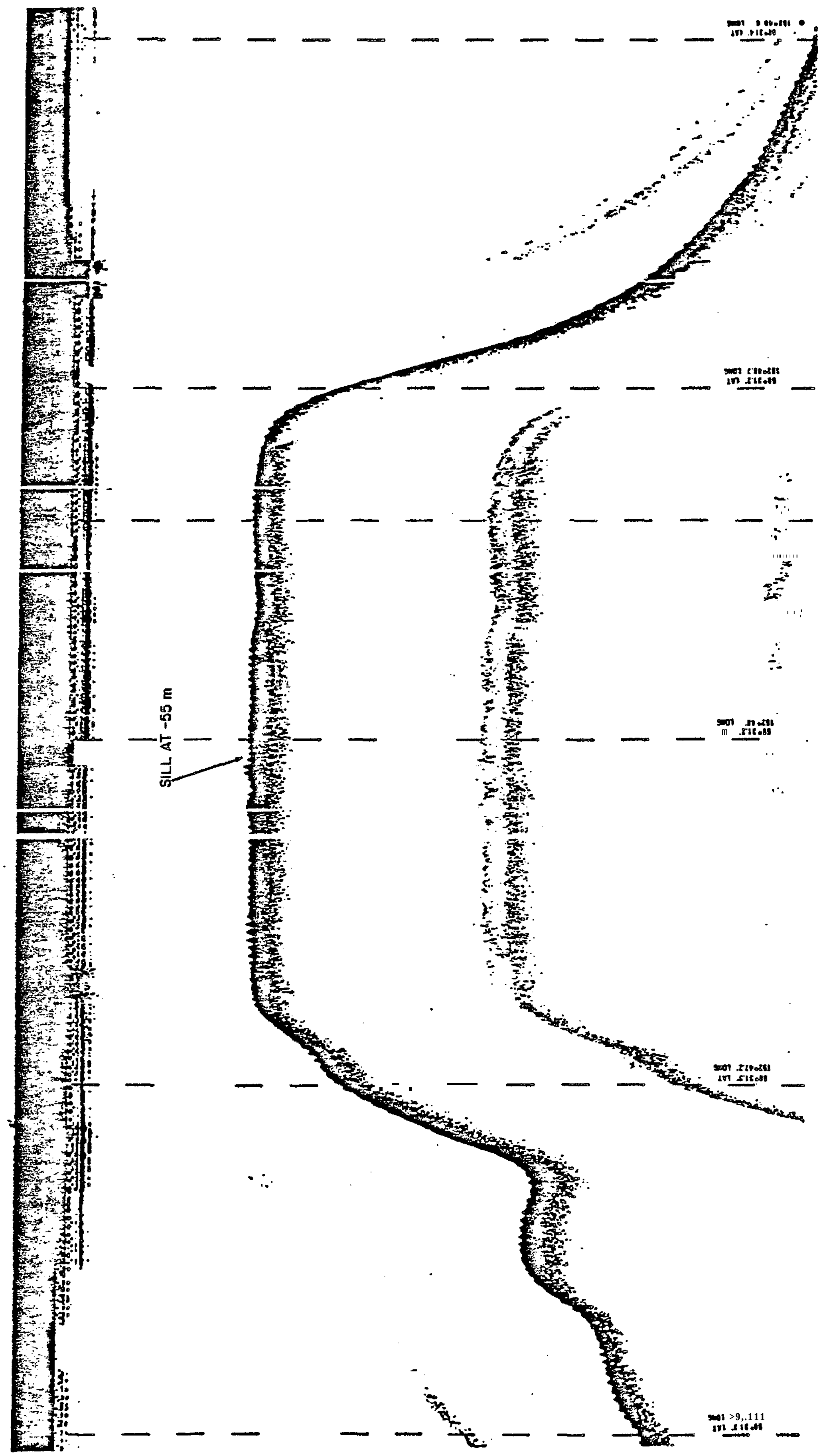
The depth horizons of Katmai Ash observed in cores also indicate varying rates of sedimentation on the shelf. Absence of ash may reflect either extreme rates of sediment deposition or regions of no deposition. The cores with ash layers, however, clearly suggest rates of sedimentation between 1 mm/yr and 10 mm/yr. The rate of sedimentation on the shelf is, therefore, quite high. In order to reach sediment deposited during the early stages of late Wisconsinan Transgression, it will be necessary to use coring devices capable of deeper penetration. On the other hand, precise positioning and coring of sediments from the immediate vicinity of sills and on the terraces may provide sediments of late Wisconsinan Glaciation with shallower penetration.

The fauna observed in core sediments, unfortunately, did not provide significant clues to the environment of deposition since none of the species reflected a specific range of depth tolerance.

Normally, the wedge of a sediment prism deposited in intervening basins of a fiord or sea valley should be close to the sill. Therefore, a short core from the vicinity of the sill should include sediments of the earlier transgressive and regressive episodes. Most cores retrieved from near sill areas were between 10-20 cm long and consisted of contemporary sediments. The sill slopes are generally covered with sands, which permit very limited corer penetration. Longer cores, up to 1.5 m in length, obtained from deeper areas of basins, because of high rates of sedimentation also contained only contemporary sediments. The corer also failed to retrieve sediments of neoeuxinian or brackish water environments such as may have prevailed in fiords with exposed sills during lower sea level stands.

The distinctive Katmai Ash horizon in a few cores, and sediment characteristics in others, indicate that the core sediments are of recent deposition and, therefore, not well suited to achieving the purpose of this study. In the absence of datable material deposited during the late Wisconsinan Glaciation and/or early stages of the last marine transgression, it is rather difficult to establish the sequence and chronology of earlier sea level stands.

The bathymetric transects over the sills and terraces along the Kodiak-Afognak Shelf, however, proved to be quite useful. These transects showed that sills are indeed erosional features as discussed earlier, and are mostly devoid of morainal deposits (Figs. 1-63 and I-64). Terraces, the salient erosional features, are quite frequent on the shelf (Fig. I-65). On the basis of bathymetric charts, all sills and terraces in the study area were located and their depths recorded.


SILL AT -55 m

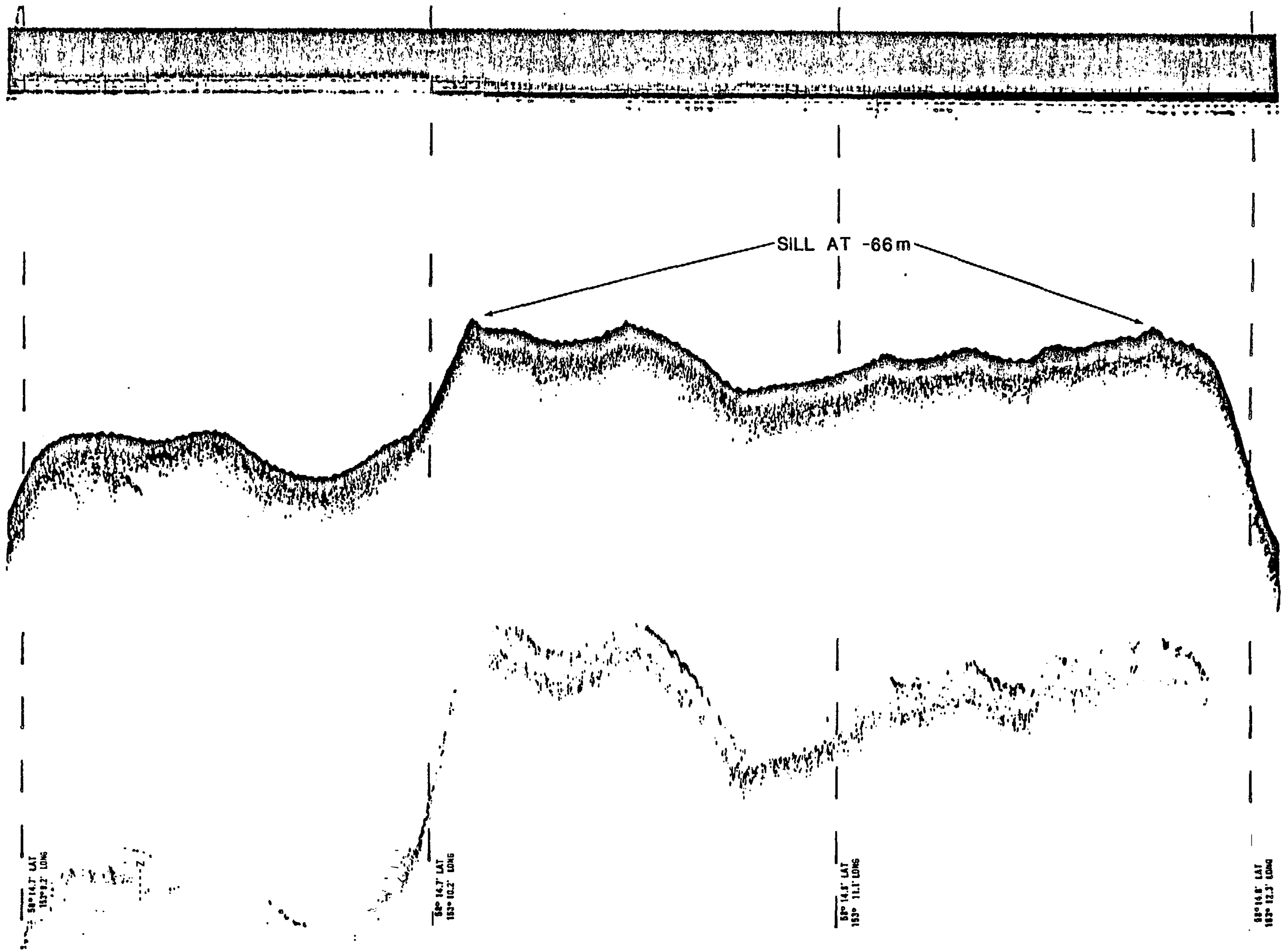
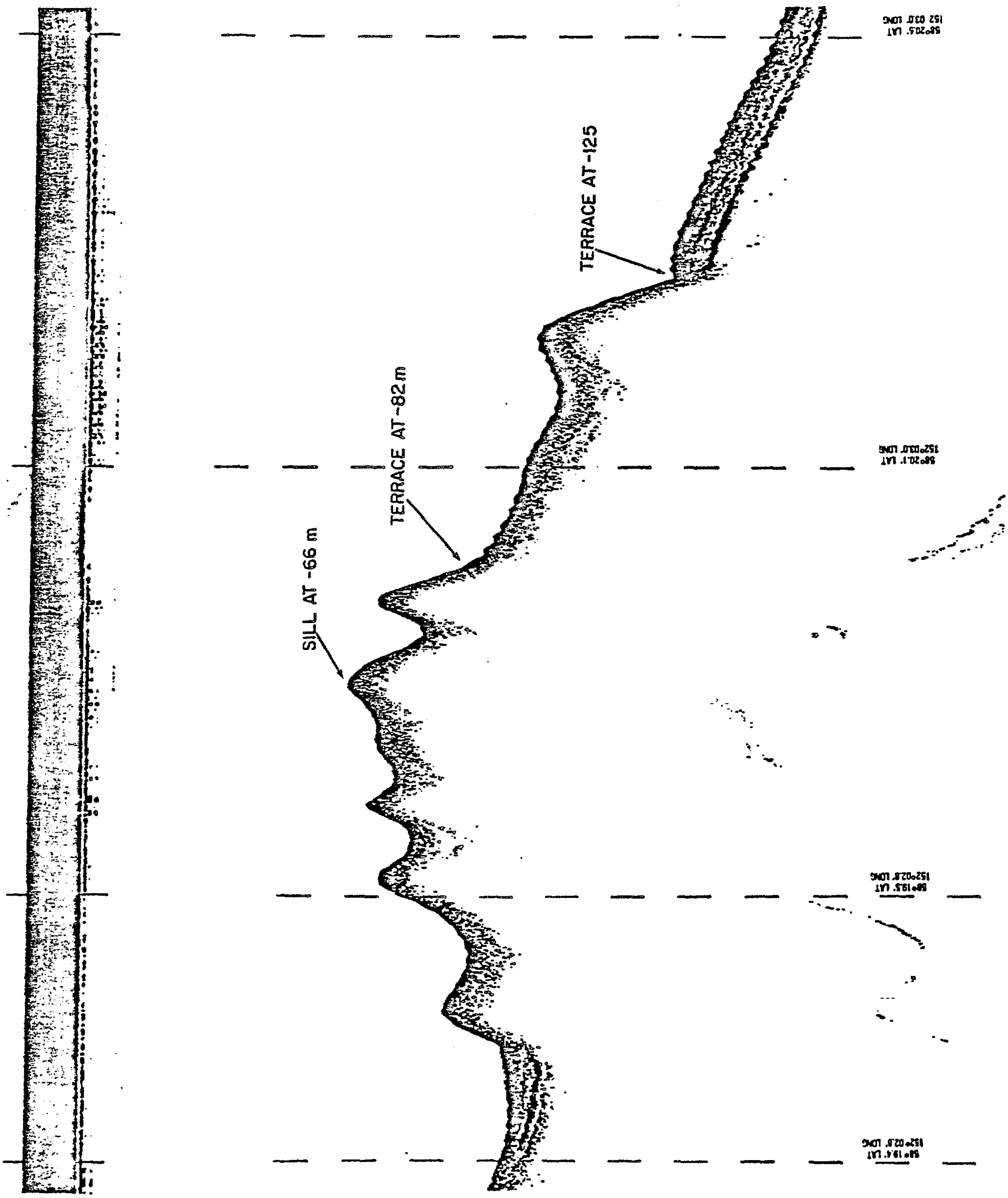


Figure I-64: Sill on the Kodiak-Afognak Shelf.


TERRACE AT -125
TERRACE AT -82 m
SILL AT -66 m

Detailed examination of published bathymetric charts from the northwestern Gulf of Alaska revealed that there were 359 sills (including basin enclosures) and a few conspicuous terraces. Except for three terraces which occur at water depths of -12 to -17 m and -27 to -32 m, three sills at -34 m, -40 m, and -54 m respectively, and six sills at -48 m, the other 345 sills and terraces observed occur along one of the six submerged horizons.

Nine sills were found at the -125 m water depth, 35 at the -82 m depth, and 55 at -66 m water depth, including major passes on the Aleutian Shelf. The largest number of sills and terraces, a total of 162, occur between depths of -52 m and -58 m. This horizon is most prevalent along the Gulf of Alaska. It is interesting to note that Bering Strait also crests at -55 m below present sea level. The next higher zone of sills and terraces lies between -36 m and -40 m water depth where 39 sills were observed. The shallowest zone for sills and terraces observed occurs between -26 m and -29 m depth. This zone has 45 sills and terraces. The sills and terraces included in this study lie between the -25 m isobath and the shelf break.

These data categorically demonstrate that almost all sills and terraces occur along six submerged horizons. The average depth of these horizons are -125 m, -82 m, -66 m, -55 m, -38m, and -28 m. Clearly, all of the submerged features of each zone do not precisely occur at these respective depths. However, deviations from these fixed horizons are relatively few and do not exceed ±3 m from the average. Such variations probably have resulted from one of three factors:

(1) The bathymetric c charts used for this study recorded depths in fathoms. Because depths were given in whole numbers (fathoms), conversion to meters will inevitably result in an error of ±1 meter or more.

(2) In relation to wave approach, some open shorelines are subjected to deeper erosion than those which lie away from the path of waves. Therefore, differential erosion factors may cause variation in depths of the above features of up to 2 meters.

(3) Variations in rates of sedimentation as reflected by cores may cause deviations in depth of some of the features.

Another important observation concerning sill and terraces depths along the axes of fiords and sea valley is the arrangement of these features. Invariably, the seaward sill is the deepest, with landward sill depths progressively shallower. In fiords where a shallow sill occurs at the mouth, the inner sills invariably relate to the six horizons discussed earlier. The sequential arrangement and occurrence of sills on six horizons strongly suggests that the cresting of sills is the combined result of successive rise in sea level and wave erosion. Conformity of almost all sills and terraces to one of the six horizons indicates that, in the past, sea level must have stood stationary for a considerable time at each of these horizons in order to develop such sills and terraces. The processes for such a development are proposed earlier (Figure I-38). Furthermore, the continuum of each horizon along shelves of the Kodiak-Afognak Island Group, the Alaska Peninsula, and the shelf off Unimak and Umnak islands 800 kilometers to ttie southwest indicates that these features are the result of the same erosional process throughout this vast region. Such processes can only be due to shoreline erosion along the Pacific coast during lower sea level stands, and must have formed synchronously.

Surficial sediments prevalent on the shelf and on adjacent land clearly show that, during ice ages, much of the Gulf of Alaska Shelf was glaciated. Glacial deposits on the Kodiak-Afognak Islands, Alaska Peninsula, Unimak Island and Umnak Island reflect the fact that much of the land underwent valley glaciation. Upwarping and downwarping along the shelf has been minimal, and has not affected the depths of the six horizons in relation to present sea level stand. It is, therefore, safe to conclude that the shelf region was not under an ice sheet of sufficient thickness to cause downwarping of the crust due to ice load and upwarping during interglacial stages.

Past tectonic activity along the Gulf of Alaska, on the other hand, may have caused local uplift and subsidence. The consistency of these horizons thus should be correlated to some stable region, preferably adjacent to the study area.

The Bering Shelf, in contrast to the Gulf of Alaska Shelf, has been quite stable with no evidence for significant tectonic activity since the late Tertiary. It is also suggested that, during ice ages, sheet ice cover on the shelf was limited. Evidence for paleosealevel stands observed on the Bering Shelf, therefore, could be quite reliable. Seemingly, much of the depositional shoreline attendant to earlier sea level stands has been overridden, and most terraces obliterated, on this unusually flat and broad shelf. There are, however, a few prominent sills, terraces, and abrupt breaks in shelf gradient which provide evidence for earlier lower sea level stands in this region. Two conspicuous terraces on the Pribilof Ridge at about (depth is not precisely measured) -70 m and -60 m water depths were observed by Dr. James Gardner, USGS, Menlo Park, California (personal communication).

There are two major breaks in the gradient of the Bering Shelf occurring at -80 m, and -55 m. Bering Strait, a prominent sill connecting the Chukchi and Bering seas, lies at -55 m. Other sills observed on the Bering Shelf lie in Shpanberg Strait, between St. Lawrence Island and the Alaskan Mainland. The strait lies on a structural arch which separates the southern shelf from Norton Sound to the north. There are two prominent sills on this arch.

Erosions? features indicative of earlier, lower sea level stands on the stable Bering Shelf and on the tectonically active Gulf of Alaska Shelf occur at similar horizons. It, therefore, appears that since the formation of these submerged features, the Gulf of Alaska Shelf has not undergone major subsidence or uplift. This of course does not mean that the landmass and the slope-trench regions adjacent to the shelf have also. There are numerous raised benches throughout the Alaska Peninsula reflecting either periodic uplift or higher sea level stands. Similarly, subsidence along the slope has been recently discovered. In spite of uplift and subsidence along adjacent regions, the shelf appears to lie on the hinge area and, therefore, has undergone the least isostatic change. The six horizons of sills and terraces on the Gulf of Alaska Shelf appear then to be paleosea-level stands which apparently have undergone minor or no isostatic change since their formation in the recent past.

Core sediments obtained by NOAA personnel did not provide data for depositional chronology of these sills and terraces, but did provide some information concerning paleoenvironments of the shelf. In spite of the lack of chronology, the observed horizons could be compared with world wide sea level stands in an attempt to determine their age and the sequence of their development. World-wide data for paleosealevel stands as reported by various investigators were gathered from published literature and plotted to draw a generalized sea level curve. It is interesting to note that, in spite of the diversity in age determination techniques and location, the data fit remarkably well. The six sea level stands on the Gulf of Alaska inferred from geomorphic features also seem to fit this curve. The sea level stand curve shown in Figure I-23 does not show three of the Gulf of Alaska sea level stands, corresponding to the first three interglacial stages. This is because the study was restricted to the shelf region lying between the -25 m isobath and the shelf break. A careful scrutiny of shallow water bottom features will undoubtedly also present evidence for -14 m and -6 m paleosealevel stands on the Gulf of Alaska Shelf.

Correlation of the Gulf of Alaska sea level stands with the general world-wide curve suggests that bottom features on the shelf may not have formed during the last recession of ice since in view of the rapidity of this retreat, it is to be expected that features prevalent over large regions may not have had time to develop. Longer durations of sea level stands, during maximum stages of glacial and interglacial stages, are more appropriate to formation of these features on the shelf. Once formed, however, these shoreline features must have provided ideal locations for early coastal communities. During the last marine transgression, these communities might have migrated up the six horizons with the encroaching sea and, with the rapid rate of sedimentation observed in most cores, it is quite possible that remnants of such early human occupation of these horizons are well preserved.

CHAPTER II
LATE WISCONSIN ENVIRONMENTS AND FAUNAL RESOURCES OF THE ALASKAN CONTINENTAL SHELVES

Sam W. Stoker

A. Introduction:

During the height of the last major Wisconsin glaciation, 25,000 to 20,000 years ago, sufficient seawater was invested in continental glaciers to lower sea level by about 125 m, thus-exposing much of the presently submerged continental shelves. Over some areas, such as the Chukchi and northern Bering Sea, this emergent shelf formed a vast plain of subcontinental proportions; in other regions, such as the Pacific coast of Alaska, the generally steep gradient and relatively narrow breadth of the shelf limited emergence to much smaller and less contiguous areas. As the enormous continental glaciers retreated at the close of this final ice age, sea level rose once more to resubmerge the continental shelves. This chapter attempts to reconstruct, in general terms, the climatic and ecological sequences which attended that last submergence, including faunal resource concentrations which might have attracted human predators.

B. Glacial Mechanisms:

Within any discussion of Pleistocene events it seems relevant to touch, at least cursorily, upon the major theories of ice age causes and mechanisms. Since, however, these 'long range' theories of global climatic oscillation and subsequent glaciation have little direct bearing on the relatively 'short range' regional considerations dealt with in this report, they will only be summarized.

The 'long range' theories may be divided into two categories--terrestrial and extraterrestrial--though there is some overlap. Extraterrestrial theories consider global temperature fluctuations at the earth's surface to be the principal mechanism behind the ice ages, and generally credit such fluctuations to varying solar activity related to sunspots or solar storms.

The second category relies on events or circumstances which are more self-contained within the earth's terrestrial/marine/atmospheric system. These theories include: (1) varying insulation values of the earth's upper atmosphere due to cloud cover or volcanic discharge; (2) disruption and instability of atmospheric circulation patterns as the result of orogeny and continental uplift; (3) continental drift and concentration of land masses in the higher latitudes of the northern hemisphere, thereby effectively impounding the Arctic Ocean and restricting oceanic circulation cells; (4) varying albedo (reflectivity) at the earth's surface; (5) polar wandering; (6) any combination of the above.

A more extensive review of these mechanisms may be found in Flint (1971). All of these theories deal on the level of global generalities, with explanations of why climatic oscillations began and why they are apparently continuing. Of more relevance to this report are what may be termed 'short range' events, such as the climatic fluctuations and resultant ecological sequences which characterized the Late Wisconsin period over the continental shelves of Alaska.

C. Late Wisconsin Climatic Chronology:

Available data and interpretations regarding Late Wisconsin climatic sequences, while sufficient to establish a general chronological outline, offer only sketchy detail and, in some cases, appear to be contradictory.

However, there is general agreement, based on glaciology, micro-paleontology, and oxygen isotope research, that the final Wisconsin glacial maximum extended from about 25,000 to 20,000 B.P. (Frenzel 1973; Karlstrom 1966; Dansgaard et al. 1969; Swanston 1969). The glacial maximum seems to have been universal and roughly synonymous over northern North America, though there is some indication of a time lag or temporal disconformity in the higher latitudes of Alaska. Maximal glaciation, for instance, may have persisted in the northern Brooks. Range until as late as 18,000-17,000 B.P. (Porter 1964b; Hamilton and Porter 1975). The climate during this period of maximal glaciation was almost certainly colder and probably drier than at present over most of Alaska, including the vast emergent Beringian plains.

Following this glacial maximum, evidence indicates a gradual warming trend over most or all of northern North America, probably with multiple minor fluctuations, extending from about 20,000 to roughly 13,000 B.P. At about 13,000 B.P., this warming trend probably accelerated significantly, culminating in an early hypothermal, or temperature maximum, sometime between 13,000 and about 11,000 B.P. (Langway et al. 1973; Urry 1948; Erickson and Wollin 1956; Curray 1965; Erickson et al. 1964a, b; Heusser 1966; Kind 1967; Dansgaard et al. 1969). Again, however, there is evidence of a time lag for northern Alaska, with this hypothermal perhaps delayed until 11,000 to 8,000 B.P. over northern Beringia (McCulloch and Hopkins 1966; McCulloch 1967; Matthews 1974), and possibly as late as 9,000-7,000 B.P. in the Alaskan arctic (Detterman 1979; Porter 1964).

This first warm period was probably followed by a brief (1 ,000 to 2,000 year duration) reversal to colder temperatures (Heusser 1966; Miller and Anderson 1974; Dansgaard et al. 1969; Langway et al. 1973), after which the post-glacial warming trend continued and culminated in a second major hypothermal or 'climatic optimum'. For southeastern Alaska, this hypsothermal is dated by various authors at 5,500 to 3,250 B.P. (Miller and Anderson 1974), 7,050 to 4,150 B.P. (McKenzie and Goldthwait 1971), and 3,500 B.P. (Heusser 1953). The range of these dates generally agree with corresponding ones from Greenland (Langway et al. 1973; Dansgaard et al. 1969), northern Beringia (McCulloch and Hopkins 1966; McCulloch 1967), the Brooks Range (Porter 1964; McCulloch 1967), and the Mackenzie Delta and the Alaskan north slope (Detterman 1970; Mackay and Terasmae 1963; Ritchie and Hare 1971; Livingston 1957), and Siberia (Kind 1967). Following this final hypothermal, from about 3,000 B.P. onward, another reversal to cooler temperatures is in evidence, continuing to the present time.

D. Topographic Features Favoring Resource Concentration:

In order to evaluate the general resource potential of an area, and to predict specific locales of-resource concentration, certain criteria must be developed which are applicable within the context of available information. Ideally, such criteria should embrace a wide range of factors, including topography, temperature regime, precipitation, drainage patterns, soil type, and on ad infinitum. In reality, however, sufficient information is rarely available for accurate predictions or estimates when dealing with present circumstances, much less those of the distant past. Therefore, since specific environmental data are not available over the time span considered, it has been necessary to establish criteria based on factors which are essentially independent of such variables, at least for purposes of predicting zones of relative resource concentration. These criteria are primarily topographic.

A concern of paramount importance is whether or not present seabed relief reflects the relict topography of the continental "shelf during periods of subaerial exposure. In general this is probably the case, given the geologically brief time span dealt with, even when factors such as seabed erosion and deposition are considered. Another assumption which must be made is that the continental shelves are, essentially, extensions of the mainland and that, during periods of emergence, the physical and biological environments of the exposed shelves were similar to those of the adjacent land mass. It is also necessary to assume the behavioral fidelity of numerous faunal species, and that within-species patterns of behavior have remained relatively consistent over the past 20,000 years. Such assumptions are necessary, even though there are several examples of species, both terrestrial and marine, which have altered life styles drastically in response to predation pressure or environmental change in historic times.

A set of eight criteria have been applied to reconstruct locales of probable faunal resource concentration and/or availability during the Late Wisconsin. Three of these criteria apply to terrestrial environments, five to marine coastal environments. All are essentially topographic in nature.

In the terrestrial environment, the topographic features favoring faunal concentrations are:

i. river valleys, which provide diversification of both habitat and food resources and which act as corridors for large mammal movements;

ii. passes and topographic constrictions which tend to funnel large mammal movements and provide migration routes from summer to winter range;

iii. south-facing slopes, which provide critical high-protein forage in the spring and early summer; and north-facing slopes where late summer and fall range might be available.

In the marine coastal environment, the criteria taken into consideration are:

i. spits, capes, and headlands which, in addition to their obvious advantages as lookout points, frequently provide hauling and rooking grounds for marine mammals and nesting sites for marine birds;

ii. straits, which act to funnel movements of marine mammals and fish;

111. zones of probable upwelling and nutrient enrichment, such as areas adjacent to the-continental slope-or, in some cases, the lee of significant capes and headlands;

iv. river mouths or estuaries attractive to anadromous fish and their retinue of predators;

v. benches or terrace escarpments which, as sea level rose following the Late Wisconsin glacial maximum, would have provided some degree of horizontal coastal stability.

Over broad, flat expanses, such as characterize most of the Bering Sea shelf, a relatively small vertical rise in sea level would cause a more significant transgression of the shoreline than would be the case along an escarpment. While these areas would possess no inherent advantage in terms of resource concentration, they would provide a greater degree of temporal stability. In an earlier report, Sharma (1977) proposed that such terraces might, in fact, represent Late Wisconsin stillstands or periods of vertical sea level stability.

In the following section, discussing climatic and ecological successions over the emergent continental shelves, these criteria are applied to reconstruct resource concentration and availability attractive to human hunters. For organizational reasons, the total area under consideration, which includes most of the Alaskan continental shelves, is divided into three major regions: the Beaufort Shelf, Beringia, and the North Pacific Shelf. This latter region is divided into subregions. These divisions reflect major geographical and biological factors, and may be considered as more or less self-contained ecological units.

For each region, an environmental sequence spanning the final resubmergence of the continental shelves is discussed. Necessarily theoretical in nature, these environmental reconstructions will include questions relating to climate, extent of glaciation, extent of sea-ice cover, dominant vegetational type, and probable faunal distributions.

E. <u>The Beaufort Shelf</u>:

The continental. shelf of the Beaufort Sea would have been, during periods of maximum emergence, a relatively narrow (50-100 km wide), flat plain fringing the northern edge of Alaska. Of all the regions to be considered, this is perhaps the least complex, though not necessarily the least controversial. It is also, in some respects, the most well known in terms of Late Wisconsin paleoclimatology and paleobotany. In spite of (or perhaps because of) this relatively large amount of information regarding the Late Wisconsin over the North Slope and Beaufort Shelf, several conflicting theories have arisen regarding climatic and ecological successions.

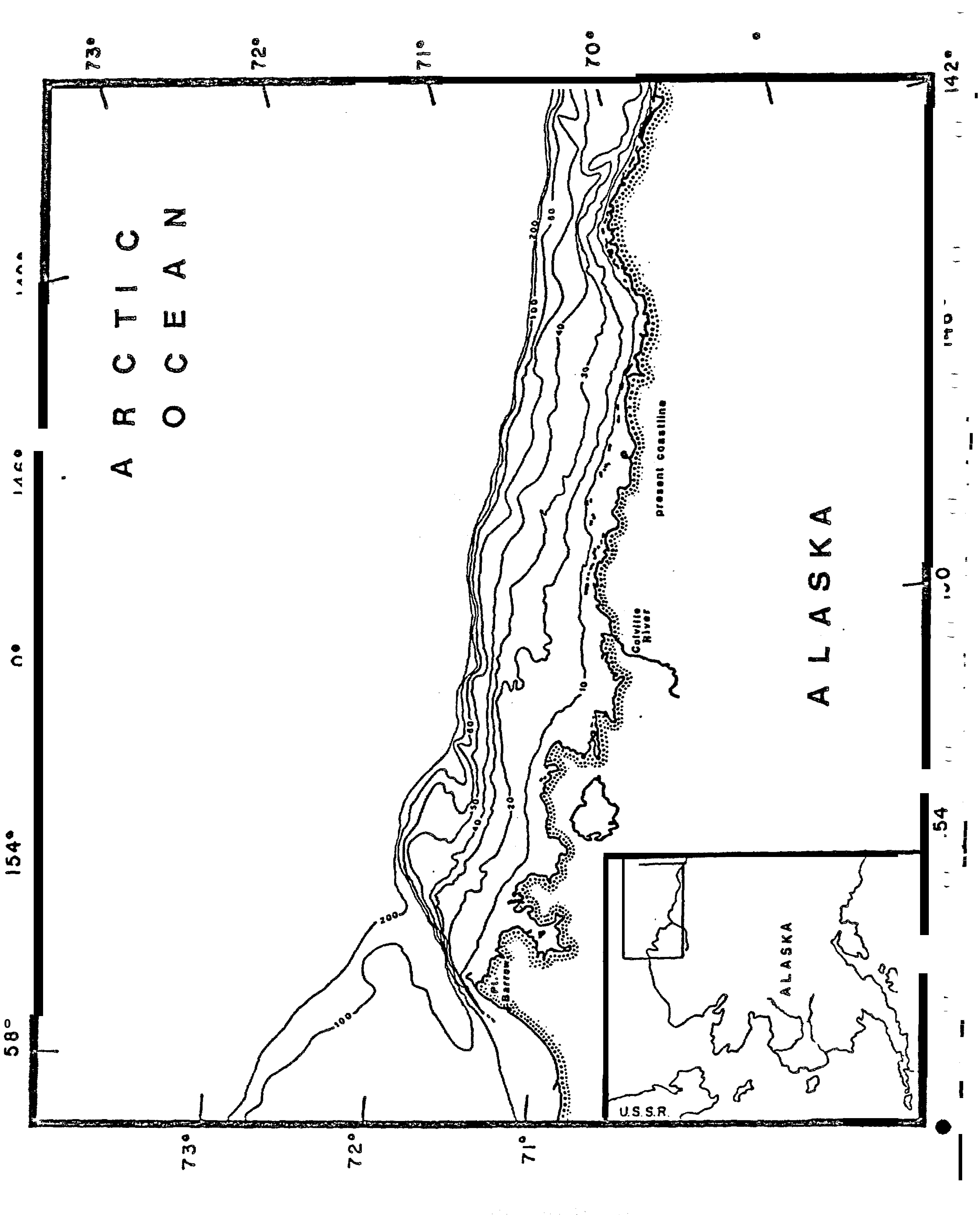
1. Present Geography and Environment:

The north continental shelf of Alaska consists of a flat plain sloping gently downward from the foothills of the Brooks Range through the present shoreline of the Beaufort Sea to the edge of the continental slope in the Arctic Ocean. Though the present scope of work calls only for treatment of the now-submerged marine portion of this shelf, in ecological, geological, and geographical terms the entire area must be considered as contiguous, at least during its emergence as a land mass.

The terrestrial portion of this shelf consists of a vast enclave fringing the northern coast of Alaska, walled off to the south by the Brooks Range and to the east by the approach of the Romanzof Mountains to the sea in the vicinity of the Canadian border (Fig. II-l). It is a region of low, rolling hills and flatlands, dissected by numerous rivers which issue from the Brooks Range or its foothills and meander northward to the Beaufort coast. The vegetation is composed primarily of herbaceous tundra, with willow growth along the stream courses and boggy muskeg tundra in the low flatlands. As will be discussed later, this vegetational pattern probably reflects rather recent (Late Holocene) climatic changes and was probably not characteristic during the late Wisconsin. Most of the streams traversing this region, particularly the major ones, form extensive braided outwash plains which support sedges and grasses in greater proportion than observed in the herbaceous tundra of the arctic foothills. Similar outwash plains may have occupied a critical role in large terrestrial mammal ecology during late Wisconsin times.

Though winter snow accumulation in the Brooks Range and its foothills can be considerable, the average annual precipitation over the coastal plains is low, 100 mm or less (Holmgren et al. 1973). Were it not for extensive shallow permafrost underlying most of the area and that what little precipitation that falls is locked up in snow and ice for most of the year, the region would be a desert. In the river valleys and outwash plains, where shallow permafrost does not occur, a desert-like condition is approached during the warm, dry summers. During the spring runoff these rivers reach flood proportions after which they frequently subside, those which are not glacier-fed, to little more than a trickle by late summer.

The terrestrial mammals providing the greatest subsistence resource potential within this region are caribou and moose, the caribou being of primary importance due to its far greater numbers. Caribou, in fact, probably represent the key species in the large mammal ecology of the area, providing much of the diet of the various predators and scavengers--grizzly bear, wolf, fox, and wolverine. During the summer, the caribou frequent the rolling hills and flatlands from the northern slopes of the Brooks Range to the Beaufort coast. The moose, being browsers, concentrate within


ARCTIC OCEAN
ALASKA
present coastline
Colville River
Pt. Barrow
U.S.S.R.
ALASKA
73°
72°
71°
70°
142°
154°
200
100
50
40
30
20
10

the willow growth along upper stream courses. At times during the summer, when the wind fails, caribou also seek out these relatively open, sandy stream beds--not in search of food but in an attempt to escape the persistent hordes of insects--where they are easily ambushed by predators such as the wolf, grizzly bear, and human hunters. During the winter, much of the caribou population abandons the region, migrating through the passes of the Brooks Range to more hospitable winter pastures to the south (Irving 1964).

In addition to moose and caribou, Dan sheep are found in the Brooks Range and, until the last century, musk oxen frequented the foothills and flatlands of the region. Some small mammals--ground squirrels, marmots, arctic hares, lemmings--are also found in the area, though probably never in sufficient abundance to provide more than a supplemental resource. The same is true of birds, particularly ptarmigan and waterfowl, and of fresh-water fish such as pike, grayling, burbot, and lake trout. Due to the migratory or hibernating nature of most of the above-mentioned species, faunal resources within the region are drastically reduced by the onset of winter.

The Beaufort Sea, which presently covers the northern portion of the Beaufort Shelf, is a shallow, fringing embayment of the Arctic Ocean. Its present coastline is flat, relatively straight, and generally monotonous. For nine to ten months of the year the entire Beaufort Sea and Arctic Ocean is locked in sea ice broken only by infrequent leads and polynyas. During the brief summer, from about mid-July to mid-September (Reimnitz and Barnes 1974), a narrow band of open water exists between the low barrier islands and the coast, and offshore from these islands for variable distances of a few kilometers to tens of kilometers, depending on wind direction and velocity. During summer, the winds are generally moderate and blow from the south and east, tending to move the melting and broken ice offshore. During the fall and winter, these winds are from the north and west, sometimes attaining hurricane velocities (Kovacs and Mellor 1974). In all seasons the wind appears strongest along the coast, diminishing both inland and seaward.

The nearshore islands are of considerable importance to the coastal ecology of the region both as habitat and as protective barriers against the ice and seas of the Arctic. They consist of linear series or archipelagos of low and unstable, in fact migrating (D.M. Hopkins, oral communication), deposits of sand and gravel stretching along the coast. During fall storms these islands are frequently inundated by waves and over-ridden by ice, and are in a continual process of rearrangement and redeposition by ice-push and nearshore currents.

Present marine currents along the Alaskan sector of the Beaufort Sea coast trend anticyclonic, from east to west, probably in response to summer wind patterns. It appears that this anticyclonic circulation has as its locus a fairly tight gyre situated northeast of Point Barrow, in the southern Arctic Ocean (Wilson 1974).

Within the deep basin of the Beaufort Sea and Arctic Ocean, a three-layered structure is apparent, consisting of (1) an upper stratum of low temperature but also low salinity Arctic Water extending to -200 m (2) an Atlantic Water stratum of higher salinity and warmer temperature (greater than Cl°C) extending from -200 to -900 m and (3) Arctic Bottom Water, of high salinity and sub-zero temperature, extending from -900 m to bottom (0' Rourke 1974). All of the continental shelf lies within the upper 200 m of Arctic Water.

This upper 200 m of Arctic Water is complex in terms of both origins and properties, Derived primarily from indigenous sources (ice melt, terrestrial runoff) and from the Bering Sea, this near-surface water displays summer temperatures ranging from -1.6°C to 3.0°C. There is a marked tendency toward warmer water in the westernmost reaches, presumably the result of incoming Bering Sea water (Hufford 1974). Within this 200 m layer there is strong density stratification and isolation of the upper few meters during the summer as the combined result of salinity and temperature. The greatly reduced salinity observed in this near-surface layer is the result of both ice-melt and terrestrial runoff. Predictably, such salinity stratification is strongest in the vicinity of major river mouths (Hufford 1975; Wiseman et al. 1974). Once such a pycnocline is established due to salinity, the surface layer, now held in contact with the warmth of the summer sun, is also brought up in temperature-and further decreased in density, thus strengthening the stratification.

Probably as a result of this stratification and consequent isolation, the shelf water is generally poor in the nutrients necessary for phytoplankton growth. Only near the Canadian border, and occasionally offshore near the continental slope, do nutrients approach even moderate levels, perhaps as the result of limited- weak upwelling (Hufford 1974). In the eastern, Canadian, section of the Beaufort Sea, the anticyclonic circulation observed over the Alaskan sector appears to be reversed, resulting in weak cyclonic upwelling circulation patterns (Wilson 1974).

Faunistically, the Beaufort Sea hosts a mixture of high-latitude forms of both Pacific and Atlantic origin. (MacNeil 1956). The benthic standing stock biomass within the deeper zone, along the continental margin, is comparable with other high-latitude regions. In the shallower zone, however, the Beaufort Sea is quite depauperate in comparison with either the Chukchi Sea to the west or the North Atlantic to the east (Carey et al. 1974). In terms of species suitable for human food, very scant resources are presently available of either invertebrates (Wacasey 1974) or marine mammals (Sergeant and Hock 1974). It is probable that this observed paucity of invertebrates and, consequently, of species higher on the food chain, is the result of (1) generally low nutrient levels available for primary productivity, (2) a generally harsh environment and limited period of open water, and (3) the effects of intense and almost continual ice-gouging and scouring to the limits of the continental shelf (Kovacs and Mellor 1974).

Marine mammal species frequenting (or at least visiting) the area consist of bowhead whales, beluga (white) whales, Pacific walrus, ringed seal, bearded seal, and polar bear. The cetaceans (bowhead and beluga whales) are primarily seasonal visitors, venturing into the Beaufort Sea only during the summer (Sergeant and Hock 1974; J.J. Burns, oral communication). Likewise, the bearded seal and Pacific walrus, both feeders on benthic invertebrates, normally enter the area only during the summer and only in limited numbers. During the winter the walrus abandon the Beaufort

Sea altogether for more hospitable wintering grounds in the central and southern Bering Sea. Some bearded seals do winter in the Beaufort, though the majority of them also move to the more fractured ice zones of the eastern Chukchi and Bering seas.

The only marine mammals to remain in the area as truly year-round residents are the ringed seal and its chief predator, the polar bear. Though available to human hunters and utilized as a subsistence resource, the ringed seal, a small and solitary phocid which dens on the shore-fast ice, does not occur in sufficient density to provide a primary resource. Being dependent on the ringed seal, the same is obviously true for the polar bear. Passing mention should also be made of two other marine mammals which occasionally venture into the Beaufort Sea from the Atlantic Arctic--the hooded seal and the narwhal--though the incidence of either of these species in the region is so rare as to be negligible, at least during historic times.

Probably the marine resource of greatest importance to human subsistence hunters are the anadromous fish which enter major streams during their summer spawning migration. Chief among these are whitefish and arctic char, which support a limited coastal fishery in the region at this time. Some marine fish, such as arctic cod and sculpins, are available in limited numbers at certain times of the year, though never in sufficient quantity to provide a stable resource.

Permanent or semi-permanent settlements tend to concentrate along the coast, particularly near the mouths of large rivers where marine resources (anadromous fish and marine mammals) may be supplemented by terrestrial resources (caribou and moose), or in areas such as the passes through the Brooks Range, where terrestrial mammals (caribou) are likely to be concentrated with some degree of dependability along their migration routes.

2. The Arctic Ocean:

In any consideration of Wisconsin conditions in arctic North America, several controversies are encountered. Perhaps paramount among these pertains to the condition of the Arctic Ocean itself during this last major glaciation and subsequent retreat. One view, supported by Dorm and Ewing (1966, 1968), Lamb (1974), and Lamb and Woodroffe (1970), is that the central Arctic Ocean remained unfrozen at least through the mid-Wisconsin, perhaps contained a cyclonic upwelling system, and was the source for much of the precipitation forming the North American continental glaciation. The opposing view (Pewe 1975; Colinvaux 1964; Hughes and Denton 1977) is that the Arctic Ocean was frozen throughout the Wisconsin, at least to the extent presently observed, and that it may have been subject to a thick, Antarctic-type ice cap during the early and mid-Wisconsin.

These opposing views are, unfortunately, often formulated on lines of evidence which, though not incorrect in themselves, bear little relationship to one another. One of the major lines of argument applied in support of the frozen Arctic Ocean theory is that of temperature (Colinvaux 1964; Emiliani 1972; Clark 1971). Within this argument, oxygen isotope ratio and micro-fossil evidence is interpreted as indicating that Arctic surface temperatures were at least as cold as at present during the Wisconsin glacial, and probably were colder. It can be argued, however, that when considering a deep ocean basin such as the Arctic, the salinity/density stratification of the surface water is the crucial consideration, not the temperature itself. If the surface salinity is sufficiently lowered to result in stratification, isolating this surface layer and maintaining it in contact with subfreezing air temperatures, then freezing will occur. This is the condition witnessed today, chiefly as the result of stratification as previously described. If, on the other hand, this salinity stratification is not present, and the cooled surface water is permitted to mix vertically with the warmer, high salinity subsurface water, then surface freezing might not occur. The vertical stratification of the Arctic Ocean waters may be of considerable significance within this argument. If sea levels were lowered by 125 m, as was the case during the glacial maximum, then the ocean surface layer would be brought within proximity of the 200 m deep Atlantic Water layer, which is of high salinity and relatively warm temperature. The sources which presently supply the low salinity, low temperature Arctic Surface Water would be greatly reduced during the glacial maximum by the severing of Bering Strait and by decreased terrestrial runoff, leaving the deeper Greenland-Faroe sill as the only communication between the Arctic Ocean and another sea, the North Atlantic. It is also of interest that the Atlantic Water layer in the Arctic Ocean displays a circulation pattern counter to the present surface circulation (Hufford 1974), in other words, cyclonic. This, perhaps, lends support to the arguments for strong cyclonic circulation in the Arctic basin during the Wisconsin glacial as proposed by Lamb (1974) and Lamb and Woodroffe (1970). Such cyclonic circulation would contribute to the breakdown of vertical stratification.

Another line of argument used in support of the open-Arctic theory is that the Arctic Ocean was essential as a moisture source for the massive North American glaciation which ensued during the Wisconsin (Dorm and Ewing 1966). Other authors, however, feel that glacial evidence indicates that the Arctic Ocean never, in fact, served as such a precipitation source (Pewe 1975).

In an earlier report (Stoker 1976), support was lent to the view that the central Arctic Ocean was probably unfrozen during much of the Wisconsin, feeling that considerations of salinity/density stratification were paramount to those of temperature as such. The view expounded in that report was that as continental and mountain glaciation ensued, and as sea level fell to expose the Bering Strait, the Arctic would be deprived of its principal sources of low-salinity surface water. This destruction of the Arctic Surface Layer, perhaps in conjunction with cyclonic circulation as proposed by Lamb (1974) and Lamb and Woodroffe (1970), could result in a breakdown of the salinity stratification, leading to vertical mixing or even positive upwelling of the warmer, high salinity Atlantic Water and consequent wastage of the Arctic ice pack. Pewe (1975), however, from an analysis of Wisconsin glacial patterns, finds no reason to believe that the precipitation source for North American continental glaciation was other than the North Atlantic. If the Arctic Ocean was open during this period, it should have served as a precipitation source.

Also, recent geological evidence in the form of glacial erratics (the Flaxman Formation) of Canadian origin, found on the barrier islands of the Beaufort Sea, would seem to indicate significant ice transport at least along the margin of the Arctic Ocean , with anticyclonic circulation (Hughes and Denton 1977; D.M. Hopkins, oral communication). The current interpretation regarding the Flaxman Formation is that it could not have been accumulated in the relatively short time period since the Late Wisconsin resubmergence of the shelf, at least not by ice-rafting which presently occurs along the coast (D.M. Hopkins, oral communication). Lowered sea level during the Wisconsin glacial would have left the coast emergent (assuming vertical geologic stability), and the conjecture is reached (Hughes and Denton 1977) that perhaps the Arctic Ocean hosted a very thick Antarctic-type ice sheet which resulted in downwarping of the Beaufort Shelf. The ice sheet, moving in a westerly, anticyclonic direction from the Canadian Archipelago, could account for such glacial deposits.

While the theory of a thick Wisconsin ice sheet over the Arctic Basin cannot be dismissed, it is difficult to accept. There seems to be no other evidence to indicate that the Beaufort shelf was isostatically depressed during this period. Invertebrate fossil evidence from the Arctic Ocean and Beaufort Sea (MacNeil 1956; Faas 1962) suggest that the benthic environment was at least as favorable as it is today, which seems unlikely if an extensive ice-sheet had existed. Glacial evidence from the Canadian Arctic and Greenland also appears to refute heavy Late Wisconsin ice cover over the Arctic Ocean (England and Bradley 1978). The question of Late Wisconsin ice cover in the Arctic Ocean remains unresolved and resolution must await new data and new lines of evidence.

Whether the Arctic Ocean was ice-covered or open during the Wisconsin glacial is important. If the Arctic was ice-free during this period, particularly if its circulation pattern conformed to that of a cyclonic upwelling gyre, then it could have hosted a considerable marine fauna. Cyclonic upwelling at this latitude would probably result in greatly enhanced seasonal primary productivity in the near-surface layers, such as presently occurs in Antarctic waters. Such productivity could in turn support an increased fauna at all levels of the food chain. An open-water central Arctic might then have provided attractive habitat not only for the Pacific-Arctic marine mammals currently found in the region, but may have enabled some of the Atlantic-Arctic species, such as the hooded seal and narwhal, to migrate into the area. As mentioned previously, these species are occasionally found in the area at present, though rarely so.

If, on the other hand, the Arctic Ocean was frozen throughout the Wisconsin, it might have been even more faunistically depauperate than at present. Falling sea level during the onset and climax of glaciation would have extended the terrestrial margin out to the continental slope and the edge of the permanent Arctic ice pack. This circumstance would virtually eliminate the shallow nearshore zone of open summer water essential to benthic feeding species such as the walrus and bearded seal. Davies (1958) considers that during the glacial maximum the Arctic Ocean and its fringing seas, including the Beaufort, would not have been habitable by any pinniped except the ringed seal. There is no paleontological evidence to the contrary.

3. <u>Late Wisconsin Climatic Sequence</u>:

There are differences of opinion concerning the sequence of climatic events and vegetational transitions which characterized the Late Wisconsin over the North Slope and Beaufort Shelf. Though the climatic sequence hypothesized for this region follows roughly that described for northern North America in general, there are enough departures and controversial elements to warrant, at the risk of repetition, a brief resume of various views.

On the basis of pollen profiles from the Mackenzie Delta, Mackay and Terasmae (1963) interpret a climate colder and drier than at present for the period 8,500 to 7,500 B.P. followed by one warmer and drier than at present from 7,500 to several thousand years B. P. For the last several thousand years they propose a climate similar to the present along the Beaufort coast.

A significantly different sequence of events is indicated by other pollen cores, however, also taken from the Mackenzie Delta (Ritchie and Hare 1971). The sequence described from these cores is of a dwarf birch and shrub tundra habitat from 12,900 to 11,600 B.P., encroachment into the area by spruce with a forest-tundra complex from 11,600 to 8,500 B.P., spruce-birch forest from 8,500 to 5,500 B.P., alder and shrub thickets from 5,500 to 4,000 B. P., and shrub tundra again from 4,000 B.P. to present. It seems unlikely if, as Mackay and Terasmae propose, the climate was indeed colder and drier than at present from 8,500 to 7,500 B.P., the spruce-birch forest indicated by Ritchie and Hare could have existed.

A single poplar log unearthed in situ on the Sagavanirktok River (Detterman 1970), and radiocarbon dated 8,400 ± 300 years B. P. seems to support the conclusions of Ritchie and Hare. Detterman extrapolates from this evidence that the climate at that time was considerably warmer than at present along the Beaufort coast.

Colinvaux (1964) interprets pollen evidence from near Point Barrow, Alaska, as indicating a gradual climatic amelioration from 14,000 B.P. to present, apparently with no drastic fluctuations in either climate or vegetational regime.

Pollen analysis from Umiat, Alaska (Livingstone 1957), seems to indicate a climate colder than at present from 8,000 to 7,500 B.P., with herbaceous tundra, followed by a warmer period from 7,500 to 6,000 B.P. supporting dwarf birch. Livingstone feels that his warm interval climaxed at about 6,000 B.P., after which the climate again cooled to its present condition. Livingstone's analysis, then, would seem to support the sequence proposed by Mackay and Terasmae rather than that of Ritchie and Hare. Livingstone (1955) himself, however, admits that pollen evidence may in fact be a poor indicator of climatic fluctuations due to local anomalies in pollen concentrations. Also, Colinvaux (1964) concedes that it might take as long as 4,000 years for the flora, as interpreted from pollen profiles, to reflect climatic change.

Based on glacial evidence from the north side of the Brooks Range, Porter (1964), and Hamilton and Porter (1975) propose a general warming trend with rapid glacial wastage from the Late Wisconsin maximum to 12,780 ± 440 B. P., at which time a significant glacial readvance occurred

(Itkillik II). This was apparently followed by another warm period of glacial wastage, interrupted by a minor glacial readvance (Itkillik III) at about 8,000 B.P.

Mention should also be made of evidence, mostly in the form of in situ logs and stumps, interpreted by McCulloch and Hopkins (1966) as indicating a warm interval on the Seward Peninsula starting perhaps as early as 11,000 B.P. and terminating by about 8,000 B.P. This warm period might correspond to the glacial retreat expressed by Porter (1964) as occurring between the Itkillik II and Itkillik III readvances, and with the warm interval proposed by Detterman (1970) and Ritchie and Hare (1971) for roughly the same period.

At any rate, the chronology and sequence of climatic events for the Beaufort terrestrial shelf seem to be, like the question of the Arctic Ocean, in doubt at this time and certainly open to conjecture. For purposes of this report a sequence synthesized from the above views will be employed.

This hypothetical sequence sets the Late Wisconsin glacial maximum at about 25,000 to 20,000 B.P. (Frenzel 1973). Following this maximum, a period of warmer and probably wetter weather ensued over the North Slope, lasting til 1 about 13,000 B.P. (Hamilton and Porter 1975). Fol lowing the Itkillik II readvance, another warm and possibly wet period probably occurred, lasting from about 11,000 to 8,000 B.P. (McCulloch and Hopkins 1966; Ritchie and Hare 1971; Detterman 1970). Yet another cold period of minor glacial readvance (Itkillik 111) probably followed (Porter 1964; Mackay and Terasmae 1963; Livingstone 1957), lasting from about 8,000 to 7,000 B.P. This readvance was again succeeded by a warm interval from 7,000 to 4,000 B.P. (Porter 1964; Mackay and Terasmae 1963). From roughly 4,000 B.P. to present, the climate has probably remained relatively cold and dry, as is presently observed (Mackay and Terasmae 1963; Ritchie and Hare 1971; Livingstone 1957). This sequence is outlined below.

Time Interval	Conditions
20,000-13,000 B.P.	Post-glacial (Itkillik I) warming, glacial retreat
13,000-11,000 B.P.	Cooling, glacial readvance (Itkillik II)
11,000-8,000 B.P.	Warm, probably moist interval
8,000-7,000 B.P.	Cooling, minor glacial readvance (Itkillik III)
7,000-4,000 B.P.	Third warm interval, glacial retreat
4,000 B.P.-Present	Cooling to present climate

4. Reconstruction of Events and Environments:

a. Late Wisconsin Glacial Maximum: 25,000 to 20,000 B.P.

During this final glaciation, sea level was probably depressed by some -125 m worldwide, sufficient to expose virtually all of the continental shelf of the Beaufort Sea to the edge of the continental slope and the margin of the permanent Arctic ice pack. Without sufficient evidence to the contrary, it must be assumed that the ice pack was present and was at least of the extent and magnitude presently observed. The nearshore marine environment would likely have presented scant resources for subsistence hunters. With little open water available even in summer between the coast and the permanent ice pack, and with virtually no shallow benthos available to walrus and bearded seals, marine mammal-species were probably limited to the small and solitary ringed seal and its predator, the polar bear. In addition, there would have been little available in the way of marine fishes or intertidal invertebrates due to the low primary productivity and to the extensive ice scouring which must have abraded the nearshore zone. During this glacial maximum, the streams flowing into the Beaufort Sea from the Brooks Range were probably much reduced or heavily laden with glacial silt thus providing poor conditions for spawning runs of anadromous fish which presently visit the area.

During this initial period, then, subsistence attention must have. been directed primarily at terrestrial resources, which might have been considerable. Even during the height of Wisconsin glaciation, the area between the Brooks Range and. the Beaufort Sea coast was largely unglaciated. Valley glaciers extended no further than 50 km north of the mountain front (Hami I ton and Porter 1976).

There seems to be some difference of opinion, however, as to vegetational environments which might have prevailed during this period. One view (Pewe 1975; Livingstone 1957; Heusser 1966), based on pollen profiles, is that the region was dominated by herbaceous shrub tundra throughout most of the Late Wisconsin, with an increased complement of sedges and grasses. This concept of a vegetational regime differing only slightly from the present seems somewhat at odds with paleontological evidence indicating a large mammalian fauna dominated by grazers (horse, bison, mammoth). Pewe (1975) conjectures that such grazers were primarily concentrated along the stream courses and outwash plains, where grassland habitat might have been more prevalent.

Another possible scenario is that, though the river valleys and outwash plains may have been the concentration loci of the grassland habitats and grazing herds as proposed by Pewe (1975), the opposite was more probably the case, with these stream courses supporting the willow growth depended upon by browsers such as moose and mastodon. The valleys might also have supported, as a result of the greater moisture and permafrost potential along their flanks, elements of the herbaceous tundra environment favored by species such as caribou. The river valleys may have been desirable settlement areas for subsistence hunters, providing fuel, water, some shelter from the persistent winds, and a habitat of diverse resource potential.

The climate during this glacial maximum was probably one of cold, dry winters with sweeping winds out of the north and northwest. These winds, in fact, may be a key to the survival of the large grazing herds, the mechanism needed to keep the north-facing slopes of the, winter range swept free of snow. Summers were probably warm and dry, as at present, but with predominant winds from the west and northwest rather than from the east as is presently the case (Lamb and Woodroffe 1970).

b. Post-Maximum Glacial Retreat: 20,000 to 13,000 B.P.

Following the Late Wisconsin maximum, the weather ameliorated, growing warmer and probably wetter over the Beaufort Shelf. Massive glacial wastage ensued, and the Beaufort Sea once more crept up to reoccupy most of its emergent shelf. As it reoccupied the shelf, and as the climate warmed, a summer band of open water, perhaps more extensive than that observed today, may have fostered increased productivity and standing stocks of marine mammals, fish, and invertebrates. The streams entering the sea, however, though greatly enlarged by glacial melt, may have been extremely turbid with glacial silt. Such turbidity may have discouraged anadromous fish seeking spawning grounds. It might also have weakened the primary productivity potential of the nearshore Beaufort Sea as a result of inhibited light penetration, thus compromising the overall carrying capacity of the nearshore environment. Also, with the Bering Strait still closed, the Beaufort was isolated from the warmer Bering Sea Water and walrus and bearded seal probably remained south of the Strait. These factors suggest that a primarily marine-directed subsistence economy was unlikely during this period, though marine resources may have been available as a supplemental or alternate resource.

As the climate became warmer and wetter, the rivers were swollen, fanning out over the flatlands to form extensive outwash plains, while at the same time a brush and tundra environment encroached within the rolling hills. Consequently, grazing herds were probably replaced in the uplands and across the flats (now reverting to mesic tundra) by browsers and tundra-adapted animals whose range was expanding out of the river valleys. Grazers may have occupied the valleys and outwash plains, where remnants of the grasslands still survived (Pewe 1975).

c* Glacial Readvance: 13,000 to 11,000 B.P. (Itkillik II)

On the Beaufort coast, this apparent resurgence of cold climate probably brought about some lowering of sea level and retreat of the Arctic Ocean shoreline back across the shelf, though the magnitude of this retreat is wholly speculative. It almost certainly brought on more severe ice conditions along this coast, probably to the detriment of most marine mammal, fish and invertebrate populations.

In the terrestrial realm, the herds of large grazing mammals may by this time have been driven to extinction by changing environmental conditions, or forced into refugia along the stream courses and outwash plains, leaving most of the region to musk ox, caribou, and moose. It is assumed that the requirements and distribution patterns of these species would have been essentially the same as presently observed.

d. Second Warm Interval: 11,000 to 8,000 B.P.

During this period it seems probable that the climate turned warmer and wetter. Increased areas of open summer water over the shallow Beaufort Shelf may have encouraged the expansion of marine populations, particularly marine mammals, in the nearshore zone. However, increased turbidity may have compromised, to some degree, such favorable conditions. Bering Strait would have been re-opened, permitting access to the Beaufort Sea by the marine mammal populations and warm, high-productivity waters of the Bering Sea.

On the exposed shelf, brush thickets, and perhaps even spruce and birch, may have encroached down the stream courses and through the hills to as far north as the Beaufort coast (Ritchie and Hare 1971; Detterman 1970). The effect of this change on subsistence resources of the region is uncertain. The tundra-adapted species such as caribou and musk ox might have seen their range and numbers reduced, and may have been partly replaced in resource importance by more woodland-adapted animals such as moose.

e. Glacial Readvance: 8,000 to 7,000 B.P. (Itkillik III)

This glacial readvance, apparently minor in extent, is of uncertain cause and duration (Hamilton and Porter 1976). The assumption is made, for purposes of this report, that this readvance was the result of climatic events, as seems indicated to some extent by Mackay and Terasmae (1963) and Livingstone (1957).

This period probably saw little change in the nearshore marine environment of the Beaufort coast. There might have been a trend toward increasingly severe ice conditions and decreasing river-borne glacial turbidity, though the magnitude of these effects is uncertain. On the terrestrial shelf, the brushlands conjectured for the preceding warm interval were probably vanishing by this time, reverting to herbaceous tundra, with a corresponding shift in faunal compositions.

f. Third Warm Interval: 7,000 to 4,000 B.P.

The dates for this final warm period are open to question. The opening date of 7,000 B.P. is based on the probable termination of the Itkillik III readvance, which might not, in fact, have been caused by climatic fluctuations (Hamilton and Porter 1975). If the Itkillik III readvance was not due to climatic causes, this warm interval can be considered as an essentially unbroken continuation of the previous warm interval beginning at about 11,000 B.P. The termination date of this interval is also uncertain. Some evidence (Livingstone 1957) indicates that this warm period climaxed as early as 6,000 B.P., after which the climate once more began a return to colder conditions.

The environment of both the nearshore Beaufort Sea and the terrestrial North Slope were probably very similar to those described for the previous warm interval from 11,000 to 8,000 B.P. In the Beaufort Sea, increased temperatures probably resulted in an expanded ice-free zone along the coast during the summers, providing improved conditions for marine mammals such as walrus, bearded seal, and cetaceans. In the terrestrial realm, pollen evidence (Ritchie and Hare 1971) indicates alder and shrub thickets. As mentioned previously, however, such extrapolations from pollen evidence should probably be applied with caution (Livingstone 1955; Colinvaux 1964).

9" Final Phase: 4,000 B.P. to Present

Following the warm interval described above, the climate cooled and became drier, and has remained so until the present time. By now the brush and forest habitat had retreated to south of the Brooks Range, replaced on the North Slope by herbaceous mesic tundra. Faunal composition and distributions throughout this period were probably very similar to those observed at present, with caribou the numerically dominant large mammal species. The only major difference between the start of this period and present is that the musk ox, probably at one time a major element of the fauna, was killed off by human hunters in the last century.

In the marine environment also, conditions and faunal compositions have probably remained fairly constant over the past 4,000 years. Bowhead and beluga whales, walrus, and bearded seals utilize, to a limited extent, the nearshore zone of open water during the summer. The only year-round marine mammal residents are the ringed seal and its predator, the polar bear.

During the temporal span discussed, a shift in resource utilization by subsistence hunters may have been necessitated. Early in the sequence, primary dependence may have been on large terrestrial grazing mammals, augmented by browsing mammals found along the stream courses. By the time of the Itkillik II glacial readvance, some 13,000 years B.P., this dependence had probably shifted to browsing and tundra-adapted mammals, supplemented by or alternated with marine resources along the coast. By the time of the second warm interval (11,000 to 8,000 B.P.), significantly enhanced marine potential, coupled with changing terrestrial conditions, might have favored increased reliance on marine resources. Favorable subsistence locations probably shifted correspondingly, from inland valleys or areas of topographic relief early in the sequence to major stream mouths along the Beaufort coast and to the passes in the Brooks Range later in the sequence.

5. Areas of Enhanced Resource Potential on the Beaufort Shelf:

In view of the lack of topographic relief exhibited by the Beaufort Shelf, and keeping in mind the severe physical environment which must have prevailed during most of the Late Wisconsin over this region, only two areas can be described as having significantly enhanced resource potential.

The first of these lies just offshore from Barter Island in the eastern sector of the Alaskan Beaufort. The relatively steep seaward-facing slopes of this area might have been attractive to terrestrial grazers seeking fall range, and would have provided viewpoints for hunters of both terrestrial and, later on, marine mammals. These slopes would have resulted in relative horizontal stabilization of the coastline as sea level rose during submergence. In addition, topographic evidence indicates that this area might have been the recipient of one or more rivers during submergence, perhaps hosting seasonal runs of anadromous fish.

The other area of interest lies in the far western Beaufort, offshore from present Point Barrow. North and west-facing slopes would have provided viewpoints for hunters of terrestrial and marine mammals, resulted in coastline stability, may have attracted terrestrial grazers, and may have funneled movements of large terrestrial mammals migrating along the coast. After the flooding of Bering Strait, this area would have provided enhanced marine potential, primarily in the form of walrus, bearded seal, and bowhead whales.

6. Post-Glacial Disturbance of the Beaufort Shelf:

While the shallow Beaufort Shelf was perhaps not subjected, during its post-glacial 'resubmergence, to the severe surf and storm-wave conditions which must have prevailed over much of the Bering Sea and North Pacific Coast, it did undoubtedly suffer rather severe disturbance from ice scouring and gouging. The permanent Arctic ice pack has acted to protect the Beaufort Shelf, shortening the fetch of open water over which waves are generated during the severe fall storms, and thus partially sheltering it. The ice itself, on the other hand, driven in tabular sheets and massive ice-ridges before this wind, creates damage of its own. Kovacs and Mellor (1974) have ascertained that present pressure ridges over the shelf will sometimes ground, gouging the bottom, in depths of water exceeding 80 m. The accumulated frequency of such ice gouges, which sometimes attain widths of 100 m and run for many km, is estimated at 10 to 15 per linear km over the major part of the shelf. The depths of these ice-gouges into the substrate sometimes exceed 5 m (Kovacs and Mellor 1974).

F. Bering and Chukchi Shelves

This is the largest unit to be considered, and includes the continental shelves of the Bering and Chukchi seas from Alaska to Siberia and from the Pribilof Islands in the south to the edge of the Arctic Ocean (Fig. II-2, II-3). In spite of its vast area, however, the environment of the region, both physical and biological, was probably fairly uniform during emergence. Ecological transitions across this shelf were most likely due to latitudinal gradients, with no apparent ecological barriers or abrupt topographic boundaries. In the marine realm, at least, this appears to be the case today, with the Bering and Chukchi shelves supporting a strongly interrelated biological system which extends unbroken from Bristol Bay to the Arctic Ocean (Stoker 1978).

1. Present Geography and Environment:

Due primarily to its vast size and latitudinal breadth, the region includes a much greater range of terrestrial habitat than does the Beaufort

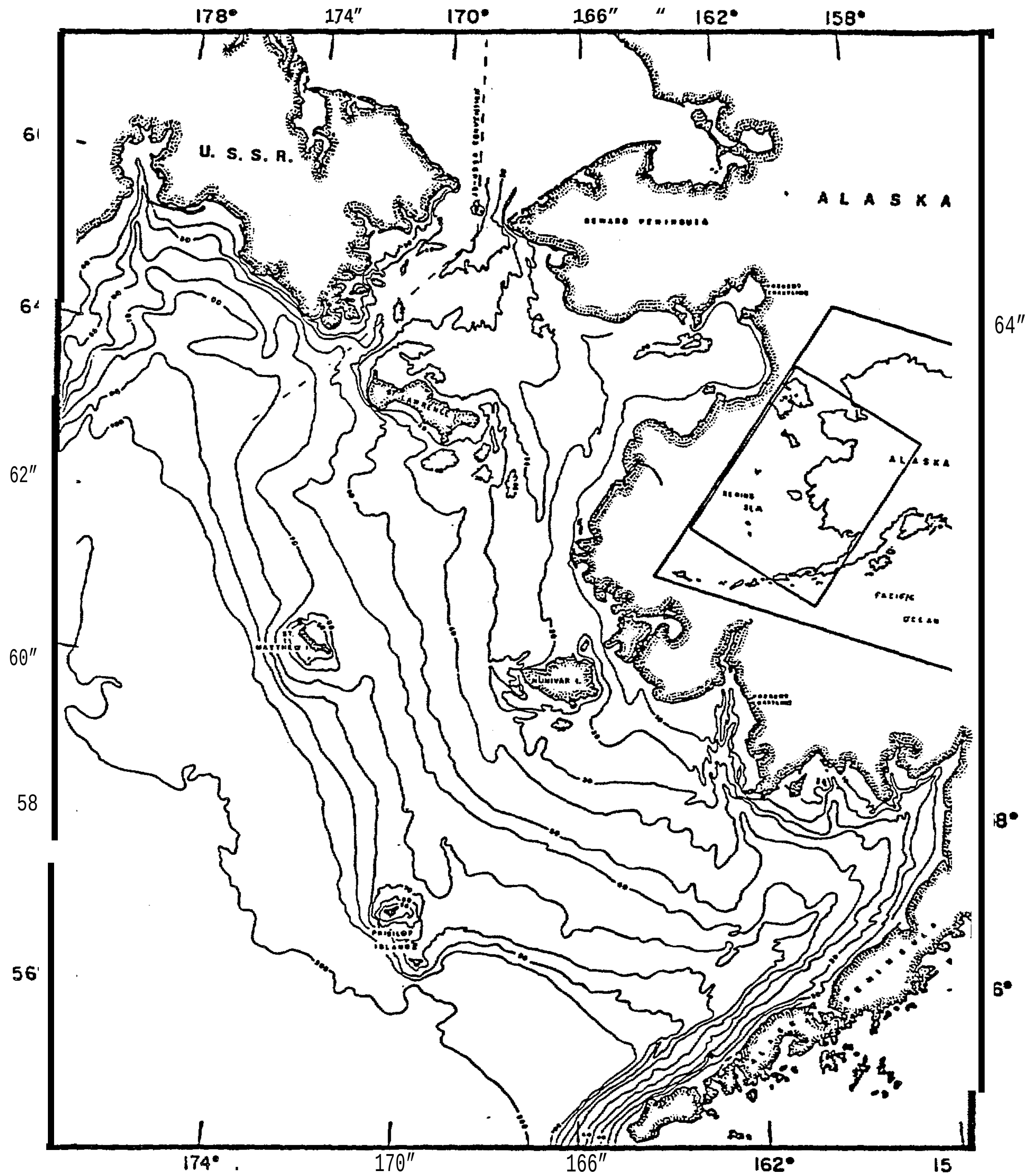


Fig. II-2: Bering Sea Shelf and Present Coastline.

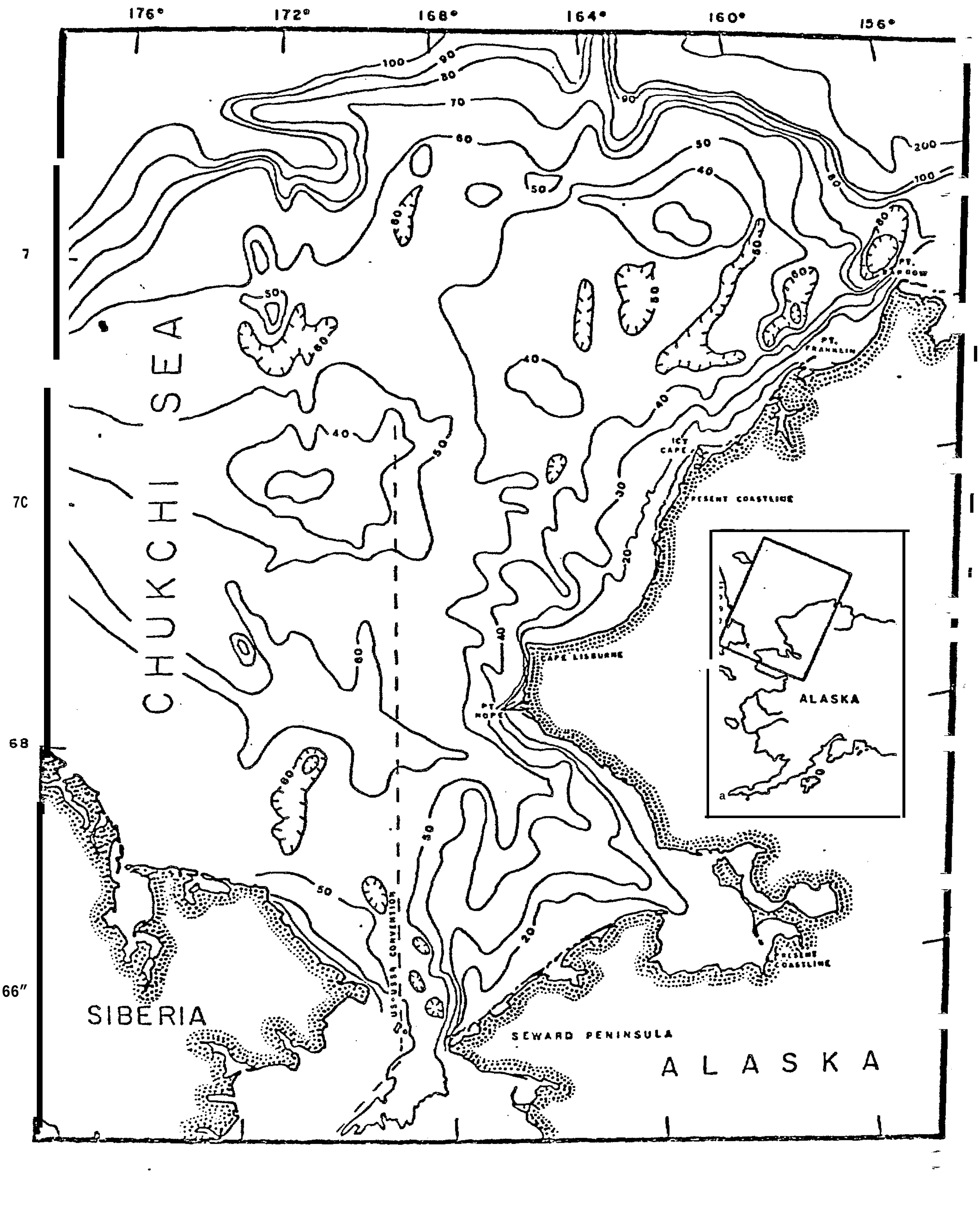


Fig. II-3: Chukchi Sea Shelf and Present Coastline.

Shelf. Predictably, there is a significant temperature/climate gradient from south to north., though this is moderated by the buffering influence of the Bering and Chukchi seas. The main climatic division seems to be at Bering Strait, with everything north of the strait considered arctic in character while everything south of it, including the Bering Sea side of the Alaska Peninsula, is considered transitional between maritime and continental (Joint Federal-State Land Use Planning Commission for Alaska 1973) .

The topography of the present Bering Sea coast varies considerably, from the steep volcanic terrain of the Alaska Peninsula to the flat wetlands of the Yukon-Kuskokwim Delta. Several mountain systems approach the coast--including the Kuskokwim Mountains along northern Bristol Bay, various small ranges on the Seward Peninsula, and elements of the Brooks Range along the Chukchi coast--and are usually separated by large areas of wet muskeg tundra such as those which characterize the base of the Alaska Peninsula and Kvichak Bay, the Yukon-Kuskokwim Delta, Norton Bay, the north side of the Seward Peninsula, and Kotzebue Sound.

The vegetation of the region is dominated by mesic tundra, ranging from the very wet muskeg tundra of the flats to herbaceous shrub tundra in the hills and uplands. In addition, spruce and hardwood forests penetrate to the coast along the northern edges of Kotzebue Sound, Norton Sound, and Bristol Bay.

As might be expected, the large mammalian fauna consists primarily of browsers and tundra-adapted forms. Moose, the most ubiquitous species, presently inhabit the entire area except for the Alaska Peninsula outward from Port Moller. Caribou are almost equally widespread, excluded only from the Yukon-Kuskokwim Delta and northern Bristol Bay. In addition to these two principal species, Dan sheep occur near the Chukchi coast in the western fingers of the Brooks Range, and musk-ox, killed off in the last century, have been reintroduced to Nunivak Island, the Seward Peninsula, and the Chukchi coast. With the exception of "the wetlands of the Yukon-Kuskokwim Delta, brown (grizzly) bear also range over the entire area. In addition to these large species, numerous forms of small game occur in varying numbers throughout terrestrial Beringia, including hares, ground squirrels, several species of grouse and ptarmigan and abundant waterfowl.

In general, the terrestrial resources of Beringia are quite similar in composition to those of the North Slope, consisting primarily of moose and caribou. Over the northern portion of Beringia the situation closely approximates that of the Beaufort, with caribou the dominant terrestrial resource and moose a secondary alternate. South of Bering Strait this situation is usually reversed, with moose as the primary terrestrial resource and caribou, if present at all , relegated to secondary status.

Marine resources, however, are quite different from those of the Beaufort Sea in both abundance and diversity. While the Beaufort Sea is quite clearly an embayment of the Arctic Ocean, the Bering Sea is part of the North Pacific System. The Chukchi Sea, while considered to be oceanographically part of the Arctic Ocean along with the Beaufort Sea, is biologically more interrelated with the Bering Sea and, through it, the North Pacific.

North Pacific water enters the Bering Sea through the deep passes in the Aleutian Chain, flows generally north across the shelf, and eventually funnels through Bering Strait into the Chukchi Sea. There is some coastal intensification of this northward flow, and entrainment of the Yukon and Kuskokwim river discharges. Although current velocity drops off abruptly north of Bering Strait, this northward movement of Bering Sea/North Pacific water continues to the Arctic Ocean, endowing the Chukchi Sea with warmer temperatures and richer faunal resources than most other seas of comparable latitude. The Chukchi Sea appears, in fact, to be very dependent on the Bering Sea not only for its physical properties but for its biological capacity as well. Much of the high primary productivity of the northern Bering Sea, as well as organics entrained from the Yukon and Kuskokwim rivers, are swept through Bering Strait into the south-central Chukchi Sea where, because of the abrupt drop in current velocity, they are allowed to settle to the bottom. The benthos of this region is, correspondingly, some of the richest in the northern hemisphere in terms of standing stock (Stoker 1978) and provides summer feeding ground for numerous marine mammals and birds, including the California gray whale.

All of the Bering and Chukchi continental shelves are subject to seasonal sea ice. This ice, however, is far from detrimental to the rich marine system of the region as it provides substrate for early spring primary productivity in the northern Bering Sea (McRoy and Goeri ng 1976), and offers a platform for marine mammals such as walrus, bearded seal, ringed seal, and harbor seal, which are not truly pelagic. It also, of course, offers a platform for subsistence hunters in pursuit of these animals.

Primary marine resources consist of marine mammals and anadromous fish, with the species of importance varying abruptly from area to area and even from village to village depending on local conditions. In general, anadromous fish are more important south of the Seward Peninsula, with marine mammals and terrestrial mammals serving as secondary or alternate resources, while in the Bering Strait-St. Lawrence Island vicinity and along the Chukchi coast marine mammals are the primary resource, supplemented with terrestrial mammals and anadromous fish. Since most of the marine mammals, as well as the anadromous fish and terrestrial large mammals, are migratory, subsistence economies of the region are extremely seasonal in character.

Marine mammals of primary importance for subsistence resources include Pacific walrus, bowhead whale, bearded seal, ringed seal, and beluga whale. These are ranked more or less in order of importance to the region, though this is somewhat difficult to determine since villages tend to be quite selective regarding marine mammal species taken. In addition to these primary species, other marine mammals taken on occasion include ribbon seal, Steller sea lion, polar bear, and northern fur seal.

Anadromous fish of importance include all of the species of salmon occurring in Alaskan waters as well as sheefish, arctic char, and several species of whitefish. As observed for other facets of the subsistence economy, regional differences are obvious. In the Bering Sea, salmon are clearly of paramount importance, while in the Chukchi Sea sheefish, char, and whitefish compete with salmon for priority.

In addition to marine mammals and anadromous fish, several species of marine fish (cod, sculpin, halibut, sole), and marine invertebrates (crab, shrimp, clams, snails) are available in the nearshore environment and are utilized to seine degree. Marine birds, particularly those such as auklets, murres, gulls, and puffins, which nest in dense rookeries, also provide an important subsistence resource.

In the Bering Sea region south of the Seward Peninsula, village sites are located along streams in order to take advantage of the salmon runs, and are sometimes some distance from the sea. On the Seward Peninsula and along the Chukchi shore, villages are located almost always on the coast, with capes and headlands favored as sites due to their potential for marine mammal exploitation.

2* Late Wisconsin Climatic Sequence:

The climatic history of Beringia following the final Wisconsin glacial maximum was probably very similar to that of the Beaufort Shelf. After the glacial maximum of about 20,000 B.P., the region apparently underwent a period of gradual climatic amelioration, becoming slowly warmer and wetter until roughly 13,000 B.P., at which time there seems to have been a sudden acceleration toward much warmer temperatures. This shift culminated in an early hypothermal sometime between 11,000 and 8,000 B.P. (McCulloch and Hopkins 1966; McCulloch 1967; Matthews 1974), followed by a brief reversal to cooler temperatures. Another relatively warm, moist period then ensued, with a second hypothermal somewhere between 5,000 and 3,000 B.P. After 3,000 B.P. the climate again cooled somewhat and has remained so until the present. The biological environment would, of course, have been determined by, and would have reflected these climatic shifts.

3. Reconstruction of Events and Environments:

a. Late Wisconsin Glacial Maximum: 25,000 to 20,000 B.P.

At this time, with sea level some 125 m below present, virtually all of the Bering and Chukchi shelves would have been emergent as a vast, monotonous plain. With the exception of a few river valleys and a scattering of remnant highlands which persist today as islands (the Pribilofs, the Diomedes, St. Matthew, Nunivak, St. Lawrence, King Island), it was the flattest terrain on the face of the earth.

The rivers that traversed this plain, while few in number, were impressive in magnitude--the Yukon, Kuskokwim, and Kobuk on the American side, and the Anadyr on the Asian. The Yukon, Kuskokwim and Anadyr flowed generally southward across the Beringian Plain to the deep basin of the Bering Sea, while the Kobuk turned northward to the Arctic Ocean. During the height of glaciation it may be presumed that the discharge of these rivers, particularly the Kobuk, was decreased. During the onset of glacial wastage and resubmergence, however, their discharge was probably magnified. Given the terrain traversed by them, it seems likely that they followed braided, meandering patterns not unlike the present Yukon and Kuskokwim where they cross extensive flats.

Though most of the region included in Beringia was undoubtedly glacier-free during this and subsequent periods, there is some disagreement concerning the extent of glaciation along its margins. This is particularly true of the Alaska Peninsula, as will be discussed in more detail in the following section pertaining to the Pacific coast. One view is that the Alaska Peninsula sustained extensive and heavy glaciation during the Late Wisconsin; the other is that it was virtually glacier-free. In addition to possible glaciation on the Alaska Peninsula, there is evidence of extensive local glaciation in the Kuskokwim Mountains just north of present Bristol Bay (Porter 1967), and, of course, in the Brooks Range to the north.

As a result of the greatly expanded land mass created by this emergent shelf, the climate of Beringia would have been much more continental than is presently the case, and was almost certainly severe. Winters were probably longer and colder than at present, with the summers shorter and warmer (Hopkins 1972; Dillon 1956; Hulten 1963). The arctic low-pressure center may have been intensified during this period, resulting in increased cyclonic circulation and stronger and more persistent winds with a more northerly component. These winds may have kept the vast plains swept free of snow for the large grazing herds which frequented it. In keeping with the increased continentality and altered atmospheric circulation, precipitation, both as rain and snow, was probably scantier than at present over the region.

This general climatic pattern would have varied somewhat with latitude. The more southern region, adjacent to the open Bering Sea, would have been somewhat warmer and wetter than the northern shelf where a truly continental arctic climate would have prevailed. As mentioned earlier, this south to north gradient was probably fairly gradual, with no sharp divisions into climatic or ecological provinces.

As was the case regarding the Beaufort Shelf, the exact character of the biological environment during, and for some time following, the glacial maximum is a matter of some debate. This is particularly true when it comes to vegetation patterns, though most palynological studies relating to Beringia indicate a dominant steppe-tundra environment during and immediately preceding the glacial maximum, (Colinvaux 1964; Heusser 1966; Cwynar and Ritchie 1980). In all probability this was a dry (xeric) biome with a considerably elevated proportion of grasses and sedges. The large mammalian fauna of this period, dominated as it was by grazers (horse, bison, mammoth), would seem to support this concept of a xeric steppe-tundra (Guthrie 1976).

It seems likely that the mammalian fauna occupying the Beringian Plain was very similar in all aspects to that proposed for the Beaufort Shelf. Early in the sequence, the grazers, the so-called ‘mammoth fauna’ (Guthrie 1976), probably dominated the region, with browsers such as moose and caribou in a secondary position.

Considering the aridity and general harshness of the climate, plant productivity on the emergent shelf was probably rather low, necessitating constant movement by grazing herds. It also seems likely that there might have been general north-south seasonal migrations in deference to latitudinal gradients.

During the period of gradual climatic amelioration following the glacial maximum the steppe-tundra underwent gradual changes, with encroaching replacement of the xeric biome, with its high proportion of grasses and sedges, by mesic herbaceous forms. The faunal composition would have altered correspondingly over this period, with gradual replacement of the once-dominant mammoth fauna by browsers and tundra-adapted species.

Along the southern margin of this plain lay the Bering Sea, shrunk during maximum emergence to little over half its present size and restricted to its deeper zones. There were probably fairly strong nearshore currents trending east to west, with inflow through the deep passes along the eastern Aleutian Arc and outflow through the western Aleutian or Kommandorsky passes. This current flow might have resulted in upwelling along the continental slope, which would have promoted enhanced biological productivity at all levels of the food chain.

It is almost certain that the nearshore Bering was subject to seasonal sea ice extending to the continental slope, where upwelling from the deep basin would have prevented its further expansion as it does today.

The nearshore environment probably contained most, if not all, the marine mammal, bird, fish, and invertebrate species presently found in the Bering and Chukchi seas, though certainly in altered ratios and distributions. Of the marine mammal species now present in the Bering and Chukchi seas, the only ones which might have remained north of the emergent Bering Strait, and thus isolated from the Bering coast, were the polar bear and ringed seal. Species of primary resource interest probably included walrus, bearded seal, harbor seal, possibly ringed and ribbon seal, otarid seals such as the northern fur seal and Steller sea lion, and various cetaceans.

All of the pinniped species are shore- or ice-dependent to one degree or another, and would have been vulnerable to human predation. In addition to being shore- or ice-dependent for hauling and calving purposes, the walrus and bearded seal, both bottom feeders, are unable to maintain themselves in water depth much in excess of 50 meters and would have been geographically limited to what remained of Bristol Bay, the Kamchatka embayment and the Sea of Okhotsk on the Asian side, and a narrow nearshore band along the southern edge of the Beringian Plain. These species probably wintered along the ice edge and within areas of rifted ice. During the presumably ice-free summer, they would most likely have concentrated in Bristol Bay and along the Alaska Peninsula, and perhaps in the vicinity of the Pribilof Islands in response to high-productivity feeding areas and suitable hauling rounds. Harbor seals, ribbon seals, and ringed seals (if they were present), may have had similar distributions, with summer concentrations in the vicinity of river mouths and estuaries where anadromous fish might have been available, and perhaps along along glacier faces of the Alaska Peninsula. Harbor seals presently congregate along glacier faces in southeastern Alaska, presumably as a result of the increased abundance of pandalid shrimp found there (personal observation). The otarid seals--sea lions and fur seals--would probably have led a more pelagic life during the winter, but in the summer would have returned for breeding purposes and formed dense rookeries, as they presently do, on rocky capes and islands such as the Pribilofs.

In addition to marine mammals, which were probably abundant and vulnerable to human-hunters along the Bering coast, it seems likely that streams and rivers emptying into-the Bering-Sea would have hosted "summer spawning runs of anadromous fish, notably-salmon. Other nearshore resources-might have included various spec-ies of marine fish and invertebrates, and marine rooking birds.

One other marine mammal species of note, the Stel ler sea cow, probably inhabited the Bering Sea at this time. Judging from its feeding habits, however, which required dense and extensive beds of the larger seaweeds, the Beringian range of this mammal was probably limited to islands of the Aleutian-Kommandorsky Arc which were inaccessible by land.

It seems reasonable to assume that the marine resources of the Bering coast were about as abundant and available during the Late Wisconsin as they are today, and would probably have been sufficient to sustain permanent or semi-permanent human habitation sites. Choice locales for such sites might have been river mouths or estuaries where anadromous fish would have been available, or capes and headlands where marine mammals and birds might have been concentrated. Terrestrial mammals--particularly the large grazers--might have provided an alternate or even primary resource.

As the climate warmed following the glacial maximum, the distribution and composition of the marine fauna, like the terrestrial, would have altered correspondingly, though in what manner is difficult to say. It is possible that this "warming trend might have encouraged the expansion of open-water species such as the otarid seals while proving detrimental to ice-associated species such as the walrus and bearded seal. At the same time, however, rising sea level would have expanded the potential range available to "these latter species. Once Bering Strait was resubmerged (16,000-14,000 B.P.), these ice-adapted species assumed, or resumed, a migratory existence to follow the seasonal advance and retreat of the ice edge back and forth across the Bering and Chukchi seas.

The northern border of Beringia during maximum emergence was the edge of the Arctic Ocean, the Chukchi Shelf having been abandoned to its limits by the sea. The Arctic might have been ice-free in its central basin and inhabited by several marine mammal species presently limited to the Atlantic. On the other hand, it may have remained solidly frozen throughout the sequence. In either case, the northern coast of Beringia must have presented an extremely inhospitable environment prior to breaching of Bering Strait, with extensive shorefast and pack ice and limited nearshore marine productivity and diversity. The two marine mammal species which are at all likely to have been present along this forbidding coast, the ringed seal and the polar bear, are more or less solitary by nature and would have been difficult prey. It is doubtful that anadromous fish, marine fish, shellfish, or even marine birds would have occurred in large numbers or concentrations along this shore.

After communication was opened through Bering Strait, however, conditions across the expanding Chukchi Sea were probably much improved. Not only would the species formerly limited to the Bering Sea have access, at least seasonally, to the Chukchi, but the productivity and habitat potential of the Chukchi Sea itself would be elevated by the flow of warmer, nutrient-rich water through Bering Strait from the south.

b. Early Warm Interval: 13,000 to 8,000 B.P.

The dates for this event are somewhat uncertain. The climatic optimum probably did not occur until sometime between 11,000 and 8,000 B.P., though the climatic shift which led to it may have taken place as early as 13,000 B.P. A rather sudden reduction in the grass and sedge component of the biome, with a corresponding increase in herbaceous forms typical of mesic tundra, seems to have taken place about 13,000 B.P. in adjoining regions (Cwynar and Ritchie 1980; Ager 1975), and probably applied to the Bering and Chukchi shelves. Around the end of Wisconsin time, there may also have been treeline encroachment onto the Seward Peninsula (McCulloch and Hopkins 1966).

This rather drastic and sudden climatic and vegetational change wrought an equally drastic change in the faunal composition of the region, with replacement of the grazing herds, which had formerly dominated the Beringian Plain, by browsers such as moose and by animals more at home on mesic tundra such as caribou and musk ox. By 13,000 B.P., or shortly thereafter, the 'mammoth fauna' was essentially extinct in Beringia.

c* Climatic Reversal: 8,000 to 7,000 B.P.

Again, the dates as well as the magnitude of this event are largely open to conjecture. All that can be said with any degree of certainty is that it took place sometime between the early warm interval, described above, and the second which lay between 5,000 and 3,000 B.P.

The consequences of this reversal are equally unknown. It would undoubtedly have had some effect on the vegetational regime of the region, though apparently not enough to encourage a return to xeric steppe-tundra. Consequently, the qualitative composition of the Beringian fauna probably did not change during this reversal, though the quantitative ratios may well have.

d. Hypothermal: 5,000 to 3,000 B.P.

Though precise dates for this event are uncertain, evidence from the Bering and Chukchi coasts and adjoining regions indicates a general climatic shift of major proportions for this period. The time framework of 5,000 to 3,000 B.P. is supported by investigations from the Seward Peninsula and Chukchi coast (McCulloch and Hopkins 1966; McCulloch 1967), the Brooks Range (Porter 1964; McCulloch 1967), the Mackenzie Delta and the Alaskan North Slope (Detterman 1970; Mackay and Terasmae 1963; Ritchie and Hare 1971; Livingstone 1957), southeastern Alaska (Miller and Anderson 1974; McKenzie and Goldthwait 1971; Heusser 1953), Greenland (Langway et al. 1973; Dansgaard et al. 1969), and Siberia (Kind 1967).

Elevated temperatures and possibly increased precipitation levels during this period probably led to the widespread replacement of xeric tundra by mesic shrub tundra, willow and alder brushland, and perhaps even, in some areas at least, taiga during this period. This ecological shift undoubtedly occasioned major changes in faunal distributions and in quantitative ratios of species present, though it apparently did not lead to the large-scale and abrupt replacements and extinctions which seem to have characterized the earlier post-glacial warming period of 13,000 to 8,000 B*P.

e. Second Climatic Reversal: 3,000 B.P. to Present

At about 3,000 years before present, perhaps as early as 4,000, the climate underwent yet another shift, cooling once more and remaining so until the present time. During this final phase, the ecology of the region, both terrestrial and marine, was presumably much as it is today, with similar resource distributions.

4. Areas of Enhanced Resource Potential on the Beringian Shelf:

Due to the flat and rather monotonous topography of the present Bering and Chukchi shelves, it is difficult to predict, with a few exceptions, where faunal concentrations would have occurred at any given time. There are, nevertheless, a few areas where attractive topographic features are apparent, the most notable being vicinity of the Pribilof Canyon and northern Bristol Bay.

Most of the Bering Sea coast, particularly the central coast from the Pribilofs west to the Kamchatka embayment, would have been an open, wind-swept shore of sand beaches and dunes, probably wracked by severe and frequent storms and subject to heavy surf. The Bristol Bay and Pribilof Canyon regions, however, would have been somewhat sheltered from such open-ocean effects, and would have presented a more hospitable environment. They would also have been the most likely regions of marine upwelling and enhanced marine productivity at all levels of the food chain, and were probably outlets of river systems attractive to anadromous fish. Topographic features in northern Bristol Bay would seem to indicate past drainage courses of several rivers--particularly the Kvichak, Nushagak, Togiak, and Kuskokwim--across the upper part of the Bering Shelf. In addition to anadromous and freshwater fish resources, these drainages would have channeled movements of terrestrial mammals and would have provided some degree of shelter and habitat diversity. The nearshore region in the vicinity of their outlets would probably have been zones of enhanced marine productivity and would have been particularly attractive to phocid and otarid seals and smaller cetaceans such as harbor porpoise and beluga whale. The extent and availability of these resources would have varied somewhat depending on the climate and its effect on stream volume and turbidity, though in exactly what manner is difficult to say. Periods of warmer climate might have been more conducive to biological activity in general, including anadromous fish populations, but the glacial wastage promoted by this warming would also have led to increased flow rates and turbidity, which might have had the opposite effect.

In the Pribilof Canyon area, nearshore upwelling along the continental slope would almost certainly have led to enhanced marine productivity. This embayment was probably also the recipient of rivers flowing south across the shelf, perhaps including the Yukon (Sharma 1976). The topographic relief, or lack of such, does not, however, permit the exact delineation of these drainages. This area would have been particularly attractive to marine mammals--including walrus, phocid and otarid seals, and various cetaceans--and to marine birds as a result of the enhanced marine productivity and the proximity of favorable hauling and rooking grounds. Of all the coastal areas, this region was the only one close enough to the continental slope upwelling zone to have remained essentially ice-free during the winter.

In addition to a very favorable marine situation, the south-facing slopes of the Pribilofs might well have provided a seasonal attraction for terrestrial herbivores, thus permitting some degree of resource diversification. This combination of factors would probably have made the Pribilof region, particularly the vicinity of St. George Island, a very desirable location for subsistence hunters throughout the year. By about 13,000 B. P., at the beginning of the abrupt climatic shift following the glacial maximum, sea level would again have encroached to return the Pribilofs to island status.

In addition to northern Bristol Bay and the Pribilof vicinity, favorable locations might have been the areas adjacent to Nunivak and St. Lawrence islands, where there were north and south-facing slopes attractive to grazers and where topographic constrictions would have funneled movements of large terrestrial mammals and, after submergence, marine mammals. They would also have provided desirable hauling grounds for marine mammals and rooking areas for marine birds. The vicinity of St. Matthew Island would also have provided attractive hauling and rooking grounds for marine mammals and birds, and slopes for grazing mammals in the summer and fall. Theo other Bering Sea area of interest, Bering Strait, would probably have funneled north-south migrations of large terrestrial mammals as it presently funnels migrations of marine mammals.

On the Chukchi Shelf, it is difficult to define areas of probable resource concentration due to generally poor topographic resolution, severe climatic conditions, and limited resource potential which probably prevailed over the region prior to the flooding of Bering Strait. There are some areas, notably shoals in the central and northern Chukchi, where north and south-facing slopes might have provided some attraction for grazers prior to submergence. The only definable areas of the Chukchi likely to have possessed any degree of potential are shallow topographic constrictions (possibly river drainages) just north of Bering Strait and in Kotzebue Sound, and the shelf adjacent to the Point Hope-Cape Lisburne promontory where increased nearshore productivity and hauling and rooking grounds for marine mammals and birds might have provided sufficient marine resources late in the climatic sequence.

5. Post-Glacial Disturbance of the Beringian Shelf:

Most of the Bering Sea shore of Beringia was an open, unprotected coast subject to severe storms and to heavy surf. As sea level rose and the beach migrated over the shelf, it probably destroyed or redistributed most terrestrial deposits to a depth in excess of one meter (Guthrie 1976). The implication is, then, that the chance of site survival along this coastline would have been slim except in sheltered areas or perhaps along river mouths and estuaries where rapid sedimentation might have buried and preserved them from such destruction. In addition, most of the Bering and Chukchi shelves (with the exception of embayments such as Bristol Bay, Norton Sound, and Kotzebue Sound) have been subject to ice gouging and scouring subsequent to submergence, though the magnitude of this disturbance is uncertain. There has also been some degree of post-submergent current erosion, particularly in Bering Strait which is virtually swept free of all but the coarsest sediments.

G. Pacific Coast

The region considered here includes all of the Pacific coast of Alaska from Kayak Island in the western Gulf of Alaska (Longitude 144°W) to Umnak Island in the Aleutians (169°30'W) (Fig. II-4). This is primarily an area of mountainous, irregular, and often glaciated coastline, and is by far the most complex of all the regions thus far considered in terms of topography, physical environment, and ecological diversity.

Based on considerations of topography, climate, and biological distributions, this region seems to be divisible into four fairly well defined provinces: (1) the western Gulf of Alaska and Prince Wil 1 i am Sound from Kayak Island west to the Kenai Mountains, (2) the Kenai Peninsula northwest of the Kenai Mountains, including Cook Inlet and the mainland coast southwest to the base of the Alaska Peninsula (about Cape Douglas), (3) the Pacific. coast of the Alaska Peninsula and the proximal Aleutian Islands, and (4) Kodiak Island. In some cases, these provinces can, with validity, be further subdivided into local enclaves.

1. Present Geography and Environment:

a. Province 1:

Over the eastern sector of province 1, from Kayak Island to Hinchinbrook Island, the coastal morphology is dominated by low, deltaic outwash deposits, coastal bogs and marshes, extensive mudflats, and low barrier islands. Several major rivers empty into the Gulf of Alaska within this eastern sector, principal among which are the Copper and Bering. In the vicinity of Katalla, this low coastal relief is interrupted briefly by the approach of the Ragged Mountains and associated forested uplands to the sea. The Katalla enclave may have served as an ice-free refugia during the height of Wisconsin glaciation.

The coastal ecosystem over most of this eastern sector is dominated by low, wet tundra and meadow. The major exception to this rule is the Katalla enclave, where forest and alpine tundra predominate. Within the low areas characterized by wet tundra there are also extensive growths of alder and willow along stream courses, and sometimes broad expanses of coarse salt grass on the barrier islands and along the mainland beaches.

The western sector of the province, which includes Prince William Sound and the southeast coast of the Kenai Peninsula, is an area characterized by rugged, heavily forested islands and deeply dissected coastlines, with numerous swift streams and tidewater glaciers. Over most of

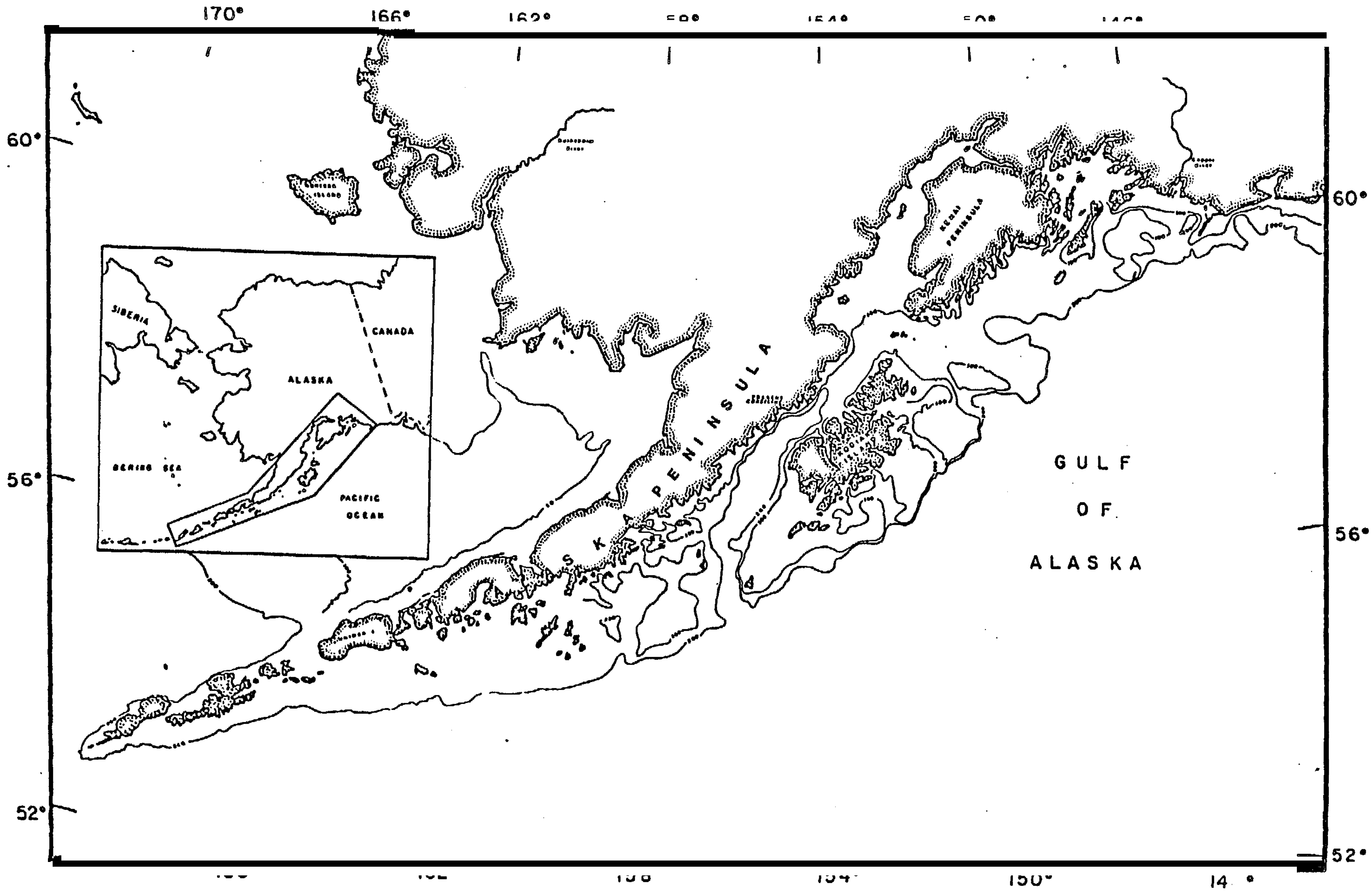


Figure II-4: Map of Pacific Coast Region.

this sector, and within the Katalla enclave of the eastern sector, climax vegetation in the lower elevations is dominated by dense forests of Sitka spruce and western hemlock, with local enclaves of muskeg tundra, salt grass flats, and willow and alder thickets. In the higher elevations, above 300 m, alpine tundra prevails.

The weather over this entire province is classed as maritime (Johnson and Hartman 1969) and is dominated by the influence of the Alaskan Gyre, a marine current system which sweeps counterclockwise around the Gulf of Alaska. Precipitation over the entire area is relatively heavy, ranging from 200 to 250 cm per year and averaging 225 cm per year. The mean annual temperature is 5°C, with a seasonal variation of only 7° to 8*C. Snow sometimes accumulates to -considerable depths, particularly in the higher elevations. The area is not subject to extensive sea ice, though seasonal ice forms in shallow bays and estuaries, particularly within Prince William Sound.

Indigenous large mammal species are brown bear, black bear, and mountain goat. Goats frequent virtually all of the higher elevations on the mainland and on the larger islands. Both brown and black bear inhabit the mainland forests, though only brown bear have colonized the larger islands. There is also, at present, a viable moose population in the Copper River delta and elk and black-tailed deer on several of the larger islands, both the result of transplants during this century. Numerous species of smaller mammals also inhabit the area, and freshwater fish--principally cutthroat and Dolly Varden trout--are found in virtually all of the clear streams. Wildfowl are found over the entire region, and are particularly numerous in the Bering River flats and Copper River delta.

Nearshore marine resources are fairly abundant, with harbor seals, Steller sea lions, sea otters, and various species of marine and anadromous fish and marine invertebrates found throughout the area. Harbor seals are especially numerous in the Copper River-Controller Bay vicinity, while sea lions and sea otters are more common among the islands and mainland bays of Prince William Sound and the Kenai Peninsula. The availability and diversity of marine resources of all types is generally higher along the Prince William Sound-Kenai Peninsula coast due to greater habitat variability. All of the area is characterized by high tidal ranges--3.7 to 4.6 m in most places--making intertidal resources such as marine invertebrates readily available where they occur. Large runs of anadromous fish utilize, according to the preference of their species, virtually all of the streams of the area. While the marine resources of the region are considerable, they do not attain the abundance and diversity of adjacent areas such as Kodiak Island to the northwest or the Alexander Archipelago to the southeast, primarily due to the current transport and salinity structure of the region.

Prince William Sound is virtually an inland sea, with limited water exchange. Almost all of the inflow is through Hinchinbrook Entrance, and most of the outflow through Montague Strait. The inflow through Hinchinbrook Entrance includes low salinity, high turbidity Copper River water entrained and swept up the coast by the Alaskan Gyre. Within Prince William Sound this salinity/turbidity effect is further accentuated by glacial runoff, which entrains and outflows through Montague Strait and sweeps southwest along the Kenai Peninsula coast (Dr. Thomas Royer, University of Alaska, unpublished data). Lowered surface salinity results in generally intense vertical stratification and restricted nutrient exchange. In combination with increased surface turbidity and restricted light penetration, the effect is lowered productivity at the primary and subsequent levels. The salinity effect itself may be extreme enough to directly suppress or exclude the development of some elements of the intertidal and shallow subtidal community. This seems especially probable for intertidal invertebrate populations, which appear depressed both in terms of standing stock and diversity when compared with adjacent areas of similar habitat.

Anadromous fish resources do not, on the other hand, appear to be adversely effected by these conditions. These are seasonal spawning populations, and do not rely on the productivity of that particular area for their major growth and development. The same can be said of the pinniped marine mammals--seals and sea lions--which follow the runs of anadromous fish. The only areas within which physical conditions or low resource availability and diversity might discourage human settlement are the Copper River delta and the Bering River-Controller Bay flats. Considering the general paucity of large terrestrial mammals, any subsistence economy in this region must be based primarily on marine resources.

b. Province 2:

Within the second ecological/geographic province, the northwest side of the Kenai Peninsula is in striking contrast to the southeast side, which is a relatively strait, featureless coast with generally flat terrain. Spruce-hemlock forest occupies the better-drained portions of this coast, particularly toward the south, while muskeg tundra and stunted black spruce and birch prevail in the northern lowlands.

Across Cook Inlet, the Alaska Peninsula coast is rugged and mountainous for the most part, deeply indented by bays and fiords and, in all " respects, more similar to the southeast Kenai coast. This region is also dominated by spruce-hemlock forest in the lower elevations, though large areas of wet tundra, willow-alder thickets, and salt grass flats occur.

The climate of the Cook Inlet-Northwest Kenai province is significantly colder and drier than the Kayak Island-Southeast Kenai unit considered earlier, and is considered transitional rather than maritime. The mean annual precipitation here is only 56 cm per year, ranging locally from 50 to 150 cm, with a mean annual temperature of from 2° to 5"C.

The smaller terrestrial mammal fauna of this province is essentially the same as for the previous unit, though the large mammal fauna is somewhat different. Brown and black bear are common to both areas, though mountain goat is absent west of the Kenai Mountains. Moose, however, are abundant in the Kenai lowlands north of Kachemak Bay and along the Alaska Peninsula, and caribou are presently found in the Kenai lowlands. The caribou population is, however, the result of a recent transplant.

Marine resources, particularly anadromous fish, also offer some potential, though in generally lesser abundance and diversity than for adjacent areas. Sea lion and sea otter, for instance, do not generally frequent Cook Inlet north of Kachemak Bay.

Cook Inlet conforms to the classic estuarine system, with oceanic water of high nutrient content and relatively high salinity entering at depth and along the right-hand (Kenai) shore. Terrestrial runoff of low salinity and high turbidity, conversely, stratifies near the surface and outflows along the Alaska Peninsula shore. This situation results in increased productivity near the mouth of the inlet, particularly along the Kenai shore, but seems to suppress marine productivity and diversity within the inlet and along the Alaska Peninsula shore. The same general system applies, individually, to each of the bays and coves encountered. Tides in Cook Inlet run very high, between 7 and 10 m.

Cook Inlet offers sufficient resources to support subsistence economies over virtually its entire extent, though the focus of such economies varies with locality. In the Kenai lowlands north of Kachemak Bay, for instance, terrestrial resources, principally moose, might play a dominant role in the economy, with anadromous fish as a secondary or alternate resource. On the Alaska Peninsula side, the reverse would more probably be the case. Fortunately, as for Prince William Sound, the anadromous fish frequenting the area are not at all deterred by the biologically unfavorable oceanographic conditions of Cook Inlet, and are seasonally plentiful in many of the streams.

c. Province 3:

The third ecological/geographic province of the Pacific Coast encompasses all of the Alaska Peninsula south and west of Cape Douglas, including the Semidi and Shumagin Islands, and the proximal islands in the Aleutian Chain. It is, like the first province, a region dominated by a maritime climate and economy. The annual precipitation at Cold Bay, near the end of the Peninsula, averages 85 cm/yr. with a mean annual temperature of 2°C.

With a few local exceptions, the coastline of this province is volcanic and mountainous, deeply indented by numerous complex bays and inlets and sprinkled with rocky islands. This coastal complexity, combined with the relatively warm and nutrient-rich influence of the Alaskan Stream, supports a marine biota of considerable abundance and diversity in terms of marine and anadromous fish, marine mammals and birds, and marine invertebrates. Marine mammals presently inhabiting the region include harbor seals, Steller sea lions, northern fur seals, sea otters, and various cetaceans.

Of these, the harbor seal was probably the marine mammal species of greatest year-round availability to coastal habitants of the region shortly prior to and at the time of white contact (Clark 1968). This species is of moderate body size, semi-gregarious, and seems equally at home on pack ice, shore-fast ice, sandy spits and beaches, or rocky headlands and offshore islands. It is a year-round resident of the area and is accessible to coastal hunters at all seasons, though to varying degrees. It is most susceptible during the pupping season in late spring and early summer, and while feeding on summer spawning runs of anadromous fish in the bays and river mouths.

The other pinniped which is a year-round resident is the Steller sea lion. Of fairly large body size, this animal is strongly gregarious, hauling and rooking in dense colonies on rocky headlands and offshore islands during the summer, where it would be quite vulnerable to subsistence hunters. During the winter months it assumes a more pelagic existence and is less accessible, though it is available as prey to some extent at all seasons of the year.

The northern fur seal is also a seasonal resident or migratory visitor to this region. During the summer this species rooks in dense colonies on the Pribilof Islands in the Bering Sea, after which it returns to a primarily pelagic existence in the southern Bering Sea and North Pacific. It does frequent the coast to some extent during this pelagic and migratory phase however, and was utilized by subsistence hunters to some degree as evidenced by prehistoric midden remains on Kodiak Island (Clark 1968).

The sea otter, another species presently common in the region, is a shallow diver tied to a coastal existence. It prefers rocky bays and inlets where some shelter is afforded from the storms of the open sea and where the subtidal and intertidal invertebrates, upon which it feeds, are found in abundance.

In addition to such coastal-dependent or coastal-oriented marine mammals, numerous cetacean species frequent the area and might be attractive to subsistence hunters either as prey or as stranded finds. Beluga whales and harbor porpoises, which venture into river mouths in pursuit of anadromous fish, are particularly vulnerable.

This coast also offers considerable resource potential in the form of marine and anadromous fish, marine invertebrates, and marine rooking birds. River mouths, particularly, are desirable subsistence locales due to the seasonal runs of anadromous fish and marine mammal predators which frequent them, while rocky inlets and bays are rich in intertidal resources such as marine invertebrates.

In addition to marine resources, the Alaska Peninsula offers considerable terrestrial resource potential in caribou and moose. Both of these species inhabit, in varying proportions and densities depending on local conditions, virtually all of the Peninsula with the exception that moose do not occur outward from about Port Moller-Stepovak Bay. Brown bear are also ubiquitous over the Alaska Peninsula and some of the offshore islands, and a transplanted population of bison resides on Popof Island in the Shumagin Group.. Small game likewise provide some resource potential on both the Peninsula and on some of the adjacent islands. Only on the Peninsula itself, though, do terrestrial resources offer any real alternative to the prevalent marine-based economy.

Vegetation of the Alaska Peninsula-Proximal Aleutian Island province is dominated by alpine tundra in the uplands and mesic tundra in the lowlands, with local stands of spruce-hemlock forest along the base of the Peninsula and as far west as Amber Bay. In addition, there are extensive zones of alder-willow brush along stream drainages, and saltgrass flats along the coast.

d. Province 4:

Kodiak Island, the fourth and last-ecological province of the Pacific coast to be considered here, is very similar in climate and topography to the Alaska Peninsula coast. Like the Peninsula, the coast is generally mountainous and rugged, and is even more deeply dissected by fiords and complex bays. As might be expected from its position astride the Alaskan Stream, the climate is even more strongly maritime than the mainland and is slightly warmer and wetter, with a mean annual temperature of 6°C and mean annual precipitation of 144 cm. The marine resources of Kodiak are, likewise, very similar to those described for the Alaska Peninsula-Proximal Aleutian Island province in terms of composition and distribution, and are at least as abundant in every instance.

In terms of terrestrial fauna and resource potential, however, Kodiak is very different. Like the Alaska Peninsula, the vegetational regime varies, depending on local conditions, between spruce-hemlock forest, alder and willow brush, wet muskeg tundra, alpine tundra, and grass meadows. Spruce-hemlock forest is particularly common on the northern end of Kodiak Island itself and on adjacent Afognak Island (included in the Kodiak province, as are the Trinity Islands to the south). Most of Kodiak itself is classed as alpine tundra and high brush, while spruce-hemlock forest dominates Afognak. The Trinity Islands are characterized primarily by wet tundra.

The mammalian fauna which inhabits these islands, at least the indigenous fauna, is extremely depauperate as compared to the mainland. Like the Prince William Sound-Controller Bay enclave described earlier, and for essentially the same reason, the large herbivorous fauna found over most of the mainland coast and interior is absent from Kodiak and the adjacent islands. As the Prince William Sound-Controller Bay enclave was isolated by glaciation during the Late Wisconsin, so Kodiak was isolated by its insular position. Of the 20 mammalian species currently found on Kodiak, only 6 (brown bear, land otter, short-tailed weasel, tundra vole, red fox, little brown bat) are indigenous (Clark 1968). Any subsistence economy in the Kodiak province, therefore, must have relied almost totally on marine resources.

2. Climate Sequence:

There seems to be some disagreement as to the climatic sequence which prevailed over the Pacific coastal region during the Late Wisconsin, though such disagreement generally pertains to temporal or regional detail rather than to major climatic shifts. For the early part of the period, prior to about 12,000 B.P., little concrete information is available. Karlstrom (1955, 1957, 1966) described a general glacial withdrawal for the Cook Inlet region at 19,000 B.P., which presumably reflects climate amelioration following the Wisconsin maximum. Glacial evidence from Prince of Wales Island (in the Alexander Archipelago to the southeast of the study area), however, indicates glacial advance for the period 20,000 to 15,000 B.P. (Swanston 1969). This Prince of Wales Island advance might, of course, merely reflect local conditions. Karlstrom proposes that the next major glacial retreat in the Cook Inlet region took place about 15,500 to 15,000 B.P. (Table II-l). If this retreat is construed as reflective of climate warming, a possible conflict again arises. In this case the conflict stems from palynological evidence from the Pacific Northwest (Heusser 1966) which indicates a cold, dry climate for the period 15,000 to 12,500 B.P. Again, such evidence may be indicative only of local conditions.

The next major glacial retreat evidenced in the Cook Inlet area is dated at 12,500 B.P. This retreat corresponds very well with Heusser's (1966) pollen evidence from the Pacific Northwest, which indicates a warm, wet climate for the period 12,500 to 11,000 B.P. Glacial evidence from southeastern Alaska (McKenzie and Goldthwait 1971) indicates rapid glacial retreat dated 10,940 B.P. Widespread micropaleontological and oxygen isotope evidence from other areas in the northern hemisphere also suggest a sudden general warming trend dated to about 13,000 to 11,000 B.P. (Langway et al. 1973; Urry 1948; Erickson and Wollin 1956; Curray 1965; Erickson et al. 1964a,b).

While accepted by most sources as a period of major climatic reversal, this warming trend at 13,000 to 11,000 B.P. may have been of relatively short duration. Heusser (1966) feels that the Pacific Northwest in general reverted back to a cold, dry climate for the interval 11,000 to 10,500 B.P., as do Miller and Anderson (1974) for the interval 11,000 to 10,000 B.P. in the Juneau, Alaska, vicinity. Oxygen isotope data from Greenland (Dansgaard et al. 1969; Langway et al. 1973) also indicate a major reversal back to a cold climate at about this time.

By about 10,000 B.P., the climate appears to have altered course again, from cold and dry to cool and wet. This change probably entailed increased precipitation more than increased temperature. The duration of this cool, wet interval is somewhat open to speculation. Heusser (1960, 1966) feels that over the Pacific Northwest it lasted from about 10,500 to 8,500 B.P., and from about 10,000 to 8,000 B.P. in southcentral Alaska. Miller and Anderson (1974) suggest that in the Juneau vicinity it lasted only from 10,000 to 9,000 B.P. A glacial advance on Prince of Wales Island (Swanston 1969), dated at 10,000 to 8,000 B.P. may reflect this increased precipitation. Goldthwait (1966) documents a glacial advance for the Lituya Bay region for a slightly later time period, 8,600 to 7,300 B.P.

Another major reversal, back to a warmer climate, is generally postulated as occurring sometime after 9,000 B.P. For the Pacific Northwest the duration of this warm interval is dated 8,500 to 4,500 B.P. (Heusser 1966). For southeastern Alaska it is dated variously at 7,700 ± 300 B.P. to 3,500 ± 250 B.P. (Heusser 1966), 7,200 to 2,900 B.P. (Goldthwait 1966), and 9,000 to 2,500 B.P. (Miller and Anderson 1974). Miller and Anderson propose that this warm interval suffered at least one reversal to a cooler, wetter climate between 8,000 and 5,500 B.P. For southcentral Alaska, this warm interval is dated at 8,000 to 3,500 B.P. (Heusser 1960). This information accords well with Karlstrom's data from Cook Inlet indicating glacial withdrawal for 9,000 B.P., 6,000 to 5,500 B.P., 4,500 B.P., 3,500 B.P., and 2,500 B.P. At some time during this warm interval, the Late Wisconsin hypothermal, defined variously as the "climate optimum" or temperature maximum," probably occurred. In southeastern Alaska this hypothermal is

Table 11-1. Periods of glacial retreat in the Cook Inlet region according to Karlstrom (1955, 1957, 1966). The retreat dates listed below each year of reference refer to time before present.

1955	1957	1966
--	--	26,000
--	--	22,500
19,000	19,000	19,000
15,500	15,000	15,500
12,500	12,500.	12,500
9,000	9,000	9,000
5,500	6,000	5,500
--	4,500	--
--	3,500	--
--	2,500	--
1,500	1,500	1,500

dated by various authors at 5,500 to 3,250 B.P. (Mil?er and Anderson 1974), 7,050 to 4,150 B.P. (McKenzie and Goldthwait 1971), and 3,500 ± 250 B.P. (Heusser 1953). These dates generally agree with corresponding ones from Greenland (Langway et al. 1973, Dansgaard et al. 1969), the Seward Peninsula/Chukchi Sea coast (McCul loch and Hopkins 1966, McCul loch 1967), the Brooks Range (Porter 1964, McCulloch 1967), the Mackenzie delta and Alaskan north slope (Detterman 1970, Mackay and Terasmae 1963, Ritchie and Hare 1971, Livingstone 1957), and Siberia (Kind 1967).

Following this. warm interval and "climatic optimum," conditions apparently reverted once more to a colder regime. Heusser (1966) feels that for the Pacific Northwest the climate was cooler and drier between 4,500 and 3,000 B.P., and cool and wet from 3,000 B.P. to the present. Miller and Anderson (1974) indicate that for southeastern Alaska the climate may have been cooler and wetter than at present for the period 2,500 to 750 B.P. This information is summarized in Table II-2.

3. Reconstruction of Events and Environments:

a. Late Wisconsin Glacial Maximum: 25,000 to 20,000 B.P.

The climate over the North Pacific coast during this period is, to some degree, a matter of debate. It is safe to say, however, that it was at least as cold and probably colder than at present, and was probably drier that at present. Both of these conditions would have been buffered considerably by the maritime environment, particularly by the influence of the Alaskan Stream, and would have been subject to lesser seasonal gradients than witnessed by adjacent continental regions. Unlike Beringia with its vast emergent plain, the continental shelf along the Pacific coast is relatively narrow and discontinuous, and would not have resulted in an emergent land mass large enough to have influenced the climate to any significant degree.

A more serious controversy is apparent, however, when reviewing the glacial history of the region. One view (Antevs 1929; Cooper 1942; Heusser 1960; Karlstrom 1961, 1964; Klein 1965; Deevey 1949; Pewe 1975) is that virtually all of the Alaska Peninsula, Kodiak Island, and the Kenai Peninsula-Cook Inlet region were heavily glaciated to the limits of the continental shelf and virtually devoid of faunal resources until roughly 10,000 years ago. The contradictory view (Miller 1953; Reid 1970; Detterman and Hartsock 1966; Sharma 1977, 1979) is that Late Wisconsin glaciation may have been only slightly more extensive than at present over the Pacific Coast. Since questions regarding the extent of glaciation cannot, at this time, be resolved with any degree of certainty, it will be assumed for purposes of this report that the latter view prevails and that the emergent Pacific shelf was habitable during the Late Wisconsin.

Statements concerning vegetational and faunal regimes which might have existed on the Pacific shelf during the glacial maximum and early postglacial are, like those applying to the extent of glaciation, bound to be highly speculative. So far, no pollen cores have been described which pre-date about 11,000 B. P., perhaps supporting theories of severe glaciation over the region (Heusser 1958, 1965; Miller and Anderson 1974). It

Table II-2. Proposed Late Wisconsin climatic sequence for the Gulf of Alaska-Aleutian Pacific region of Alaska. Compiled and synthesized from various authors.

Period (B.P.)	Climate or Climatic Trend
20,000 - 13,000	Ameliorating from cold/dry to warmer/wetter
13,000 - 11,000	Abrupt shift to relatively warm/wet
11,000 - 10,000	Temporary reversal to cold, probably dry
10,000 - 9,000	Ameliorating to cool, probably wet
9,000 - 3,000	Warm/wet hypothermal and "climatic optimum"
3,000 - 0	Second reversal to cool/wet, as at present

must be remembered, though, that all of these cores are from terrestrial areas which might be expected to have been glaciated; none of them are from the now submerged continental shelf. If this continental shelf was not glaciated, it seems safe to assume that it supported, prior to about 11,000 B.P. at least, a tundra or tundra-steppe environment such as is generally proposed for adjacent terrestrial areas for that time period (Deevey 1949; Heusser 1958, 1965). The probability of drier, xeric steppe-tundra increases toward the end of the Alaska Peninsula where the emergent plains were broadest and where fewer high mountains were present to encourage precipitation from the moist and relatively warm marine air masses.

Once major post-glacial warming began, a vegetational sequence from tundra through willow/alder to the present pattern of spruce/hemlock forest is hypothesized for the Kenai Peninsula-Prince William Sound region (Heusser 1958, 1965; Klein 1965). On the Alaska Peninsula this trend toward a warmer, wetter climate probably saw a reduction of grasslands or xeric tundra with replacement by willow/alder brush and wet, mesic tundra, though some dry grasslands did survive locally, such as on the Shumagin Islands, through present time.

As regards faunal distributions and resource availability, at least one author (Klein 1965) feels that the Kenai Peninsula-Prince William Sound-Controller Bay region supported essentially no terrestrial mammalian fauna, except in limited areas of small mammal refugia, prior to 10,000 B.P. Klein feels that, even after climatic amelioration and glacial retreat, the spread into this region by most large mammals would have been severely impeded by natural barriers such as tidewater glaciers, ice fields, precipitous mountain ranges and large, swift rivers.

For the Prince William Sound-Controller Bay region, at least, this view seems to conform to historical distributions. With the exception of mountain goat, brown bear, and black bear (and moose and perhaps bison in the Cook Inlet locality), there is no evidence of any large mammal population during historic or prehistoric times. The evidence for bison is restricted to a single find in the Anchorage area, radiocarbon dated at 200 to 500 B.P. (R.D. Guthrie, Univ. of Alaska, vive vote). Aside from this one tantalizing specimen, there is no evidence that the large grazing populations of bison, horse, and mammoth which inhabited Beringia and the interior during this period ever penetrated south of the Alaska Range. Present populations of moose and bison in the Copper River valley, Sitka deer in Prince William Sound, and Dan sheep and caribou on the Kenai Peninsula are all the result of recent transplants, as are all of the large mammals, with the exception of brown bear, found on Kodiak Island.

The basal part of the Alaska Peninsula, from Cook Inlet to about Amber Bay, would likewise have presented very little potential for terrestrial resources during this or any subsequent period. The coastal plain in this region, even during maximum emergence, would have consisted of no more than a narrow band adjoining the present coast. This coastal band was probably dissected by swift glacial rivers which would have hindered movements along its length, and was virtually cut off from any contact with the Beringian Plain by the mountains and glaciers at its back.

Aside from possibly Cook Inlet, the only area which might have been capable of supporting a large mammal resource during this or any subsequent period was the outer part of the Alaska Peninsula and perhaps the proximal Aleutian Islands, Semidi Islands and Shumagin Islands. A considerable area of low-relief plain would have been emergent along the Pacific side of the Alaska Peninsula, sufficient to connect the proximal Aleutians, the Semidi Islands, and the Shumagins to the mainland. Unlike Beringia, however, with its vast xeric steppe-tundra, the coastal plains here were probably much wetter and supported, consequently, a biome more typical of mesic tundra or alpine tundra complex, perhaps with birch or spruce timber in some areas (Heusser 1960; Klein 1965). This environment might have supported considerable populations of large mammals such as moose, caribou, and bear, but would probably not have been favorable habitat for the large herds of grazing mammals such as frequented Beringia. In addition to a climatic and vegetational environment not conducive to such grazing populations, this coastal plain, unlike the Beringian plain, was not contiguous. The mountains of the Alaska Peninsula themselves would have presented considerable barrier to migrations between the coastal plain and Beringia, and while communication would have been possible across the low divides near the end of the Alaska Peninsula and between the Aleutian highlands, this coastal plain itself would have presented serious obstacles to free movement and migration. Numerous large freshwater lakes and rivers, probably muskeg swamps, and deep fiords and embayments all would have impeded the migratory movements which probably were essential to the Survival of the large grazing populations of Beringia, though elements of this fauna might have frequented the outermost part of this plain on an at least marginal basis.

Marine resources were probably fairly abundant along almost all of the Pacific coast, depending on the extent of glaciation, though during the glacial maximum and for some thousands of years thereafter these resources might have been scantier than is presently the case. Anadromous fish (primarily salmon) are presently a major biotic resource of the region. This might also have been true during the Late Wisconsin, though the effects of glaciation and post-glacial wastage on this resource are uncertain. During the glacial maximum, many of the spawning grounds might have been compromised due to shrunken stream conditions and the presence of glacial ice. Conversely, during the post-glacial warm period these same streams might have been swollen and choked with glacial silt.

The other resource of major potential during this and succeeding periods would probably have consisted of marine mammals. During this early phase it seems probable that marine mammal species present in any numbers over the region would have been limited to cetaceans and two or three pinnipeds (harbor seal and Steller sea lion, possibly northern fur seal). Again, the species composition, distribution, and availability of this resource would have depended to a great extent on glacial and sea ice conditions. Harbor seals seem, presently at least, to be quite adaptable to sea ice and even to congregate in the vicinity of tidewater glaciers. The same is not true, however, of sea lions and fur seals, which appear to avoid ice. In this regard it is thought that the presence of the relatively warm Alaskan Stream along this coast would have prevented the formation of extensive seasonal or permanent sea ice, though some local pack ice or shore-fast ice might have formed in the winter time, particularly in bays and inlets sheltered from the main effect of the current.

Several Bering Sea marine mammal species, the Pacific walrus, bearded seal, ringed seal, and ribbon seal all probably extended their present range southward during the glacial maximum, but primarily along the western, Siberian, side rather than along the Aleutian Chain or into the Gulf of Alaska (Davies 1958; Stoker 1976). It is not entirely impossible that some or all of these species might have penetrated into the western Gulf of Alaska during or subsequent to this last glacial maximum, but it is considered highly improbable that significant populations would have been established there. The walrus and bearded seal are both benthic feeders and are limited, apparently by their diving capabilities, to water of less than 100 m depth for feeding purposes. The Western Gulf region would have provided no extensive habitat of such depth ranges, either during the glacial maximum or during the subsequent sea level rise.

The ringed seal, solitary and adapted to denning on the shorefast ice, might have expanded into the Pacific, though it seems unlikely. There is no paleontological evidence to indicate such expansion and it seems doubtful that shore-fast ice conditions would have existed, over most of the range at least, as would be necessary to support the denning habits of this species.

The other candidate for possible expansion into this region from the Bering Sea, the ribbon seal, seems a remote possibility at best. This rather small and solitary phocid seems very strongly prejudiced toward the western or Siberian side of the Bering Sea in its distribution, and there is no evidence to indicate that it ever ventured as far east as the Gulf of Alaska.

b. Early Post-Glacial: 20,000 to 13,000 B.P.

The climate during this period is generally agreed on as cold and relatively dry, though presumably less so than during the glacial maximum of 25,000 - 20,000 B.P. A tundra or tundra-steppe vegetational regime is hypothesized for this phase, probably with some willow and alder growth in the lowlands and along stream valleys.

Terrestrial faunal resources were probably minimal during this period. No large mammal species, with the possible exception of brown bear and mountain goat, existed at all southeast of the Kenai Mountains. Moose, and possibly caribou and bison, may have inhabited the Cook Inlet region northeast of the Kenai Range and the Alaska Peninsula, though this is uncertain.

Marine resources might have been more abundant, although considerable uncertainty exists as to species composition, distribution, and availability.

c. First Warm Interval: 13,000 to 11,000 B.P.

This period almost certainly saw a major climatic reversal, from cold and dry to warm and wet, accompanied by rapid glacial retreat. The vegetational regime probably altered accordingly, with willow, alder, and perhaps spruce forest replacing, in part at least, the tundra and tundra-steppe habitat hypothesized for the preceding period.

Terrestrial resources probably did not improve significantly during this phase, though marine ones might have. Moderated climatic and ice conditions might have favored increased populations of anadromous fish, pinniped marine mammals, marine invertebrates, and marine rooking birds.

Other factors, however, shed some doubt on this extrapolation of generally increased nearshore resource potential. The sudden and major warming trend evidenced for about this time must have resulted in rapid glacial wastage, and the attendant turbidity and lowered salinity of the coastal zone might have inhibited both anadromous fish and marine primary productivity, thus affecting adversely all levels of the marine food chain.

d. First Climatic Reversal: 11,000 to 10,000B.P.

This interval is generally described as a return to a cold dry climate similar to the 20,000 to 13,000 B.P. period. It is assumed that this climatic reversal was reflected in vegetational patterns, probably resulting in expanded tundra habitat at the expense of spruce, alder, and willow.

Faunal resources might or might not have been greatly affected by this climatic shift. Certainly they could not have been improved.

e. Gradual Warming Trend: 10,000 to 9,000 B.P.

This is thought to have been an interim period of gradual climatic amelioration, becoming slowly warmer and wetter. Little can be said about vegetational changes other than assuming that, with this climatic moderation, spruce, willow, and alder probably once more began replacing tundra as the dominant habitat. Similarly, there were probably no drastic alterations in faunal resources, though the improving climate might have resulted in a gradually expanded carrying capacity.

f. Climatic Optimum: 9,000 to 3,000 B.P.

This period probably saw the most drastic environmental changes. In climatic terms this was a period of major reversal, from cool or cold to quite warm and probably wet. Temperatures probably rose steadily throughout this period to the "climatic optimum" or hypothermal somewhere between 7,000 and 3,000 B.P. It was probably a period of rapid glacial retreat, culminating in a relative stabilization of sea level at about 7,000 B.P. (Curray 1965).

Vegetational patterns probably underwent considerable alteration during this period, evolving into a primarily forest habitat composed of spruce, hemlock, willow, alder, and birch.

Faunal compositions may also have undergone some significant changes during this period. In the terrestrial realm, it is probable that even during this climatic optimum no large mammal species other than mountain goats and brown and black bear penetrated into the Prince William Sound enclave between the Kenai Range and Cape Suckling. Populations of these species, however, as well as small mammals, wildfowl, and freshwater fish, might have expanded considerably. In the Cook Inlet area, moose and possibly caribou and bison might also have provided a significant terrestrial resource, and on the Alaska Peninsula caribou and moose, particularly the latter,.were probably abundant.

This would very likely have been a period of abundant marine resources. As the climate warmed and sea level rose, the nearshore marine habitat would have expanded correspondingly in diversity, productivity, and carrying capacity. In addition to the species occupying the region at present, it is possible that two other marine mammal species of potential import, the northern elephant seal and Steller sea cow, might have expanded their range into the area at this time.

g. Final Climatic Reversal: 3,000 B.P. to Present

This period, following the climatic optimum, was one of cooling temperatures. Changes in vegetation patterns were probably fairly subtle, resulting in the dominant spruce/hemlock forest habitat seen today over most of the area. Faunal resources probably declined somewhat through this final period due to the overall worsening of climatic conditions and to the possible extinction in or evacuation from the area by the northern elephant seal and Steller sea cow.

4. Areas of Enhanced Resource Potential on the Pacific Shelf:

When considering terrestrial subsistence resources, two areas are apparent which probably could have sustained a subsistence economy based on large mammals during all or part of the time interval considered. These areas are Cook Inlet and the Alaska Peninsula outward from about Amber Bay. The latter area includes the proximal Aleutians, the Semidi Islands, and the Shumagin Islands.

a. Cook Inlet:

Within the Cook Inlet province, moose (and perhaps caribou and bison) would have been available along both the Alaska Peninsula and the Kenai Peninsula margins, and over most of present Cook Inlet itself during maximum emergence. Locales favoring a large-mammal-based subsistence economy during emergence might have been:

i. the topographic constriction between inner and outer Kachemak Bay, which would have funneled movements of large mammals;

ii. the south facing slopes of both inner and outer Kachemak Bay, which would have provided attractive spring forage;

iii. the topographic constriction west of Kalgin Island in Cook Inlet, which would have channeled north-south migrations over the emergent shelf;

iv. the emergent pass between Chisik Island and the present coastline of Tuxedni Bay, and the slopes just south of that pass in central Cook Inlet;

v. the margins of a large plateau in central Cook Inlet, of which Kalgin Island is a part, which would have provided north and south facing slopes, zones of relative coastal stability, and cover for "both ambush and protection from the elements;

vi. a topographic rise east of Chinitna Bay which would have created a long, south-facing slope and might have channeled movements of large mammals along the shores of a large lake hypothesized for central Cook Inlet during emergence.

In addition to terrestrial mammals, marine resources in the form of anadromous fish and sea mammals were probably abundant then as now along the encroaching shoreline of Cook Inlet. During the earlier part of the sequence, favorable locations might have been river mouths in central Cook Inlet; later in the sequence, as sea level rose, Kachemak Bay and the bays along the Alaska Peninsula side of Cook Inlet would have been preferable.

b. Alaska Peninsula:

During maximum emergence, three very large sub-peninsulas would have projected into the western Gulf of Alaska from the Alaska Peninsula itself. Separated by deep, sinuous inlets, these sub-peninsulas would have included, respectively, the Semidi Islands, the Shumagin Islands, and the Sanak Island group. In addition, all of the proximal Aleutian Islands westward to and including Umnak would have been part of a contiguous emergent land mass adjoining the Alaska Peninsula. This province would certainly have presented the greatest amount of emergent terrain along the Pacific Shelf, would probably have been the most favorably disposed, at least early in the sequence, toward a terrestrial large-mammal economy, and may have been the most ecologically diverse of all the Pacific provinces in terms of subsistence resources. Large populations of moose and caribou and perhaps--depending on the vegetational regime--grazing herds of horse, bison, and mammoth might have frequented this range. The highlands of the Semidis, Shumagins, and the Sanak Island group, and the south-facing slopes of the Alaska Peninsula and proximal Aleutians would have provided attractive range for large herbivores of either grazing or browsing feeding habit, and communication with the Beringian Plain was probably possible through the emergent passes of the Aleutian Islands and Alaska Peninsula. Small mammals may also have been abundant, and lake and river systems could have provided extensive habitat for waterfowl and spawning grounds for anadromous fish. Locales which might have been particularly attractive in terms of terrestrial resources are:

i. highlands of the Semidi, Shumagin, and Sanak Islands;

ii. proximal Aleutian Islands to and including Umnak;

iii. south-facing slopes of the Alaska Peninsula itself;

iv. passes across the Alaska Peninsula and between the proximal Aleutians which would have funneled movements between the Beringian Plain and the Pacific Shelf.

Marine resources in terms of anadromous fish. marine mammals and birds, and intertidal invertebrates might have been abundant-and-available over much of the coastline of this province during submergence, though areas of concentration are more difficult to define. In general, inlets, river mouths, and projecting capes and headlands would have been favorable locations. Early in the sequence the three inlets separating the large peninsulas "adjoining the Alaska Peninsula might have been particularly attractive. For all of the above locales, it is assumed for purposes of such projections that unglaciated conditions prevailed over this time interval, which may or may not be correct.

In contrast to the abundance and diversity of faunal resources projected for the emergent Peninsula outward from Amber Bay, those of the Shelikof Strait coast may have been fairly depauperate. This area probably supported some terrestrial fauna of interest, notably moose, though the range available would have been quite limited. The mountain passes across the Peninsula were probably heavily glaciated at this time, permitting very restricted access (if at all) to Beringia proper, and numerous tidewater glaciers and glacial rivers probably curtailed severely movement along the narrow emergent coast. These rivers would likely have been very swift, turbulent, and clouded by glacial discharge, with few if any lake systems or other desirable habitat attractive to anadromous fish. Glacial silt also might have suppressed nearshore productivity along this coast, which was at any rate relatively straight and unprotected from surf and was probably subject to winter ice-scouring.

The only locale which can be singled out as having somewhat more than the generally low potential evidenced by the Shelikof Strait section of the coast is the vicinity of Kukak Bay, which might have had a lake and stream system capable of attracting anadromous fish.

For the two remaining Pacific provinces considered here--Kodiak Island and the southeastern Kenai-Prince William Sound-Controller Bay region--any subsistence economy would have been almost totally dependent on marine or anadromous resources. As discussed earlier, these areas were, with the exception of a few species, devoid of any large mammal resources until the transplants of recent years. Even the few species present--brown bear on Kodiak and brown bear, black bear, and mountain goat in the Kenai-Controller Bay region--would not have provided a major resource for early subsistence hunters.

Marine resources might, however, have been quite plentiful and available, at least within certain areas. Kodiak Island, in particular, probably supported large populations of marine mammals (harbor seal, Steller sea lion, northern fur seal, sea otter, various cetaceans, possibly Steller sea cow), anadromous and marine fish, marine birds, and intertidal invertebrates. Local areas within this province which might have yielded maximum marine resources during the Late Wisconsin are:

i. the three deep inlets apparent along the southeastern side of the emergent land mass;

ii. the narrow strait between Kodiak and the Barren Islands to the northeast;

iii. the numerous inlets and river mouths along the Shelikof Strait side of the island.

Inlets and river mouths might have supported rich intertidal invertebrate populations, hosted spawning runs of anadromous fish, attracted concentrations of marine mammals and birds, and would have provided shelter from the surf and storms of the open sea. The Kodiak-Barren Islands strait would have acted as a funnel for anadromous fish and marine mammal movements from the Gulf of Alaska to Cook Inlet and Shelikof Strait. Again, such projections assume that the area remained largely unglaciated during this time period.

c. Southeastern Kenai Peninsula - Prince William Sound - Controller Bay:

While much of this region might have offered marine resources capable of supporting a subsistence economy, the complex and confusing bathymetry/topography of the region makes it very difficult to predict where concentrations might have occurred. Virtually any or all of the many bays, river mouths, and headlands of the region might have provided sufficient resources, assuming that they remained unglaciated.

APPENDIX II-A

List of faunal species and genera discussed in text.

Common Name'	Latin Name
1) Terrestrial mammals	
Arctic hare	Lepus arcticus
Arctic fox	Alopex lagopus
Bison	Bison species
Black bear	Ursus americanus
Brown bear	Ursus middendorffi
Black-tailed deer	Odocoilens hemionus
Caribou	Rangifer tarandus
Dan sheep	Ovis dalli
Elk	Cervus canadensis
Mountain goat	Oreamnos americanus
Grizzly bear	Ursus arctos
Ground squirrel	Citellus undulatus
Horse	Equus species
Lemming	Dicrostonyx groenlandicus
	Lemmus sibiricus
Little brown bat	Myotis lucifugus
Mastodon	Mammut americana
Mammoth	Mammuthus primigenius
Marmot	Marmota species
Moose	Alces species
Musk OX	Ovibos species
Red fox	Vulpes fulva
River otter	Lutra canadensis
Short-tailed weasel	Mustela erminea
Tundra vole	Microtus oeconomus
Snowshoe hare	Lepus americanus
wolf	Canis species
Wolverine	Gulo lucus
2) Pinniped marine mammals	
Bearded seal	Erignathus barbatus
Harbor seal	Phoca vitulina
Hooded seal	Cystophora cristata
Northern elephant seal	Mirounge angustirostris
Northern fur seal	Callorinus ursinus
Pacific walrus	Odobenus rosmarus divergins
Ribbon seal	Histriophoca fasciata
Ringed seal	Pusa hispida
Steller sea lion	Eumetopias jubata

Common Name	Latin Name
3) Cetacean marine mammals	
Beluga whale	*Delphinapterus leucus*
Bowhead whale	*Balaena mysticetus*
Harbor porpoise	*Phocoena phocoena*
Narwhal	*Monodon monoceros*
4) Other marine mammals	
Polar bear	*Ursus maritimus*
Sea otter	*Enhydra lutis*
Steller sea cow	*Hydrodamalis gigas*
5) Birds	
Auklets	*Aethia* species
	Cyclorrhynchus species
	Ptychoramphus species
Grouse	*Canachites* species
	Bonasa species
	Pedioecetes species
Gulls	*Larus* species
Murres	*Uria* species
Puffins	*Fratercula* species
	Lunda species
Ptarmigan	*Lagopus* species
6) Fish	
Arctic char	*Salvelinus alpinus*
Burbot	Lota iota
Cod	*Gaddus* species
Cutthroat trout	*Salmo clarki*
Dolly Varden trout	*Salvelinus malma*
Grayling	*Thymallus arcticus*
Halibut	*Hippoglossus stenolepis*
Lake trout	*Salvelinus namaycush*
Pike	*Esox lucius*
Salmon	*Salmo* species
Sculpins	Numerous genera and species
Sheefish	*Stenodus leucichthys*
Sole	Several genera and species
Whitefish	*Coregonus* species

CHAPTER III
LATE WISCONSIN AND EARLY HOLOCENE ARCHEOLOGY OF ARCTIC NORTH AMERICA

E. James Dixon

A. Literature Review of the Pleistocene Prehistory of Beringia

1. Arctic North America: .

a. General Overview:

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 regions presently occupied by the Bering and Chukchi seas. This land connection, commonly referred to as the Bering Land Bridge, 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: early and late Wisconsin. The early Wisconsin regression occurred sometime after 70,000 years ago 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 terrestrial flora and fauna between Siberia and Alaska. This communication was probably interrupted briefly during the mid-Wisconsin transgression, approximately 25,000 years ago. 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 years ago (Hopkins 1972, 1973; Sharma 1976). Three major stillstands in marine transgression have been recognized during the late Wisconsin. Figure III-1 depicts a reconstruction of late Wisconsin glaciation, approximately 18,000 years ago.

Most scholars feel that early human populations dispersed across Asia and into Alaska via the Bering Land Bridge during periods of marine regression. That Beringia supported Pleistocene fauna is evident in the form of remains secured directly from the Outer Continental Shelf off the Alaska mainland. Veniaminov (1840, cited in Jochelson 1925) reports the discovery of a mammoth tusk on St. Paul Island in 1836. Brown (1891) 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, cited in Jochelson 1925) indicates that mammoth tusks and teeth were found on Unalaska Island in 1801. More recently Pleistocene mammal remains have been recovered from the floors of both the Bering and Chukchi seas.

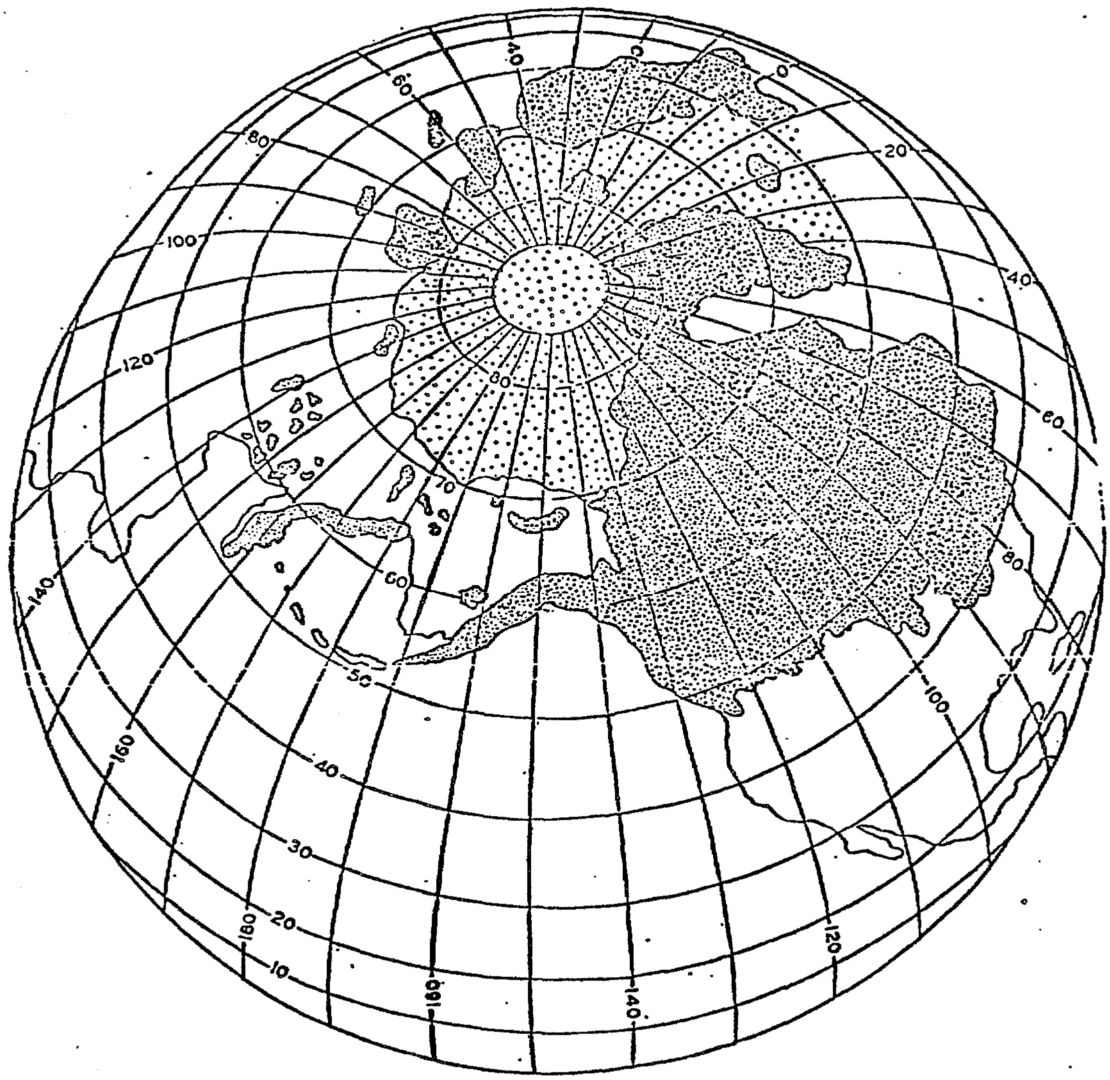


Figure III-1: Polar Projection of Beringia at the Height of Wisconsin Glaciation.

Simultaneous with marine regression in the Beringian area, the continental North American ice sheets (the Cordilleran and Laurentide) expanded and merged east of the Rocky Mountains in Canada, thus blocking the movement of flora and fauna between the Arctic and more temperate regions of North America. It may be that there was sufficient lag time in the advance of glacial ice so that the Bering Land Bridge was exposed before continental ice had blocked access from arctic North America to more southern regions of the continent.

Muller-Beck (1966; 1967) has theorized that what he terms a "Mousteroid" tradition entered the New World via the Bering Land Bridge from Asia sometime 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. A postulated later "Aurignacoid" tradition reached North American during very late Wisconsin times. Although the terms "Mousteroid" and "Aurignacoid" are of doubtful utility in describing New World archeological assemblages because they imply European origins or relationships, Muller-Beck has devised a conceptual framework which is useful in viewing the early peopling of the New World since his scheme provides a method by which early New World assemblages may be viewed in light of world criteria.

b. Campus Site:

It was not until 1935, however, and later in 1937, that N. C. Nelson presented the first archeological evidence demonstrating a strong technological similarity between artifacts of Mongolian origin and those from the Alaska Interior, based on artifacts discovered on the University of Alaska campus at Fairbanks, which include microcores and blades, scrapers, projectile points, burins and other artifact types. Burins in the assemblage were not recognized until the 1950's. Some of the specimens recovered from the 1930's excavations are illustrated in Figures III-2 and III-3. It became apparent to most observers that the core and blade industry Nelson reported demonstrated considerable antiquity, and shared topological traits with artifact assemblages reported from Asia and Europe. Nelson (1935) tentatively suggested that the Campus site material could be as old as 9,000 to 12,000 B.P. Current thinking about the Campus site, based on topological comparison with other dated Alaskan sites and later excavations in the 1960's by Edward Hosley, suggests that the assemblage results from several occupations between ca. 10,000 and 6,000 B.P. and possibly later.

Since the time of Nelson's initial report, numerous hypotheses have been advanced regarding early human colonization of the Americas via the Bering Land Bridge. They have discussed the technological similarities between artifacts of Asian and arctic North American origin in conjunction with the initial populating of the New World from Asia via Alaska. It has only been within approximately the last ten years, however, that several significant archeological sites, dating to early Holocene or late

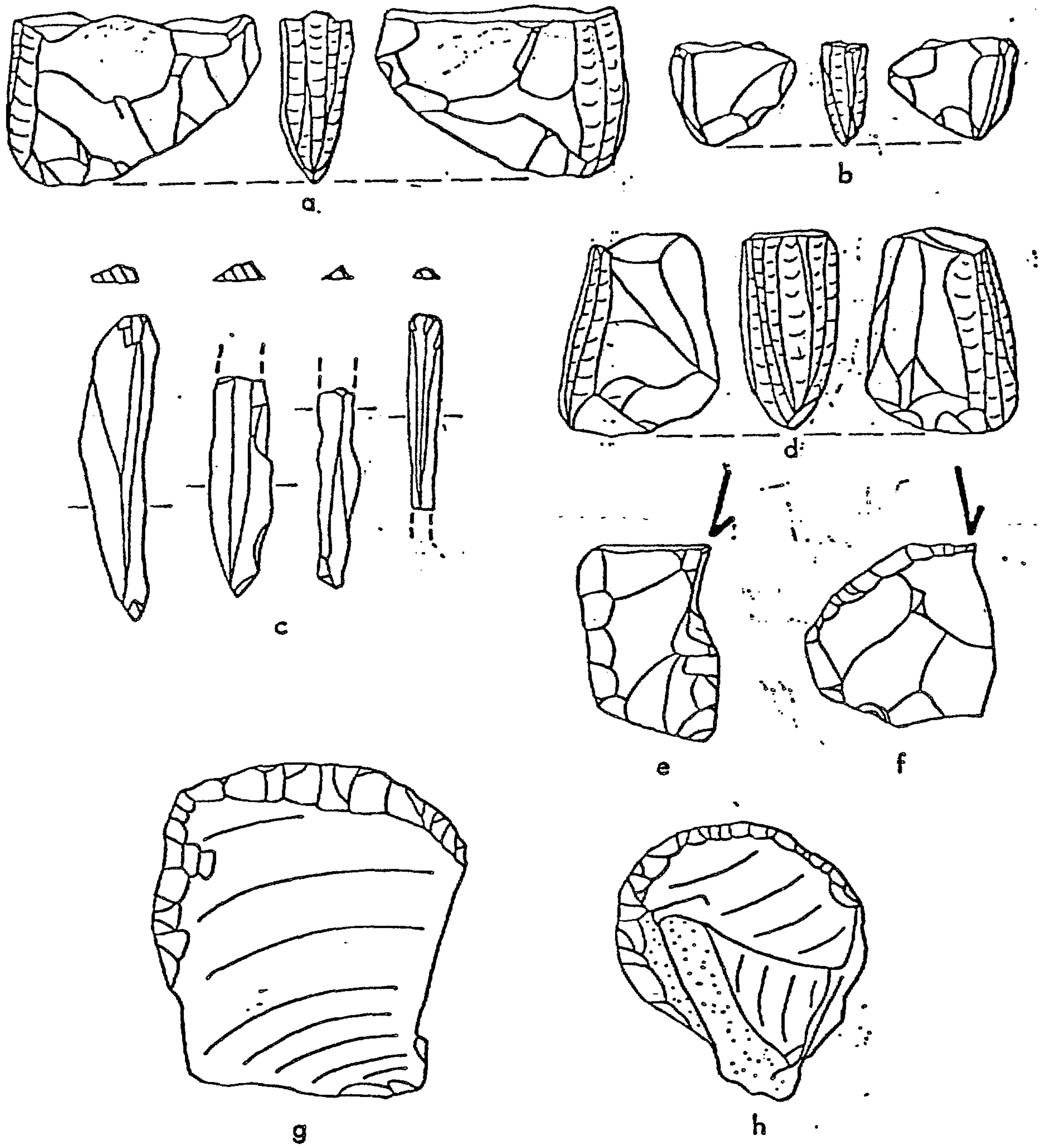


Figure III-2: Artifacts from the Campus site, Fairbanks, Alaska. Actual size. a, b, & d - microblade cores, c - microblades, e & f - burins, g & h - scrapers. All specimens depicted are from Nelson's original collection now housed at the University of Alaska Museum, Fairbanks.

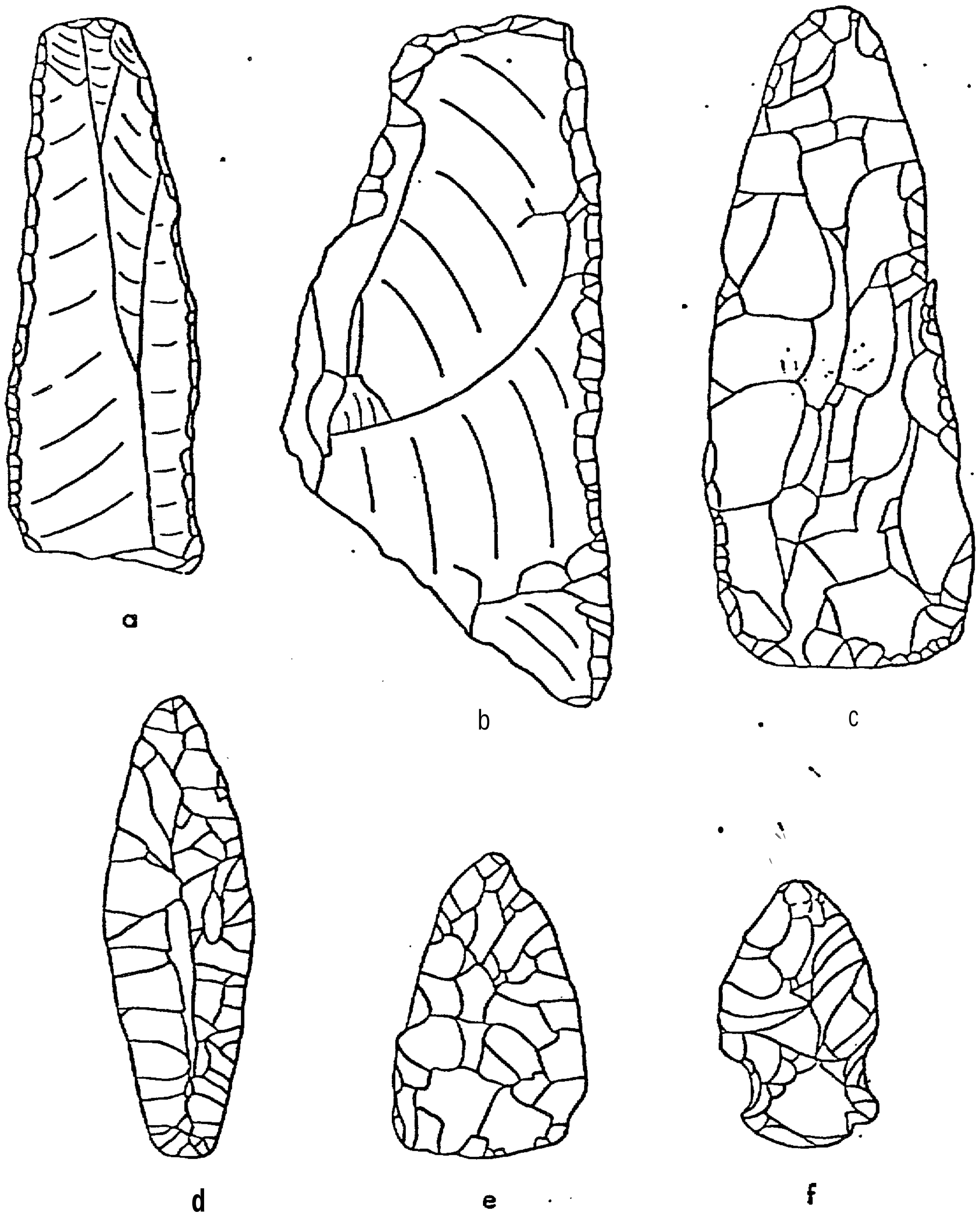


Figure III-3: Artifacts from the Campus site, Fairbanks, Alaska. Actual size. **a & b** - scrapers, c - bifacial knife, d - bifacial projectile point, e - projectile point or knife, f - notched projectile point. All specimens depicted are from Nelson's original collection now housed at the University of Alaska Museum, Fairbanks.

Pleistocene times, have been reported in the arctic regions of North America. Hopkins (1975) proposed acceptance of the Pleistocene-Holocene boundary at 10,000 B.P., and that temporal boundary is accepted for this discussion.

Pleistocene age has been ascribed on topological grounds to numerous archeological sites in arctic North America, but surprisingly few have been verified through radiocarbon or geological dating. Although topological comparison is a valid means to establish the relative age of archeological assemblages, it is only useful if the comparative material is from a dated assemblage. When compared assemblages are from sites which are widely separated geographically, there may be a greater chance for temporal error. This presentation will consider only briefly archeological assemblages for which investigators have postulated Pleistocene or early Holocene age, but which have not been subject to absolute or geologic dating techniques. The majority of data presented will be from sites which have been subjected to comparatively sound dating methods, and from which it is possible to tentatively 'characterize late Pleistocene-early Holocene prehistory in arctic North America.

c. British Mountain Complex:

MacNeish (1956) postulated an early archeological complex which he called the British Mountain complex. Since that time, geomorphological studies at Engigstciak, the type site, have demonstrated that stratigraphy at the site is unreliable as a relative dating technique due to solifluction (MacKay, Mathews and MacNeish 1961, Clark 1977). Few archeologists now accept the validity of the British Mountain complex. Campbell (1961) also theorized an early date for the Kogruk complex, an assemblage found at Anaktuvuk Pass in Alaska's Brooks Range. Campbell's claim of Pleistocene-Holocene antiquity for the Kogruk complex was largely based on topological comparisons with the British Mountain complex. However, the early temporal placement of the Kogruk complex is suspect since it proved impossible to isolate the British Mountain specimens stratigraphically. Neither the British Mountain complex nor the Kogruk complex have been dated by absolute dating methods; however, Campbell (1961) suggests the Kogruk site is probably no older than 10,000 B.P., based on deglaciation of the site area. It is possible that both researchers believed the collections were of late Pleistocene age from topological comparisons with Asian flake tool industries. The sites remain undated.

d, Palisades Complex:

J. Louis Giddings postulated an early age for archeological specimens he recovered from the Palisades at Cape Krusenstern, based on weathering of some of the specimens. He designated this assemblage Palisades I. Later analyses indicate that the Palisades I artifacts belong to the Palisades II complex, which is typified by notched projectile points and falls into the general time framework of the Northern Archaic tradition, ca. 4,600 to 6,000 B.P. (Anderson 1968).

e. North Slope Investigations:

During the summers of 1949 and 1950, Ralph S. Solecki conducted archeological surveys in several areas on the North Slope and in the Brooks Range (Solecki, 1950a, 1950b, 1950c, 1951a, 1951b, Solecki et al. 1973). With the assistance of geological survey crews working in the area, he examined the Colville River and several of its tributaries as well as areas primarily along the Sagavanirktok, Shaviovik, Kukpowruk, and Canning rivers, including Schrader Lake. He reported the discovery of "mesolithic" core and blade material, which he compared to that from the University of Alaska Campus site at Fairbanks, and fluted points, which he correlated with Paleo-Indian specimens already reported from the more southerly latitudes of the North American continent. Based on topological considerations, he felt that the fluted point specimens in his sample represented the earliest evidence for human occupation of the North Slope. Following the 1949 field season, he reported the discovery of 233 archeological sites and features (Solecki, 1950a). His finds probably encompass, albeit discontinuously, late Wisconsin through modern Eskimo occupation of the North Slope.

Thus, the 1950's and very early 1960's may be viewed as an era during which topological considerations, or sometimes simply the "general crudity" of the artifact assemblages, were employed 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 were excavated and have been subject to radiocarbon and geologic dating.

f. Chinitna Bay

Chinitna Bay, located on the north shore of lower Cook Inlet in south-central Alaska, was reported to contain a stratified archeological site which was first described as indicative of early human occupation in association with mammoth remains (Hibben 1943). The site was reportedly discovered in the 1930's by local fishermen and was briefly examined by a field party from the University of New Mexico in 1941 under the direction of Frank C. Hibben. Hibben reported that an exposed erosional bluff face near the present shoreline of Chinitna Bay revealed a cultural stratum with chert flakes in concentrations extending laterally, although sporadically, for approximately one and one-half miles and at a depth ranging from four to twenty-two feet below the existing ground surface. Mammoth remains were identified from the same stratigraphic context as the cultural material.

The depth and extent of the cultural stratum, as well as additional field commitments in Alaska during the 1941 field season, limited the effort of the University of New Mexico's field party to surface reconnaissance and a brief examination of the cultural stratum at the site. Radiometric dating techniques were unknown at that time and although the depth and stratigraphic context in which the cultural material was located suggested considerable antiquity, the glacial sequence limiting the earliest date at which human occupation could occur in Chinitna Bay was not well known.

During June of 1978, an archeological field investigation of the Chinitna Bay site was carried out by the University of Alaska. The field crew consisted of E. James Dixon and Sam W. Stoker (Co-Principal Investigators, University of Alaska), Robert M. Thorson (Geologist, University of Washington), David C. Plaskett (Research Associate in Archeology, University of Alaska), and William Civish (Bureau of Land Management/Outer Continental Shelf Office). The field party was later joined by Douglas Reger (Alaska State Archeologist). Investigations were focused on the south side of Chinitna Bay in an attempt to relocate and test the early archeological site reported by Hibben (1943).

During fieldwork it was possible to relocate Hibben's 1943 photo localities, as well as the general geologic strata which he described for the site area. However, no prehistoric cultural remains were found along this southern shore despite extensive reconnaissance and testing. Geological analyses, coupled with radiocarbon dates on key strata in the reported site area, demonstrate beyond reasonable doubt that the deposits which Hibben described are of very late Holocene age. Also based on this 1978 investigation, it appears quite certain that no early archeological sites or geologic strata from which mammoth remains could be derived exist anywhere along the south shore of Chinitna Bay.

g* Utukok River and the Driftwood Creek Complex:

In 1965 a mammoth tusk was located in a stratified deposit along an eroding Quaternary terrace of the Utukok River, northwest Alaska. Reported nearby, in the same exposure at the same depth, was a concentration of flaking debris. The tusk was found washing out of the bank four feet below the tundra surface and is reported to have rested in situ and not to have represented a redeposited specimen. The flaking debris was found 75 yards north of the tusk, and though only 13 unretouched flakes of grey chert were recovered, Humphrey felt that if the tusk and chipping debris were associated the site could represent a mammoth kill site with cultural affinities to his Driftwood Creek complex (Ibid). This site was reinvestigated by National Park Service personnel in 1978 and the association between the cultural material and Pleistocene faunal remains could not be confirmed.

h. Trail Creek Caves:

The Trail Creek Caves, located on Alaska's Seward Peninsula, have yielded the earliest evidence of Alaska's occupation by early hunters, though Larsen (1968) indicates that the stratigraphy at the caves is difficult to follow and, consequently, that the chronological interpretations are tentative. It appears that the lowest level of Cave 9 yielded several bison calcanei and a horse scapula, and an apparently associated chalcedony point. The pattern of breakage of the bison bones is reported to suggest that they were broken by man. The bison bones have been radiocarbon dated at roughly 14,000 to 15,000 B.P. (Larsen 1968). Stratigraphically above these faunal remains-were found antler projectile points and microblades. The microblades were used as insets in the bevel-based antler points which, on the basis of a C-14 date of 9,120 B.P. and topological comparisons to Band 8 at Onion Portage (Larsen 1968), may be estimated to be between 8,000 and 10,000 B.P.

i. Anangula Blade Site:

The Anangula Blade site is located on Anangula Island, an islet of Umnak Island in the eastern part of the Aleutian Chain, where William S. Laughlin, his students and colleagues have studied an exceptional and well-dated archeological sequence. Two sites on Anangula Island have been sampled. Ash deposits resulting from four distinct volcanic eruptions have provided horizon markers for establishing the relative chronology for a series of archeological sites in the Nikolski area, including those of Anangula. These deposits have been designated Ash I, Ash II, Ash III and Ash IV in order of decreasing age.

The Anangula Blade site is the earliest site in the sequence and is characterized, according to A. P. Okladinikov and as reported by Laughlin (1975), by seven Asiatic traits. These are 1) blades of the Levallois tradition, 2) the Gobi or Frontal core (torzove core), 3) pebble tools, 4) triangular "Mousteroid" projectile points, 5) the "Siberian scraper" or tci-the, 6) angle or diagonal burins, and 7) transverse burins. Laughlin (1967) described the Anangula assemblage as consisting of burins, house or tent depressions, pointed tools on blades and ridge flakes, stone vessels, rubbing stones, red ochre, and both pumice and scoriaceous lava abraders. The presence of fragments of whale bones associated with hearths and the coastal 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 dating for the Anangula Blade site is derived from a suite of 45 radiocarbon dates, 33 of which are reported by W. Laughlin (1975) and S. Laughlin et al. (1975), as summarized in Table 111-1. The additional 13 dates have been published by Aigner (1976), who has questioned the accuracy of Laughlin's estimated duration of occupation of the Blade site. For purposes of this analysis, it may be safely assumed that no matter how long the Blade site was occupied, the occupation began approximately 8,500 radiocarbon years ago. Five occupational levels appear to be sandwiched between Ash 11 and Ash III, and apparently some archeological material from the Blade site predates Ash II.

Laughlin (1975:512) states that:

> "No one archeological site can provide a type section for the entire Holocene Epoch because the Aleuts had to adjust their occupation to a rising sea level and to tectonic uplift. However, a reliable composite stratotype can be based on data from the three sites on Nikolski Bay. Ash I, well marked in all three sites appears to be the first dramatic event after deglaciation."

TABLE III-1

Anangula Blade Site Radiocarbon Dates

SPECIMEN	Date (years B.P.) Libby half-life (5570 years)	Penn half-life (5749 years)
0. GX 2232	6600 ± 320	6798 ± 330
	Hiatus (ash III)	
1. P 1836	6992 ± 91	7202 ± 93
2. P 1835	7000 ± 91	7210 ± 93
3. G-X 2233	7070 ± 240	7282 ± 247
4. GX 2235	7120 ± 240	7334 ± 247
5. GX 2241	7175 ± 240	7390 ± 247
6. GX 2237	7180 ± 250	7395 ± 258
7. GX 2243	7260 ± 320	7478 ± 330
8. P 1108	7287 ± 87	7506 ± 90
9. S1-2177	7360 ± 100	7581 ± 103
10. GX 2246	7395 ± 160	7617 ± 165
11. S1-2180	7600 ± 100	7828 ± 103
12. P 1107	7657 ± 95	7887 ± 98
13. W 1180	7660 ± 300	7890 ± 309
14. P 1102	7701 ± 93	7932 ± 96
15. P 1837	7793 ± 116	8027 ± 119
16. I 1046	7796 ± 230	8030 ± 237
17. GX 2234	7870 ± 260	8106 ± 268
18. SI-2181	7885 ± 335	8122 ± 345
19. S1-2175	7920 ± 100	8158 ± 103
20. P 1105	7932 ± 497	8170 ± 512
21. GX 2229	8055 ± 160	8297 ± 165
22. GX 2238	8060 ± 240	8302 ± 247
23. P 1104	8129 ± 96	8373 ± 99
24. S1-2182	8140 ± 485	8384 ± 500
25. GX 2240	8170 ± 240	8415 ± 247
26. P 1103	8173 ± 87	8418 ± 90
27. S1-2179	8235 ± 125	8482 ± 129
28. GX 2239	8280 ± 220	8528 ± 227
29. GX 2231	8290 ± 240	8539 ± 247
30. S1-2176	8390 ± 95	8642 ± 98
31. 1715	8425 ± 275	8678 ± 283
32. GX 2809	8435 ± 500	8688 ± 515
33. GX 2230	8480 ± 350	8734 ± 361
	Hiatus (ash II)	
34. S1-2178	9055 ± 95	9327 ± 98
35. GX 2244	9805 ± 480	10099 ± 494

TABLE III-1 (Continued)

	Date (years B.P.)	
	Libby half-life (5570 years)	Penn half-life (5749 years)
Summary (specimens 1 to 33)		
Range	6992-8480	7202-8734
Actual Span	1488	1532
Mean	7785	8019
S.D.	460.5	474.3
S.E.	80.5	82.6
Statistical range*	6864-8706	7070-8968
Statistical span	1842	1898

* ± 2 S.D.
From Laughlin 1975:510.

He feels that the three sites--Chaluka (located near Nikolski Village), the Village site, and the Blade site (both located on Anangula Island)--document a relatively constant record of human occupation on Umnak Island for the past 8,500 years. In addition, excavations at Sandy Beach Bay have documented additional occupation on Umnak Island between 4,300 and 5,600 radiocarbon years ago (Aigner et al. 1976).

j. Onion Portage:

The Akmak assemblage from the Onion Portage site, located on the Kobuk River, has been radiocarbon dated at 9,570 ± 150 B.P. or older. The Akmak assemblage is composed of recognized type cores (e.g. campus type or wedge-shaped 'cores), burins, burin span artifacts, large biface knife blades, large flake unifaces, core bifaces, large blades, backed microblades and utilized flakes (Anderson 1970).

Stratigraphically above the Akmak component at Onion Portage is Band Eight for which an occupation period between 8,000 and 8,500 B.P. has been established, based on five radiocarbon dates. Artifact material found in Band Eight consists of backed microblades, campus type microcores, 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 9,000. B.P. 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, located approximately 50 km southwest of Pt. Barrow, which demonstrates topological similarity to the Akmak collection and is probably the same age.

Based on the location of Onion Portage, the" Akmak" assemblage may be interpreted as indicating a riverine subsistence orientation in northwest Alaska south of the Brooks Range. Because of its panoramic view, the locale would have been well suited for large mammal predation.

k. Denali Complex:

The Denali complex has been defined by Frederick Hadleigh West (1967). West considered the following artifact types as 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 spans, worked flakes and retouched flakes. Topological comparisons between it and some Siberian assemblages led West (1967) to speculate that the age of the Denali complex was between 10,000 to 15,000 B.P. West later (1974) revised this assessment and estimated the age for the Denali complex-to fall between approximately 8,000 and 10,000 B.P.

West presents a series of radiocarbon determinations which date geologic events in the Tangle Lakes region, where many of the Denali complex sites have been discovered. He believes that the Denali complex must be older than 9,000 B.P. and younger than 13,000 B.P., because the sites are scattered along a moraine dated to 13,000 B.P. and are all located above the shore of a lake which drained about 9,000 B.P. A radiocarbon date from site Mt. Hayes 111 (10,150 ± 280 B.P.), an archeological site which West assigns to the Denali complex, supports his chronological placement of the Denali complex.

Holmes (1974) reviewed the Denali complex and divided it into two phases: an early and a late phase. Holmes believes that the early phase of the Denali complex may be encompassed by the Akmak assemblage, the lower levels at Dry Creek, and possibly other typologically-related finds in the Alaskan Interior. Continuity between the two phases is implied, but as yet undemonstrated (Holmes 1974). West (1975) believes that apparently more recent radiocarbon dates for Denali complex material do not characterize the complex, and that it is no younger than approximately 8,000 B.P.

l. Chindadn Assemblage

The Chindadn assemblage, recovered from the lowest level at the Healy Lake site in central Alaska, is characterized by thin, triangular projectile points, tear-drop shaped knives or projectile points, blade-like flakes, burins, and possible microblades. Eight radiocarbon samples from the Chindadn level have yielded dates ranging between 8,000 and 10,000 B.P. The period of occupation may extend as far back as 11,000 B.P. (Cook, personal communication). Cook postulates that the Chindadn (meaning "ancestor" in Athabaskan) assemblage represents the earliest manifestation of Athabaskan culture in North America.

m. Gallagher Flint Station:

Locality I at the Gallagher Flint Station (Dixon 1975), located in the arctic foothills of Alaska's Brooks Range, has yielded a charcoal radiocarbon date of 10,540 ± 150 B.P. Locality I is characterized by percussion flakes, blades and microblade cores, platform flakes, unifacially edged and damaged and retouched flakes and blades, 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 material is absent. The Locality I assemblage demonstrates technological similarities to material recovered from the Anangula site. The Gallagher Flint Station site probably served as a lookout for hunters of large mammals moving laterally along the northern foothills of the Brooks Range.

n. Groundhog Bay:

Ackerman (1974) describes a small artifact assemblage from Groundhog Bay in Southeastern Alaska, approximately 50 miles northwest of the city of Juneau. Component III, recovered from Level 4 at this site, produced two obsidian biface fragments, microblades and microblade cores, 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 B.P. The small sample recovered from this occupational horizon makes it extremely difficult to assess possible relationships with other arctic sites. Based on their proximity to the ocean, marine-oriented economies are most plausible for both the Groundhog Bay and Anangula sites. This could likely have taken the combined form of marine mammal predation, fishing and intertidal gathering.

o. Dry Creek:

At the Dry Creek site, located near the town of Healy, Alaska and adjacent to Denali National Park, fossil evidence of sheep and elk has been discovered in 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 place the earliest period of occupation at approximately 11,000 B.P. A stratigraphic level radiocarbon dated at 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).

p* Ugashik Lakes:

Dumond (1977) and Dumond et al. (1976) have briefly described archeological remains from the Ugashik Lakes and the Kvichak Bay regions of the Alaska Peninsula. Dumond has named these assemblages the Ugashik Narrows phase and the Koggiung complex, and considers both assemblages to be part of the American Paleoarctic tradition. Five radiocarbon determinations indicate that these assemblages range between approximately 9,000 B.P. and 7,500 B.P. Wedge-shaped microcores, microblades, burins, leaf-shaped bifaces and core bifaces are the artifact types which Dumond (1977) indicates typify the collection.

q. Old Crow Basin:

There also exists one tantalizing bit of archeological data from the Old Crow Basin in the Yukon Territory of Canada, which was ice-free during Wisconsin times. 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; the resultant dates range between 25,000 and 30,000 years ago.

The major source of contention regarding the antiquity of the Old Crow artifacts is whether they were manufactured shortly after the death of the animals or whether they represent later human modification of fossil bone. Preservation of Pleistocene faunal remains in Alaska and adjacent portions of Canada is exceptional. Guthrie (personal communication) has reportedly made soup from marrow preserved in the long bones of Pleistocene horse. Mammoth remains have been recovered with flesh and hide still intact. Given this type of information, skeptics argue that the Old Crow tools could have been manufactured comparatively recently (although possibly several thousand years ago) on fossil bone which was well preserved following the death of the animals. Especially questionable is the serrated edged flesher of caribou bone, dated ca. 27,000 B.P. (GX-1640). This tool is virtually identical to contemporary fleshers which are still used in Interior Alaska and northwestern Canada; modern examples are manufactured from metal files, trap springs, etc. Although it is hypothetically possible, it is difficult for many archeologists to believe that this tool type remained essentially unchanged for 27,000 years.

In addition to the tools, numerous spirally fractured bones, bone flakes and modified bones have been recovered from the Old Crow Basin (Bonnichsen 1978, Morlan 1978, Irving 1978). Proponents who accept these finds as additional evidence for the presence of Pleistocene man argue that green bone, when broken, fractures spirally while fossil or dry bone does not. The bone flakes are believed to be the result of impact blows by man in an effort to not only extract marrow, but to actually knap the bone for tools (Bonnichsen 1978, Morlan 1978). Critics agree that green bone, when broken, fractures spirally, but argue that permafrost could explain the occurrence of green fossil bone which, when worked many thousands of years later, might create the illusion that the bone was fractured shortly after the death of the animal. Proponents suggest that only man could deliver the force necessary to break the bones; however, G. Haines (personal communication) has conducted experiments by feeding zoo animals fresh and fossil bone which may contradict this assumption. He has observed that hyenas have sufficient mandibular strength to break large bones and that they can, and do, create spiral fractures. They are also capable of knapping bone during the process of chewing on the specimen. It is possible that both dire wolf and large Pleistocene cats could have produced analogous results. Consequently, it is difficult to be certain that all of the Old Crow specimens were manufactured by man, or that those that were were manufactured at the time of the death of the animals.

VonKoenigswald (personal communication) suggests that many Pleistocene bone specimens which resemble artifacts may result from chewing on the bones by predators and ruminants. These same arguments could apply to the bones recovered from the lowest levels at Trail Creek Caves, which conceivably could have been transported to the caves by predators. The antiquity of the Old Crow specimens will remain uncertain until additional specimens are recovered in situ.

r. Summary:

All the sites discussed are not of the same age, and consequently temporal variation may account for some of the technological diversity among the assemblages. It is also probable that variation between the assemblages may result from the individual function of each specific site and from the availability of materials. At least one investigator (Dumond 1977) has lumped all these collections into the American Paleoarctic tradition. Although this may be useful for synthesis purposes, it ignores many significant differences between the sites and between the artifacts they contain.

Three assemblages, the Denali complex, Chindadn, and the lowest level at Dry Creek, all indicate that by ten to eleven thousand years ago northern peoples were exploiting lake and river margin regions in interior

Alaska. Ugashik Narrows and the Koggiung complex document this type of site on the Alaska Peninsula. Locality I at the Gallagher Flint Station suggests that man was exploiting Alaska's harsh North Slope by very late Pleistocene times.

Technologically, all of these sites share a blade and core industry; however, there are significant differences between the types of cores and other associated artifact types present. What may prove to be a significant technological trait shared by the Ugashik Narrows phase, Anangula, and the Gallagher Flint Station (Locality I) is blade core rotation, a technique which is absent in the other assemblages. Locality I at the Gallagher Flint Station is the only site of this group at which burins have not been found. The Ugashik Narrows, Gallagher (Locality I) and Anangula artifacts are all manufactured from very similar raw material (mostly grey-brown metasedimentary types), in spite of their wide geographic separation. The remaining sites indicate a wide variation in raw materials selected for lithic tool manufacture, but in general contain a high frequency of fine-grained silicious rock types. Bifacially flaked projectile points are a recognized type trait in the Chindadn assemblage and the lowest level of Dry Creek, but are rare or absent at Anangula, the Denali complex sites, Akmak, Groundhog Bay, Ugashik Narrows, and the Gallagher Flint Station (Locality I). Both Chindadn and the lowest level at Dry Creek contain teardrop-shaped knives which are absent in all other assemblages. These significant technological differences suggest that considerable regional variation had already been developed by approximately 10,000 years ago.

The limited data available indicate that by ten to eleven thousand years ago every region of Alaska was populated by man, with a wide range of subsistence strategies already well developed. This wide geographic distribution and economic diversity implies that these sites may represent later manifestations of even earlier traditions which have not yet been documented.

During the Pleistocene, suitable habitats existed in Alaska for a number of animals that still live in the area, as well as several species which are now extinct. Extinct Pleistocene forms include saiga antelope (Saiga ricei), musk ox (Bootherium nivicolens, Symbos cavifrons), large-horned bison (Bison sp.), ground sloths (Megalonyx spp.), woolly mammoth (Mammuthus primigenius), great northern short-faced bear (Arctodus simus), lion-like cat (Panthera leo atrox), yak (Box bunnelli), wapiti (Cervus elaphus), camel (Camelops sp.), American mastodon (Mammut americanum), saber-tooth cat (Smilodon sp.), and horse (Equus sp.) (Guthrie 1968; Harington 1978).

Rainey (1939) implied that humans and extinct Pleistocene fauna may have existed contemporaneously in Interior Alaska, and later Larsen (1968) suggested human modification of Pleistocene bones recovered from the Trail Creek caves on the Seward Peninsula. Taphonomic analysis of Pleistocene faunal remains in the Old Crow region in the Canadian Yukon Territory have been interpreted to indicate coexistence, and even a predator/prey relationship, between man and extinct Pleistocene fauna (Irving and Harington 1973, Morlan 1978, 1980, Bonnichsen 1979).

The time of extinction of Pleistocene fauna in Alaska is unclear. The most recent radiocarbon determinations on mammoth in Alaska are 15,380 ± 300 (S 1453) and 17,695 ± 445 B.P. (S 1851) (Guthrie 1976: 129-130). A sample derived from peat recovered stratigraphically above mammoth remains in the Teklanika River valley provides another minimum limiting date of 12,340 ± 205 B.P. (GX 6284) (Guthrie: personal communication). The latest radiocarbon determination for horse is 13,640 ± 410 B.P. (I 9422) (Guthrie 1968, 1976:129-130). Thus there is a 2000 - 4000 year hiatus between the latest documented occurrence of extinct forms of Pleistocene fauna in the Alaska Interior and the earliest dated lithic assemblages, represented at Healy Lake, Dry Creek and possibly Moose Creek.

The three earliest firmly-dated Interior sites are the Dry Creek and Moose Creek sites near the community of Healy, and the Village site at Healy Lake in the upper Tanana valley. Radiocarbon determinations from all three sites suggest an age of approximately 11,000 B.P. for the lowest components. Because microblades and burins were recovered only at the Healy Lake Village site, the relationship of these assemblages to the subsequent Denali complex is unclear. A significant difference is the presence of small triangular bifacially-flaked projectile points and what are probably teardrop-shaped knife forms in the earlier assemblages and their absence in the later Denali complex. These three independent sets of data suggest the earlier assemblages are restricted temporally and exhibit significant technological differences from the later Denali complex, and may represent a separate tradition.

Cook (1969) used the term Chindadn (meaning ancestor in Athapaskan) complex to designate these specimen types at the Healy Lake Village site, the type locale. Although the temporal range for the Chindadn complex remains to be fully defined, the sites at which it has been recognized (Healy Lake, Dry Creek and possibly Moose Creek) should be regarded as minimum limiting dates for the beginning of the tradition. The earliest Denali complex dates may be regarded as maximum limiting dates for the end of the Chindadn tradition. Thus it is possible to begin to define the temporal range of the Chindadn tradition as beginning sometime prior to 11,000 B.P. and terminating shortly before 10,600 B.P. It is possible that future research may extend the temporal range of this tradition to overlap with the existence of extinct Pleistocene fauna; however, at the present time the coexistence of man and extinct Pleistocene fauna is undemonstrated in Interior Alaska.

2. Dating the Fluted Point Tradition in Alaska:

a. Background:

A discussion of fluted projectile point sites and their significance to early man research was omitted in the previous chapter in order to present a more detailed discussion of significant Alaskan discoveries. Dating fluted points in Alaska is critical to understanding the human occupation of the New World and Beringia itself. This chapter introduces recent data which strongly support a maximum limiting date (10,000 B.P.) for a fluted point tradition in Alaska and suggests chronological placement of this tradition at approximately 8,500 B.P. Assuming that the Alaskan fluted points-are historically related to Clovis or Clovis-related points from dated early man sites in the rest of North America, and that all the fluted point assemblages in North America belong to a single tradition, this 8500 B.P. date indicates that man must have penetrated the more northern regions of the North American continent prior to the coalescence of the Cordilleran and Laurentide ice sheets. The existence of such a tradition is evidenced by the presence of numerous dated early archeological assemblages that contain basally fluted projectile points exhibiting several characteristic features, such as basal margins that have been entirely ground, and lateral edge grinding that generally terminates at the hinge fracture of the channel flute. This early Alaskan date 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 sheets. It seems highly probable that the fluted point tradition developed in spatial isolation south of the continental ice and then was introduced to Alaska by peoples populating "new" (deglaciated) territory.

If the fluted point tradition were older in Alaska than in southern areas of the continent, it could support the concept that the first population of North America 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 following 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 old).

This chapter specifically deals with the late Pleistocene glacial sequence of the upper Sagavanirktok River valley, near the arctic flank of the Brooks Range, and with two archeological sites from that region, the Gallagher Flint Station and the Putu site. Both these sites are significant to the fluted point problem.

Fluted points, burins, blades and blade cores, scrapers, and waste flakes were discovered at the Putu site (Alexander 1972, 1974). Artifacts recovered from the Putu site are illustrated in Figures III-4 and III-5. The Putu site was excavated by Alexander in 1970 and 1973. The Gallagher Flint Station (Locality I) is the earliest dated occupation of the arctic slope yet discovered (Dixon 1972, 1975). Locality I is characterized by a blade and blade core technology. Blades from the site tend to be irregular and blade core rotation is common (Figure III-6). Blades from this assemblage have been defined as flakes which are longer than they are wide, demonstrate lateral symmetry, and have one or more ridges running the length of the flake. No fluted points or burins have been discovered at Locality I and, when compared to the Putu assemblage, the two collections are significantly different. Both these archeological sites lie on Alaska's North Slope, in the upper Sagavanirktok River valley, and are situated approximately 16 kilometers apart.

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 Kugarurok River and since then Humphrey (1966) , Clark (1972), and Alexander (1972) have all reported Clovis-like projectile points in northern Alaska. An additional fluted

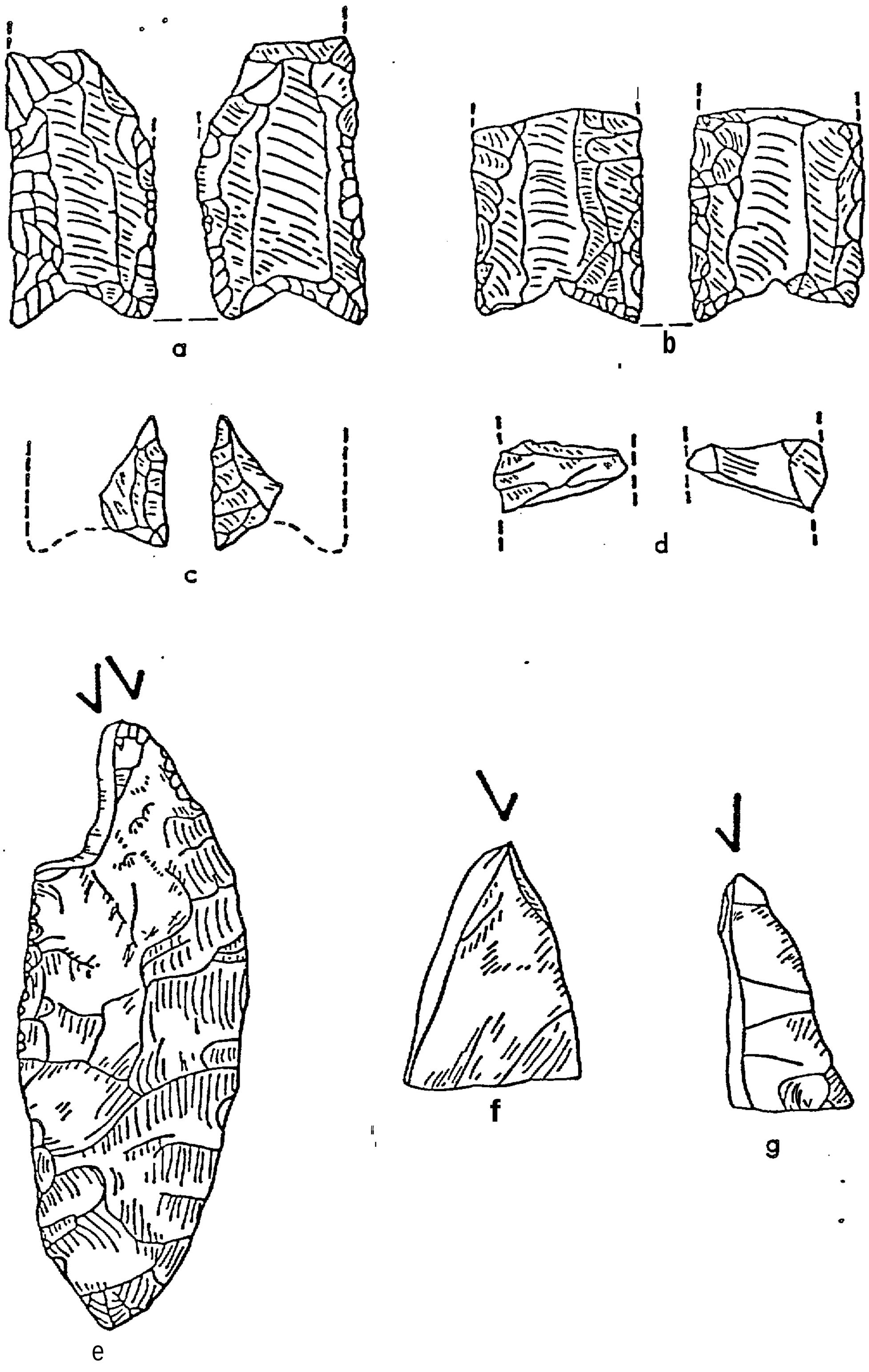


Figure III-4: Artifacts from the Putu site. Actual size. a through d - fragments of fluted points, e - burin on a biface, f and g - burins on flakes. (Redrawn from Alexander 1972 and 1974).

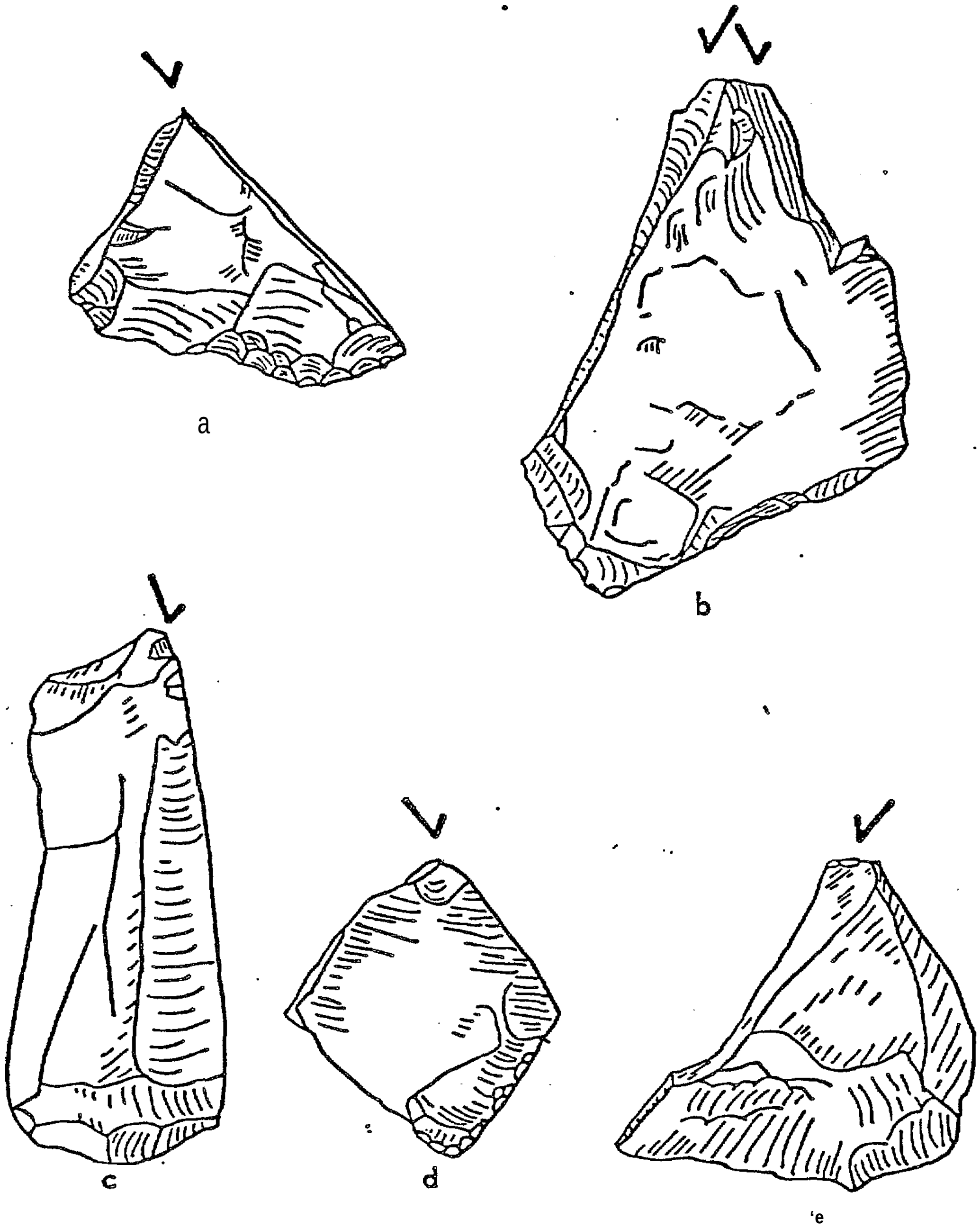


Figure III-5: Artifacts from the Putu site. Actual size. a through e - burins on flakes. (Redrawn from Alexander 1972 and 1974).

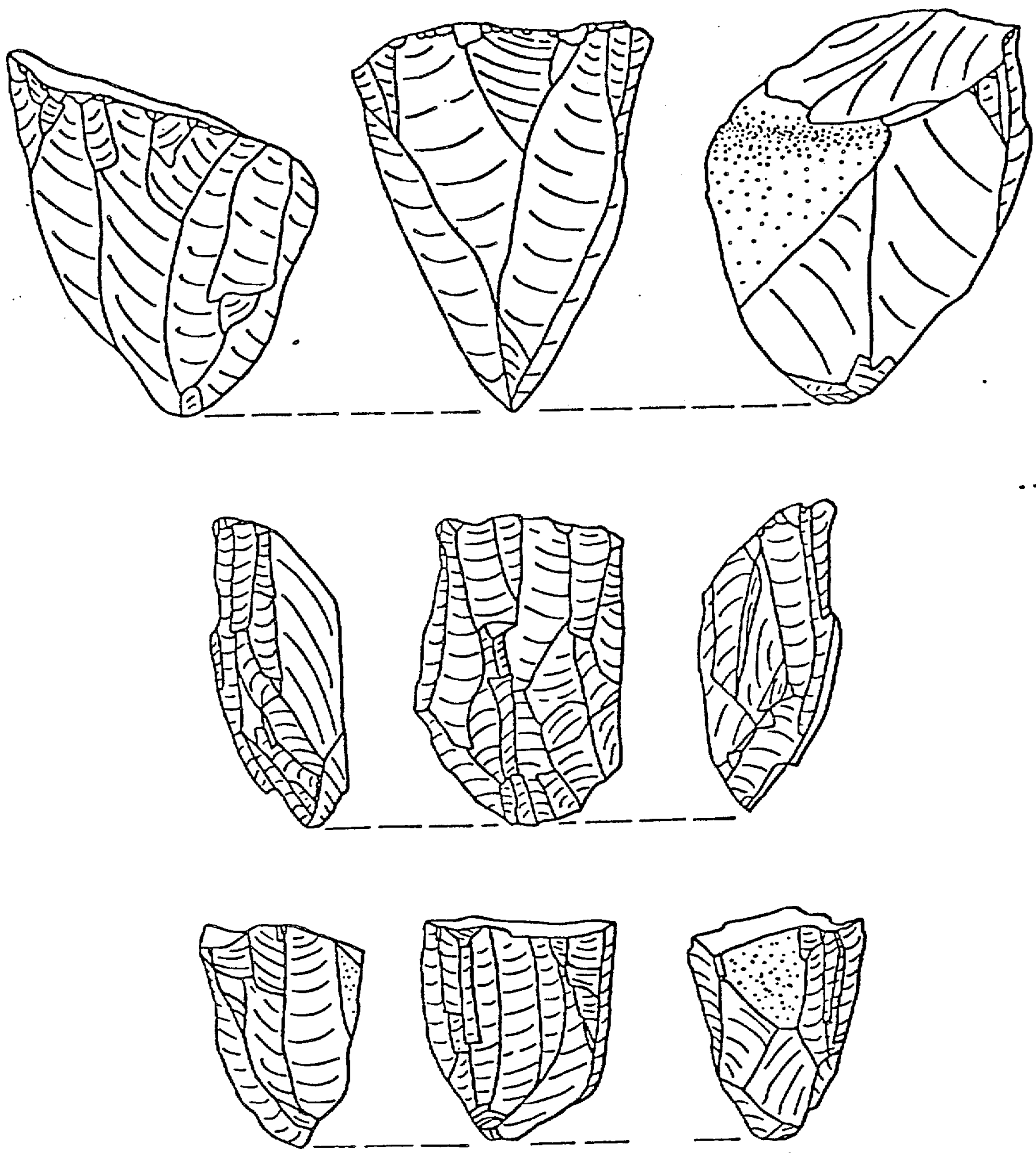


Figure 111-6: Blade and microblade cores from the Gallagher Flint Station, Locality I. Actual size.

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 undoubtable numerous others which have not yet come to the attention of archeologists. Hall (1959) suggests that two specimens have been discovered in the Bristol Bay region, although these points may be basically thinned specimens common in later archeological assemblages. Another specimen was reportedly collected as a surface find near the Denali Highway in Interior Alaska and was deposited at the University of Alaska Museum.

Basic to 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. However, there do exist significant topological differences between Alaskan fluted points and those from more southern regions of North America. The Alaskan points characteristically demonstrate multiple pressure flutes, whereas the Clovis finds are almost invariably percussion fluted and only one flake scar is generally visible following removal of the final channel flake (Flennikan, personal communication). Both point types are ground on all basal edges and lateral grinding generally terminates at the hinge fracture of the channel flake. Because of the general similarity of the Alaskan and Clovis fluted points, most researchers have assumed that somehow the finds in Alaska are related to those further south.

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 alternative hypothesis requires a south to north movement of the fluted point tradition, once again following partition of the continental ice (Krieger 1954; Wendorf 1966; Muller-Beck 1967; Bryan 1969). A major problem with the south to north hypothesis is that it requires the presence of man in southern North American 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 presented as evidence for human occupation in the Americas prior to 12,000 to 13,000 years B.P. (Bryan 1969, 1973; Alexander 1963; Adovasio et al. 1977; Gruhn 1965; and others), the interpretation of their chronological placement has been considered equivocal (Haynes 1969, 1971, 1974; Lynch 1974).

There is agreement by all who have dealt with the problem that the definitive answer to these alternative hypotheses lies in dating both the partition of the continental ice and the fluted point tradition in Alaska. The fluted point tradition has been well dated in the southwestern United States and also at Debert in central Nova Scotia (MacDonald 1968). An age ranging between 11,500 and 10,000 B.P. has been suggested for the fluted point tradition in the southwestern regions of the United States by Haynes

(1964). Because fluted points in Alaska have not yet been securely 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.

Reeves (1973) has reviewed data relevant to resolving the existence of an ice-free corridor during Late Wisconsin times. His analysis concludes that "most of the western interior plains" (of Canada) "was ice-free by 15,000 years B.P." (ibid.). However, coalescence of Laurentide and Cordilleran ice in the Athabasca Valley remains undated, and Reeves avoids speculation regarding the viability of biotic populations between the two ice sheets in regions where they were not coalesced. Most researchers accept the coalescence of the two major ice sheets during the late Wisconsin maximum (ea. 18,000 B.P.) and the time of partition of the continental ice remains undocumented.

b. Field Research in the Sagavanirktok River Valley:

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 1975). 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.

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 oil 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 cohesion, 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 10,540 ± 150 B.P. (S1-974) following the 1971 field season. An additional charcoal sample was secured from this same locality in 1974, but the radiocarbon determination is 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 10,000 and 11,000 radiocarbon years B.P.

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 comparable, 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 (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 still-stands of the Sagavanirktok valley glacier (Figure 111-7).

c* Dating:

The extent of the Itkillik glaciation and subsequent substades and stillstands are illustrated in the map (Figure III-7) prepared by Hamilton (1975). Table III-2 lists all radiocarbon determinations in the Sagavanirktok River valley relevant to the problem under consideration. The location of the two late Itkillik archeological sites, the Gallagher Flint Station and the Putu site, have been added to the map to depict their location in relation to the glacial features.

Dixon (1972) defined three stratigraphic levels at the Gallagher Flint Station. These were: Level I--the surface organic, which was a dark brown-black soil ranging in depth between approximately 2 and 10 cm. This level was absent in specific locales where wind had inhibited plant growth between 20 and 30 cm. Level 2 was subject to deflation if Level 1 was absent. Level 3--culturally sterile ice-contact deposits (maximum depth probably exceeding 20 m).

Although stratigraphy at the Gallagher Flint Station is meager, generally speaking it is a reliable indicator of relative age. Vertical stratigraphic relationships at the site are only distinguished over a period of several thousand years, however.

A total of 20 radiocarbon determinations have been obtained from the Gallagher site. Nineteen of these samples were collected from Level 1 or the contact zone of Levels 1 and 2. All dates were run on charcoal samples secured from occupational localities and all 19 samples date to within the last 3,000 years. A single charcoal sample was collected from Level 2 with a steel trowel from a depth of 20 to 25 cm at Locality I. It was stored in aluminum foil until dated by the Smithsonian Institution. The sample was subject to acid pretreatment and was thus free of contamination by roots. The resultant date was 10,540 ± 150 B.P. (S1-974). The sample appeared to be directly associated with the occupation of Locality I, for waste flakes were intermixed with the charcoal and adjacent loess. The 19 additional dates from the site are all stratigraphically above this sample, which was the deepest one recovered from the site and the only one recovered from Level 2. Contamination of the sample by coal seems unlikely because there is no source of coal in the immediate vicinity of the site. The other 19 charcoal samples do not indicate contamination by coal, for their dates seem reasonable based on topological comparison of associated artifacts with other dated sites. It is unlikely that the sample could be the result of some natural agent such as a tundra fire, since the charcoal was restricted in spatial extent to a lens approximately 30 cm in diameter.

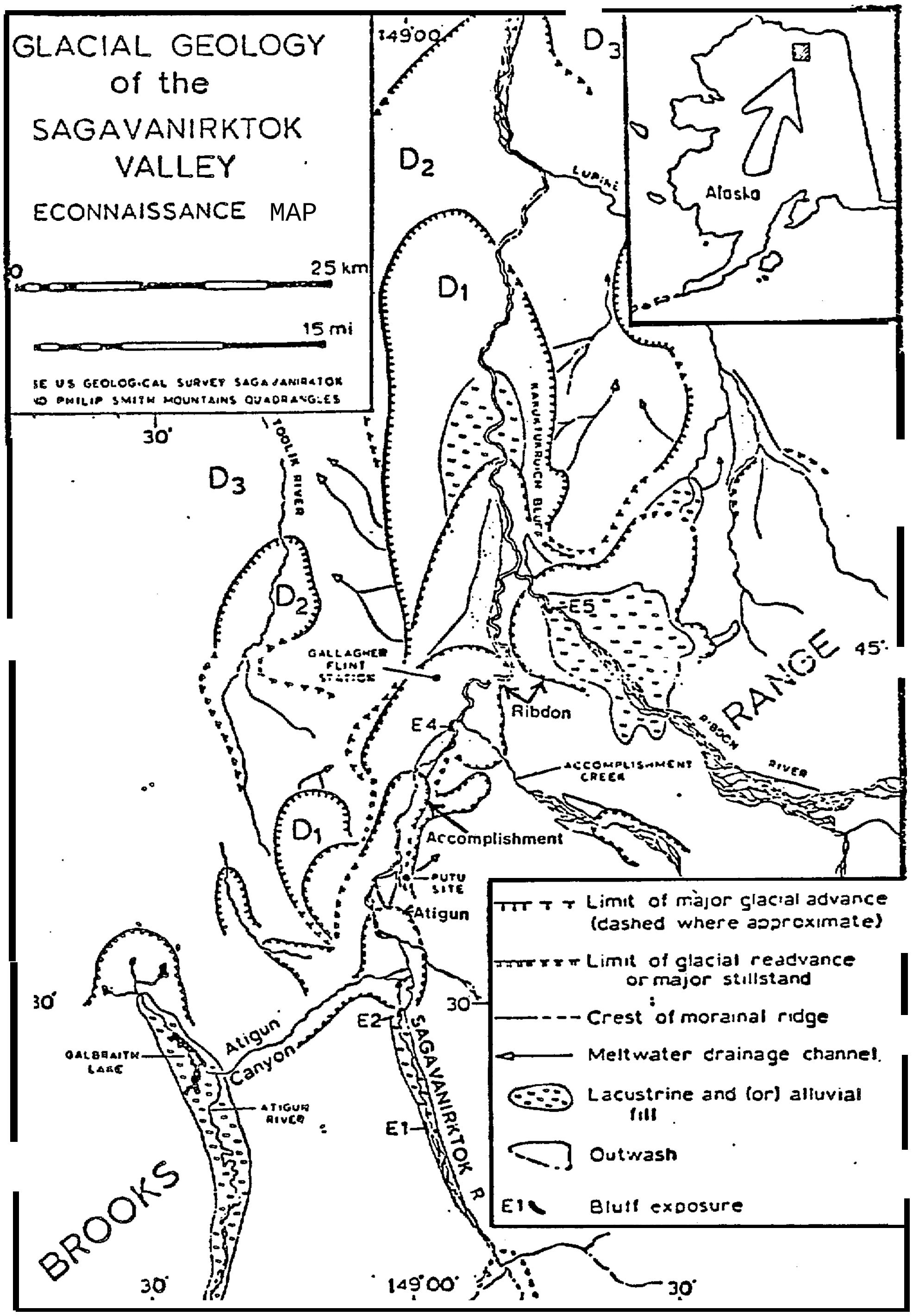


Figure III-7: Glacial geology of the Sagavanirktok Valley: reconnaissance map. Modified from Hamilton (1975).

TABLE III-2

Radiocarbon Dates from the Upper Sagavanirktok River Valley

DATE	SAMPLE NUMBER	SUBSTANCE DATED	SIGNIFICANCE OF DATE	EXPOSURE* DESIGNATION
12,780 ± 440 B.P.	AU-72	Wood (willow?)	Minimum limiting age, Ribdon readvance	E-5
12,170 ± 270 B.P.	AU-71	Detrital wood frag.	Maximum limiting age, Accomplishment readvance	E-4
11,890 ± 200 B.P.	AU-70	Woody shrubs (willow; dwarf birch?)	Approximate terminal date for alleviation behind Atigun moraine	E-2
11,760 ± 200 B.P.	AU-69	Willow	Contemporaneous alluviation behind Atigun moraine	E-1
10,540 ± 150 B.P.	SI-974	Charcoal	Occupation of Locality I, Gallagher Flint Station	---
8,450 ± 130 B.P.	WSU-1318	Charcoal	Occupation of the Putu site and limiting date for Accomplishment deglaciation	. . .
2,275 ± 110 B.P.	SI-1427	Grass	Terminal date for alleviation behind Atigun moraine	E-1
2,720 ± 45 B.P.	SI-1428	Willow	Eolian sand deposited behind Atigun moraine	E-1

*Keyed to Figure III-10.

Locality I at the Gallagher Flint Station is characterized by a core and blade industry, and an apparent absence of 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, which was discovered during the 1974 field season. 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 at the site which have been determined to represent later periods of occupation.

Because less than 50 cm of post-glacial deposition has occurred at both the Gallagher and Putu sites, the possibility of stratigraphic mixing should not be neglected at either site. However, at both sites, isolation of the early occupations is possible due to the existing, although scant, vertical stratigraphy and the horizontal distribution of the artifacts (Alexander 1972; Dixon 1975). A single radiocarbon determination from charcoal from the Putu site has yielded a date of 8,450 ± 150 B.P. The sample was collected from the occupation zone .5 m below the surface and was treated with sodium hydroxide to remove humates (Sheppard and Chatters 1976) . The date is consistent with the glacial sequence in the area and there seems little reason to doubt that it dates the period of occupation at the Putu site. This locality at the Putu site contained fluted points, 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 blades at the Gallagher Locality I have been manufactured from calcareous mudstone which grades into a coarse-grained grey-brown chert, while Putu artifacts are all made from fine-grained cherts with the exception of one obsidian fluted point.

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 difficult.

Alexander (1972) points out that the presence of obsidian at the Putu site suggests a late date because its source lies south of the Brooks Range which was, according to Porter (1964a, 1964b), “blocked by a mile high edge of ice before 7,000 B.P.” However, Alexander suggests that this date is too recent and that the site is probably older than 7,000 B.P. Alexander’s argument against such a date is persuasive, and Hamilton and Porter (1975) now consider that the main valleys and passes of the Brooks Range could have been deglaciated by 10,000 B.P.

The radiocarbon date of 8,450 ± 150 B.P. for the occupation of the Putu site also provided a minimum limiting age for the wastage of Itkillik ice in this area of the Sagavanirktok River valley (Hamilton 1975). 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 13,000 B.P. Occupation consequently occurred after that time.

The Putu kame is situated approximately 8 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 since it lay sandwiched between a steep mountain spur on the 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 observe and intercept large herbivores.

Another radiocarbon date of 12,170 ± 270 B.C., discussed by Hamilton (1975), provides a maximum limiting date for the brief Accomplishment readvance, thus indicating that the glacial kame upon which the Putu site is situated lay within a few hundred meters of the ice-choked valley until sometime after 10,500 B.P. The limiting date for the Accomplishment readvance "was obtained on small detrital wood fragments which lay along bedding planes in the sandy alluvium about 3 m below the base of the outwash" (Hamilton 1975).

This limiting date for the Accomplishment readvance indicates that the region was not suitable for human occupation until sometime after 11,500 radiocarbon years B.P. This date, coupled with the fact that it is extremely unlikely that obsidian could have entered the region from south of the Brooks Range prior to 10,000 radiocarbon years ago, strongly supports the occupational date of 8,450 B.P. for the Putu site and indicates that occupation prior to 11,000 to 12,000 B.P. is extremely unlikely. When the entire suite of eight radiocarbon dates from the upper Sagavanirktok River valley is considered, it forms a very cohesive picture of the glacial history of the region and it becomes increasingly difficult to ascribe an antiquity for the Putu site locale much beyond the 7,000 to 8,000 B.C. radiocarbon year range suggested here.

If we assume that the date for the Putu site is applicable to other fluted 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. Figure III-8 illustrates the postulated northern movement of the fluted point tradition ca. 10,000 B.P. Although it is theoretically possible that this point type was developed independently in Alaska and that there is no connection between fluted points in the "Lower 48" and Alaska, it is extremely difficult to envision the independent development of such a unique method of point manufacture prior to 10,000 B.P., 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 sample recovered from the site at Dry Creek. The striking differences between Locality I material from the Gallagher site and the Putu assemblage seem to indicate two independent developmental histories. It would seem that two such diverse technologies would have to develop in spatial and/or temporal isolation.

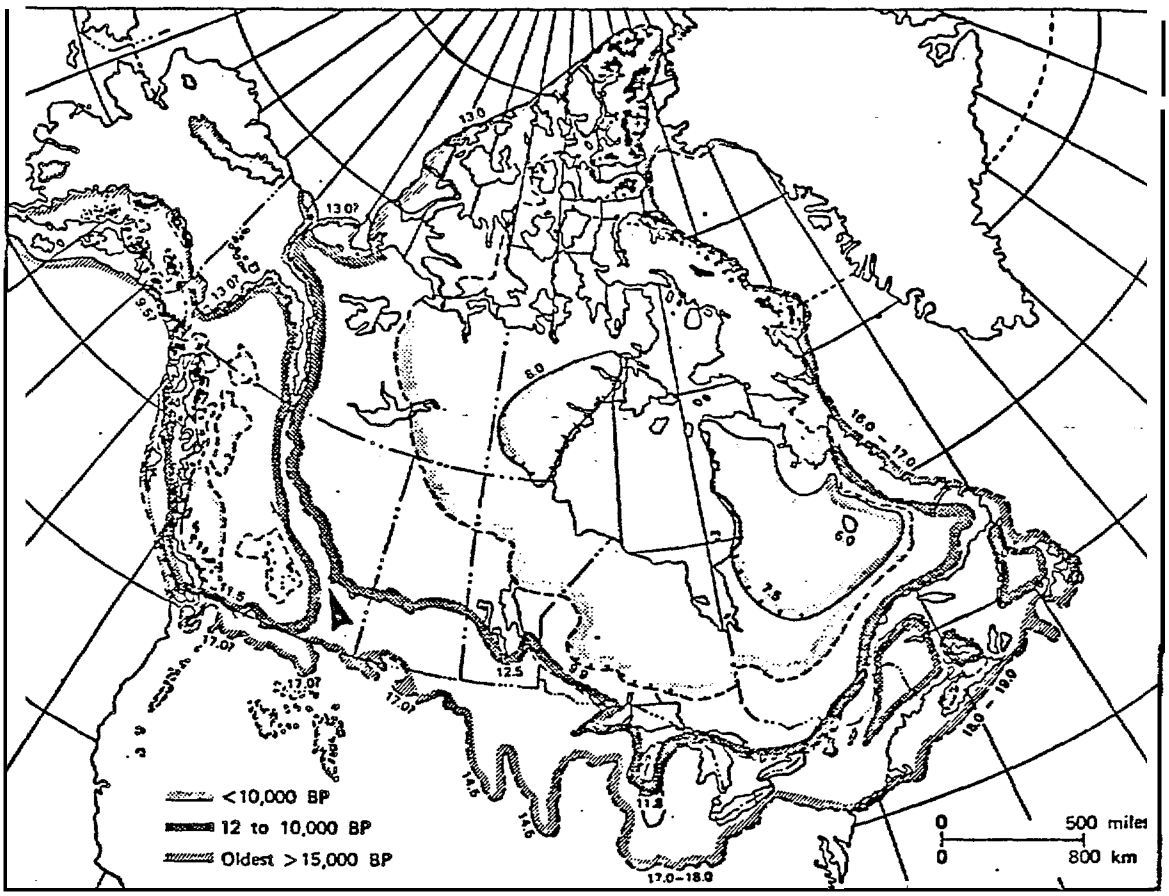


Figure III-8: Speculative model for the Late Wisconsin deglaciation of North America. From Flint (1971:492). Arrow indicates the northward movement of the fluted point tradition, approximately 10,000 B.P.

The close proximity of the two sites indicates that temporal isolation is more significant for the explanation of their contrasting lithic technologies.

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 probable that the fluted point type did not spread from Alaska to Siberia because the flooded Bering Strait most probably blocked diffusion of this tradition to Asia. No fluted points have been reported from Siberia and there is no evidence to support the possibility that the fluted point tradition has its origin in Asia and was introduced across the Bering Strait prior to 14,000 B.P.

Six independent lines of evidence strongly indicate that fluted points are more recent in Alaska than in the contiguous 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 13,000 B.P.; (2) a reconstruction of the paleogeography of the area strongly implies that the kame would have remained unsuitable for human occupation until sometime after 11,500 B.P.; (3) artifacts assumed to represent an extremely different cultural tradition (Locality I at the Gallagher Flint Station) demonstrate that the region was occupied by another cultural group approximately 10,500 years B.P.; (4) the absence of fluted points in Siberia is not inconsistent with a late date for this tradition in Alaska because land connections between Alaska and Siberia "were severed approximately 14,000 years B.P.; (5) the presence of obsidian at the Putu site implies that it was not occupied prior to 10,000 years B.P.; and (6) a radiocarbon date on charcoal from the Putu site occupational level from which the fluted points were recovered is 8,450 years B.P. and" is consistent with radiocarbon dating for the glacial sequence in the site area.

3. Recent Data from Northeastern Siberia Relevant to the Occupation of Beringia:

The first two chapters have attempted to synthesize archeological data relevant to late Pleistocene human occupation of arctic North America. The data presented support 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 for Beringia.

It is not the purpose of this presentation to provide a detailed synthesis of Siberian archeological data, but rather to present current data which documents human occupation of northeast Asia during the existence 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 the Land Bridge. A brief discussion of the Diuktai tradition is critical to this problem. As with the North American data, some northeastern Siberian sites have been ascribed Pleistocene antiquity in the absence of radiometric or sound geologic dating. To avoid confusion, only those sites which have been subjected to sound dating techniques will be discussed in detail.

The Diuktai culture represents the oldest 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; 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 has appeared in print. However, as Arndt (1976) has pointed out, continuity between Proto-Diuktai and Diuktai is implied. Undoubtable this division of Diuktai culture will require further clarification; however, at present there are at least four archeological sites which have been placed within the Proto-Diuktai continuum by Mochanov. These are Ezhantsy, Ust'-Mil ' II, Akhine I, and Ikhine II. Table III-3 lists the spatial 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 (tortoise) cores, bifacial blanks, a chisel-shaped tool, a "crude blade", waste flakes and a fragment of worked mammoth bone (Arndt 1976). 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) 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 the fact 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. Current Russian data indicate that man occupied Siberia's Aldan River valley by 35,000 B.P., a period well before the Mid-Wisconsin marine transgression on the Bering Land Bridge.

In addition, Proto-Diuktai demonstrates that man was sufficiently adapted to subsist on Asia's tundra-steppe during Early 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 Bering Strait, the restriction of Proto-Diuktai finds to the Aldan Valley may reflect 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) and is referred to

TABLE III-3

Proto-Diuktai - Chronological Placement

Compiled from Arndt (1976) citing Mochanov (1973, 1975) and Mochanov and Fedoseeva (1968). B.P. dates presented as translated.

SITE	DATE	BASIS FOR OR C14 SAMPLE No.	DATE LOCATION	ASSOCIATED FAUNA
Ezhantsy	35,000 BP?	geomorphological (3rd river terrace)	junction of the Aldan and Maia rivers	Mammuthus primigenius Coelodonta antiquitatis Bison priscus Equus caballus
Ust'-Mil II horizon C	33,000 ± 500 BP	LE-1000	60 km downstream on Aldan River from Diuktai Cave	Mammuthus primigenius Bison priscus Equus caballus
	30,000 ± 500 BP	LE-1001		
	35,400 ± 600 BP	LE-954		
horizon B	23,500 ± 500 BP	LE-999		
Ikhin I	34,000 to 31,000 BP	geomorphological (correlated with horizon C at Ikhin II)	east bank of Aldan River 284 km from its mouth	Equus caballus Mammuthus primigenius Bison priscus deminutius Citellus undulatus fossilus
Ikhin II horizon C	34,000 to 31,000 BP	geomorphological (stratigraphically below Horizon B)	"close to" Ikhin I	Mammuthus primigenius Coelodonta antiquitatis Bison priscus Ovibos moschatus Equus caballus
horizon B	31,200 ± 500 BP	GIN-1020		Same as horizon C with the notable addition of Rangifer tarandus
	30,200 ± 300 BP	GIN-1019		
	24,600 ± 380 BP	IMSOAN-153		
	24,330 ± 200 BP	LE-1131		

simply as the the Diuktai culture. Type traits for the Diuktai culture. are (Arndt 1976):

> ". . . small wedge-shaped cores; massive subprismatic cores 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 specimens of subdiscoidal and tortoise cores, spear points of mammoth tusk, and bone burnishers "(Mochanov and Fedoseeva 1975b) .

Numerous radiocarbon dates support the chronological placement of Diuktai culture and are too numerous to list here. Faunal remains from the Diuktai sites indicate that the primary resources for subsistence were horse, mammoth and bison, although numerous small game species, waterfowl and fish are reported from the type site, Diuktai Cave (Powers 1973).

The spatial distribution of Diuktai sites encompasses the Aldan, Olenek, Markha, Vitim, Maia, Indigirka and Kukhtui rivers and the Kamchatka Peninsula (Arndt 1976, citing Mochanov 1975). The site distributions may encompass the Kolyma River region as well, for Mochanov has attributed the Maiorych site to the Diuktai tradition (Powers 1973). 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 northeast, the distribution will most probably extend to the western margins of the Bering Strait.

On the basis of Powers' valuable 1973 contribution synthesizing Siberian archeological 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.

4. <u>Early Man Archeology of the Bering Land Bridge</u>:

The evidence of Pleistocene sites on both sides of Bering Strait indicates that early archeological remains are likely to be found on the Beringian shelf, including present day islands. The potential of islands in the Bering and Chukchi "seas to yield evidence of human population during Beringian times has been the subject of considerable speculation. It has long been realized that these islands were once prominent hills protruding from the relatively flat Beringian topography. However, surprisingly little non-coastal archeological field research has been conducted on these islands.

Numerous reports discuss the coastal archeology of the islands in the Bering Sea (see Jenness 1929; Collins 1937; Geist and Rainey 1936; Giddings 1967; Bandi 1969; Ackerman 1974; and others). In spite of this comparatively large body of literature treating the archeology of these islands, the most important being St. Lawrence, there is little reference to archeology in their interior portions. The coastal sites on these islands, especially St. Lawrence Island, offer extremely appealing ivory-rich midden deposits, and these magnificent sites have captured the interest of virtually every archeologist who has attempted to survey the islands. 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 displaying a marine orientation of their subsistence ecology postdate that time period. The Anangula site, located on Anangula Island, has been dated to an earlier time period though in this unusual situation tectonic uplift may have occurred at a rate faster than that of sea level rise, resulting in the existence of a coastal site predating 4,000 B.P. Other coastal sites in this general area also predate 4,000 B.P. (Aigner et al. 1976). The geographic location of the Anangula site and the occurrence of marine mammal faunal remains at the site strongly indicate a marine subsistence strategy (Laughlin 1967).

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.). 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 among the sharp scoria" (Bryan n.d.) 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 exist two other important bits of information which are significant in attempting to locate evidence of early man on Beringia. One find consists of what were believed to be artifacts from the floor of the Bering Sea by David M. Hopkins (personal communication). The sample was recovered from a depth of 40 meters, 13 kilometers east of Northeast Cape, St. Lawrence Island. These specimens have been deposited at the University of Alaska Museum.

Hopkins originally speculated that these specimens might be cultural because the barnacle attachment indicated that the spans had been removed from the parent material prior to their recovery by the dredge. They are not artifacts manufactured from dredging operations *per se*. Hopkins tentatively speculated that the 40 m contour (the depth from which the specimens were recovered) may have been inundated by 14,000 B.P., and consequently felt that if these specimens were of human manufacture, they would predate this time. John M. Campbell of the University of New Mexico later examined these specimens and reached the conclusion that the recovered lithics were not of human manufacture (Hopkins, personal communication).

An analysis of these specimens at the University of Alaska Museum supports Campbell's conclusion. The specimens are of fine-grained granite. No evidence of impact marks, which should be detectable if the flakes had been produced by either direct or indirect percussion techniques, are visible. The flakes lack positive bulbs of percussion and no indication of negative bulbs could be observed on parent cobbles. The ventral surfaces of the flakes lack radiating ripples or undulations which characterize lithic detritus of human origin. Finally, the ventral surfaces of the flakes and the corresponding flake scars on the parent cobbles are rough and irregular, suggesting frost, or thermal, spalling. This analysis indicates that these specimens may have been produced by thermal spalling when they were exposed to subaerial erosional processes during a time of lower sea level,

In 1976 and 1977, the University of Alaska Museum obtained, analyzed, and submitted for dating (Table III-4) four specimens collected from three separate fossil localities (Fig. 111-9) in the Bering and Chukchi seas. Although Pleistocene faunal material has been reported from the Atlantic outer continental shelf and near-shore islands along both the Pacific Rim and North Atlantic, as well as from Japan's outer continental shelf (Emery and Edwards, 1966; Whitmore *et al.* 1967; Hay, 1923; Jepsen, 1960), the specimens from the Alaskan outer continental shelf are unique because they are the first reported from the sea floor of the Bering Land Bridge.

The first fossil discoveries were found in an otter trawl on September 9, 1976, by Stephen Jewett while working on the NOAA ship Miller Freeman. He noted mammoth or mastodon tusk fragments among material recovered from Tow 65, Station B-14 (66°50' N. Lat., 163°49' W. Long.) in Kotzebue Sound from a depth of 26.3 to 27.3 m. On September 11, 1976, during the same cruise, on Tow 86, Station A-14 (67°47' N. Lat., 165°28' W. Long.), the crew of the Miller Freeman recovered more mammoth or mastodon tusk fragments from the floor of the Chukchi Sea at a depth of 41.8 to 42.2 m. In addition, a fragment of a mammoth mandible and tooth were also discovered during the cruise, but these specimens could not be relocated for analysis. Tusk fragments from Stations B-14 and A-14 were accepted from NOAA by the University of Alaska Museum, where they were identified and analyzed for evidence of possible cultural modification. The two specimens recovered from Station A-14 were significantly different. The larger of the two (Fig. 111-10) was a proximal fragment of a proboscidean tusk. It exhibited no evidence of rounding indicative of abrasion by water-laid sediments, and no cut marks, striations, or facets that might suggest cultural modification. Following identification and analysis, this larger specimen was photographed and a mold prepared from which casts were

Table III-4: RADIOCARBON DETERMINATIONS FOR PROBOSCIDEAN FOSSILS FROM THE ALASKAN OUTER CONTINNENTAL SHELF

Specimen No.	Description	Location	Age (^{14}C yr B.P.) Apatite	Bone Collagen	Lab sample No.	Depth (m)	Vessel	Collection date/Station
UA76-274-2a	Proboscidean tusk fragment	Chukchi Sea lat. 67°47' long. 165"28'	18.300	28,920 +2250/-1750	GX-5740-A	41.8-42.2	R/V Miller Freeman	Sept. 11, 1976/A-14
UA76-274-2b	Proboscidean (?)	Chukchi Sea lat. 67°47' long. 165°28'	27,200	No collagen recovered	GX-5741	41.8-42.2	R/V Miller Freeman	Sept. 11, 1976/A-14
UA76-274-1	Proboscidean tusk fragment	Kotzebue Sound lat. 66°50' long. 163°49'	18,440 ± 890 /	37,000	GX-5739-A	26.3 -27.3	R/V Miller Freeman	Sept. 9, 1976/B-14
UA78-53-1	Mammuthus Sp. molar	Bristol Bay lat. 57°25' long. 158°33'	18,860 ± 500	No collagen recovered	Gx-5738A	34.7	F/V SmaragD	Aug. 7, 1977

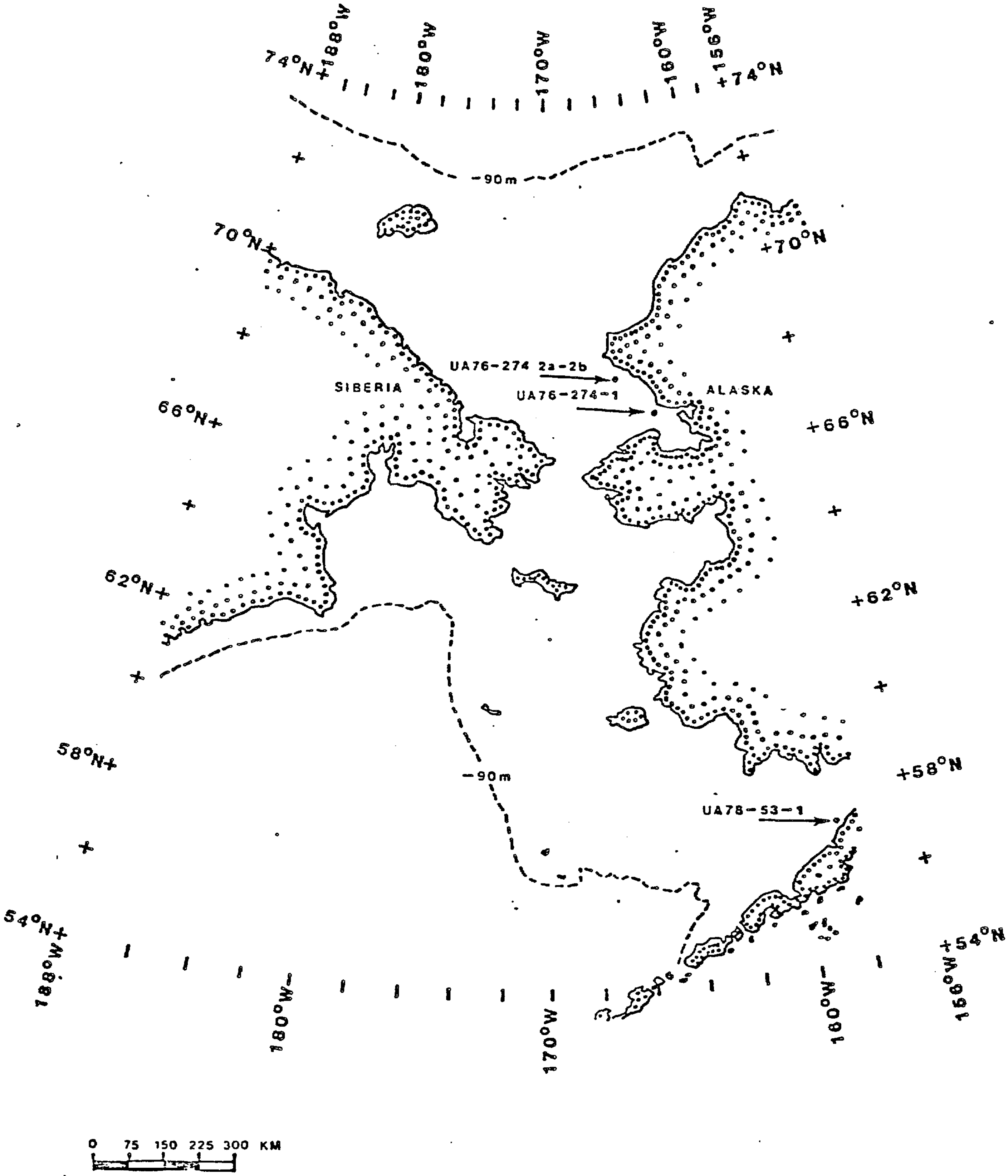


Figure III-9: Location of paleontological finds on Alaska's Outer Continental Shelf.

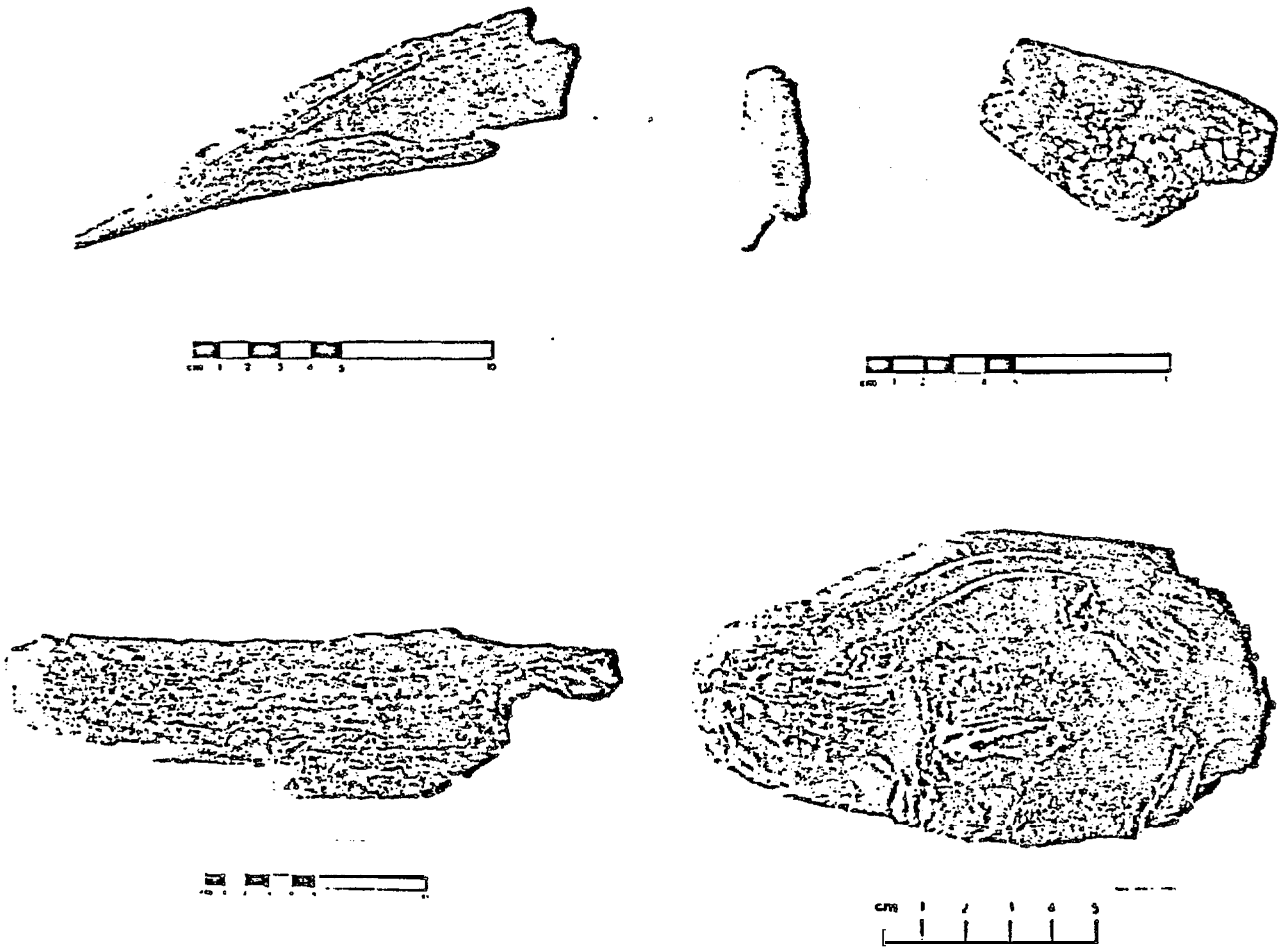


Figure III-10: Mammoth or mastodon remains recovered from the Outer Continental Shelf by the R/V MILLER FREEHAN, and the F/V SMARAGD.

made. Bone collagen recovered from this specimen yielded a 14C date of 28,920 +2250/-1750 yr B.P. (GX-5740-A).

The second specimen (Fig. 111-10) recovered from Station A-14 was composed of two fragments that fit together, suggesting that it was fractured during collection. The two fragments were rounded and exhibited minor striations suggesting postmortem modification of the specimen, either by movement along a relatively abrasive matrix, abrasion by water-borne sediments, or possibly by ice transport. No cultural mechanism need to invoked to explain the rounding, polish and striations exhibited by the specimen. Barnacles attached to its surface indicate that it probably had rested on the surface of bottom sediments, or possibly had been on the sea. floor at some time during the past. While difficult to identify, the fragments were probably proboscidean. These specimens were photographed and cast before being submitted for destructive radiocarbon analysis.

A comparatively large fragment of the outer laminae of a proboscidean tusk was recovered from Station B-14 in Kotzebue Sound (Fig. 111-10). Relatively recent fractures were discerned by their lighter surface colors on this specimen, suggesting that it was broken during collection. It exhibited no evidence of cultural modification. Following photographic documentation and casting, this specimen was submitted for radiometric dating. Bone col lagen gave an age of 37,000 yr B.P.

The fourth specimen was a nearly complete mammoth molar (Mammuthus (Fig. 111-10) recovered by Max Holberg aboard the F/V Smaragd in Bristol Bay. It was recovered from a clam dredge operating at a depth of 34.7 m. Like the other fossils, it showed no evidence of cultural modification. The specimen was photographed and cast, and then subsequently destroyed during radiocarbon analysis. No collagen was recovered from this specimen and the resultant apatite date of 18,860 ± 500 14C yr B.P. (GX-5738-A) is probably not a reliable indicator of the specimen's age.

Ice rafting of these specimens from terrestrial deposits and redeposition in marine sediments is unlikely because sediment-bearing ice is uncommon in the Bering Sea. Possible sources of ice-rafted sediments in the Bering Sea are shore-fast ice and grounded pressure-ridge ice which incorporate rounded pebbles and cobbles. Bottom sampling of Norton Sound indicates that incorporated sediments usually drop out before reaching approximately 5 km from shore (D. M. Hopkins, personal communication, 1978). Thus, the recovered Pleistocene proboscidean faunal remains from the Alaskan outer continental shelf were probably _in situ_, or if not, had undergone minimal transportation.

Barker (1967), Hassan _et al_. (1977), and Hassan and Ortner (1977) have identified problems with bone dating in general and specifically demonstrated that hydroxyapatite dates are unreliable due to postmortem carbonate substitution. Two of the dates listed in Table III-4 are determinations based on collagen (GX-5740-A and GX-5739-A) and suggest that these specimens are of middle or early Wisconsin age. The extent of marine regression, coupled with evidence suggesting that the specimens were _in situ_, implies that the fossils are the remains of Wisconsin (or possibly pre-Wisconsin) proboscideans that lived on the land bridge. Both early and late Wisconsin marine regressions extended far beyond the fossil localities which were then exposed as dry land.

The documentation of Pleistocene proboscideans on the Bering/ Chukchi continental shelf strengthens the hypothesis that man originally entered the Americas via the Bering Land Bridge during times of marine regression. It is well documented that proboscideans were prey of Pleistocene hunters in both Asia and North America, and their occurrence on the Alaskan continental shelf demonstrates that the resources were present on the Bering Land Bridge to meet the nutritional and other subsistence requirements of Pleistocene hunters. The quality of preservation of the fossils demonstrates that the Arctic marine environment is conducive to preservation of Pleistocene faunal remains, and their occurrence documents their ability to survive marine transgression. Based on these facts, there seems little reason to assume that Pleistocene archeological remains would not also be preserved, should they occur on the Alaskan outer continental shelf.

Early man archeology of central Beringia is in its infancy. This research has been able to ferret out only two possible attempts to locate human habitation of central 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. 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 exist considerable data and even more arguments in support of this hypothesis, the concept is nevertheless a hypothesis and will remain so until firmly dated Pleistocene archeological remains are recovered from Beringia proper, i.e., either the ocean floor or the islands.

In summarizing the' first four chapters, five lines of evidence strongly support human occupation of Beringia: (1) The topological diversity and wide geographic distribution of Alaskan archeological sites dating to Late Wisconsin/Early Holocene times suggests that they represent later manifestations of earlier traditions; (2) the apparent late date for the fluted point tradition in Alaska implies that man penetrated regions south of the Cordilleran and Laurentide ice prior to coalescence 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; (4) the occurrence of Pleistocene proboscideans on the Bering Land Bridge indicates the resources were available to meet the subsistence requirements of Pleistocene hunters; and (5) so little archeology has been done on the Bering and Chukchi shelves that the lack of early man sites from the region cannot be taken as evidence supporting a lack of occupation.

B. Archeological Site Prediction for the Study Area

1. The Theory of Archeological Site Prediction for Northern Hunting Cultures:

a. Economy:

The paucity of archeological data from Beringia has necessitated reliance on other data sources to develop a model to predict regions of high archeological site potential on Alaska's outer continental shelf. A basic assumption of this model is that human survival was predicated on hunting, fishing and gathering. This assumption is based on anthropological literature which suggests: (1) during Beringian times hunting and gathering was the only subsistence strategy of human societies (Murdock 1968; Clark 1969; Chard 1975; and others); (2) northern climatological factors and biological resources suggest hunting and gathering societies were focused in specific locales to exploit resource peaks; and (3) ethnographic and archeological data substantiate hunting and gathering as the only form of prehistoric economy in the area of study. A limitation of the combined archeological and ethnographic data is that it spans only the past 12,000 years in arctic North America.

Anthropologists have given much attention to hunting and gathering societies in the belief that the dev"elopment"of contemporary social institutions and the ordering and structure of modern societies have derived from adaptive social forms which evolved during the long hunting and gathering "stage" of human evolution. Murdock (1968) has demonstrated the rather drastic decline of the number of humans relying on hunting and gathering during the past 10,000 years. At the beginning of Holocene time, hunting and gathering was the economic mainstay of most of the Earth's human population. Today only a few isolated human groups continue this life style in marginal habitats unsuitable for other economic pursuits.

Lee and DeVore (1968) 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 the very beginning there was communication between groups, including 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 (Dunbar 1968) 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., plant gathering has been of limited significance in subsistence activities of Northern peoples. However, Love (1976) has analyzed the Nikolski Strandflat adjacent to Umnak Island in the Aleutians and has documented the productivity and distribution of biomass resources of the littoral zone. Intertidal gathering may have played an important role in the subsistence activities of Pleistocene inhabitants of the Bering Land Bridge.

The key to human survival in the North is the procurement of faunal resources. Northern animal species provide the mechanisms converting the large but unusable arctic plant biomass 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 to store the summer peak energy budget in the form of fats. Man's utilization of energy is consequently primarily directed to the animal species rather than to the flora itself. There exist two known methods by which man may harvest animal energy. These are herding or predation.

There exists no archeological nor ethnographic evidence for herding economies in arctic North America prior to the introduction of reindeer" herding in Alaska in the early 1900's. 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 type site. However, Giddings later withdrew his hypothesis and considered the Choris finds indicative of caribou hunting. All archeological and ethnographic data confirm human predation of animal species as the primary subsistence mechanism for the North American Arctic.

b. Settlement Patterns:

Because harvest of faunal populations was the primary subsistence activity for human populations in arctic and subarctic North America, the distribution of these populations commands a dominant role in determining former settlement locales. Chang (1962) 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 of settlement is 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), in his monograph on the Central

Eskimo, which resulted from his field work in Canada from 1883 to 1884, 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 literature relevant to subsistence activities of Northern hunters, four major faunal resource categories emerge. These are (1) terrestrial mammals, (2) marine mammals, (3) freshwater aquatic resources (waterfowl and fish), and (4) intertidal species such as clams, sea urchins, limpets, etc. The importance of these species complexes is that all, at some time in their annual cycle, form seasonal aggregates. Ethnographic literature documents methods by which man has preyed upon these aggregates. The locations of the resource concentrations, and the surpluses which result from the harvest of these resource peaks are significant factors for determining the size, location, and duration of human settlements.

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

> ". . . the settlement patterns among hunters-fishers provide a wide range of varieties particularly suitable for microtypological 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. Detailed ecological studies, such as Dunbar (1968), Irving (1972), and Rosswell and Heal (1975) discuss specific environmental factors responsible for extreme annual biomass fluctuations. Seasonal fluctuations in biotic communities in alpine and high latitude regions result primarily from poor soil development and relatively severe seasonal fluctuations in solar radiation. The phenomena of energy peaks of short duration have had a profound effect on human population distribution. As previously outlined, settlement locales and the duration of occupation may be viewed as dependent on energy harvest. Chang (1962) has expressed this by stating:

> "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 for settlements for the Nunamiut. He has delineated six different types of settlements which are: Type I settlements, which served as the central camp to which all members of the band identified themselves; Type II settlements, resulting from the seasonal disbanding of Type I settlements and generally composed of two or more families; Type 111 settlements, which consisted of hunting and fishing camps and were occupied by one to five males for a period of one to five days; Type IV settlements, which were associated with the collection and processing of task-specific non-food resources; Type V settlements, which occurred outside the band's territory and were established for purposes of courtship, visiting and trading; and Type VI settlements, which consisted of brief overnight stops while traveling.

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 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) 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 weir and the caribou fence. McKennan felt that because both were collective efforts that 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. Apparently, 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 energy required to harvest and process the faunal resources by a given population.

In short, biomass peaks concentrated human populations, which through collective efforts were able to maximize the faunal harvest. As Campbell (1968) noted, specific types of settlements result from non-food-collecting activities such as visiting, trade, quarrying activities, etc. However, such sites were dependent on surplus energy stores to support individuals while not directly involved in food collecting. 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. Consequently populations seasonally or permanently concentrated in settlements located directly at the location of predictable biomass peaks, or between areas of predictable biomass concentrations.

Such settlement locales may be considered to be the hub of aboriginal territory. Faunal resources are the most significant factor in the aboriginal effective environment. Satellite settlements result from specific resource exploitation of the effective environment around the primary energy yield locales. These sites are generally task-specific, e.g., quarrying, feather gathering, egg collecting, etc. The territory may be defined as the resource range of the population. When energy expended exceeds the energy return, limits are imposed on territorial area and configuration. Territorial range can be expanded by various weight reduction techniques, such as drying and boning meat (well documented in McKennan 1959, 1965; Wentworth 195.6; Giddings 1952, 1961; Petitot 1971; and numerous other sources). Transportation devices such as sleds and boats are also important energy-savers and may increase territorial range considerably. It is recognized that social factors affect territoriality, however the nature of the Pleistocene archeological data does not permit reliable interpretation of social factors affecting settlement locale.

2. <u>The Method of Archeological Site Prediction Applied to the Bering Land Bridge</u>:

Occupation of Beringia by early man during late Wisconsin time is probable based upon the following evidence: (1) A paleogeographic reconstruction of the region depicts a terrestrial environment of sufficient size and diversity to support human occupation (Sharma, this volume); (2) a reconstruction of probable marine mammal habitat predation (Stoker, this volume); (3) the postulated distribution for terrestrial mammals indicates that these species were concentrated in patterns which made them vulnerable to human predation; and (4) man was present in the circum-Beringian region at a time suitable for the occupation of the Land Bridge proper, indicating that man had achieved a sufficient degree of adaptation to inhabit adjacent northern latitudes and, consequently, was capable of occupying the Bering and Chukchi outer continental shelves during Beringian times.

It has been demonstrated that inhabitants of Beringia would have relied on a hunting and gathering economy, and that settlement locales of hunters are based upon resource distribution. Through paleogeographic and paleoenvironmental reconstruction it is possible to delineate paleoresource distributions. It then follows that it should be possible to delineate paleo-settlement distribution. This basic axiom furnished the criteria with which areas were ranked according to potential for archeological site occurrence on the Alaskan outer continental shelves.

Specialists were asked to formulate criteria responsible for faunal distribution resulting from geographic and climatic conditions. These criteria were applied to the reconstructed environment.

Paleographic reconstruction was done by Sharma (this volume), who developed a series of stillstand maps based on thousands of bathymetric data points which he obtained from numerous unpublished sources, for the Bering, Beaufort, Gulf of Alaska, and Chukchi outer continental shelves. His maps illustrate former stream channels and postulated lakes, and they serve as the basis for projecting faunal distributions for the Bering Land Bridge.

Stoker (this volume) utilized Sharma's reconstruction of Beringian geography to project marine faunal species distributions for Beringia. Using principles of marine science, he established criteria responsible for areas of high marine productivity and related faunal distributions. These criteria are: (1) cyclonic and nearshore upwelling; (2) regions of fresh water discharge into the marine environment; (3) postulated sea ice conditions inferred from paleoenvironmental data; (4) suitable geographical habitat for marine rooking birds; and (5) location of estuaries and river mouths suitable for concentrations of anadromous fish and their predators.

Guthrie (1976) and Stoker (this volume) faced a somewhat more difficult task because many of the species they analyzed are extinct. Factors controlling their distributions are poorly understood because there are no living representatives from which to extrapolate behavior. However, they assumed that factors relevant to the distribution of modern grazers also would have applied to extinct grazing species. Guthrie (1976) outlined the following mechanisms used to ascertain former distributions:

> "1. Irregular, rolling terrain tends to provide a longer succession of richer plant growth stages than do flat lowlands. This is particularly true of 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. "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. "5. Because of its better footing and lack of relief, river valleys are frequent movement avenues for large mammals, both ungulates and their predators."

Although there exists no firm archeological data relating to the time when marine mammal exploitation became a viable subsistence strategy in the Beringian area, it is assumed that it was possible throughout the Wisconsin history of Beringia. By using Anangula as a minimum limiting date for the demonstration of this type of subsistence strategy, we may state with some certainty that it was a viable economic base prior to ca. 8,000 to 8,500 B.P. (Laughlin 1967; Laughlin and Aigner 1975). The lack of data prior to the occupation of Anangula is attributable to eustatic sea level rise, which probably has inundated most archeological sites located along former coastlines. Marine mammal predation may have been an early Wisconsin human subsistence strategy and, consequently, it is considered a viable subsistence possibility in this study. This negates the risk of omitting what may have been extremely important, although undocumented, areas of former human habitation.

The previous section discussed probable reasons for human preference of specific ecological areas as settlement locales. It is reasonable to postulate that these ecological situations were favored settlement locales for human populations occupying the Bering Land Bridge. Drastically different climatic conditions during Wisconsin times shifted the location of habitats. Lower sea level extended coastlines hundreds of kilometers from their present position. Based on the paleogeographic reconstruction (Sharma, this volume) and projected faunal distributions (Stoker, this volume) four major ecological settings have been delineated for the Bering and Chukchi outer continental shelves during Late Wisconsin times. They are proposed as areas of high potential for archeological site occurrence. They are:

a. Marine Aquatic/Tundra-Steppe Ecotone. Although it is possible that any area along the former coast could have been the location of settlements, two specific types of locales are considered of higher site potential than other areas. These are: a) estuaries and river mouths suitable for concentrations of anadromous fish and their predators, and b) regions of cyclonic and nearshore upwelling.

b. Riverine. This ecological situation presents the possibility for combined exploitation of anadromous and resident fish, as well as ungulates and their predators using river valleys as avenues for movement.

c. Lake margins. These ecotones combine possibilities for the" harvest of waterfowl, fish, and adjacent terrestrial mammal populations.

d. Regions of constricting topographic relief. Such areas were likely to concentrate large mammal movements. It is reasonable to postulate that regions which exhibit dramatic changes in topography also exhibited changes in the biotic community reflecting topographic variation, although on the basis of current data it is impossible to determine the location and nature of biotic communities on the Outer Continental Shelf during Wisconsin times.

These four major ecological settings are postulated as areas of high potential for archeological site occurrence on the former Land Bridge and are depicted in Figures 111-11, 111-12, 111-13, 111-14, 111-15 and 111-16. The figures attempt to delineate these ecotones for each of the major sea level stillstands for both the Bering and Chukchi outer continental shelves during late Wisconsin times. The high potential areas outlined above accurately identify the general archeological situation during the time of human occupation for every known archeological site older than 10,000 years ago.

Watanabe (1968) has identified one universal trait for Northern hunting and gathering cultures, which is "a settled life in winter." Such settlements are located in regions of high faunal productivity. Surplus energy stores which sustain winter settlements may be supplemented by harvest of large mammal species in winter range and by local small game resources. Although there are exceptions, such as the Nunamiut and the Central Eskimo, winter settlements generally require substantial modification of the natural environment for the construction of some form of winter shelter. It is postulated that the four major ecotones which have been defined for the Bering Land Bridge were areas where the greatest possibility for Northern food gatherers to store energy existed, and consequently, comparatively large winter settlements may have been located in these areas. It seems most probable that such sites, when submerged, would be easiest to detect using geophysical instruments.

Field tests were designed to verify the site potential modeling by attempting to locate archeological sites dating to Beringian times on the Outer Continental Shelf. Two independent tests were developed: 1) a marine archeological survey from the University of Alaska's research vessel, the R/V ACONA, in the area identified as the marine aquatic/ tundra-steppe ecotone south of the Pribilof Islands, and 2) a terrestrial archeological

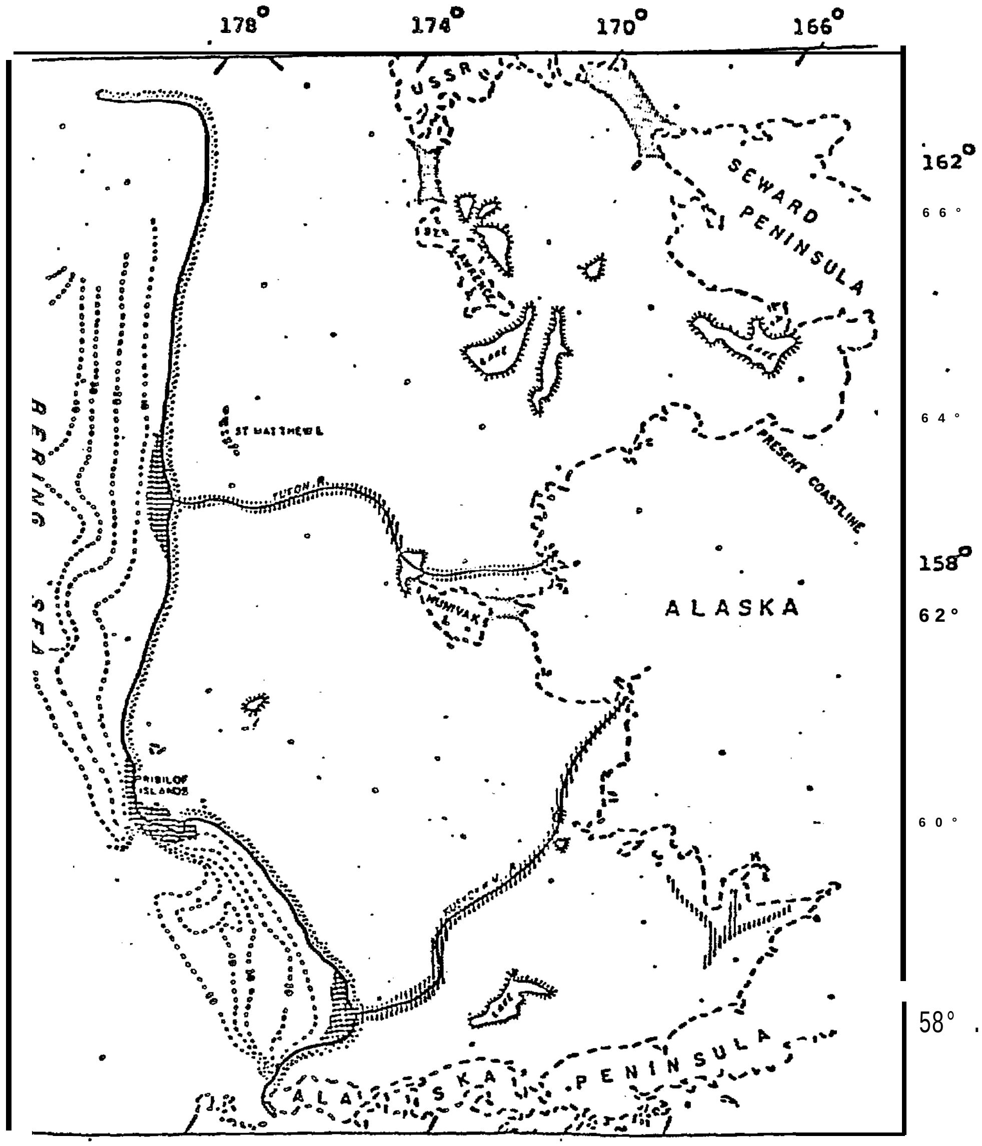


Figure 23: Bering Sea, Standstill I, 22,000 B.P. Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 11314-lb and unpublished data of the university of Washington.

▤	River Mouths and Nearshore Upwelling	☐	Constricting topography concentrating large mammal movement
▥	Riverine/Tundra-Steppe Ecotone	◇	Freshwater b~c/Tmdra-Steppe Ecotone

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

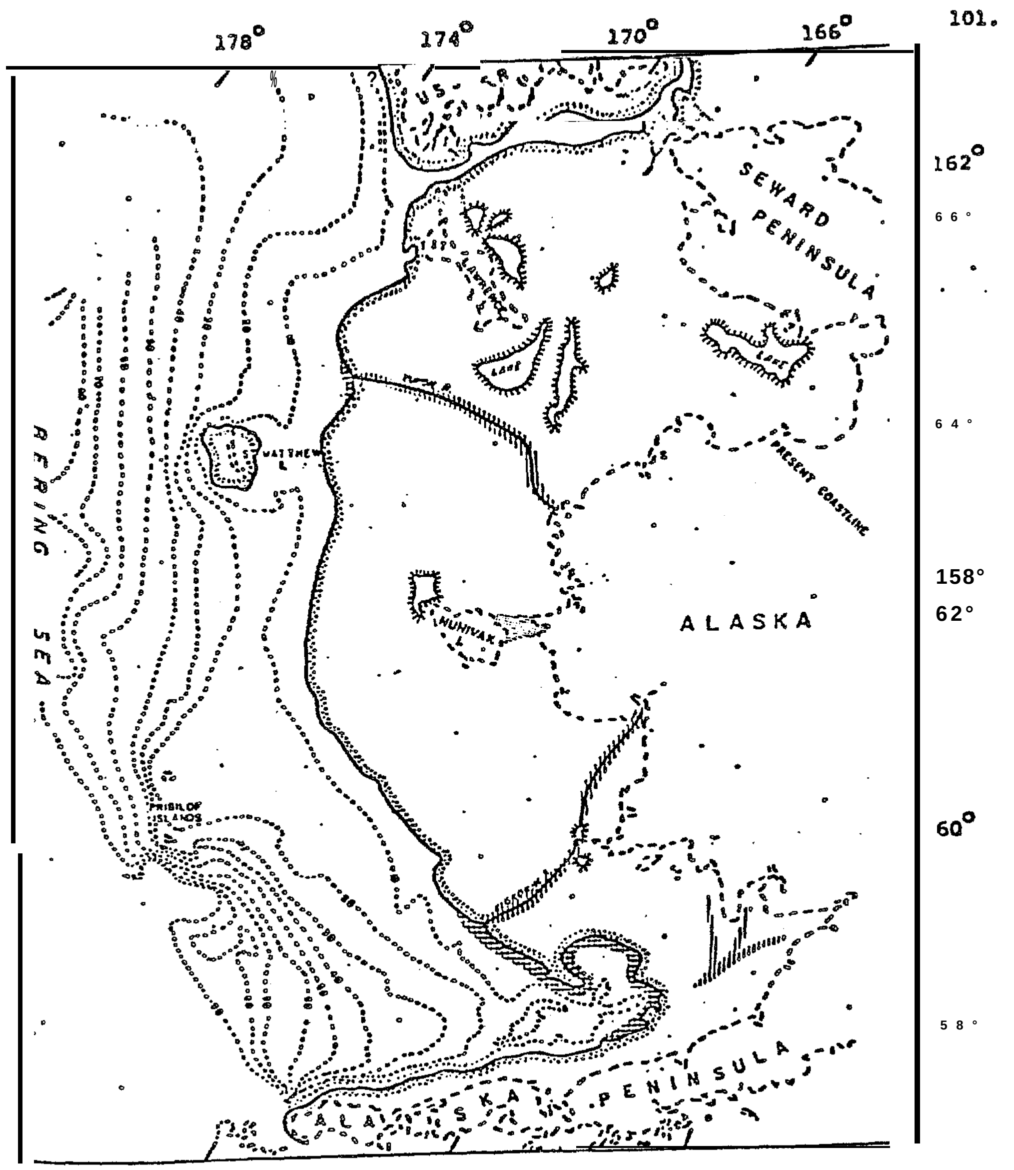


Figure 24: Bering Sea, standstill II, 16,000 B.P.
Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 1814-10B and unpublished data of the University of washin9ton-

River Mouths and Nearshore Upwelling

Riverine/Tundra-Steppe Ecotone

constricting topography concentrating large mammal movement

Freshwater Lake/Tundra-Steppe Ecotone

Figure III-12: Bering Sea, Stillstand 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.

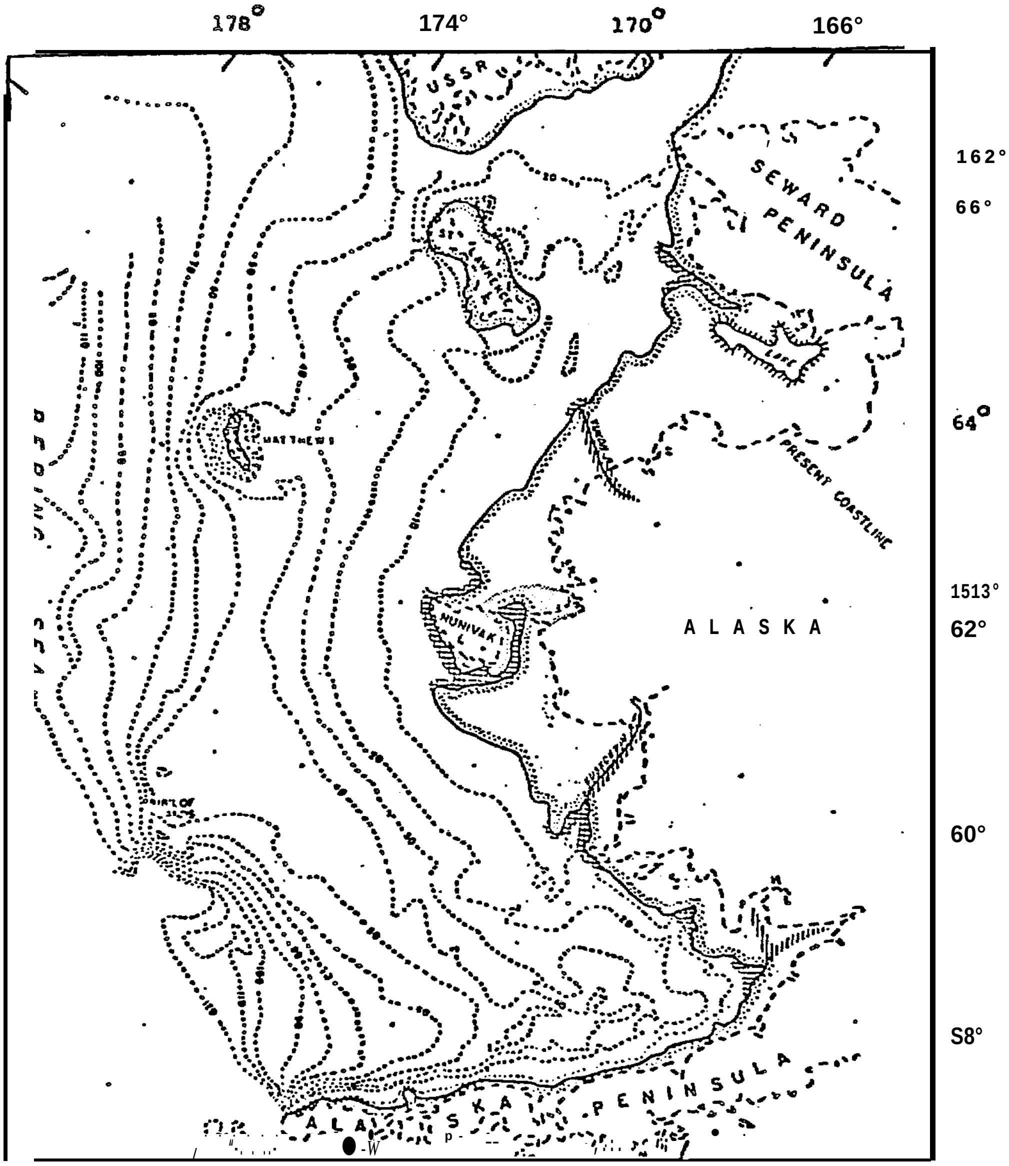
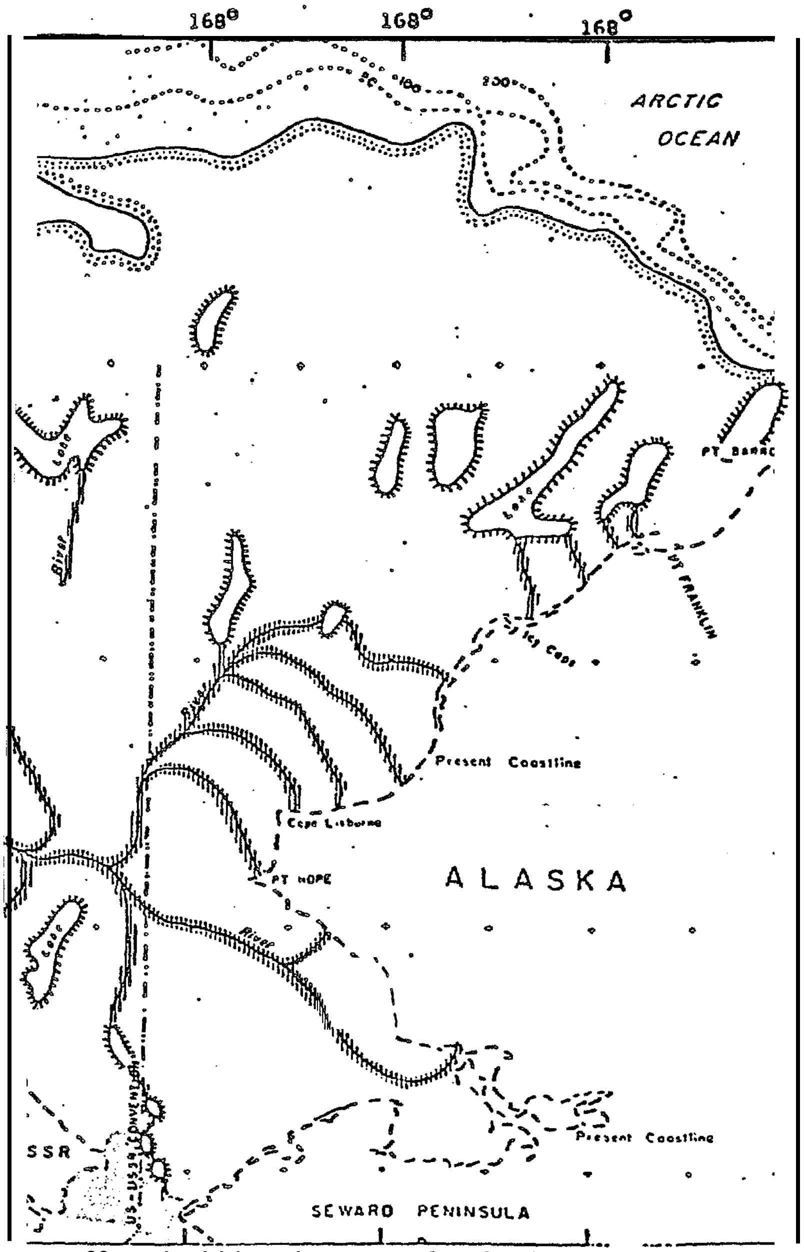


Figure 25: Bering Sea, Standstill III, 11,000 B.P.
Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 1814-10B and unpublished data of the University of Washington.

▤	River Mouths and Nearshore Upwelling	☐	Constricting topography concentrating large mammal movement
▥	Riverine/Tundra-Steppe Ecotone	▨	Freshwater Lake/Tundra-Steppe Ecotone

Figure III-13: Bering Sea, Stillstand 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.



gure 26: Ch&chi/Arctic coast. Stand still 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.

River Mouths and Nearshore Upwelling

Constricting topography concentrating large mammal movement

Riverine/Tundra-Steppe Ecotone

Freshwater Lake/Tundra-Steppe Ecotone

Figure III-14: Chukchi/Arctic coast, Stillstand I, 22,000 B.P. Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711 N-17B, 1711 N-18M, 1714 -11B, 1714 N-12B, 1814 -10B and unpublished data of the University of Washington.

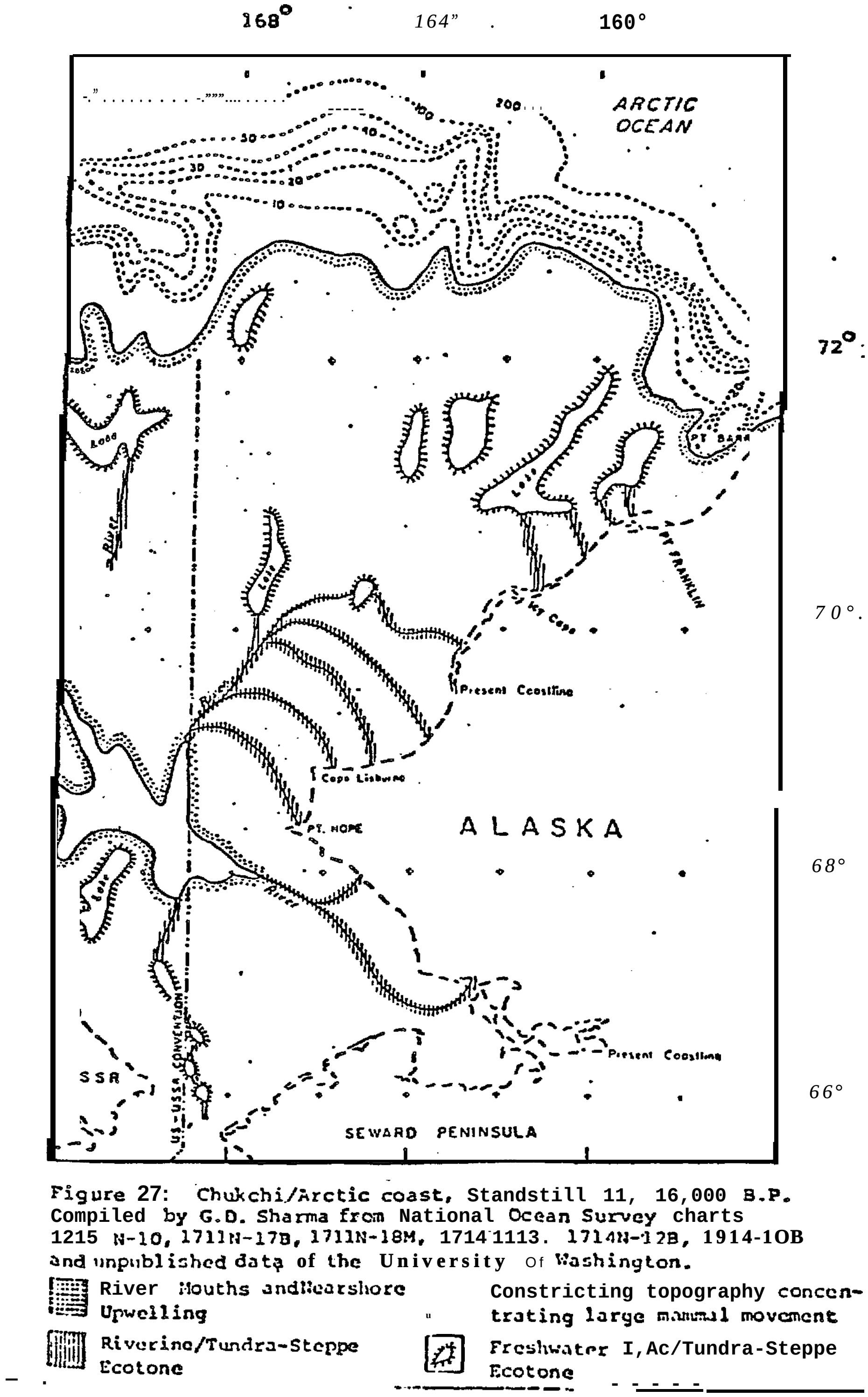


Figure 111-15: Chukchi/Arctic coast, Still stand II, 16,000 B.P. Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711 N-17B, 1711 N-18M, 1714 -11B, 1714 N-12B, 1814-10B and unpublished data of the University of Washington.

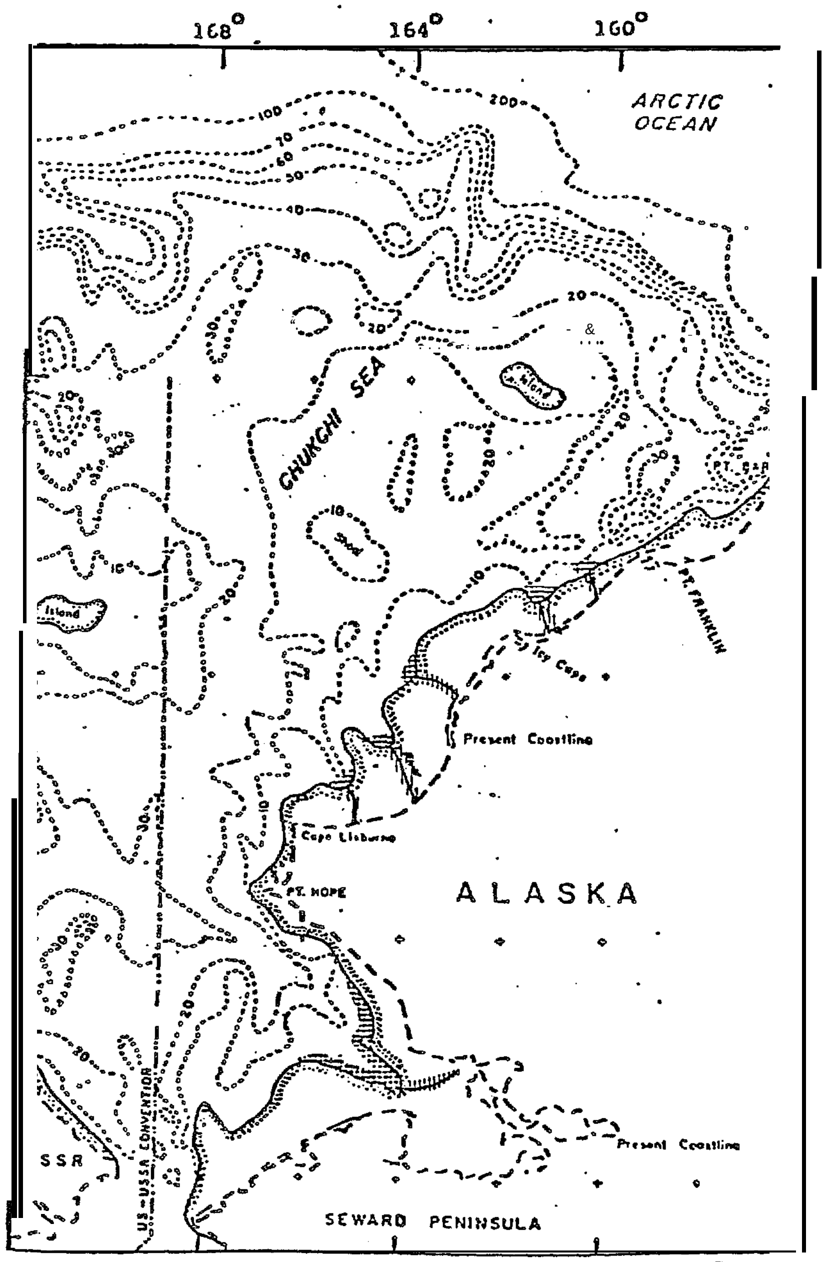


Figure 28: Chukchi, Standstill III, 11,000 B.P.
Compiled by G.D. Sharma from National Ocean Survey charts 1215 N-10, 1711N-17B, 1711N-18M, 1714-11B, 1714N-12B, 'IE14-10B and unpublished data of the University of Washington.

- River Heaths and Nearshore Upwelling
- Riverine/Tundra-Steppe Ecotone
- u Constricting topography concentrating large mammal movement
- Freshwater Lake/Tundra-Steppe Ecotone -

Figure III-16: Chukchi, Stillstand III, 11,000 B.P. Compiled by Gil. Sharma from National Ocean Survey charts 1215 N-10, 1711 N-178, 1711N-18M, 1714-118, 1714N-12B, 1814-10B and unpublished data of the University of Washington.

survey of St. Matthew Island. Following sections discuss the methods and results of these surveys.

C. Field Research

During the course of the various Outer Continental Shelf cultural resource studies, four field programs were undertaken to document Pleistocene man in the Beringian region. These were: 1) a marine archeological survey near the Pribilof Islands, 2) a terrestrial archeological survey of St. Matthew Island, 3) an archeological survey of Chinitna Bay, and 4) archeological survey and testing of cave deposits along the Porcupine River. Each of these field programs are discussed below.

1. The Marine Archeological Survey near the Pribilof Islands:

The marine archeological survey represents a pioneering effort in the study of man and the Bering Land Bridge. It applies new technology to the comparatively old problem of documenting human population of the New World via the Bering Land Bridge. It is the first marine archeological survey conducted in northern latitudes and, although unsuccessful in locating a submerged archeological site, it was definitely successful in determining that such surveys are feasible. Marine archeological survey methods may ultimately expand archeological research to vast regions of the Outer Continental Shelf which have, until recently, been impossible to investigate. From an archeological perspective, the marine environment is comparatively pristine in terms of human disturbance of archeological sites. Though scallop dredges and other bottom fishing devices have created some surficial disturbances of the bottom sediments, these disturbances are so minimal that the Outer Continental Shelf offers an opportunity for the scientific investigation of vast areas of the globe which have not been subject to severe human disturbance and modification throughout much of Holocene times. Organic preservation in submerged sites is generally excellent and archeological remains on the Outer Continental Shelf could yield valuable data possibly not available in any other depositional environment. Certain kinds of archeological sites may only be located on the Outer Continental Shelf; for example, marine subsistence sites dating prior to 10,000 B.P. Data critical to answering specific archeological problems, such as the evolution of marine mammal subsistence strategy and associated technology, may be available only through investigation of submerged archeological sites located on the Outer Continental Shelf.

Marine archeological survey in the Bering and Chukchi seas is not an easy task. The attempt to predict the location and then accurately identify in the field an archeological site the size of a precontact winter settlement, in a region beneath two seas approximately one-third the size of the continental United State is, at the very least, an extremely difficult undertaking. Difficulties are amplified when one considers that the ocean is ice-covered for eight months of the year, is subject to severe storms when ice-free, and lacks sufficient navigational aids to locate a ship's position within as much as several miles of error. In addition, logistic problems are formidable and ship's procedures for such surveys in the northern latitudes are not established. The difficulties encountered in executing the marine archeological survey are far too numerous to list here. Suffice it to say that the very fact the survey was performed is, in itself, a measure of success. However, as navigational aids are improved in the Bering and Chukchi seas, and survey procedures and methods "refined, the actual task of conducting the surveys will become easier.

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. The vessel was only available for use by the research team for a period of ten days and this included running time for the ACONA to return to its home port in Seward, Alaska.

The area selected for archeological survey was the former marine aquatic/terrestrial ecotone south of the Pribilof Islands. It was felt that this region would have been highly suitable for human habitation during land bridge times because postulated marine upwelling south of the Pribilofs would have made this marine environment highly productive. In addition, Guthrie (1976) defined the southern slopes of the island and" adjacent portions of the continental shelf as spring and summer range concentrating large mammals. Adverse weather conditions made an examination of this area impossible. Consequently, an area on the northeast side of St. George Island was selected to permit the 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 (1976) ship cruise report.

Figure 111-17 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. Despite our recognition that this was not a high potential area, the decision was made to survey the north side of the island. Thus, the model was not tested for a high potential 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 the bathymetric charts, a prominent submerged feature was identified. At some point in the past, this geologic feature was a point jutting northeastward from St. George Island during a period of sea level rise. According to Sharma's (1976) paleogeographic reconstruction, 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

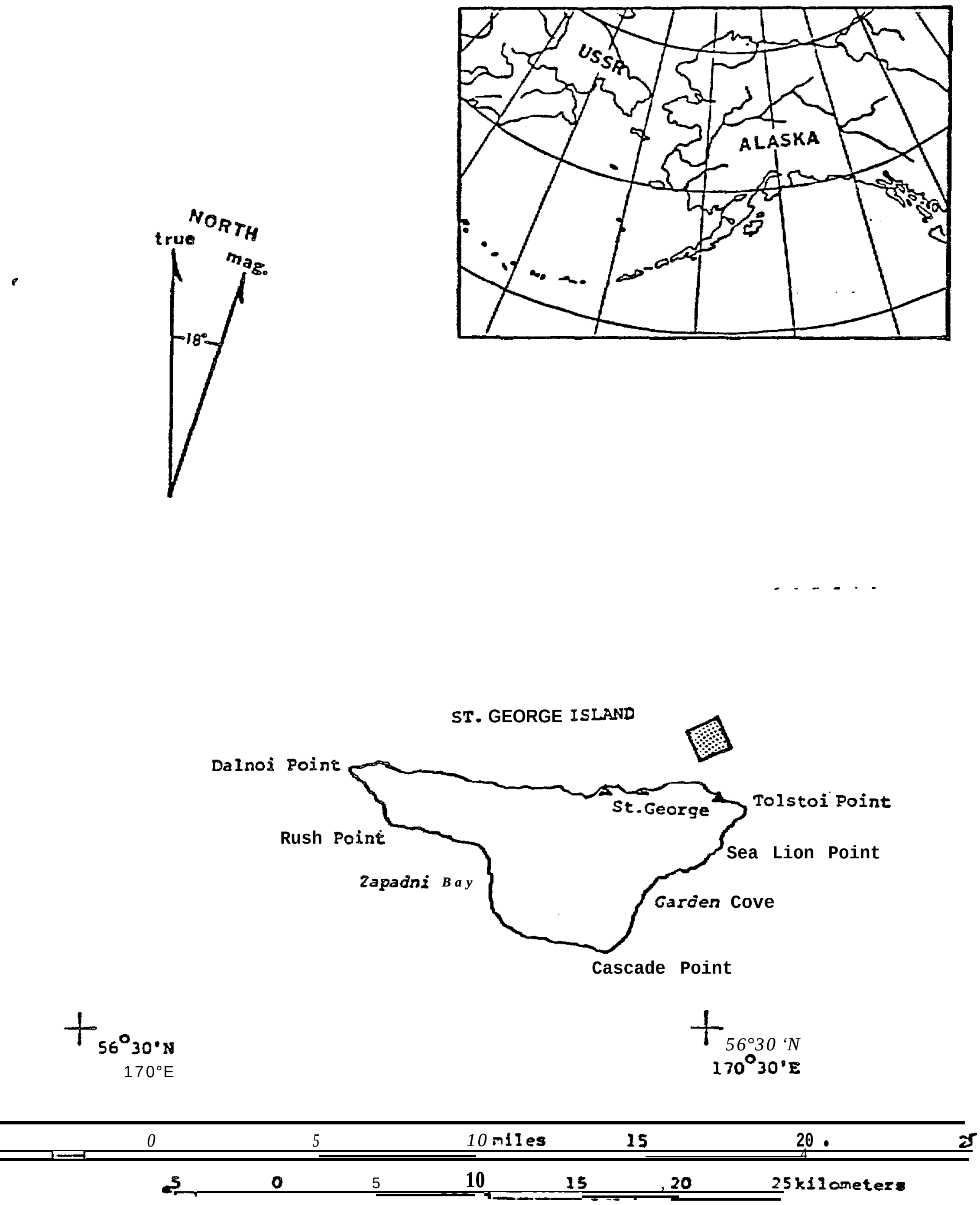


Figure 111-17: St. George Island and survey site location. Survey site one square mile. Shore stations are indicated by triangles.

population occupying this area would have been 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, 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. 8,500 B.P. According to Guthrie (1976) 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. 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. According to the preceding analysis, it would not be likely that an archeological site would be found in such an area. None were found.

The marine archeological survey of a one square mile area (the equivalent of a standard oil lease block) was executed utilizing a hull-mounted sub-bottom profiler (Raytheon, portable survey system, Model RTT-1OOA), 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.) for such a survey. 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. The survey tracks are illustrated in Figure 111-18. 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 inches per minute so that the data strips would be compatible and facilitate analysis. The 150 m intervals selected 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 anomalies which could not be attributed to natural agents were noted at that time. If any such anomalies had been noted during the course of the survey, an attempt to core the anomaly or to take a grab sample would have been considered. 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 and no anomalies which could be attributed to possible archeological site occurrence were noted in any of the records.

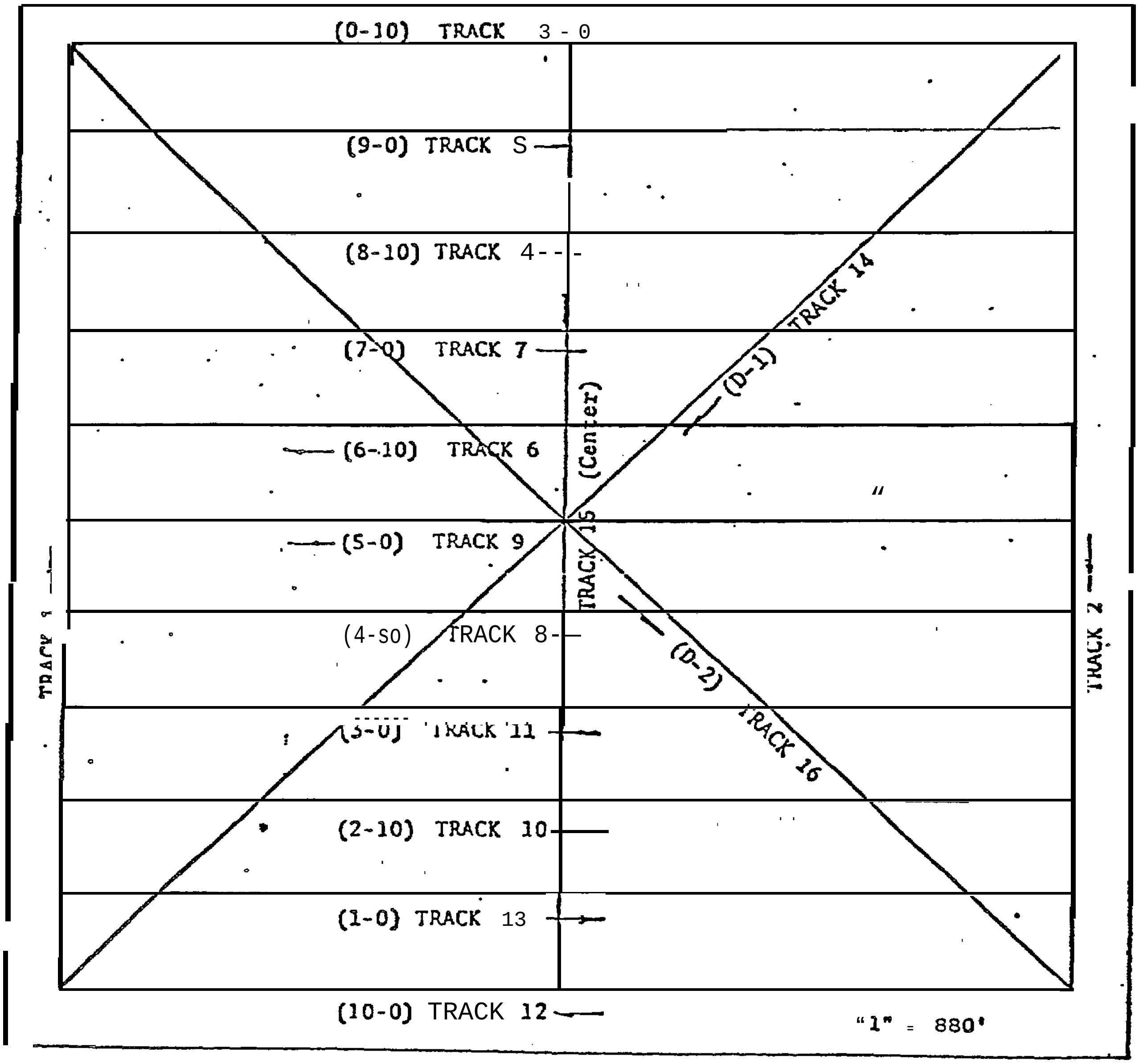


Figure III- 18: Square Mile Quadrant and Survey Tracks. . Survey tracks numbered according to sequence run. Vertical course 332°, horizontal course 242°. Courses referenced to True North. From Stoker (1976).

The sub-bottom profile (Fig. 111-19) 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 landform 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. 111-20) of the survey area, and it can readily be noted that elevation decreases seaward from the source of the flow. Stoker's (1976) analysis of the magnetometer data indicates that this flow occurred prior to the Late Wisconsin sea level rise. Stoker (1976) contoured the magnetometer records at 100 gamma intervals for the survey area (Fig. III-21). Stoker (1976) noted that:

> "This bathymetric formation is an ancient lava flow of reverse polarity, probably exceeding 300,000 years in age (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."

Areas of relatively low relief within the survey area 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 on this record. Further evidence supporting deposition of sands in these areas of low relief is the poor penetration achieved by the sub-bottom profiler. Hopkins " (personal communication) suggests that the sand may have accumulated when the island was attached to the mainland, possibly 16,000 to 20,000 years ago. In other areas of the Alaskan shelf, good penetration has been achieved using this same sub-bottom profiler, where the sediment structure consists largely of silts and similar fine-grained material. The poor penetration realized from the sub-bottom profile records is attributed to surficial deposits, i.e., lava and sand. Figure III-19 shows the side-scan and sub-bottom profile records which depict "rock outcrops" with intervening areas being filled with 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 illegible.

Side-scan sonar records of the overlapping passes of the R/V ACONA were synthesized into a photo mosaic which delineates the major bottom features and visually portrays the general topography of the survey area. The photo mosaic facilitates interpretation. Coupled with the geologic history of the area, it aids in further delineation of high probability locales 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 overstressed that it is no substitute for the original records. However,

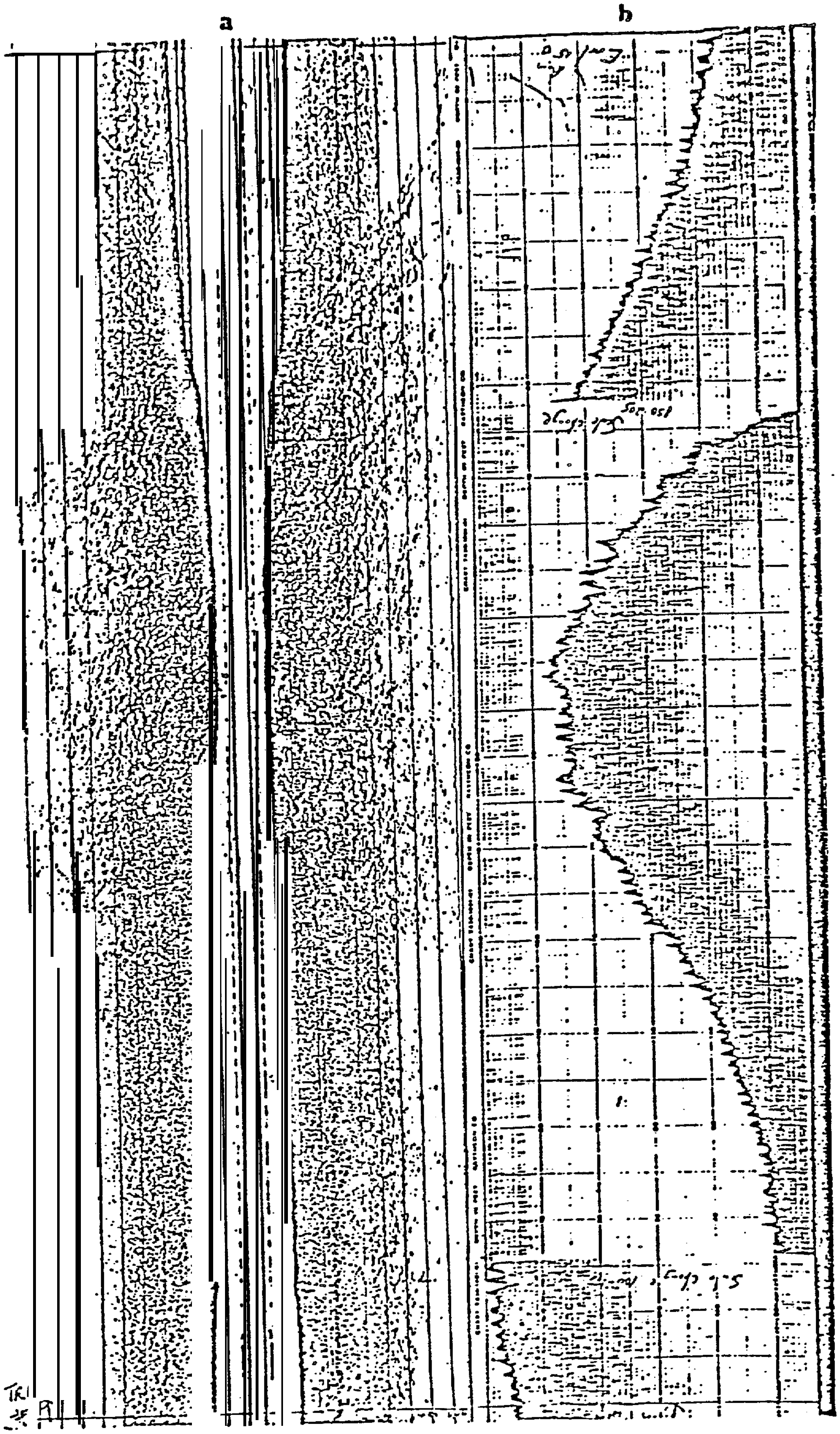


Figure 111-19: Side-scan and sub-bottom profiles.

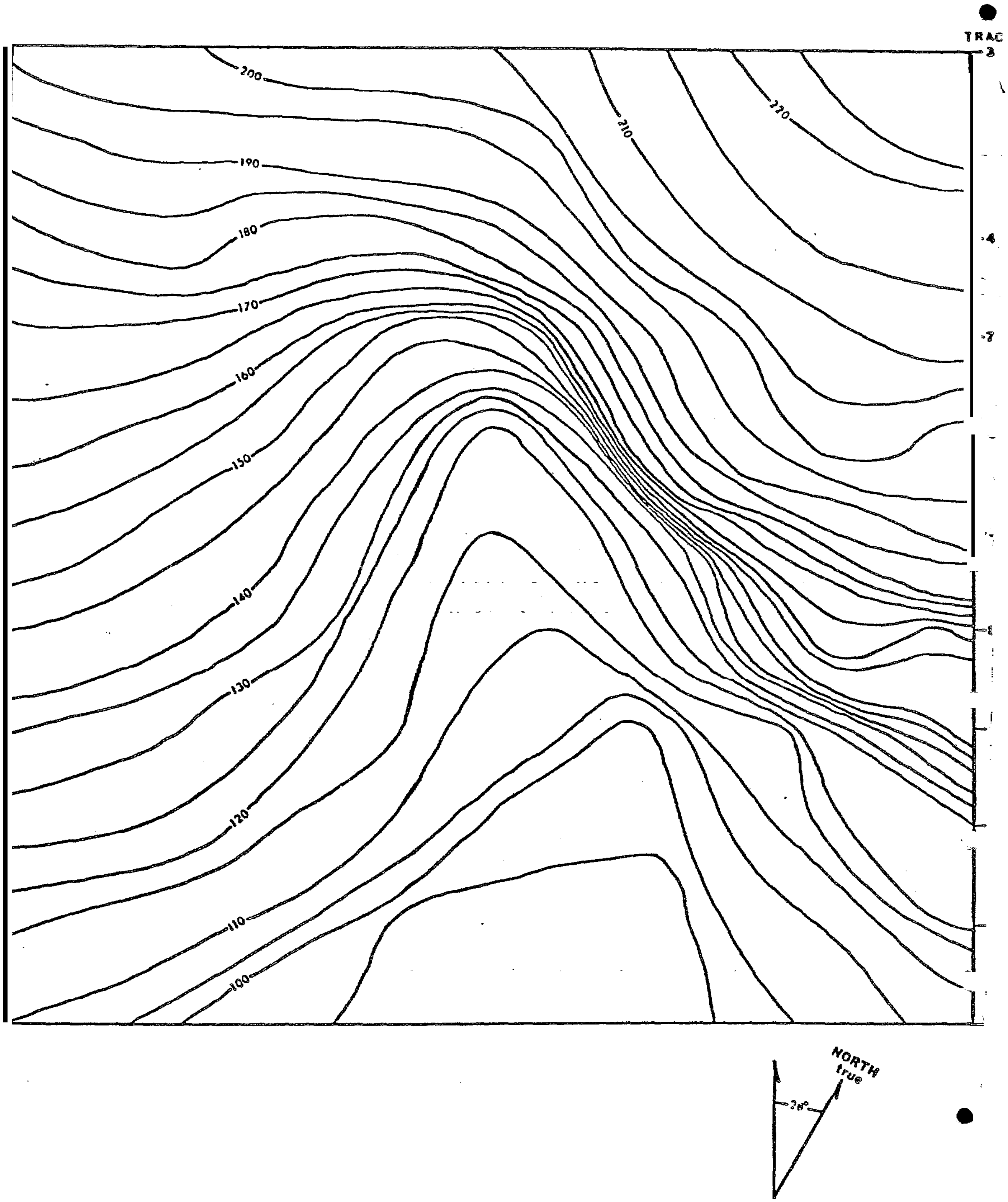
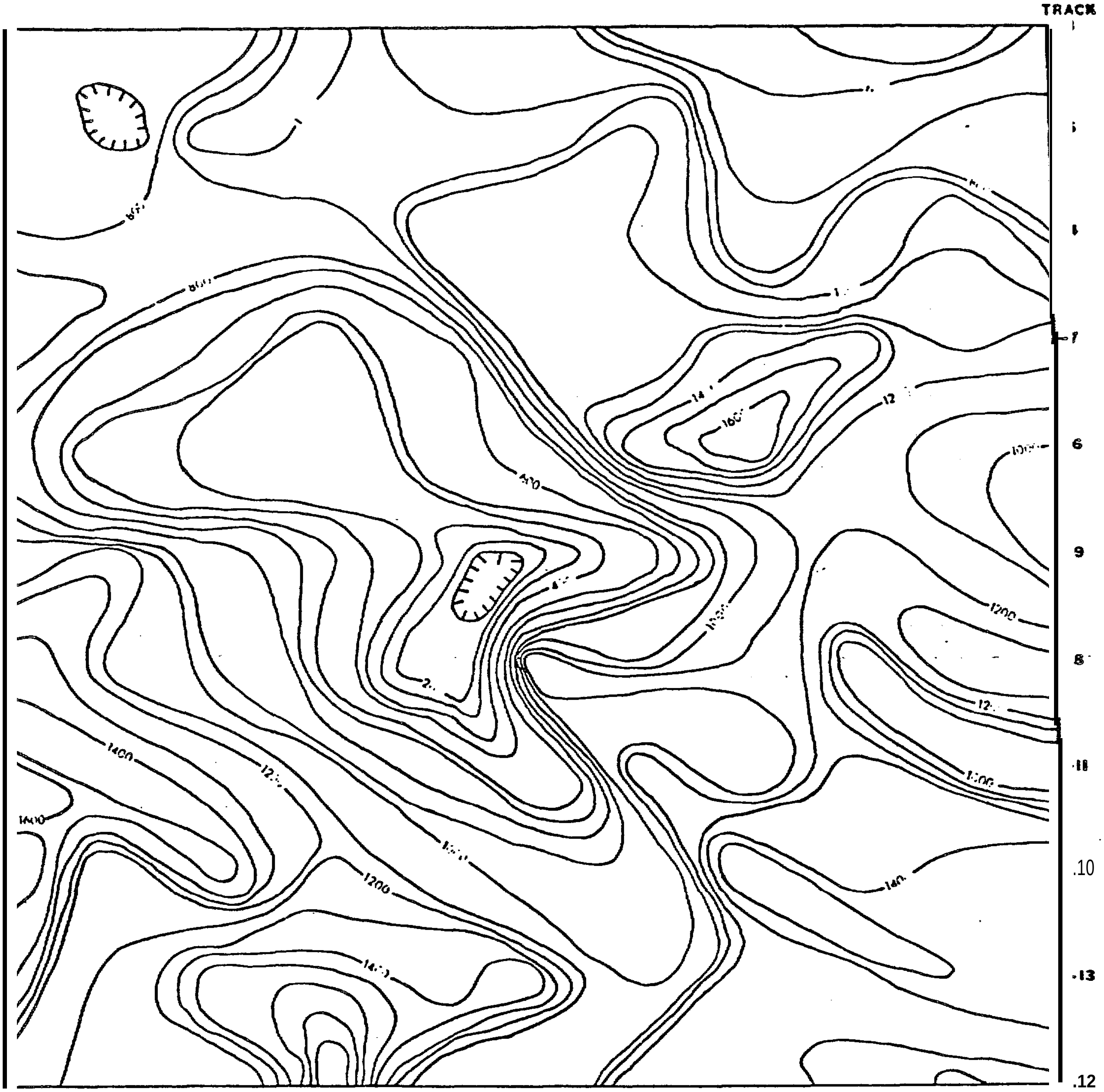


Figure III-20: Topographic contour map.



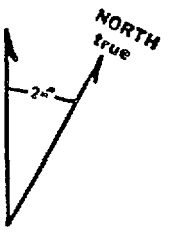


Figure 111-21: Total Field Intensity Geomagnetic Contours. 100 Gamma contour interval. One square mile area. From Stoker (1976).

it does permit one to focus special and thorough attention to analysis of chart records on specific high potential areas within a survey area.

As a supplemental aid for this level of interpretation, a topographic contour map (Fig. 111-20) 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 serve this purpose better. Experience suggests that, if at all possible, the sub-bottom profiler should not be hull-mounted, since the rocking motion of the ship in response to wave action creates dips and peaks in the corresponding chart records.

The magnetometer and sub-bottom profile records were contoured. These techniques serve to lend interpretative strength to analysis of the survey area 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 historical sites, such as shipwrecks, in other study areas has been demonstrated.

Three analytical methods have been developed for 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 potential 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, homogeneous sediment structure and minimal magnetic variation. In addition, it cannot be overstressed that none are substitutes 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 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 the 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 potential than surrounding areas were thoroughly examined. No anomalies which could possibly be interpreted as evidence of former human habitation or shipwrecks were discovered.

2. Terrestrial Archeological Survey of St. Matthew Island:

St. Matthew is the most isolated and remote of the Bering Sea islands which were, at one time, hills rising from the Bering Land Bridge. During Beringian times the island was most certainly a significant landmark rising out of the rather flat, featureless plain, and would have provided a likely focal point for Paleolithic hunters. With the late Wisconsin rise in sea level, St. Matthew Island was severed from the mainland sometime between 22,000 and 16,000 years ago.

The selection of St. Matthew was based on a number of considerations. Although the island was not interpreted as occupying an ecotone during the three late Wisconsin stillstands which were analyzed, it did present potential for spring and early summer range for grazing mammals. The island was uninhabited at the time of historic contact and it was therefore hoped that this would increase the probability that any prehistoric archeological remains might date to Bering Land Bridge times. In addition, according to what little historical information is available for the island, it has been the scene of little human activity during historic times. It was believed that this could greatly enhance the chances of detecting early man sites, since archeological remains from later periods would not mask earlier cultural remains. 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.

The archeological survey was conducted by a five-member field crew between July 23 and July 31, 1976. In addition to this researcher, Guthrie, and Stoker, the field crew included Glenn Bacon and Mary Lee Morris. This 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. This researcher and Bacon surveyed the large central valley which bisects 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 lithic 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 survey interests.

Survey conditions were poor since, comparatively speaking, the island lacks Pleistocene deposits suitable for archeological preservation. Although the larger valleys have accumulated Quaternary deposits, the surfaces of most elevated areas were covered with frost-spalled rock. Attempting to locate stone artifacts in this extensive jungle is not only frustrating, but a futile experience. Natural agents have produced literally millions of "naturefacts," many of which bear an uncanny resemblance to tool forms characteristic of known Wisconsin archeological assemblages, such as blades and flake cores. However, the context of the St. Michael specimens indicates that they cannot be attributed to former human occupation of the island. Prior to this archeological survey, the paucity of information relating to the island made it impossible to know that the depositional situation would not be conducive to preservation and detection of archeological remains.

In addition, 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) are in an advanced state of decay and clearly indicate the poor preservation of surface organic remains.

A ventifact layer 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 subaerial erosion. Loess deposition was negligible, thus possibly indicating that during Pleistocene times St. Matthew Island was not situated close enough to a source area, such as an outwash plain, from which wind-blown silts could have been derived.

The survey at 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, the 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 had a piece of baleen lying directly on its upper surface. Bedding above the log in the exposed section indicated that the specimen was 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 and was later submitted to Geochron Laboratories for radiometric dating; the resultant date was 625 B.P. ± 140 radiocarbon years. It is impossible to ascertain whether this association represented evidence of human occupation of the island, or was a rather fortuitous and somewhat unlikely natural depositional situation. Whatever the case, the locale demonstrates little, if any, evidence of human occupation relevant to this study. The radiocarbon date is supported by the fact that the locale is no older than approximately 4,000 B. P., a time sea level reached its present height, and consequently contributes little to demonstrating Pleistocene occupation of the island.

A 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 David 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 obvious recent age of the assemblage does nothing to support a Pleistocene occupation.

The fact that the terrestrial archeological survey of St. Matthew Island did not produce evidence of human occupation during Pleistocene times is not accepted by this researcher as a definitive test of the archeological site potential modeling for the following reasons: (1) Adverse weather conditions limited the survey duration to only three full days on 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.

3. Archeological Survey of Chinitna Bay

The following description of the reinvestigation of a reported early man site at Chinitna Bay, Alaska is abstracted from Thorson, Plaskett, and Dixon (1980).

The Chinitna Bay site, described by Frank C. Hibben (1943), provided an opportunity to test the hypothesis that late Pleistocene man entered North America via the Bering Land Bridge into Alaska, inhabiting and migrating southward along broad areas of emergent continental shelf exposed during times of lowered sea level (Fladmark, 1979). The site area lies immediately adjacent to a broad submerged continental shelf at the base of the rugged glacierized Aleutian Range, and may have been uplifted in the recent past, thus creating a unique opportunity to surficially investigate an area of formerly submerged continental shelf.

Chinitna Bay is a 20-km-long, 5-km-wide marine inlet that lies on the west side of lower Cook Inlet about 200 km southwest of Anchorage, Alaska (Fig. III-22). The archeologic site was reported to extend for several kilometers along the south side of the bay, and to contain lithic artifacts that were associated with mammoth remains. The presence of such a site would demonstrate that early man and mammoth locally inhabited the subaerially exposed continental shelf adjacent to the present southern Alaska coast during Pleistocene time.

The Chinitna Bay site was reported to extend for approximately 2.4 km along the western and southwestern side of the bay (Hibben, 1943). According to the site description "material is not exposed for all of this distance, nor are signs of habitation continuously visible," however, "chips were grouped in concentrations throughout the entire extent of the site, as though marking chipping areas," and "by following these various strata along the upper beach where they are exposed, it is evident that the habitation level throughout the mile and a half extent, if this can be considered all one site, rises and falls as though the site were originally on several low hills or knolls along the shore" (Hibben, 1943, pp. 257-259). The cultural material was reported <u>in situ</u> and eroding from "a dark colored stratum of humus, which immediately overlies a hard, compact, iron-stained blue clay layer, which forms extensive portions of the beach along this side of the bay" (Hibben, 1943, p. 258). Although most of the lithic material was reported to consist of chips, several points from the Chinitna Bay site were described and classified as being "similar to Yuma-like forms as those recovered at Clovis, and which may be regarded as contemporaneous with, and possibly affiliated with, Folsom" (Hibben, 1943, p. 259). In

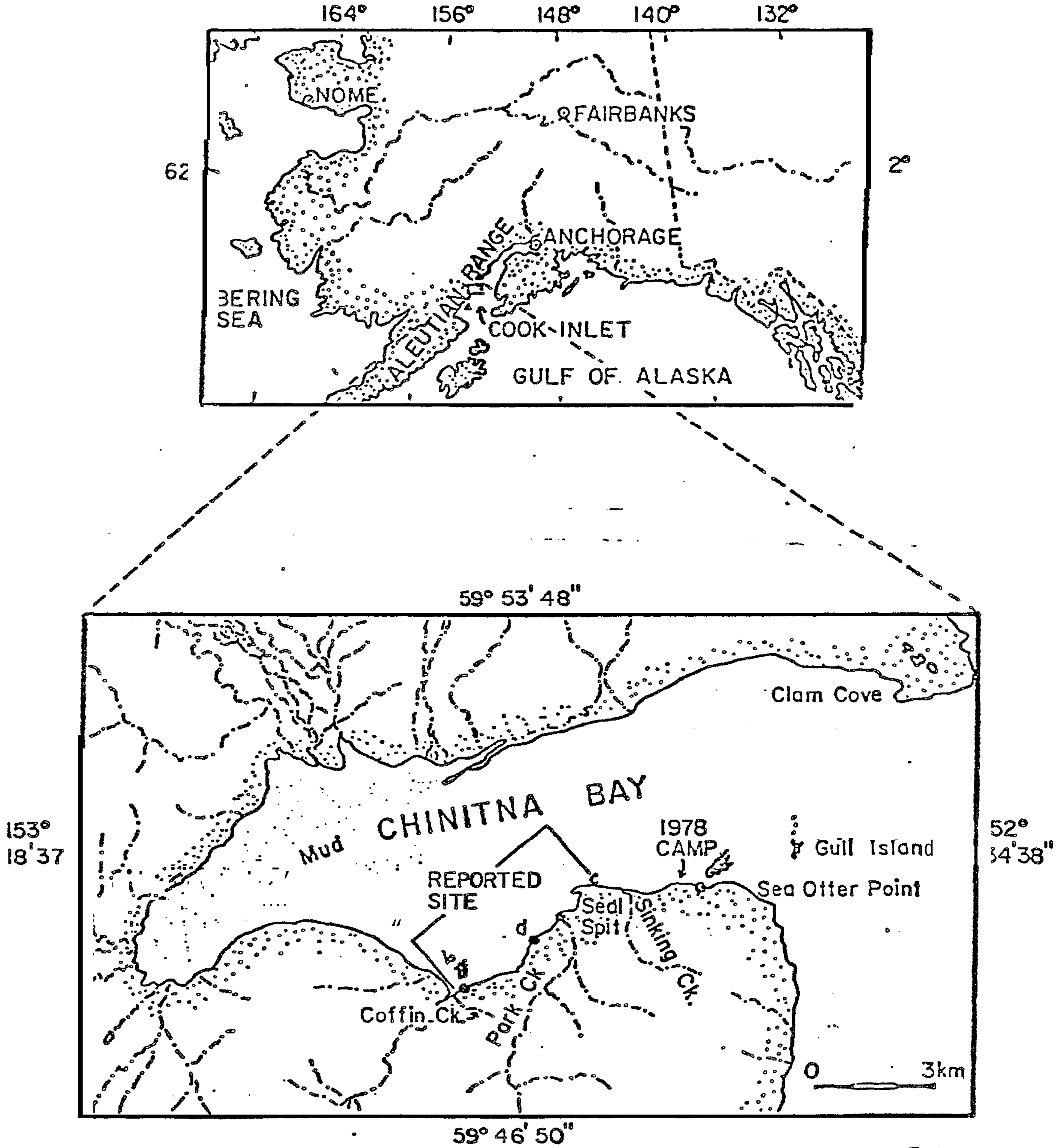


Figure 111-22: Chinitna Bay Study Area.

addition to lithic artifacts, charred wood was reported to occur sporadically throughout the site.

Bone material was not abundant and was reported only from the southern end of the site area. Some of the bone fragments were reported to be the remains of mammoth (Mammuthus sp.), the only genus identified at the site. Although no written report is available on the bone identification, and the present location of the specimens is unknown, Hibben has recently stated (written comm., 1978a) that the identification was made by the late Dr. Chester Stock (Paleontologist, Calif. Inst. of Tech.). The provenance of the recovered bone is unclear (1943); did not specifically state whether the fragments were found in situ. In a more popularized account Hibben (1946, p. 125) stated that "protruding here and there from the bank, or scattered in sodden fragments on the beach, were the bones of mammoths." Recently, Hibben (written comm., 1978b) stated that the mammoth bones were "awash in the surf."

Stratigraphic descriptions of specific exposures at the Chinitna Bay site were not reported in Hibben (1943), however, a generalized description of the site stratigraphy was given. The generalized sequence apparently was a composite that was derived from observations made over the entire 2.4 km of coastal exposure, because no identical sequence was found at any one beach-cliff exposure examined in 1978. The sequence includes five major stratigraphic units (numerical designations not used in Hibben's 1943 article): Unit 5, the lowest layer consisted of "a hard, compact, iron-stained blue clay layer, which forms extensive portions of the beach along this side of the bay." Unit 4, "the habitation layer (immediately overlying the blue clay layer), "is marked by a dark colored stratum of humus. Objects of human origin are, for the most part, scattered on the top of the blue clay after the humus has been washed away, or are actually found in the humus layer itself. Sporadic tree stumps marked the humus layer of the occupation level as these were being exposed. Roots and occasional whole stumps were upright and apparently in original growing position." Unit 3, "immediately superimposed on top of the humus and the occupation level, was a layer of muck, of loess-like consistency. The muck varied in thickness from four feet at the south end of the site near the creek mentioned before, to 22 feet near the center and north end." Unit 2, "near the top of the muck layer, a volcanic ash 3 inches thick could be sporadically traced." Unit 1, "superimposed as a capping on the muck layer was a considerable stratum of peat of apparently modern origin, which extended up to and including the grass roots and the peat layers of the present surface" (Hibben, 1943, p. 258).

The reported description of the stratigraphic sequence at Chinitna Bay site in Hibben (1943) coincides almost exactly to the stratigraphic descriptions made in 1978 along the south shore of Chinitna Bay. The compass directions reported in that article, however, are consistently at least 45° east of their actual orientation. No other bays along the west coast of lower Cook Inlet have the same coastal morphology or deposits as that described by Hibben in Chinitna Bay (Detterman and Hartsock, 1966).

During Quaternary time Chinitna Bay was repeatedly inundated by large east-flowing glaciers that originated in the Aleutian Range (Karlstrom, 1964). During the Naptowne Glaciation, the most recent major interval of ice accumulation, valley glaciers that descended from ice fields of the range crest and from the flanks of Mount Iliamna coalesced in Chinitna Bay to form a piedmont lobe that extended well beyond the margin of the bay. The major mountain peaks stood well above the surface of the glacier lobe at this time. The Naptowne Glaciation almost certainly correlates with other late Wisconsinan glacial advances elsewhere in Alaska (Karlstrom, 1964), and probably dates between 25,000 and 10,000 yr B.P. Radiocarbon dating of raised marine sediments near Anchorage (Schmoll et al., 1972) indicates that Naptowne-age glaciers in upper Cook Inlet were undergoing rapid retreat by 14,000 to 13,000 ^{14}C yr B.P.

Prominent moraines near the heads of the valleys that flank Mount Iliamna extend no farther than about 5 km beyond the outer margins of present glaciers. These moraines, which correlate with the Alaskan Glaciation (Neoglaciation) of Karlstrom (1964), indicate that climates fluctuated during Holocene time, but that large-scale, post-Naptowne glacierization did not occur (Detterman and Hartsock, 1966).

The large, glacially carved valleys that descend from the flanks of Mount Iliamna and the Aleutian Range merge with the western end of Chinitna Bay. Streams that occupy these valleys are partially fed by glacial meltwater and are currently discharging large quantities of mud and silt into the bay. These fine sediments are rapidly reworked by tides, currents, and waves resulting in the formation of large mudflats near the head of the bay 'and near the area of the reported archeologic site. East of the site area, toward the mouth of the bay, the presence of active taluses, landslides, and sheer cliffs along the shoreline indicate that rapid coastal erosion is occurring.

"The areas in Chinitna Bay that are periodically inundated by high tides form widespread salt marshes that contain a lush cover of salt-tolerant vegetation. During exceptionally high tides, a thin layer of gray mud is deposited on the vegetated surface of the salt marsh. Driftwood and isolated clumps of stony gray mud and gravel may also be deposited on the salt marsh during these events. Organic material, consisting of distinct layers of grassy peat with occasional wood fragments, commonly occurs near the top of the muddy sediments. With increasing depth the organic material becomes more finely divided, and the stony gray mud appears to have a bluish-gray color and a fetid smell due to the lack of oxidation.

A small, but laterally continuous, wavecut bench is commonly present at the seaward limit of the salt marshes. Mudflats, covering an area of several square kilometers, extend seaward from the salt marsh environment. At low tide, sediments of the mudflat can be observed; they exhibit isolated clasts and lenses of angular gravel, occasional fragments of detrital waterlogged wood, and isolated disarticulate shells of marine pelecypods in a very silty matrix.

Berms of gravel are commonly built at the upper limit of tide throughout the Chinitna Bay area. The gravel consists largely of platy fragments of mudstone and sandstone derived from the sedimentary rock formations in the area. The lithology of the modern beach gravel shows very little variation in both texture and composition. Near the mouth of Covey and Sinking Creeks small alluvial fans have been built into the bay. These fans are composed of gravel that shows slightly less variation in composition than most of the beach gravel and which the fan clasts also appear to be slightly more rounded due to stream transport.

Stratigraphic sections were carefully measured and have been described for 13 localities along the south side of Chinitna Bay between Coffin Creek and Sea Otter Point, and at one locality on 'Gull Island (Thorson et al., 1979). Base-level control for all of these sections was the high afternoon tide of June 5, 1978, which was 524 cm above mean sea level. The origin of the deposits at each of the section localities was interpreted largely through comparisen with the modern littoral sediments and features (Fig. III-23).

Sections S1 through S6 consist largely of clayey silt and silty clay with common dispersed gravel clasts and wood fragments. Occasional marine pelecypods (Mya spp.) and gastropod (Neptunea spp.) are present in the deposits where they are gray and unoxidized. Oxidation is common near the top of the sections, and becomes increasingly pronounced in the higher sections. Subangular gravel was found near the base of Section S6 and is presumed to underlie Sections S1 through S4 as well. The clayey sediments form a blanket over the older beach gravel, and clearly originated as marine muds and (or) salt-marsh deposits. A radiocarbon date of 375 ± 120 yr B.P. (GX-5655) from wood near the top of the marine mud at Section S3 indicates a relatively recent age for the deposits (Table III-5).

Sections S7 through S1O exhibit completely oxidized clayey silts and silty clays that contain occasional thin interbeds of subangular gravel, peat layers, and paleosols. Collectively these sediments are interpreted to be largely marine muds and salt-marsh deposits that overlie beach gravel (Fig. 111-23). The interbedded peat layers and paleosols suggest that intervals of subaerial exposure interrupted the generally submergent conditions. Subrounded gravel , which is present in Section S9, is interpreted as alluvial in origin. A radiocarbon date of 300 ± 130 yr B.P. (GX-5656) was obtained from a wood sample taken from the peat unit near the bottom of Section S7 (Table III-5). This date indicates that the sediments are very young, and that the average sedimentation rate in the area prior to recent uplift must have been on the order of 1 cm/yr.

Section S12 consists of at least 10 m of angular monolithologic bouldery rubble in a very poorly sorted mud matrix (Fig. III-23). This sediment occurs as part of a large earthflow complex that now appears to be largely stable. The blocky colluvium lies unconformably over a bluish-gray, clayey silt that includes two prominent, woody, peat layers. A very vivid oxide-stained zone occurs at the contact between the colluvium and the clayey silt. Oxidized, unbedded, clayey silt, which lies below the peat-bearing clayey silt, conformably overlies subangular gravel at the base of the exposure. The peats are interpreted as terrestrial organic layers that bracket and overlie salt-marsh deposits. The basal unit is interpreted as beach gravel. A radiocarbon date of 285 ± 100 yr B.P. (GX-5658) was obtained from wood collected from the upper peat unit, and indicates that the salt-marsh deposits and the colluvium are slightly older and younger, respectively, than this late Holocene date.

The upper surface of Gull Island forms a prominent terrace that now lies about 12.5 m above sea level. Field studies in 1978 supported the interpretation of Detterman and Hartsock (1966) that this terrace is a

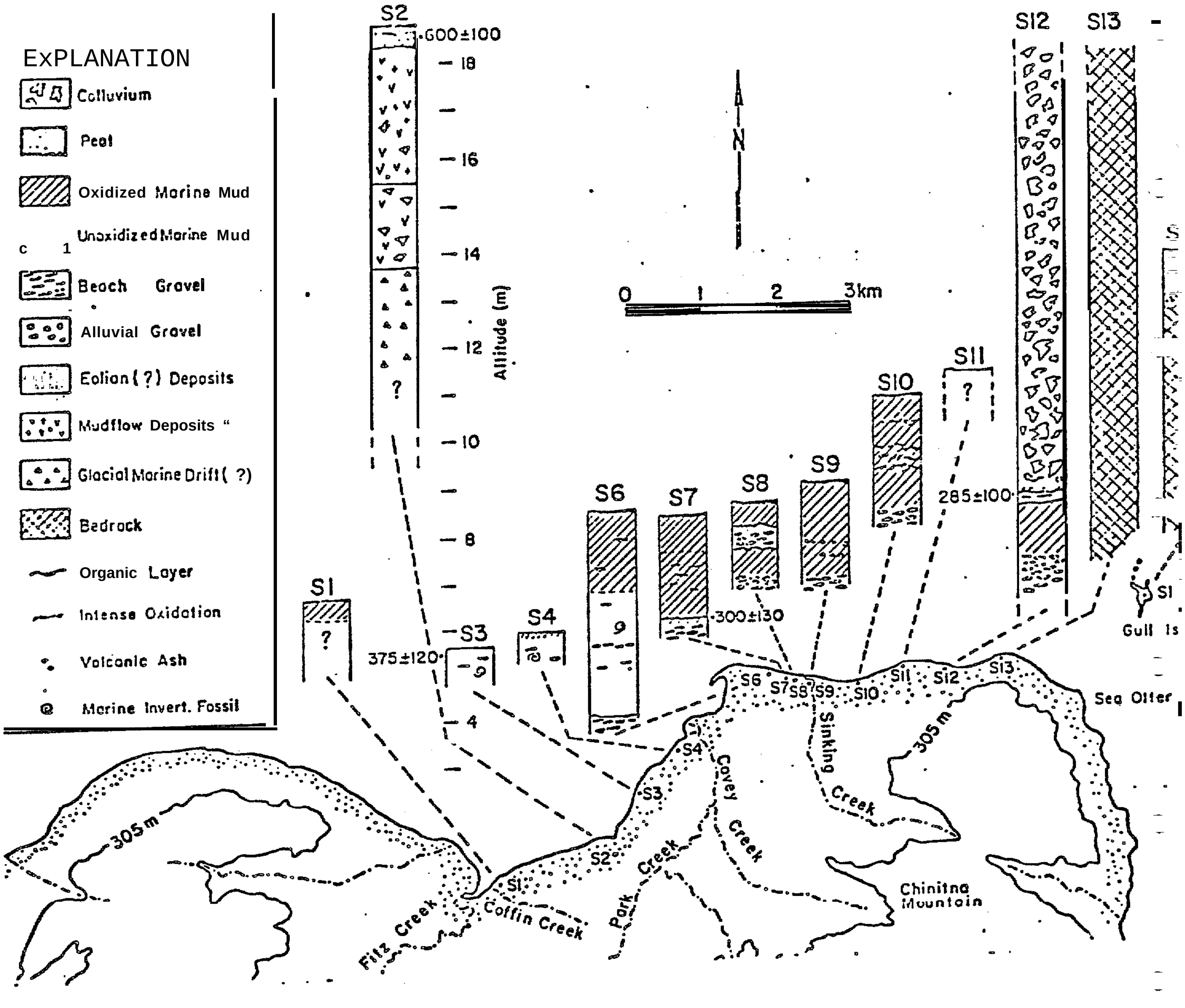


Figure III-23: Generalized stratigraphic sections of beach-cliff exposures along the south shore of Chinitna Bay. Vertical scale indicates altitude above mean sea level and thickness of exposures. Section S5 not shown. Refer to Table III-5 for description of the radiocarbon samples. Contour line at 305 m (1000 ft) shown.

TABLE III-5

RAD1OCARBOM DATES OBTAINED FROM SAMPLES COLLECTED ALONG THE SOUTH SHORE OF CHINITNA BAY

Lab No.	Age (^{14}C yr B. P.)	Material dated	Location (section)	Stratigraphic significance	Inferred relation to the reported site
GX-5658	285 ± 100	Compressed wood	S12	Maximun age for earthflow activity and minimum age for deposition of salt marsh sediments.	Not applicable.
GX-5656	300$. ±30	Compressed wood	s?	Dates peat horizon at 2.4 m depth within salt marsh sediments.	Dates occupation 1 evel
GX-5655	375 ± 120	Wood	53	Dates upper part of littoral sediments.	Maximun age of occupation levels..
GX-5654	600 ± 100	Peaty silt	S2	Dates middle of capping peat deposit at Coffin Creek, and minimum age for ash deposition.	Not applicable.
GX-5657	4,190 ± 155	Organic silt	S14	Minimum age for cutting of marine abrasion platform. Dates inferred episode of eolian deposition.	Not applicable.

marine abrasion platform cut into bedrock by wave action. Sediments that overlie the terrace (Section S14; Fig. III-23) are radically different from sediments on the mainland; interbeds of silty fine sand and well-sorted sand overlie weathered bedrock in this exposure. The silty fine sands appeared very similar to loess in the field; laboratory size analyses (Thorson et al., 1979) support this interpretation. Well-sorted sand layers within the unit interpreted as loess also appear to be eolian in origin. A radiocarbon date of 4190 ± 155 yr B.P. (GX-5657) was obtained from finely divided organic matter present near the middle of the silty fine sand unit, and indicates that the eolian cap is at least several thousand years old.

Section S2, near Coffin Creek, is also radically different from Sections S3 through S10 (Fig. 111-23). Section S2 is capped by a 55-cm-thick deposit of peat and peaty silt that includes a well-defined layer of light-colored volcanic ash. A radiocarbon date of 600 ± 100 yr B.P. (GX-5654) was obtained from a peat sample taken from just below the ash bed. The peat overlies brown clay and clayey sand that contain abundant fragments interpreted as lapilli and abundant zones of angular, monolithologic, rock rubble. The clayey sediments are interpreted to be a weathered mudflow that originally contained a mixture of tephra and local rock rubble; the tephra appears to have been subsequently weathered to a very plastic clay. The underlying unit, between 13.5 and 15.5-m altitude, is very poorly exposed, but is also interpreted as largely colluvial in origin. Below the colluvial sediments in Section S2, subrounded quartz granules and pebbles are dispersed in a matrix of gray silt and sandy silt. The pebbles apparently reflect a provenance different from all other gravel deposits in the south Chinitna Bay area, and may have been derived from the large quartz-diorite pluton that lies several kilometers to the northwest along the axis of the Aleutian Range (Detterman and Hartsock, 1966). The apparently exotic nature of the "quartz clasts, and their occurrence as dispersed clasts in a fine matrix, suggest that this unit originated as glacially transported debris that was deposited in standing water. Because the local topography would not have easily permitted the formation of an ice-dammed preglacial lake during glacier recession, the stony gray silt is interpreted as glacio-marine in origin. It probably was deposited at a time when the sediment locality lay below sea level and when glaciers were calving into Chinitna Bay.

Detterman and Hartsock (1966, p. 63) report that evidence for recent uplift is widespread along the west side of lower Cook Inlet. This region, however, did not experience uplift during the 1964 Alaska Earthquake (Plafker et al., 1969). The wave-cut surface on Gull Island, which is at least 4000 years old, now lies at about 12.5 m above mean sea level. The salt-marsh deposits, which are widespread along the south shore of Chinitna Bay, are now elevated as much as ca. 10 m above mean sea level, well above the highest limit of recent storms and tides. Elevated beach ridges at Section S11 now lie as much as 9 m above mean sea level. The following relations indicate that these beach ridges become progressively older away from the present shore: ridges become larger, with the oldest three ridges having trees that reach maximum basal diameters of 50, 20, and 7 cm; the slope angles on the faces of the beach ridges decrease inland; beach gravel becomes more oxidized inland; and driftwood becomes more decayed inland from the beach. Beach gravel is now more common in the littoral zone than in the elevated salt marsh deposits. Detterman and Hartsock (1966, p. 63) interpreted this to indicate that recent uplift has caused the local streams to dump more coarse debris into the littoral zone.

Stratigraphic sections S3 through S11 were measured from beach-cliff exposures that were cut into the elevated salt-marsh deposits by wave action. The top of each exposure appears to lie along the same flat geomorphic surface. This surface, which appears to be continuous between. all exposures, becomes increasingly higher, better drained, more forested, and more poorly exposed toward the east (Fig. III-24). This suggests that the upper surface of the salt marsh has been tilted down toward the west. Although the apparent slope of the surface varies, an approximate westward slope of about 3 m/km can be estimated for the surface. The three radiocarbon dates of 375 ± 120, 300 ± 130, and 285 ± 100 yr B.P. (same age within 1 sd) indicate that tilting, which occurred after sediment deposition, took place since several hundred years ago. Therefore, if Sections S3 through S11 are indeed related to the same topographic surface, it has been tilted at a rate of about 1 m/km/100 yr during the past several centuries. The progressive offlap of the elevated beach ridges in the area suggests that tilting may have been progressive or episodic. The tops of Sections S3 and S4 appear to lie on the tilted surface, but these exposures are presently submerged during storms that are coincident with very high tides.

The surface of the salt-marsh deposits at Section S1 appears to lie above the general surface defined by Sections S3 through S11 (Fig. III-24). Its relationship to the older surface is unclear. The wave-cut platform at Gull Island is higher than all raised salt-marsh sediments, and appears to be on the same general trend of deformation. The Gull Island surface must be at least 4000 years old; hence it considerably predates the salt-marsh surface defined by Sections S3 through S11. Therefore, Gull Island must" have been uplifted and (or) tilted independently of the sections on the mainland. Firm conclusions regarding the pattern of crustal tilting in Chinitna Bay cannot be made on the basis of the present data. Several different crustal blocks, which could be tilting at different rates, may be present.

The position of global sea level has not changed greatly within the past several centuries (Clark et al., 1978). Neoglacial expansions of glaciers in the Aleutian Range were very small relative to late Wisconsinan ice volumes; hence, isostatic response to these ice accumulations probably was negligible. Therefore, the recent uplift of the south shore of Chinitna Bay relative to sea level probably resulted from tectonic movements. Local variability in the pattern of uplift, and the apparently rapid rate of emergence, support this interpretation.

At the culmination of the Naptowne Glaciation, sometime between about 25,000 and 13,000 yr B.P., Chinitna Bay was filled to an altitude of about 600 m with glacier ice that originated in the Aleutian Range. The glacier extended eastward well beyond the mouth of the bay, and may have coalesced with other east-draining ice streams to form a piedmont ice lobe along the margin of Cook Inlet. Raised marine sediments and possible elevated marine

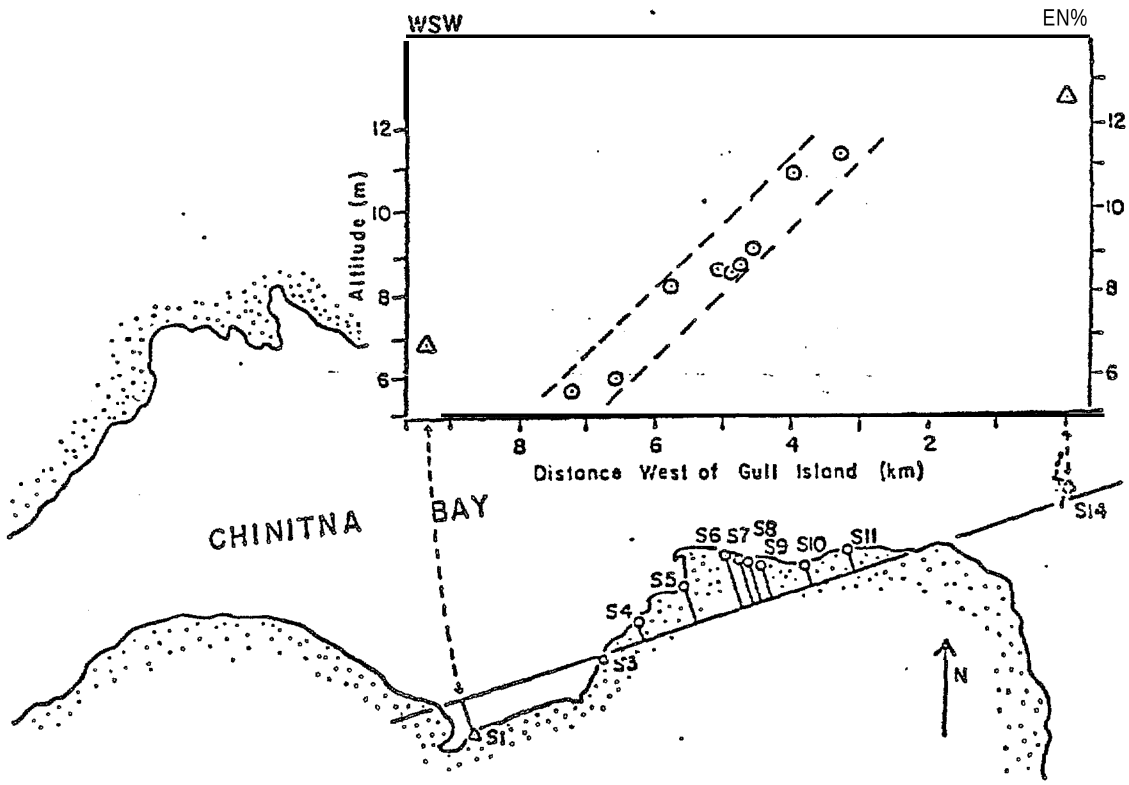


Figure III-24: Altitudes of top of selected stratigraphic sections plotted as a function of distance west of Gull Island. Altitudes measured with a spirit-level above mean sea level. Numbers on map refer to locations of stratigraphic sections (Fig. 111-23). Circles represent points that all appear to lie on the same terrace surface.

strandlines in upper Cook Inlet (Schmoll et al. , 1972), the presence of possible glacio-marine drift in Chinitna Bay (Section S2), and regional theoretical considerations (Clark et al., 1978) suggest that the Chinitna Bay area may have been isostatically depressed below sea level during recession of the Naptowne glacier, about 14,000 to 13,000 yr B.P.

Evidence for Holocene volcanic activity along the south shore of Chinitna Bay is preserved only in Section .S2 near Coffin Creek (Fig. III-23). The thick deposit interpreted to be volcanic mudflow sediments probably accumulated after a volcanic eruption that deposited tephra. Because there is no local source for tephra in the valley of Coffin Creek, the mudflow probably accumulated during or following an eruption of Mount Iliamna or Mount Augustine. Tephra may have blanketed the entire Chinitna Bay area during this inferred eruption, but was preserved only in Section S2. Because no tephra was found in the cap of windblown sediments on Gull Island, the inferred volcanic episode probably predates middle Holocene time. All of the remaining sections studied (S1 through S12) apparently postdate this inferred eruptive episode. Formation of peat began near Coffin Creek at least 600 yr ago and appears to have continued to the present time. A thin layer of volcanic ash, preserved near the middle of the peat, suggests that at least one volcanic eruption occurred in the Chinitna Bay area within the last 600yr.

The sediments that cap Gull Island are interpreted as eolian in origin, yet there is no present eolian source area for the fine sandy silt. A source area must have existed during middle Holocene time when this sediment accumulated. Three interrelated hypotheses can be invoked to account for the postulated expanded source area: (1) the floor of Chinitna Bay and the adjacent continental shelf may have been exposed above sea level during sediment accumulation; late Holocene eustatic rise of sea level may have subsequently submerged the sediment source area; (2) increased sedimentation rates in Chinitna Bay may have caused the bay to become largely filled with silt and alluvial sediments, providing a source area for the windblown sediments; (3) oscillating tectonic movements may have first elevated and later submerged the floor of Chinitna Bay and possibly the adjacent continental shelf above and below sea level, respectively, during eolian sedimentation. These hypotheses lead to the inference that the Gull Island sediments probably accumulated when sea level lay below its present position and (or) possibly at times of increased sedimentation rates. The Holocene glacier fluctuations were probably too small to have caused very large increases in sedimentation rate, and eustatic sea-level rise in the past 4000 yr appears to have been only about several meters. Therefore, if the radiocarbon date of 4190 ± 155 yr B.P. is correct, windblown sediments at Gull Island probably accumulated during a tectonically caused early to middle Holocene emergent condition.

Stratigraphic relations within the salt-marsh deposits that now lie above sea level indicate that local sea level in Chinitna Bay continued to vary through the past several hundred years. The basal beach gravels in Sections S5 through S12 indicate that a minor marine regression occurred several hundred years ago. Prior to that regression, sea level probably stood above its present altitude. Following the regression, salt-marsh sediment accumulated at a rapid rate. The peat interbeds, the presence of thin paleosols, and the possible beach gravels within the salt-marsh deposits in Sections S6 through S10 suggest that sea level fluctuated during latest Holocene time. These features, however, could possibly have been caused by unusually large storms.

The present of emerged beach ridges, a wave-cut platform, and salt-marsh deposits; the possible westward tilting of the shoreline features; and the absence of a source area for the windblown sediments on Gull Island indicate that major tectonic movements occurred during middle and late Holocene time. The south shore of Chinitna Bay has been uplifted at least 5 m during the past several thousand years. Within the last few centuries, minimum sedimentation rates and minimum uplift rates were about 1 cm/yr.

Stratigraphic Section S2 almost certainly marks the western end (Hibben's northern) of the reported archeological site. This section, from the top down, exposes peat, volcanic ash, brown clayey sediments of colluvial origin, and gray silt; it corresponds well with the thick peat, ash, muck, and blue clay sequence described by Hibben (1943) at this end of the site.

At the eastern end of the site area (Hibben's southern) Section S6 exposes, from the top down, organic material, yellowish-brown silt, and dark clayey silt; this observed sequence appears identical to the sequence of peat, muck, and blue clay which were described for this end of the site in 1943. Several other factors suggest that Section S6 marks the eastern end of the site. It is located near Sinking Creek, which may be the small, unnamed creek mentioned by Hibben (1943); the deposits shown in Plate XIVC (Hibben, 1943) are nearly identical to those exposed in this area; Section S7 lies just south of, and contains strata similar to, Section S6, but also contains a thin peat layer separating brown clayey silt from a lower, less-oxidized, clayey silt; this peat layer could be the humus stratum that was identified as the cultural layer; although not *in situ*, upright tree stumps near Section S6 lie at the approximate level of the humus layer, as described by Hibben (1943).

Hibben (1943) states that the "muck varied in thickness from four feet at the south end of the site near the creek mentioned before to twenty-two feet near the center and north end," and "here and there, this muck layer was shot through by lines and veins of iron stain." At Section S6 near Sinking Creek and at Section S2 near Coffin Creek 175 cm (5.7 ft) of yellowish-brown silt and 460 cm (14.6 ft) of brown, sandy, gravelly clay occur, respectively. Both exposures are riddled with small concretions and veins of iron oxide. The striking correspondence in location, orientation, thickness, and staining of both the muck stratum described in 1943 and the yellowish-brown deposits of Sections S6 and S2 provides convincing supporting evidence that the north and south ends of the reported site have been relocated.

The vegetated and gullied nature of the slope, its steepness and height, the presence of boulders at the base of the exposure, and the position of the "habitation level" relative to the overlying angular, bouldery, muddy sediments in Plate XIVb (Hibben, 1943) strongly suggest that this photograph was taken near Section S12, where identical features were also observed in 1978. If this is correct, the photograph was taken about 2 km east of the southeast end of the site as reported in 1943 (Fig.

III-22). Because Hibben possibly also included the shoreline between Sinking Creek and the photo locality (Section S12) as part of the site, this area was subjected to careful archeologic testing and stratigraphic study as well. No evidence for prehistoric human habitation was found in this vicinity.

The "blue clay stratum," which was described by Hibben throughout the site, consists of unoxidized marine mud. The interbeds of beach-single gravel, the presence of marine invertebrate fossils, and the identical appearance of modern mudflat sediments provide convincing evidence that the sediments accumulated in a littoral environment. Grayish clay at Section S2, which is interpreted as glacio-marine in origin, was included within the "blue clay stratum" as described by Hibben in 1943.

The humus layer, which was described by Hibben as the cultural horizon, appears to consist of one or more peaty layers that formed as accumulations of organic debris on the salt marsh surfaces. The presence of wood in some of the peaty layers indicate that trees were present locally, but the thinness of the organic layers, and the absence of oxidation, large logs, and root casts suggests that the salt-marsh surfaces were never well enough drained to support forest vegetation.

The widespread muck "of loess-like consistency" consists mainly of oxidized mudflat and salt-marsh sediments. Altered volcanic mudflow deposits at the western end of the site area, and blocky, colluvial rubble east of the site area apparently were also included within the muck stratum by Hibben.

The stratum of peat that was reported as capping the stratigraphic sequence at Chinitna Bay site was described to vary in thickness from 30 (1 ft) to 183 cm (6 ft). At the western end of the site area, near Section S2, the capping peat reaches a maximum thickness of 55 cm. At the eastern end of the site area, near Section S6, capping peat is only about 5 cm thick. As interpreted by Hibben, these peat deposits are of terrestrial origin and are of relatively recent age.

Of the four radiocarbon dates on samples taken from beach-cliff exposures along the south shore of Chinitna Bay, two have direct bearing on the age of the reported archeologic site. A wood sample was obtained from a peat layer at Section S7 that is thought to be the humus layer (occupation level) described in Hibben (1943). This sample yielded a date of 300 ± 130 yr B.P., and indicates that the "occupation level" is no older than several hundred years. A wood sample was obtained from near the top of the "blue clay stratum" at Section S3, which is the exact locality shown in Plate XIVd of Hibben's (1943) report. This sample yielded a radiocarbon date of 375 ± 120 yr B.P. and provides a maximum age for the Chinitna Bay site. Considering the relatively large standard error of these dates and the variability of the ^{14}C calibration curve for this broad time interval, the dates can be used only to indicate an age less than about 500 years for the reported archeologic sediments.

Although described in 1943 as occurring at the northern end of the archeological site, Section S2 is stratigraphically unrelated to, and older than, Sections S3 through S12, which occur over most of the reported site area. Therefore, the radiocarbon date of 600 ± 100 yr B.P., obtained from Section S2, does not bear significantly on the age of the Chinitna Bay site. Section S12 was also found to contain a stratigraphic sequence that differed from that of the major site area. The date of 285 ± 100 ^{14}C yr B.P. demonstrates the recency of earthflow activity in this area.

The sediments associated with the reported "occupation level" at the Chinitna Bay site, the "muck" and "blue clay stratum," are exclusively littoral in origin, and apparently accumulated in a mudflat and (or) salt marsh environment. The habitation level also accumulated in a salt marsh environment that apparently never became well-drained enough to support forest vegetation.

Radiocarbon dates from the Chinitna Bay site near the reported mammoth locality are no older than several hundred years. No mammoth remains have been described elsewhere in Alaska that are younger than about 15,000 yr B.P. (Guthrie, 1976). Furthermore, no pre-Holocene unconsolidated sediments that could have served as a source for mammoth remains are known to occur either in Chinitna Bay or in the entire lower Cook Inlet region. The extremely young age and marine origin for sediments in the site area indicate that mammoth could not have inhabited the south shore of Chinitna Bay during sediment deposition. The only large mammal bones of comparable size found in the site area during 1978 were the remains of two beluga whales (Delphinapterus leucas) that-had been washed onto the tidal mudflat near the center of the fires.

The boundaries of the reported Chinitna Bay archeologic site were relocated during the 1978 field investigations. The site area lies along the southern shore of Chinitna Bay between Sinking Creek to the east and Coffin Creek to the west. Comparison of photographs taken in 1943 by Hibben, and those taken during 1978 field work indicates that little shoreline erosion has occurred between 1943 and 1978. Widespread evidence for recent uplift along the south shore of Chinitna Bay indicates that the reported archeologic site could not have been completely buried since the early 1940s. It is therefore unlikely that the site has been either destroyed or buried since its investigation by Hibben. Because evidence for complex crustal tilting of the site area is widespread, it is also unlikely that any ancient archeologic site could have been preserved for 2.4 km along the shoreline.

The geologic strata that were described for the site area in 1943 bear an unmistakable resemblance to the stratigraphy observed along the south shore of Chinitna Bay in 1978 and documented in this report. Geologic analyses, coupled with radiocarbon dates on critical strata, demonstrate that the sediments in the site area are very late Holocene"in age, and that deposition occurred in an intertidal mud flat environment. The age and depositional environment of these strata preclude any association with mammoth. It is difficult to reconcile these findings with the interpretations of the Chinitna Bay artifacts and faunal material reported by Hibben. Two factors that contribute to this difficulty include: (1) the exact in situ provenance of the reported artifacts and faunal material is unknown, making precise stratigraphic correlations speculative; and (2) the present location of these materials is unknown, thus making them unavailable for reexamination and positive identification.

Artifacts and faunal remains from the "Chinitna Bay" site described by Hibben can only be accounted for in two ways: either (1) the artifacts and (or) faunal material are of very late Holocene age and associated with salt-marsh deposits in the site area; or (2) the archeologic and faunal material are much older than the geologic contexts in the site area and are therefore stratigraphically out of place. The latter possibility seems remote, especially since there are no strata exposed in the site area from which older archeologic material can be derived and reworked. It is also unlikely that other natural or cultural process would result in selective transportation of such a large quantity of older archeological material into the recent geologic strata of the site area.

Hibben assigned the Chinitna Bay materials to the "Early Man" category on the basis of two major assumptions: (1) at that time, certain lithic artifacts such as Hibben's "Yuma-like" projectile points were thought, on topological grounds, to occur early in human prehistory; and (2) the large mammal remains found by Hibben were thought to be mammoth, a species considered to be an early time-stratigraphic marker. Association between the reported mammoth remains and the "Yuma-like" projectile pointswas probably presumed because both lithic and fauna? materials were independently thought to indicate considerable antiquity. Both of these fundamental assumptions now appear questionable because: (1) no longer is the Yuma type considered as a useful or homogeneous topological or temporal concept in the Southwest United States where it was defined (Wormington, 1957), and its applicability to Alaskan prehistory has not been demonstrated; and (2) the occurrence of modern large mammal bones (beluga whale) in the center of the reported site area brings into serious question Hibben's undocumented identification of the bone fragments as mammoth.

In conclusion, no data from either Hibben's description of the Chinitna Bay site or from our interdisciplinary 1978 investigation can be used to demonstrate the occupation of the lower Cook Inlet region. Therefore, early evidence from the reported Chinitna Bay site cannot be used to test the hypothesis that early human habitation and migration occurred on the continental shelf adjacent to southern Alaska. An intensive regional archeologic survey, with careful documentation of sites which might be discovered, is necessary for proper testing of the coastal habitation hypothesis.

4. Archeological Investigations of Cave Deposits on the Porcupine River, Alaska

The Porcupine River cave research was initiated in an effort to verify human occupation of North America coeval with lower sea level on Alaska's Outer Continental Shelf, i.e., during Pleistocene times. The Lower Ramparts region of the Porcupine River (Fig. III-25) was selected for survey with criteria which were thought to characterize areas with good potential for yielding datable evidence of the presence of man in Alaska during the Pleistocene. These criteria include: (1) The region remained ice-free during Pleistocene times; (2) the area contains caves which were considered highly favorable for the preservation of organic material cultural remains (3) caves are often loci for human activity in Alaska and elsewhere; (4) many of the caves in the Lower Ramparts area are situated on south-facing slopes which lack permafrost and are favored archeological

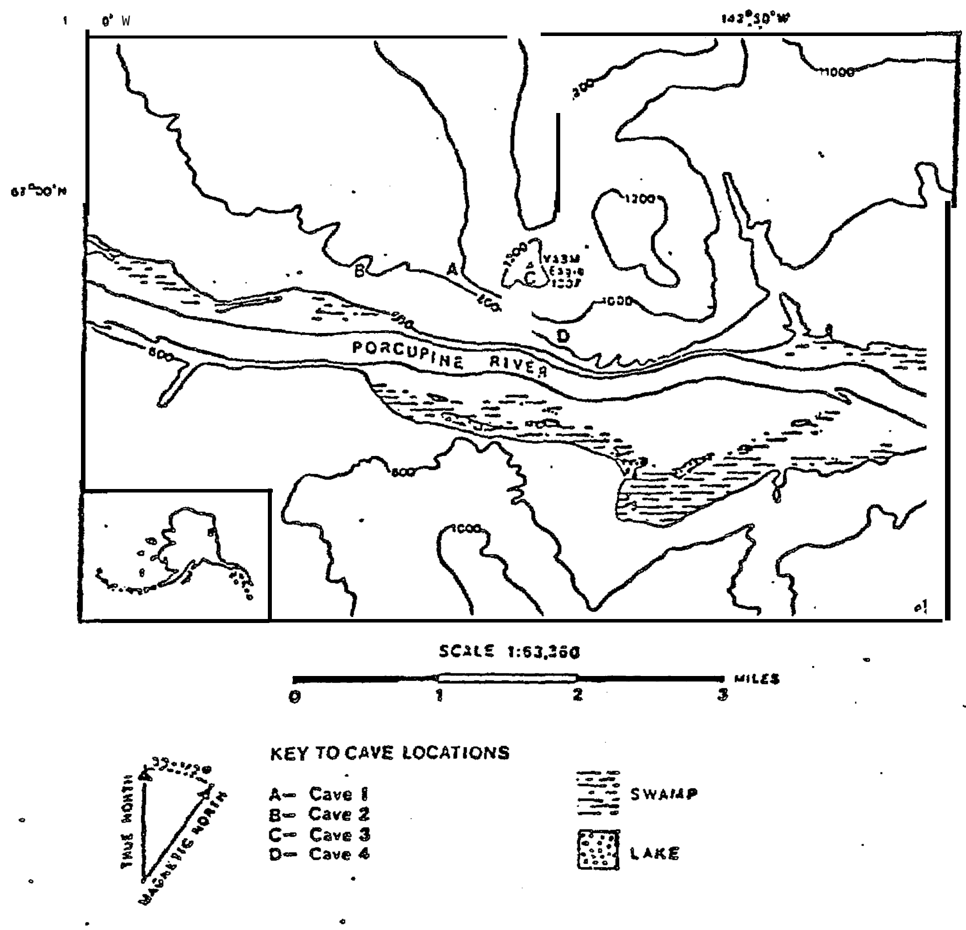


Figure III-25: Porcupine River study area.

site locales; (5) the caves are located on a major river system and thus were adjacent to major biotic resources during the Pleistocene; (6) a sequence of river terraces in the Lower Ramparts area presented excellent criteria for relative dating, and document long-term proximity of the caves to the river.

Preliminary criteria were formulated for selecting specific caves for systematic testing. These were:

1) Safety - any cave selected for testing had to appear geologically stable, minimizing danger to survey crews from rock fall or roof collapse.
2) Accessibility - caves suitable for testing had to be reasonably accessible by pedestrian travel.
3) Size - Caves selected for testing had to be large enough to offer shelter for one or more persons.
4) Deposition - Any cave selected for testing had to exhibit more than 20 cm soil deposition.
5) Elevation - Caves selected for testing had to be located at an elevation above the most recent river terrace, because it was most likely that caves at these higher elevations contained sediments dating to the Pleistocene.

Through the application of these criteria, four caves were selected for testing and each was ascribed a field number sequentially in the order in which testing occurred. Each cave was mapped. and photographed prior to testing. Metric grids utilizing one-meter intervals were superimposed on each cave deposit and all tests were conducted in systematic fashion with both vertical and horizontal data being recorded. Back dirt from each excavation unit was hand-screened utilizing ¼-inch mesh screens. The tests were conducted using standard archeological techniques (trowels, shovels, brushes, etc.). Although a soil auger was available, its use was limited because it was often repulsed by the abundant rock fall characteristic of cave deposits. The location of these caves is shown in Figure III-25. A synoptic discussion of the field results is presented below for each cave.

Cave 1. This cave is situated approximately 68 m above the Porcupine River along a series of limestone outcrops bisected by a sequence of talus slopes and cones. Cave 1 is on the north side of the river and commands a panoramic view to the south overlooking the flats below, the Porcupine River and the flats and terraces across the river. The view to the north is obscured by the slope behind the cave. Access to the cave from the flats below is relatively easy along the adjacent talus slopes, and a comparatively small flat surface, possibly a terrace remnant, exists immediately in front of the cave. The cave is small, averaging slightly less than a meter in width, a 1 ittle over three meters in depth and slightly less than a meter in height, prior to systematic testing (Fig. 111-26).

Four major stratigraphic units identified during systematic testing were designated Units 1 through 4 from the surface downward (Figure III-27). Unit 1 consists of comparatively rich dark brown/black organic soil containing animal feces (primarily porcupine) near the surface, mammal bone and limestone clasts of various sizes. Unit 1 was formed during the past 3,470 ± 90 14C years (DIC-1332), as suggested by a single radiocarbon

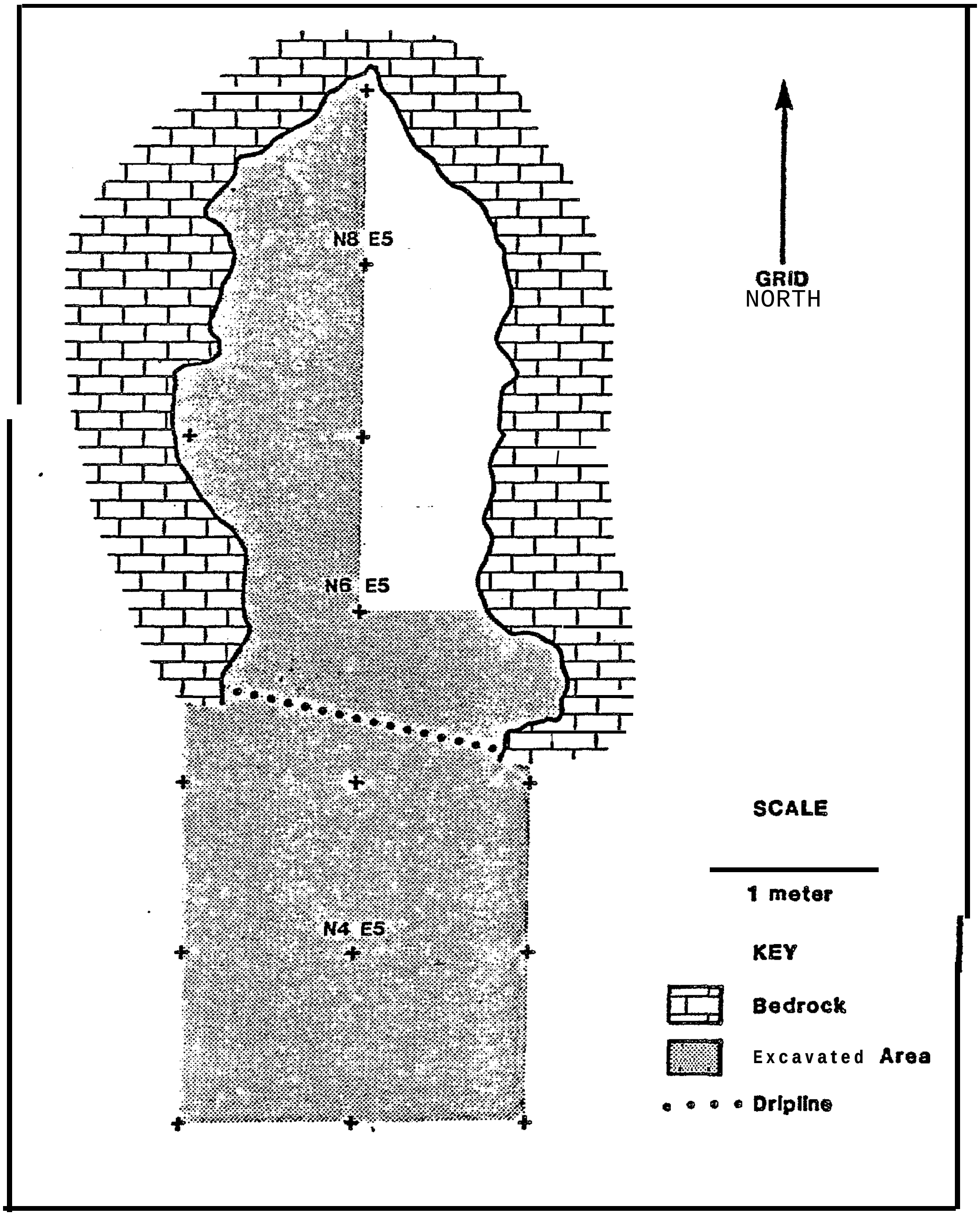


Figure 111-26: Plan View, Cave 1.

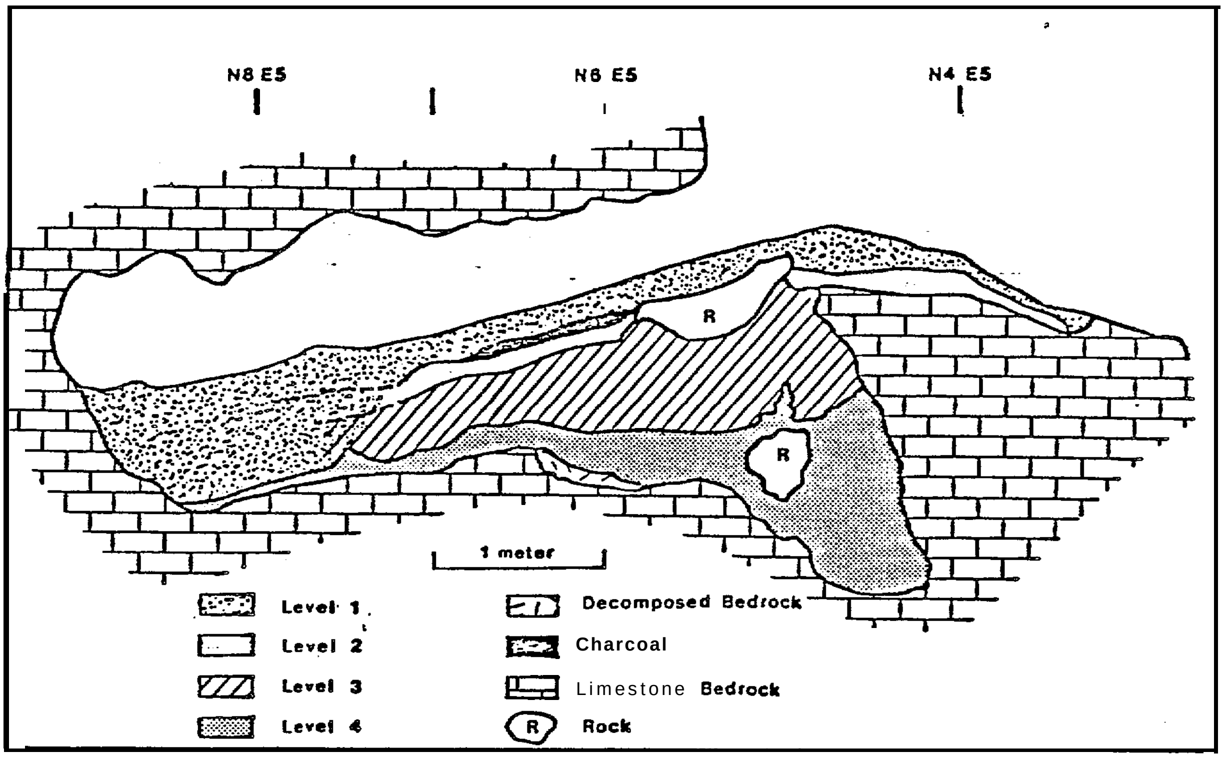


Figure III-27: Stratigraphic Profile, Cave 1.

determination run on charcoal derived from a cultural horizon which occurs at the contact of Units 1 and 2. Unit 2 consists of a medium brown loess with incorporated limestone clasts and faunal remains.

Units 3 and 4 were virtually indistinguishable from one another on the basis of texture and color; however, the contact between the two was readily apparent during excavation. Unit 3 was compact, requiring the use of a rock hammer during testing. Unit 4 was relatively soft and could be excavated easily with a trowel. This abrupt transition in compaction was the basis for the distinction between Units 3 and 4. It is unknown whether this boundary has true time stratigraphic significance, or whether it is the result of soil chemistry such as ground water conditions and mineral leaching. Both Units 3 and 4 were composed of a uniform and apparently simultaneous deposited mixture of loess and extremely small (silt-sized) particles of decomposed and weathered limestone, and were a very light brownish-grey color. Both units contained numerous limestone clasts and the remains of large and small mammals, as well as birds.

Cave 1 was the only cave systematically tested in which undisturbed stratigraphic units dating to the Pleistocene were discovered. The age of the oldest stratigraphic unit, Unit 4, is indicated to be ca. 21,000 yr B.P. by two radiocarbon determinations (DIC-1333, 21050 ± 330 yr B. P.; DIC-1334, 21780 ± 310 yr B.P.) run on bone collagen. The only known cultural horizon at Cave 1 occurs at the contact of Units 1 and 2 and is approximately 3,500 ^{14}C years old (DIC-1332, 3470 ± 90 yr B.P.). It is stratigraphically above Units 3 and 4, which contain Pleistocene faunal remains. It is reasonable to conclude that the Pleistocene/Holocene boundary for this deposit occurs at the contact between Units 2 and 3 (Fig. III-27) based on these three ^{14}C determinations and the occurrence of extinct fauna in only Units 3 and 4.

Late Wisconsin Environment. The fauna recovered from Units 3 and 4 includes Arctic hare (*Lepus othus*), collared lemming (*Dicrostonyx* sp.), hoary marmot (*Marmota caligata* or *broweri*), and Alaska vole (*Microtus miurus*). The occurrences of these species support Guthrie's (1968) suggestion that during classic late Wisconsin time the Interior Alaska climate was drier and colder than present. Also the occurrence of these species in direct association (in a primary depositional context) with horse, bison, caribou, sheep, and possibly mammoth, all primarily grazers, supports a prevailing opinion (Ager 1975, Matthews 1976, Hopkins 1979) that grasses may have composed a relatively high percentage of the available plant resources during the Pleistocene.

Other specimens recovered from Units 3 and 4 include mink and/or ermine (*Mustela vison* or *Mustela ermines*), Arctic ground squirrel (*Spermophilus parryii*), Brown lemming (*Lemmus* sp.), Snowshoe hare (*Lepus americanus*), Yellow-cheek vole (*Microtus xanthognathus*), Red fox (*Vulpes vulpes*), birds, and possibly black bear (*Ursus americanus*). Several of these species are ubiquitous (found in a variety of habitats') while others are most commonly associated with the boreal forest. Thus, the ecosystem in the immediate vicinity of Cave 1 during the late Wisconsin appears to have no contemporary analog. It is important to note that the faunal assemblage from Cave 1 probably represents the remains of prey selection by carnivores from an area probably no more than a few kilometers from the cave.

These data support earlier paleontological studies which have implied a colder, drier, grassy environment during the height of the late Wisconsin in central and northern Alaska. However, the preliminary analysis of faunal remains from Cave 1 suggest a more complex paleoecological model for central and northern Alaska and the Yukon Territory, similar to that proposed by Schweger and Habgood (1976: 73). They (i bid.) suggest that considerable ecological diversity may have existed throughout Beringia, both spatially and temporally, during Wisconsin time. They believe this is masked by poor stratigraphic control and provenience of fossil Pleistocene vertebrates and by pollen spectra dominated by Cyperaceae (45-70%) with Gramineae and Artemisia (species associated with drier steppe-like conditions) composing only approximately 25% of the spectra. Data from Cave 1 tend to support this interpretation and suggest that archeological research designs for locating Pleistocene age sites which rely solely on ecological reconstructions based on a vast steppe-like biome may not be viable.

Cultural Analysis. During Unit 3 and 4 times, Cave 1 -was probably occupied sporadically by non-human predators which transported faunal material into the cave. Virtually every bone larger than microtine mandibles or small mammal phalanges is fractured. No articulated skeletal remains were found. The assemblage displayed a variety of fracture patterns, some of which can be ascribed on the basis of puncture marks, "scooping" marks, etc., to carnivore and rodent gnawing. However, most specimens do not display physical evidence of carnivore alteration.

Relying on faunal analysis alone, one might conclude that the spirally fractured bones in Units 3 and 4 were the result of human modification. Yet, no charcoal, lithic debitage, burned bone, or tools were recovered from Units 3 or 4. There is no indication that the cave was used even briefly by man during this interval, unless the occurrence of fractured bone, including that of large animals not associated with cave habitats considered sufficient evidence to demonstrate human utilization of the cave.

Cave 2. Ten distinct stratigraphic units were observed in a one meter wide test trench which was excavated from the interior of the cave to outside the entrance (Fig. III-28). The maximum depth of the excavation was 5.5 meters. Wall collapse in the test trench was a major problem during excavation. Generally, the deposits were loosely consolidated. Individual stratigraphic units ranged in consistency from unsorted large and medium sized rubble, to fairly well sorted fine-grained deposits. Charcoal was observed in several layers, and was densely concentrated in a few locations. Numerous well preserved bone specimens representing small to medium sized mammals were recovered throughout the deposits, and several fractured bone fragments representing a large mammal in the moose size range were found in fine-grained deposits 5.5 meters below the present cave floor. The breakage of these deeply buried large mammal bones and the deposits from which they were recovered (possibly indicating an early stable cave floor) are suggestive of carnivore activity. No unequivocal cultural material was recognized. Excavations at this cave had to be abandoned because the unstable deposits created serious hazards to the

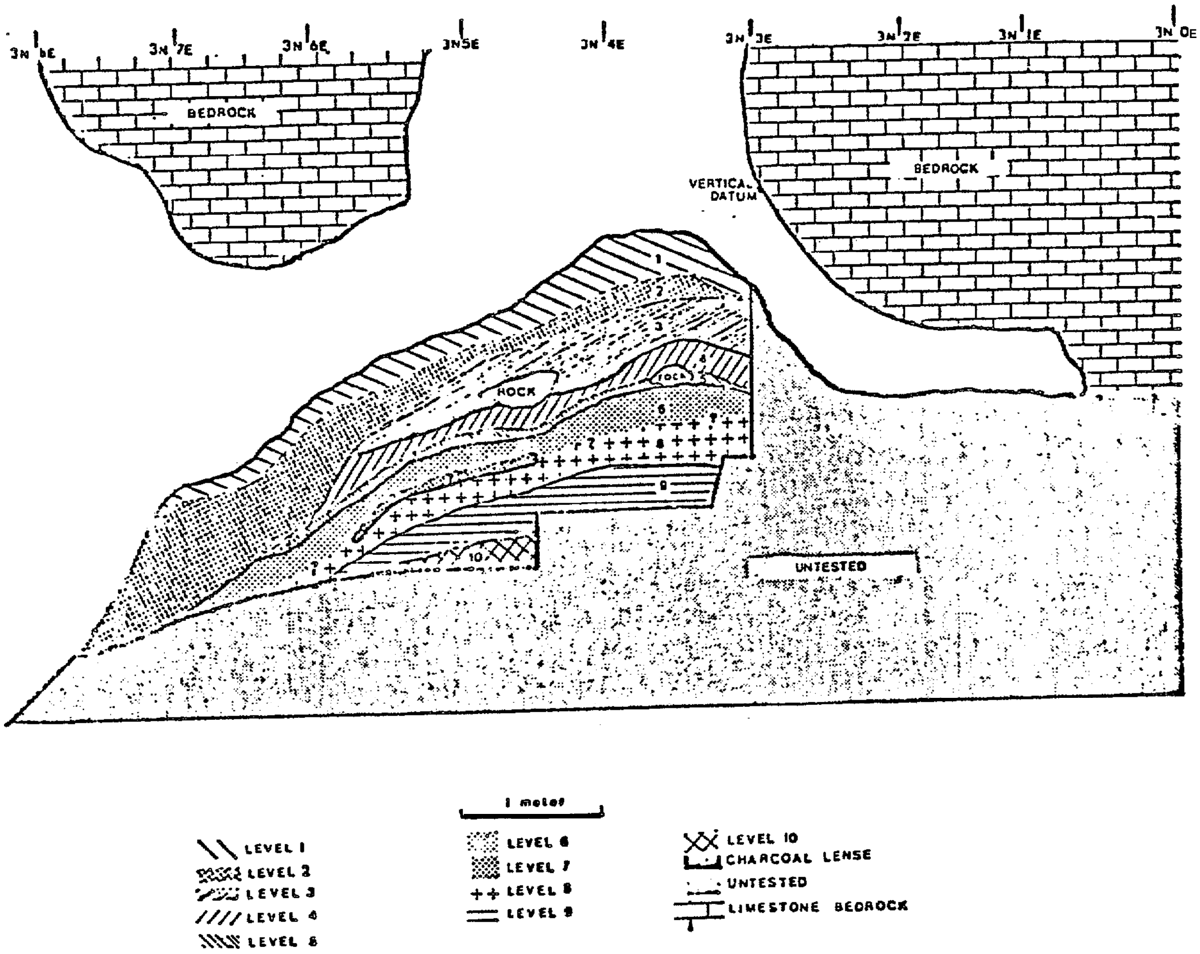


Figure III-28: Strati graphic Profile, Cave 2.

excavation crew. The bottom of the deposit was not reached, however ^{14}C age determinations on charcoal from the lower levels of this deposit indicate that it is probably no older than 7,000 yr B.P. Thus the stratigraphic units tested at Cave 2 did not demonstrate sufficient age to provide a valid test for human occupation of Alaska during times of Pleistocene marine regression.

Cave 3. Testing was begun at what initially appeared to be an almost completely filled cave with only a portion of the arched roof visible. Excavation revealed that this cave was not of a size or configuration which could have been occupied by humans. This cave consisted of little more than a 50 cm high solution cavity which extended into bedrock. The investigation of Cave 3 illustrates the difficulties of determining the archeological potential of partially buried caves through excavation.

Cave 4. A number of layers, which were divided into four major stratigraphic units, were excavated vertically to a depth of 4 meters below the cave floor. The" bottom of the cave deposits was not reached during testing. Stratigraphic units consist largely of fine-grained eolian sediments. Organic layers and charcoal lenses were also observed. A variety of well-preserved bone was recovered and small, medium, and large mammals are represented. However, no stone or bone tools indicative of human occupation of this cave were discovered.

D. Summary

This discussion has presented a summary of information bearing on the human habitation of the Bering Land Bridge. This synthesis has included the following major points. (1) Analysis of the Pleistocene prehistory of arctic North America; the distribution and diversity of archeological sites dating to Late Wisconsin-Early Holocene times strongly suggests that these sites are later manifestations of even earlier traditions; (2) A suggested late date (ca. 8,500 B.P.) for the fluted point tradition in Alaska strongly suggests that man penetrated regions south of the continental ice prior to coalescence of the Cordilleran and Laurentide ice sheets. (3) Recent archeological data from Siberia indicates that man had achieved a sufficient level of adaptation to inhabit adjacent northern latitudes 35,000 years ago, thus making the human population of the Bering Land Bridge feasible. (4) The fact that no archeological sites of Wisconsin age have been discovered on the Bering Land Bridge or the eastern Beringia region reflects a lack of research and cannot be taken as proof that man did not inhabit the area. (5) The body of anthropological literature and theory relating to Northern hunting cultures indicates that settlements of Wisconsin hunters are most likely to be discovered in areas where surplus faunal harvests were possible. (6) Specialists were called upon to reconstruct the paleogeography and project faunal distributions for presently submerged areas of Beringia. Methods were developed for identifying areas of high archeological site potential on the Bering Land Bridge.

This study integrates diverse evidence supporting the human occupation of the Bering Land Bridge into a comprehensive model for Pleistocene settlement patterns. It presents a human" settlement pattern model which is integrated in terms of geographic specificity. This model has included three levels of spatial analysis directed to facilitate marine archeological survey:

1. Continental -- a reconstruction of the paleogeography of Beringia (the Outer Continental Shelf stretching between Asia and North America, presently including the floors of the Bering and Chukchi seas), and adjacent terrestrial areas.

2. Regional --- an analysis of specific areas within Beringia, based on paleogeographic reconstruction and including probable seasonal distributional patterns of terrestrial and marine mammal populations.

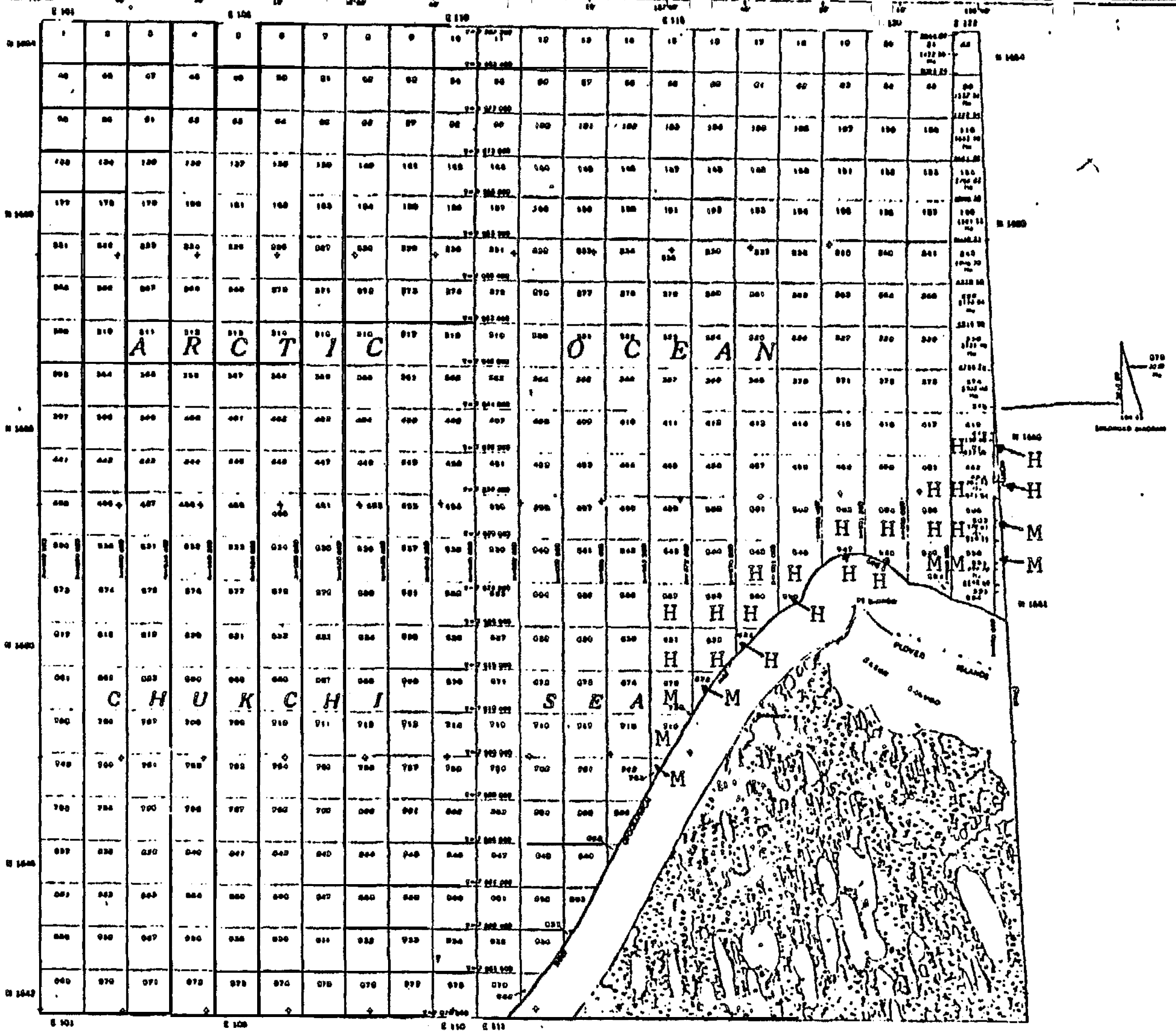
3. Sectional -- a one square mile survey area equivalent to (but not the same as) a U.S.G.S. section.

USGS protraction diagrams are included in Appendix III-A which rank potential lease blocks on the Alaska Outer Continental Shelf in order of high, moderate, and low archeological potential using the foregoing model.

Appendix III-A

List of Protraction diagrams showing areas of archeological low, medium, and high potential on the Alaska Outer Continental Shelf (82 'maps).

Page



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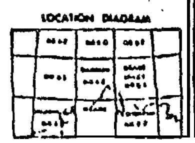
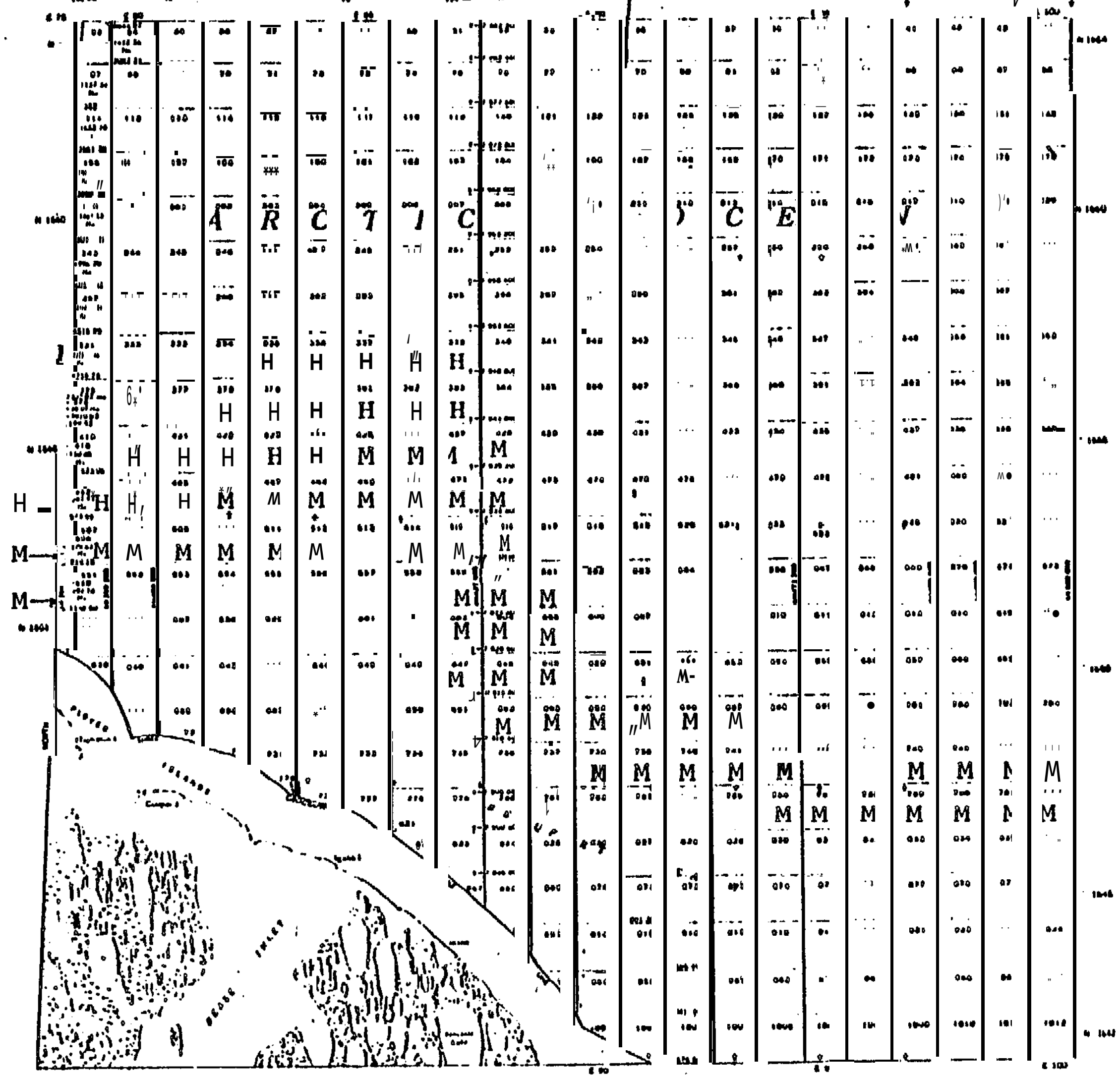
H	Area of high potential
M	Area of moderate potential
	Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM





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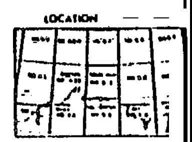
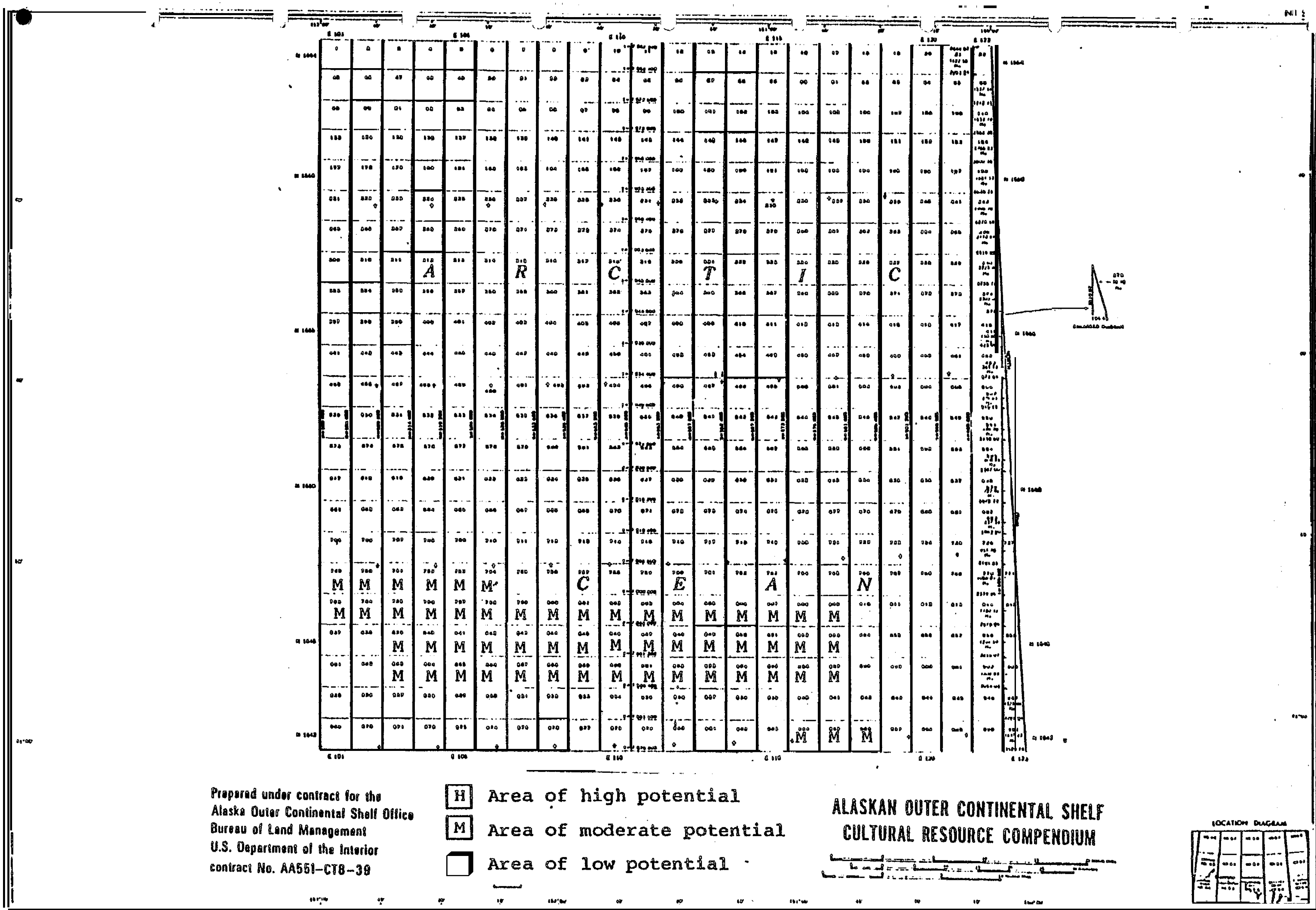
CULTURAL RESOURCE COMPENDIUM

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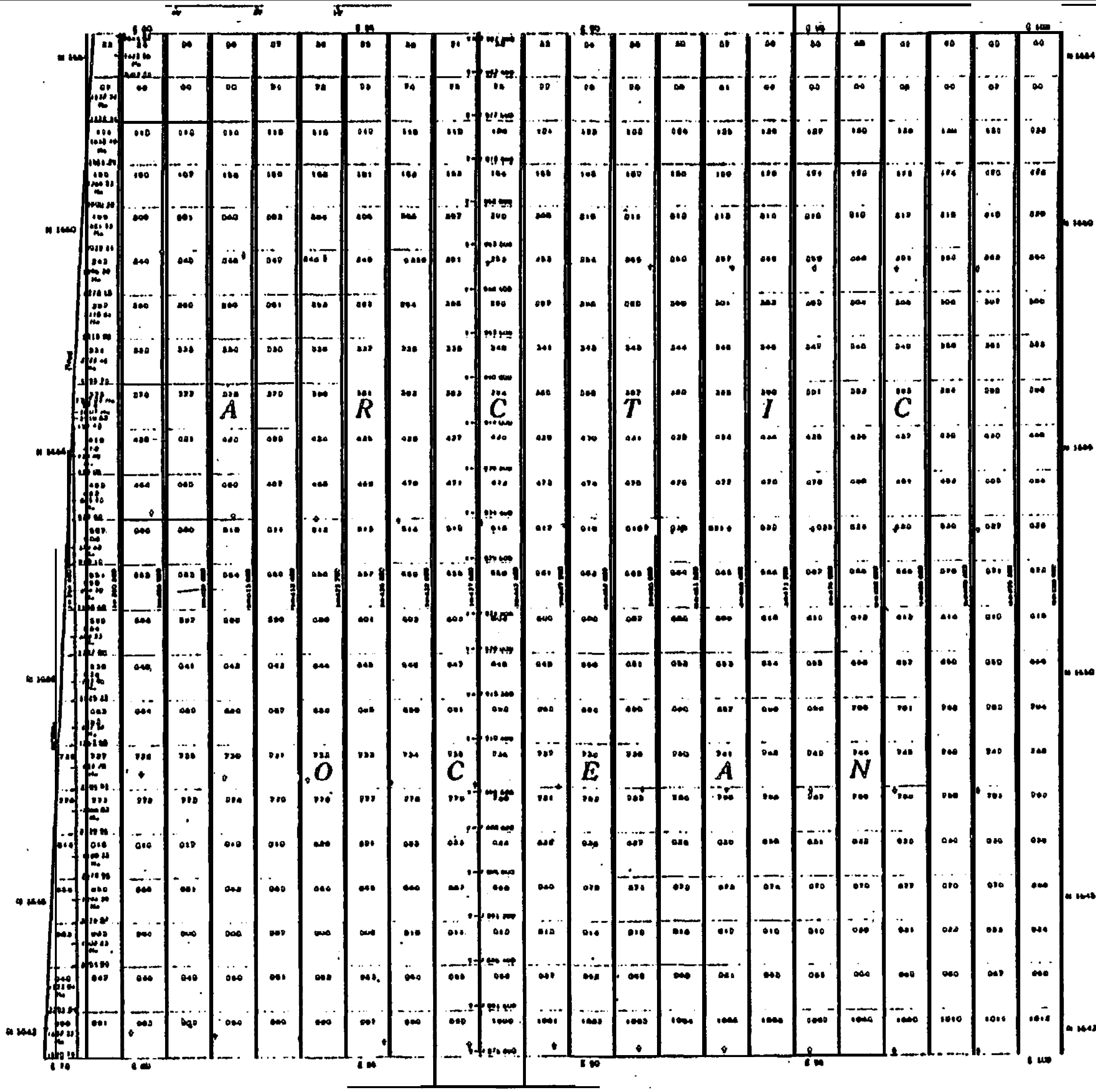

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ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

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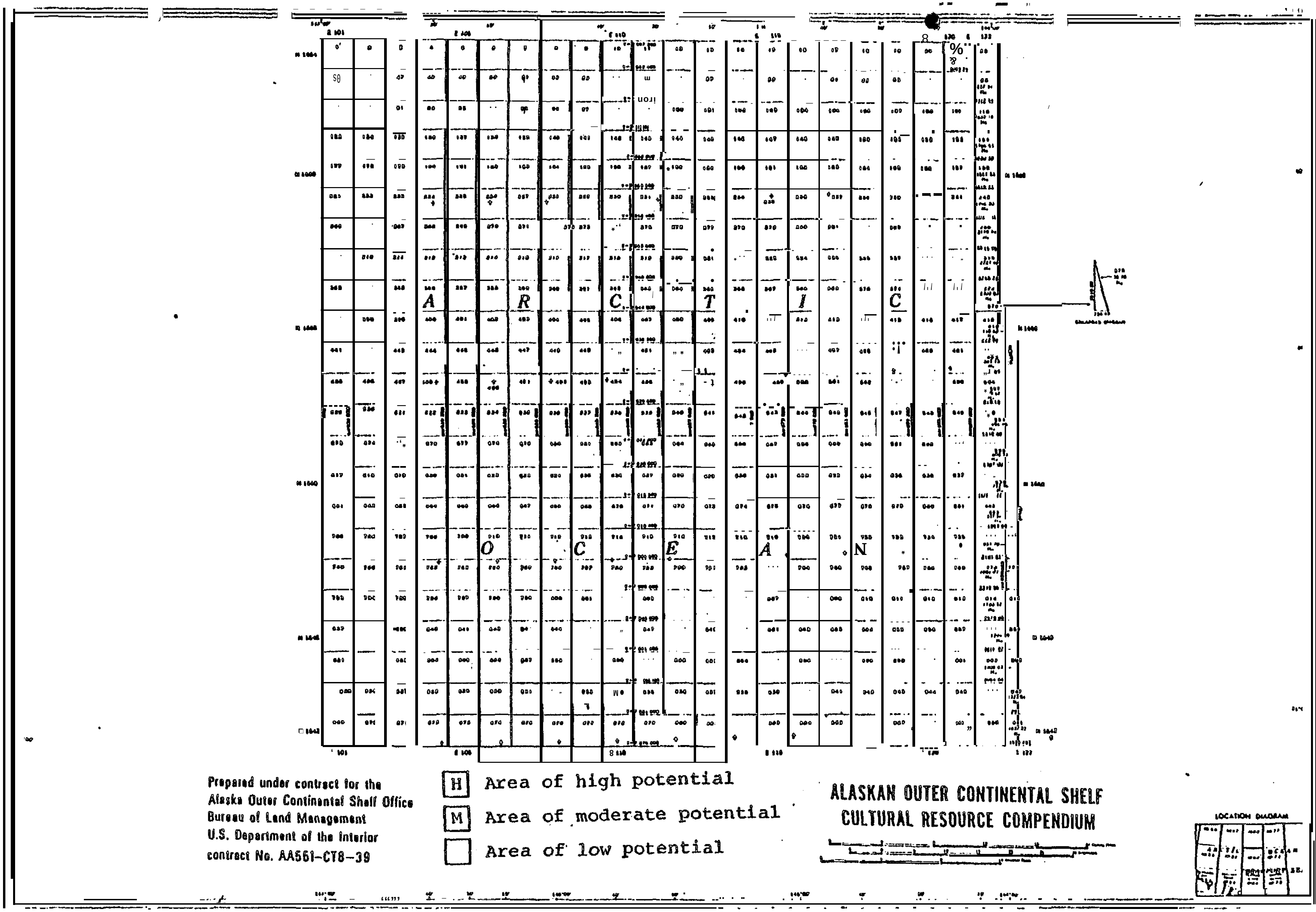
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LOCATION DIAGRAM
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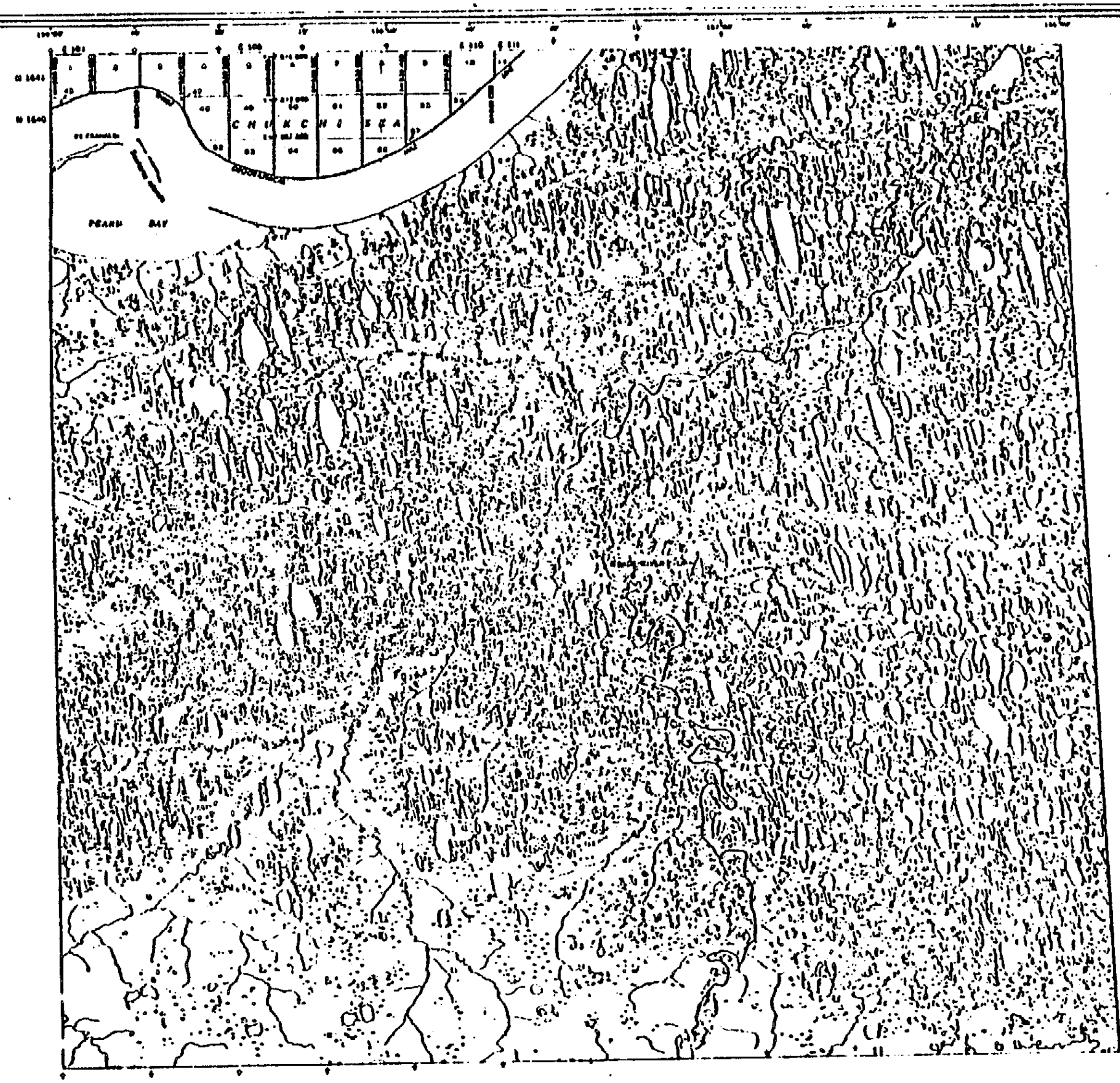

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CULTURAL RESOURCE COMPENDIUM

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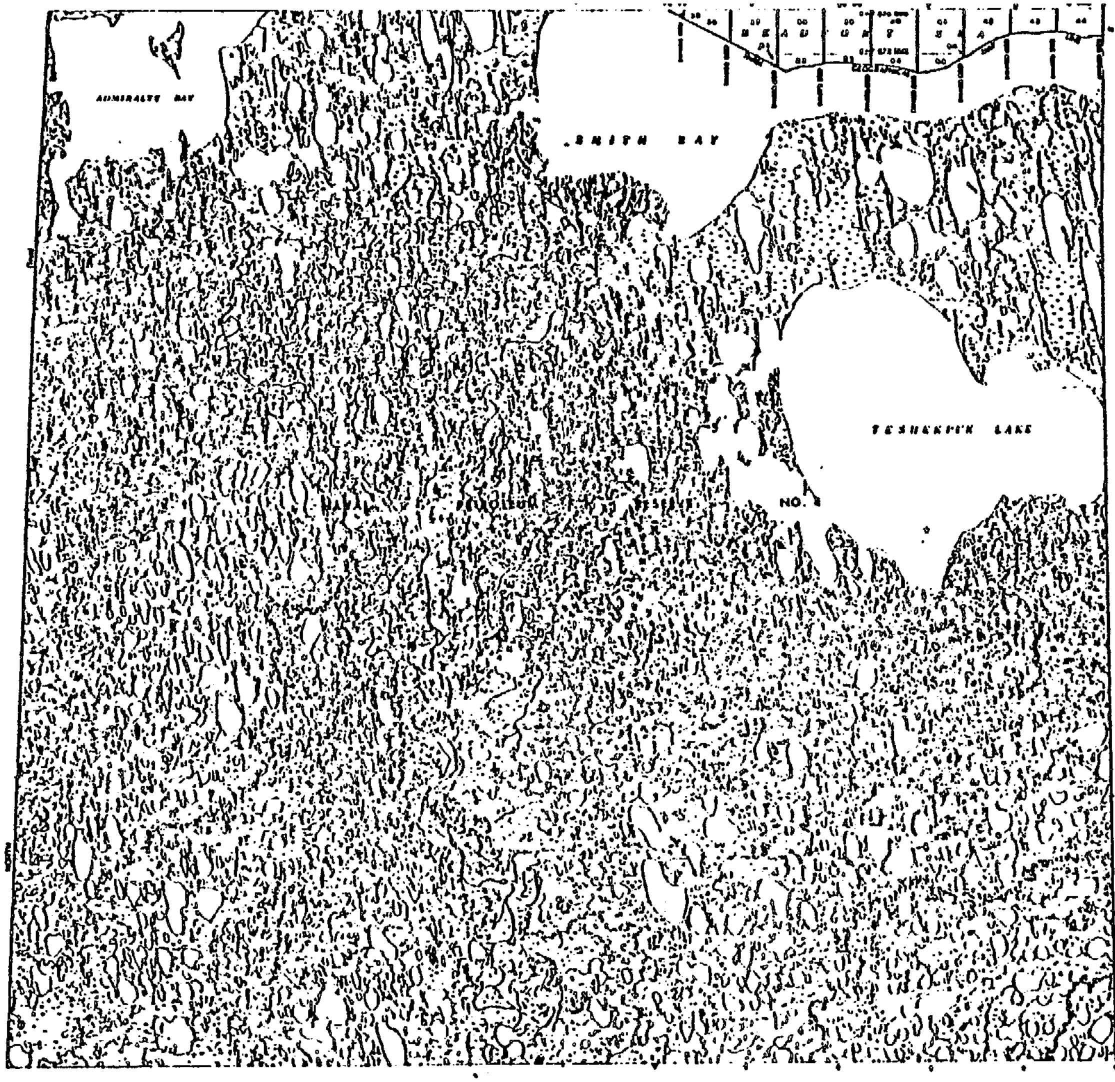

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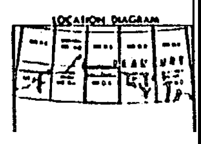

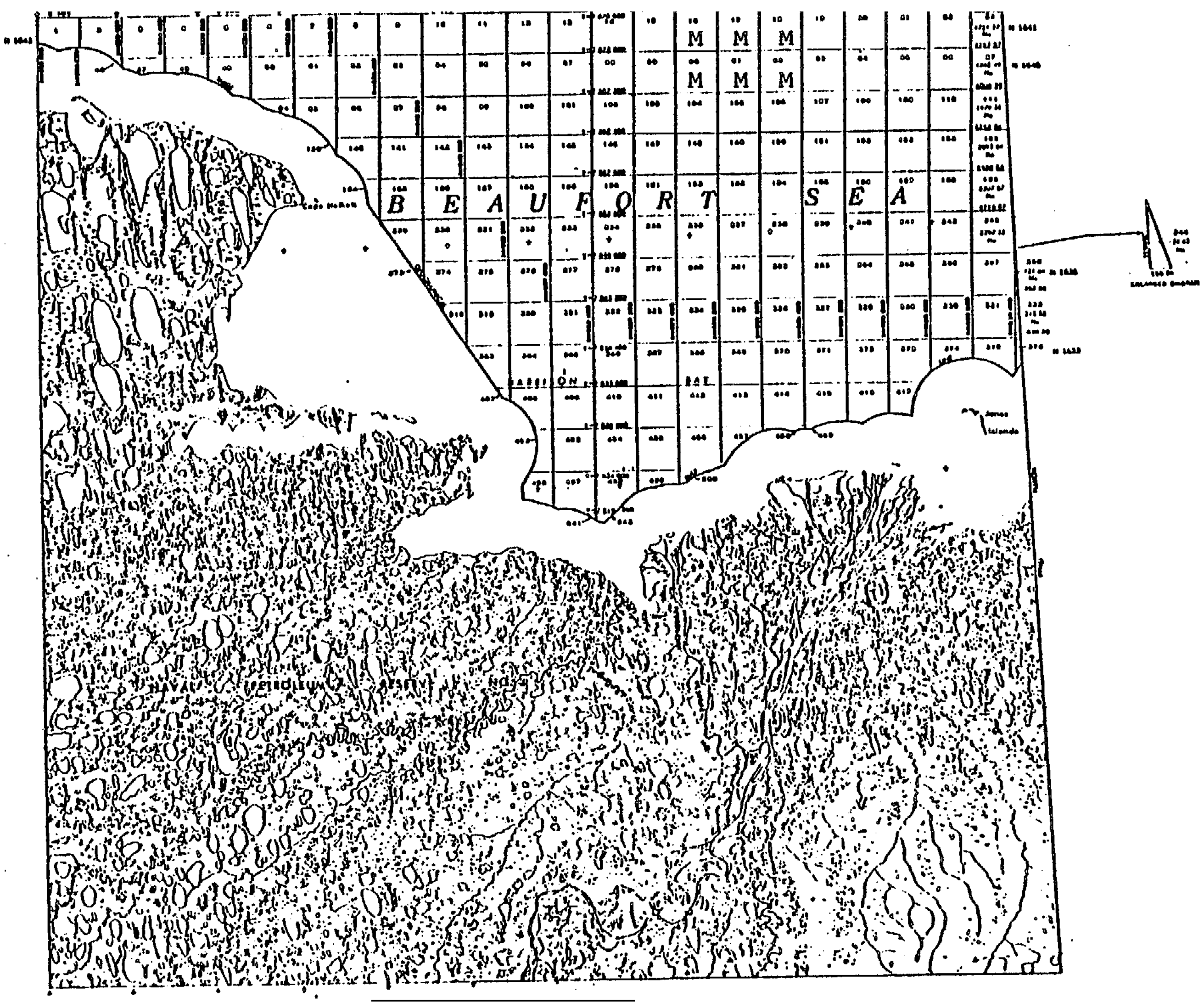

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Area of low potential

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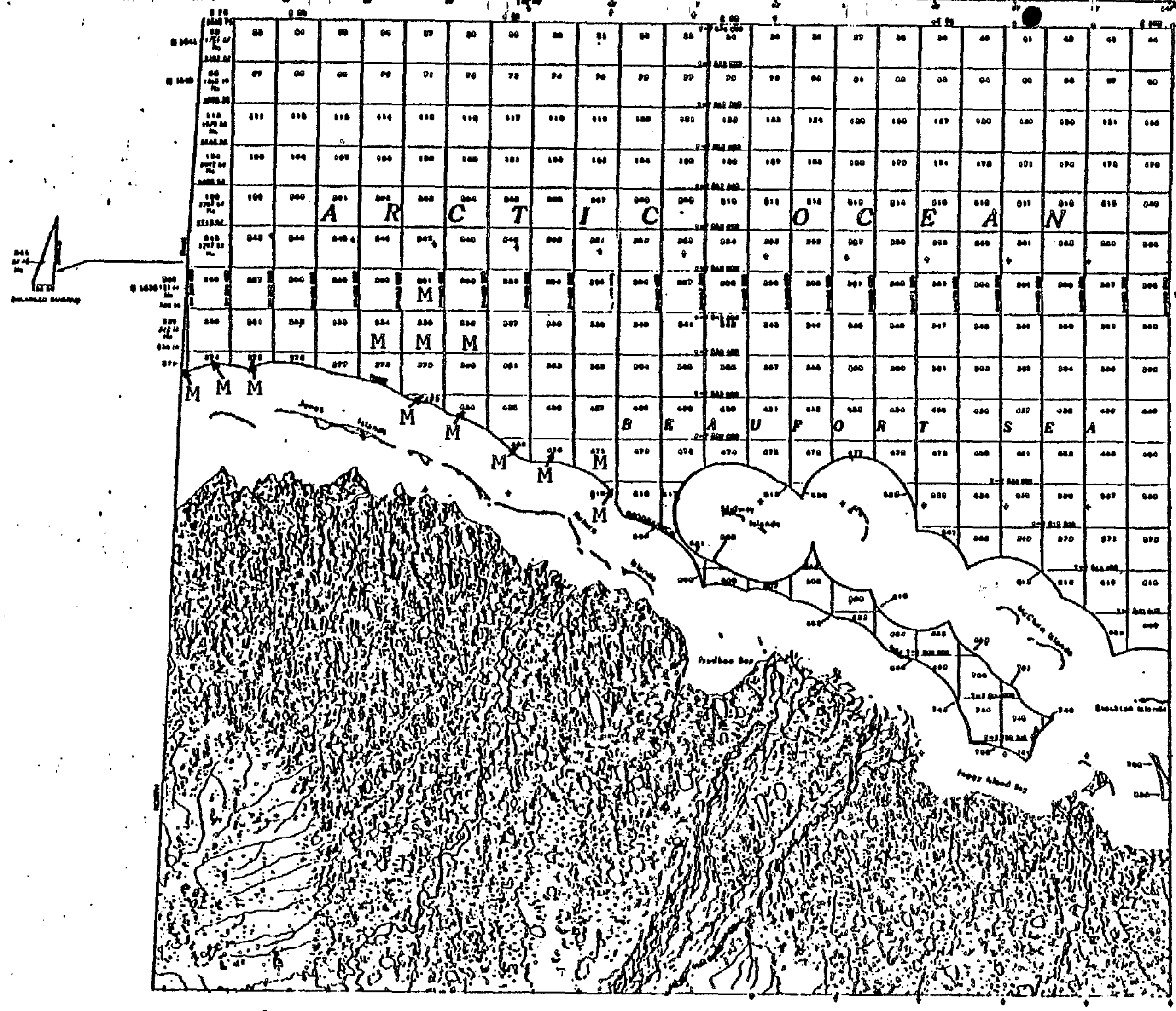

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ALASKAN OUTER CONTINENTAL SHELF CULTURAL RESOURCE COMPENDIUM

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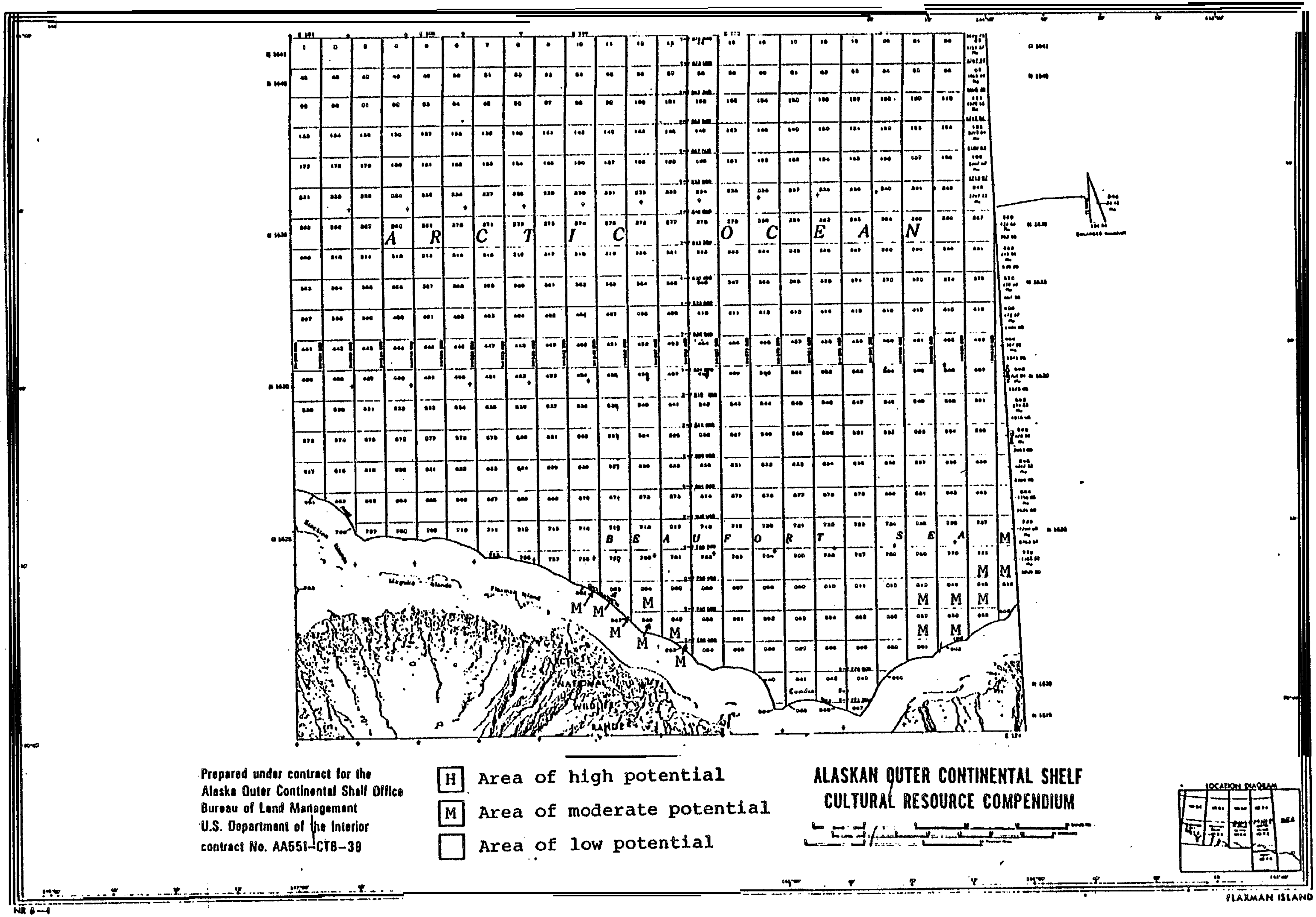

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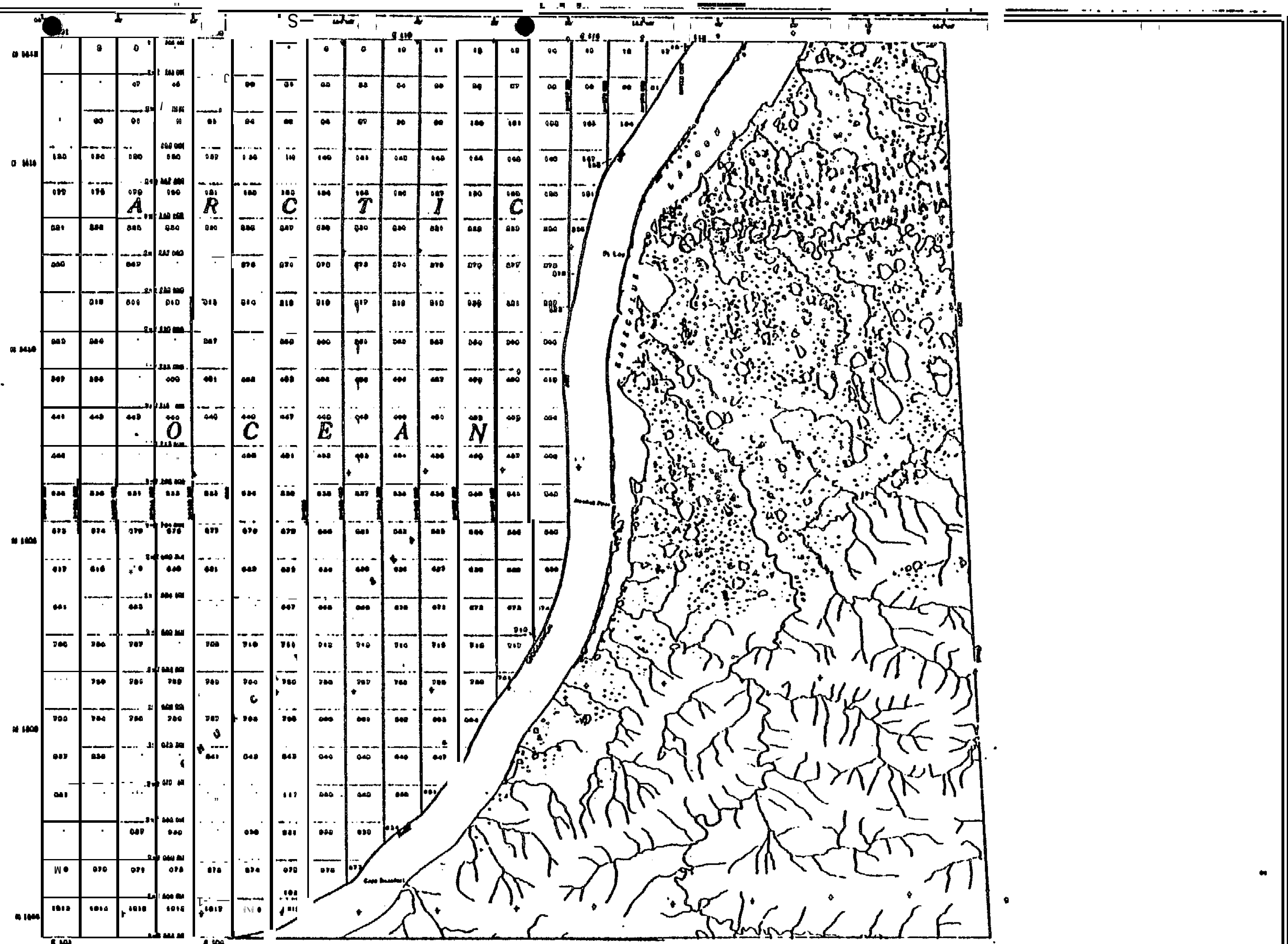
ALASKAN OUTER CONTINENTAL SHELF CULTURAL RESOURCE COMPENDIUM



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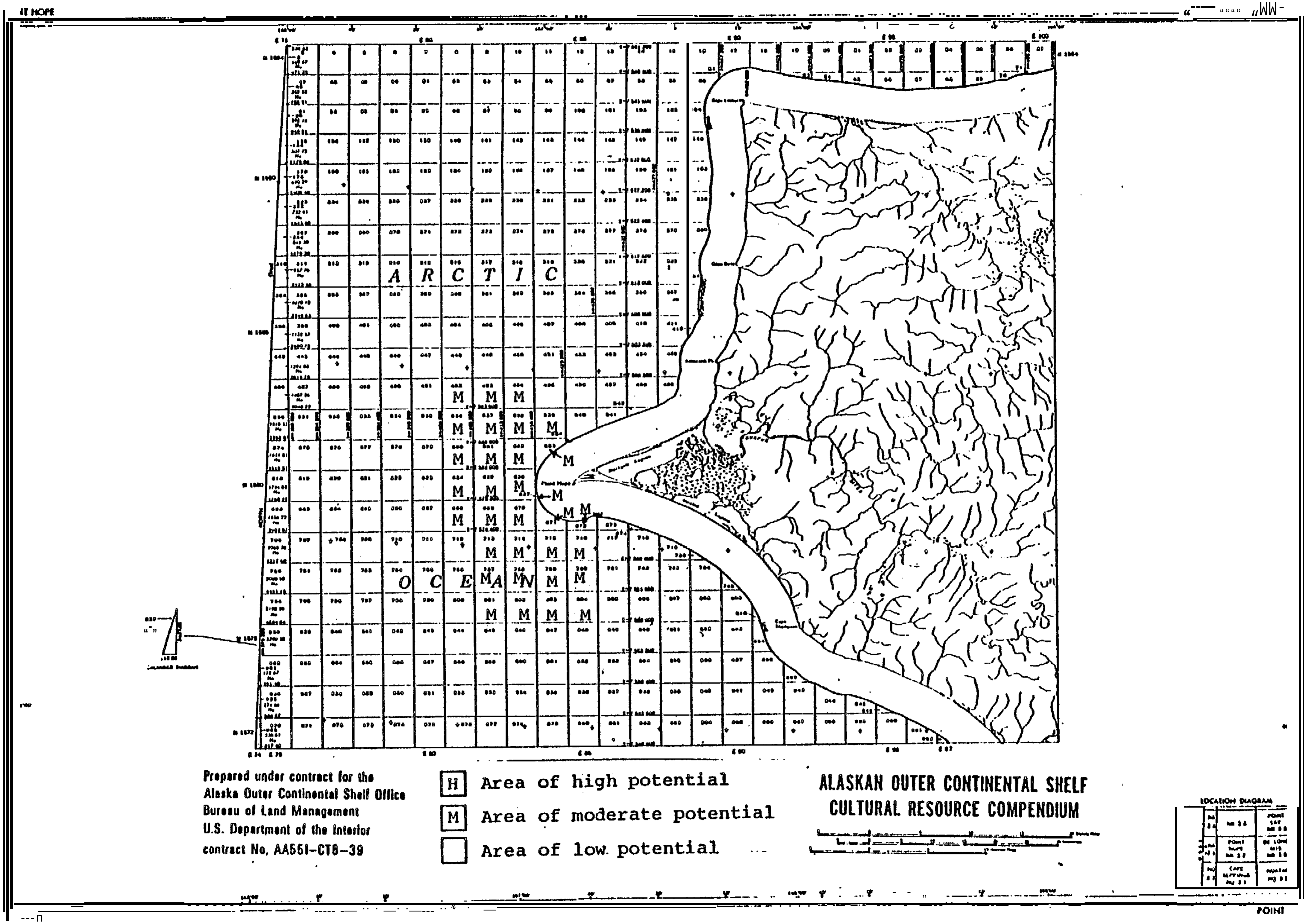
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LOCATION DIAGRAM
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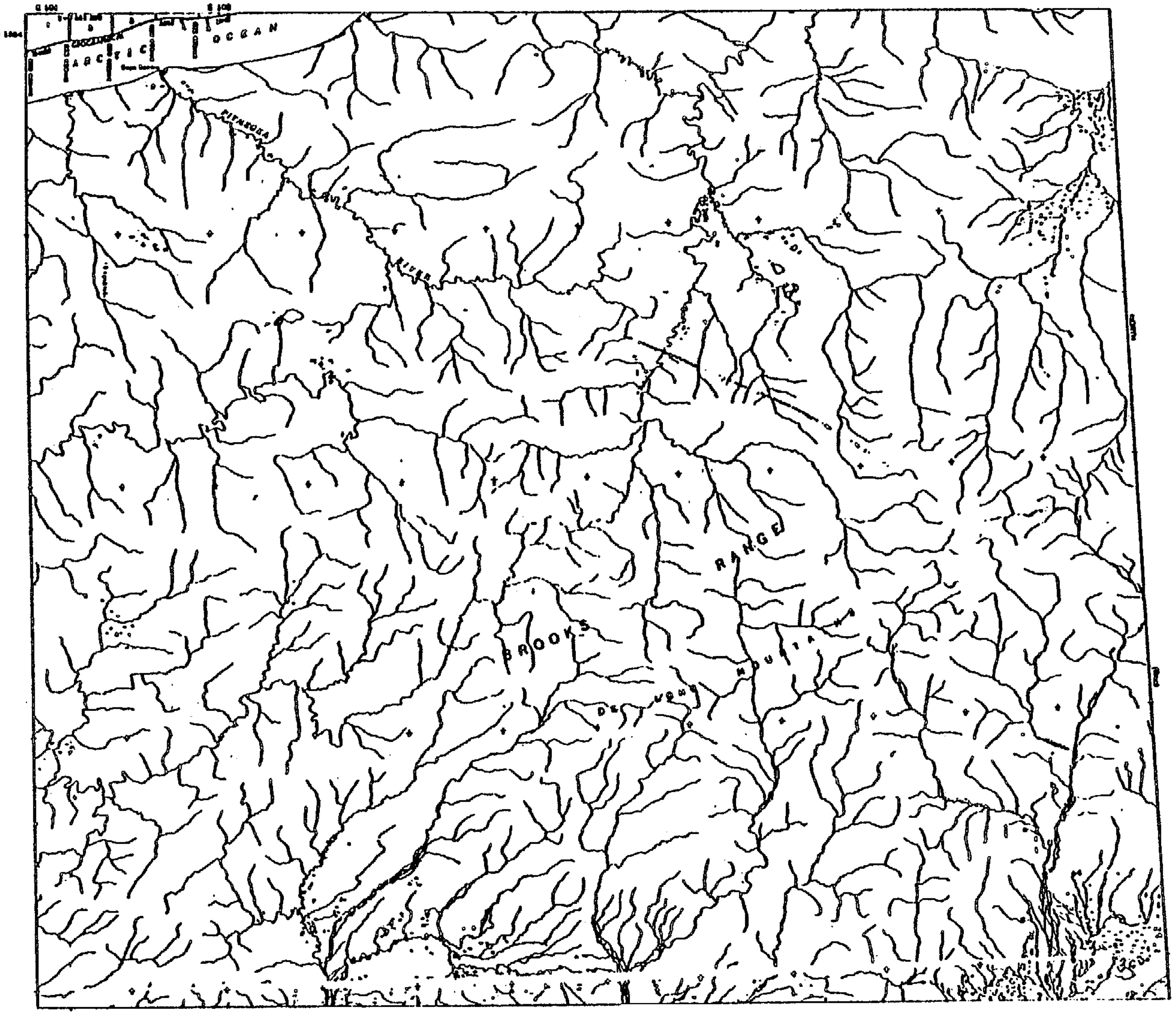

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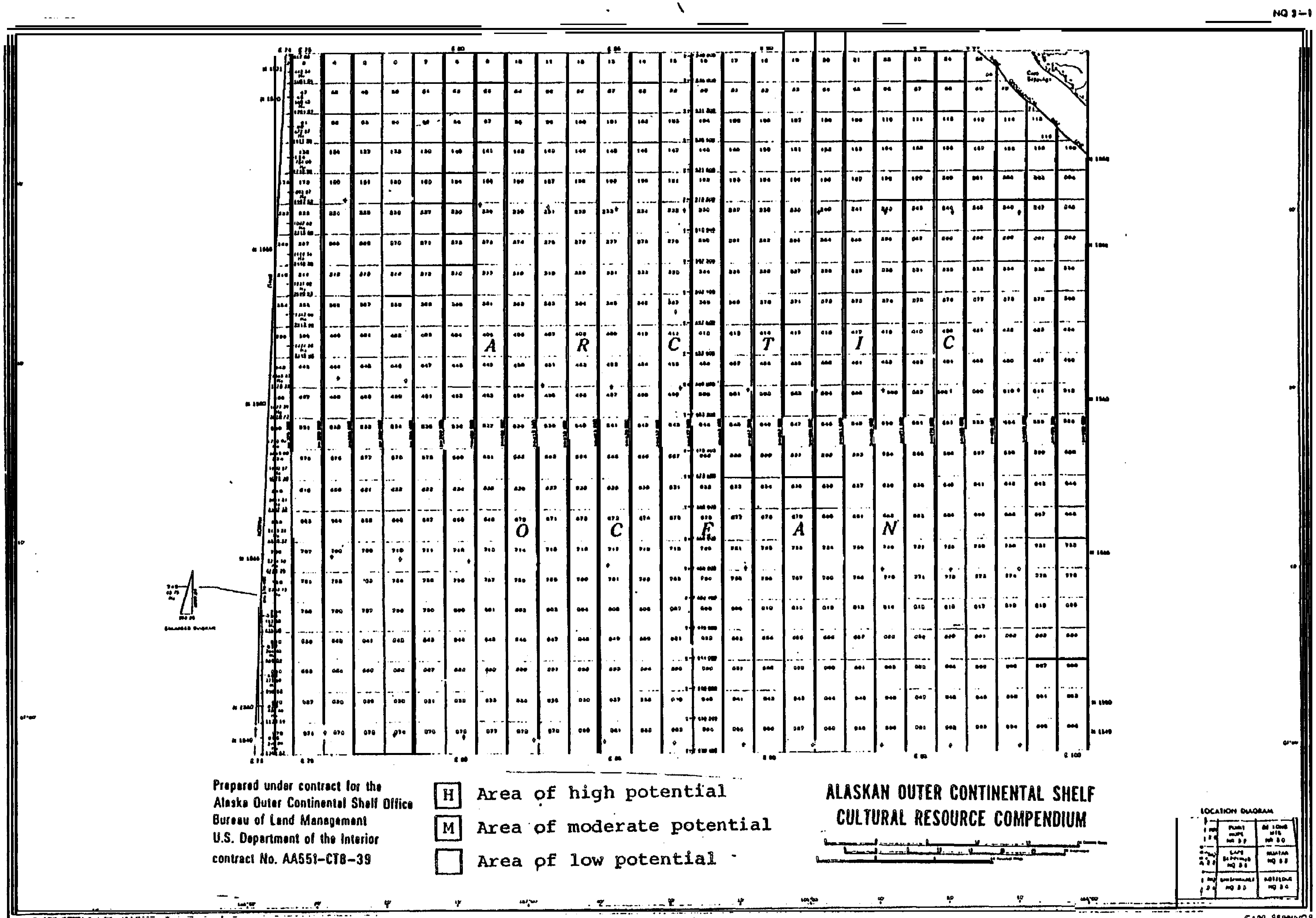

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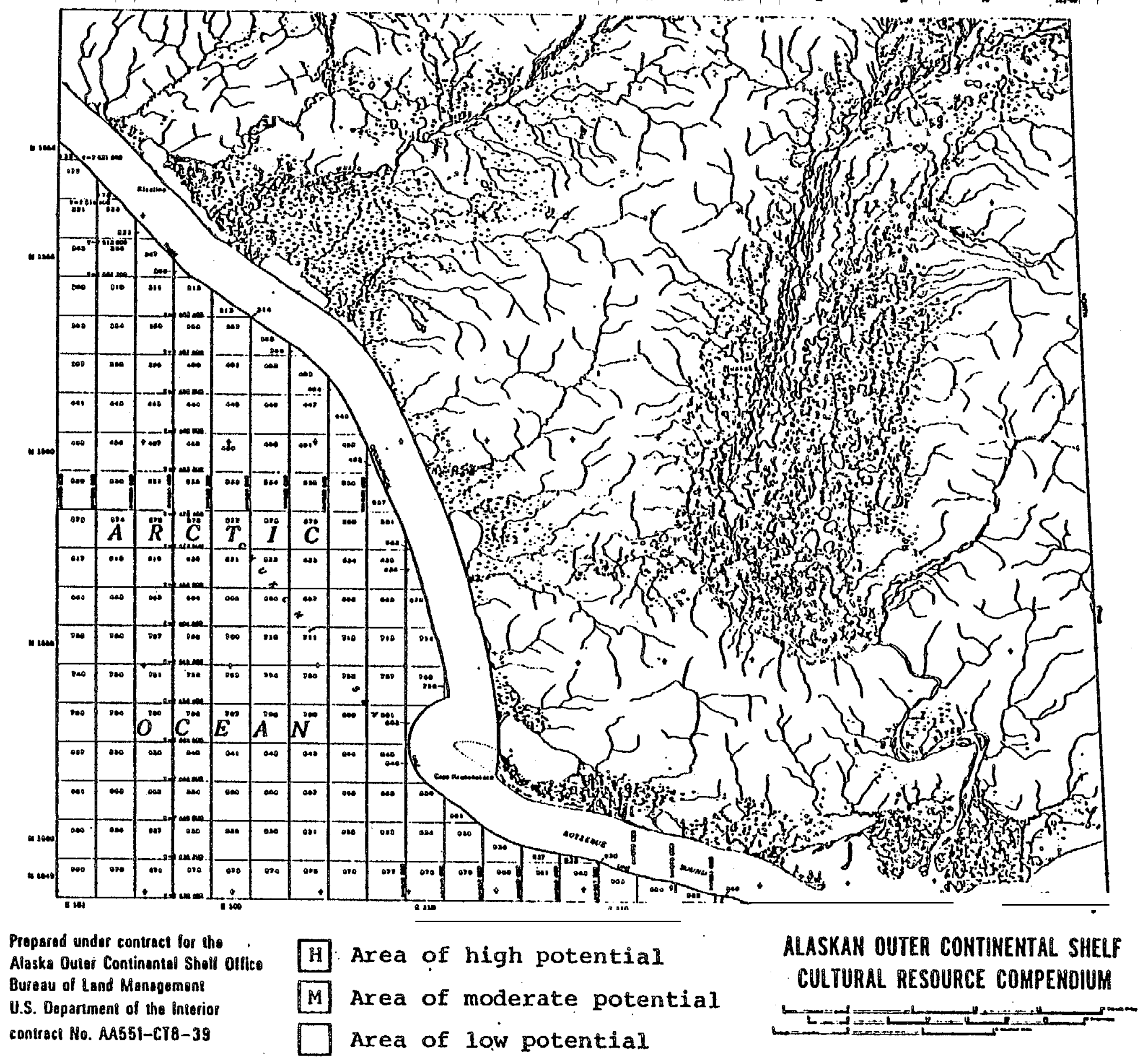
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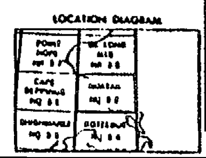
CULTURAL RESOURCE COMPENDIUM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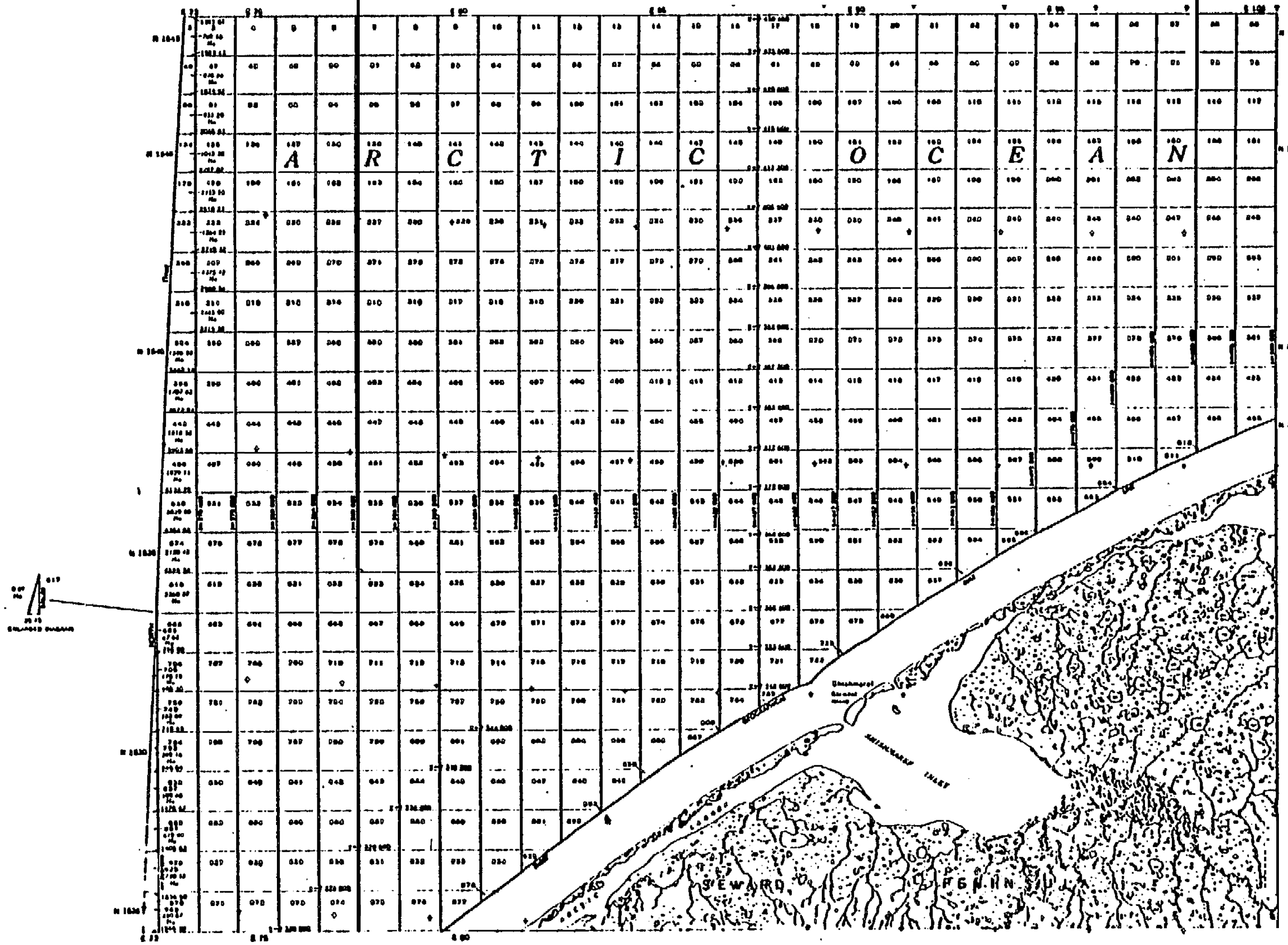

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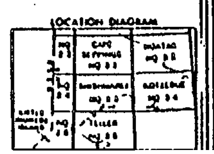

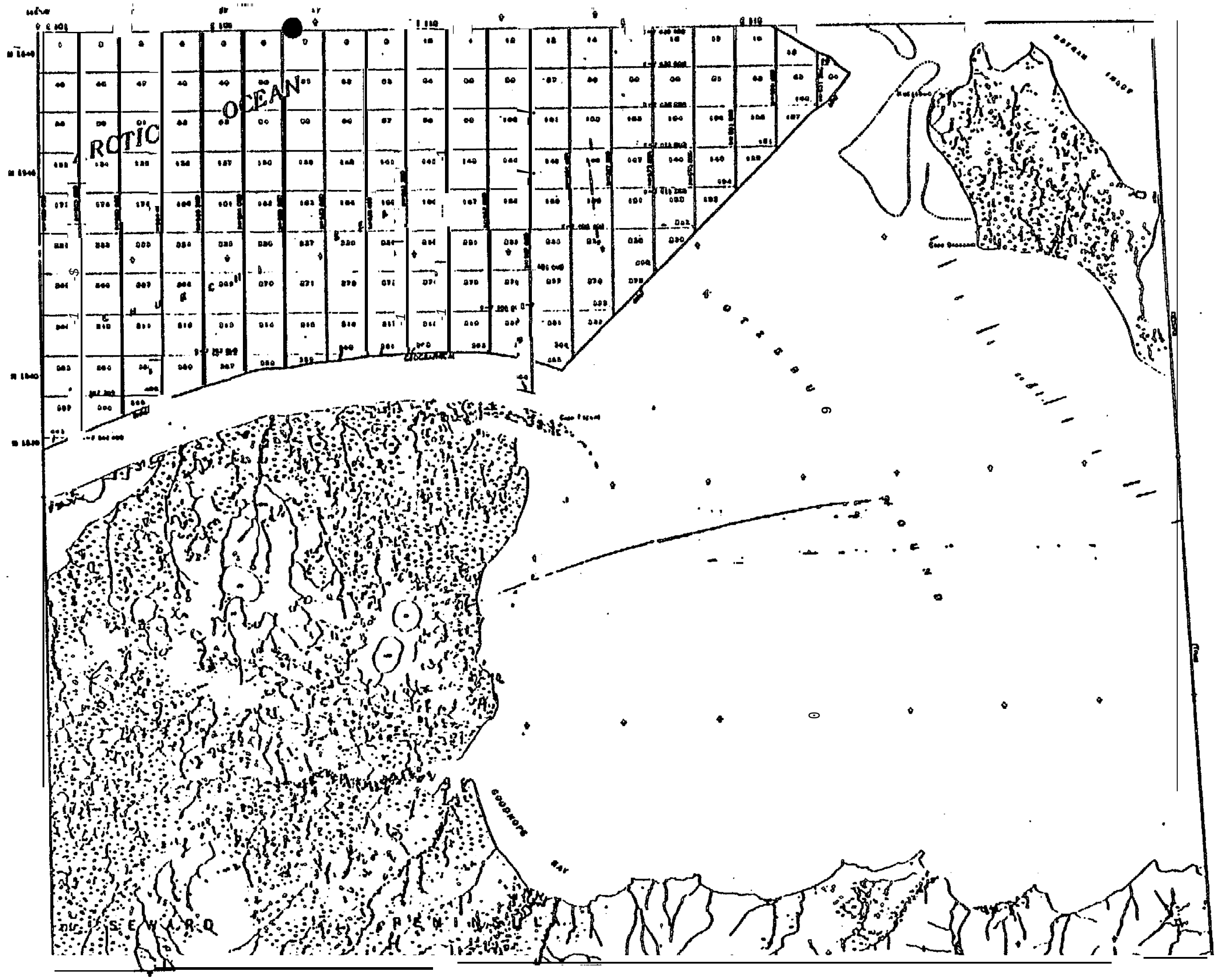

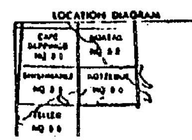

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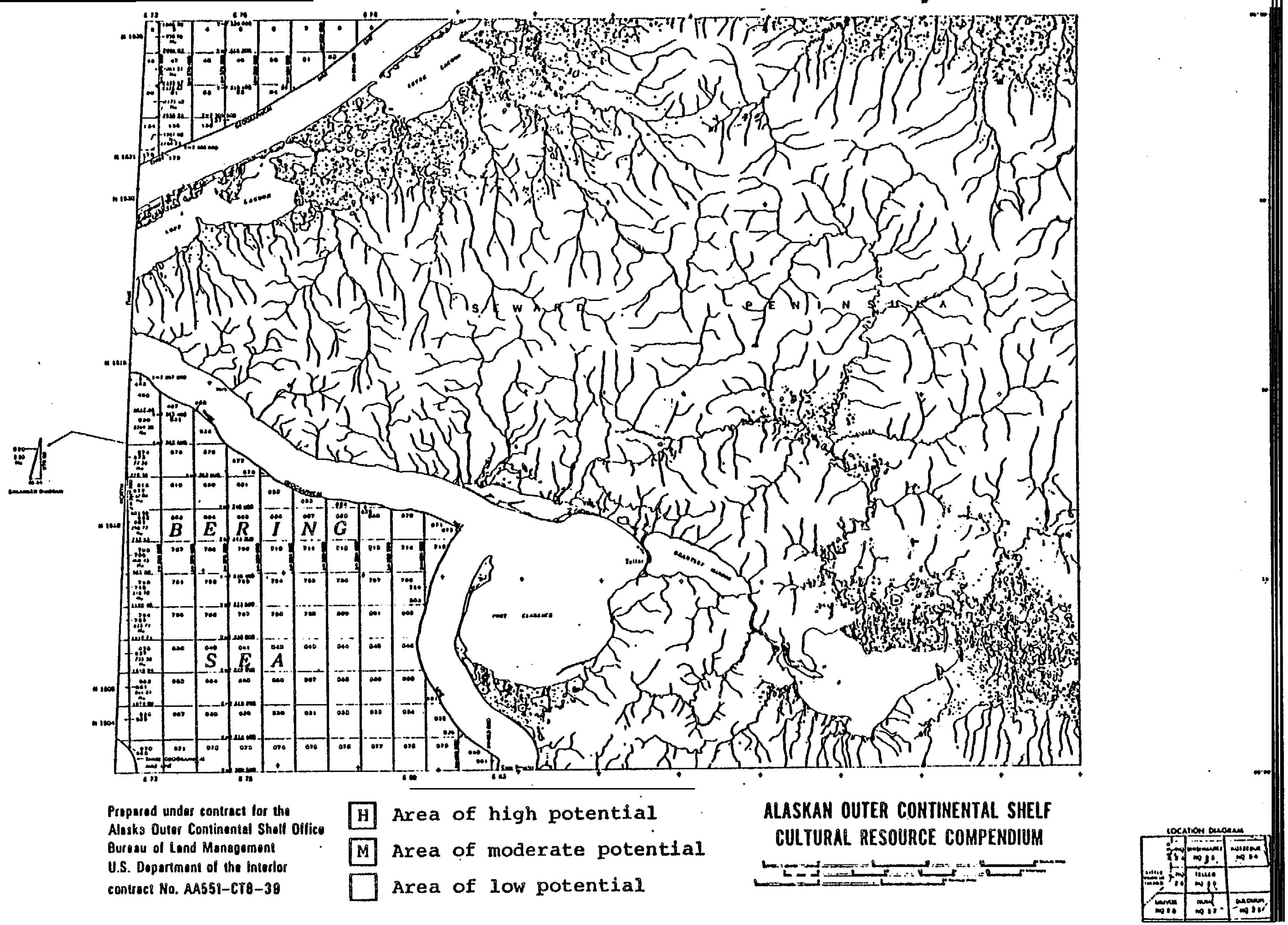

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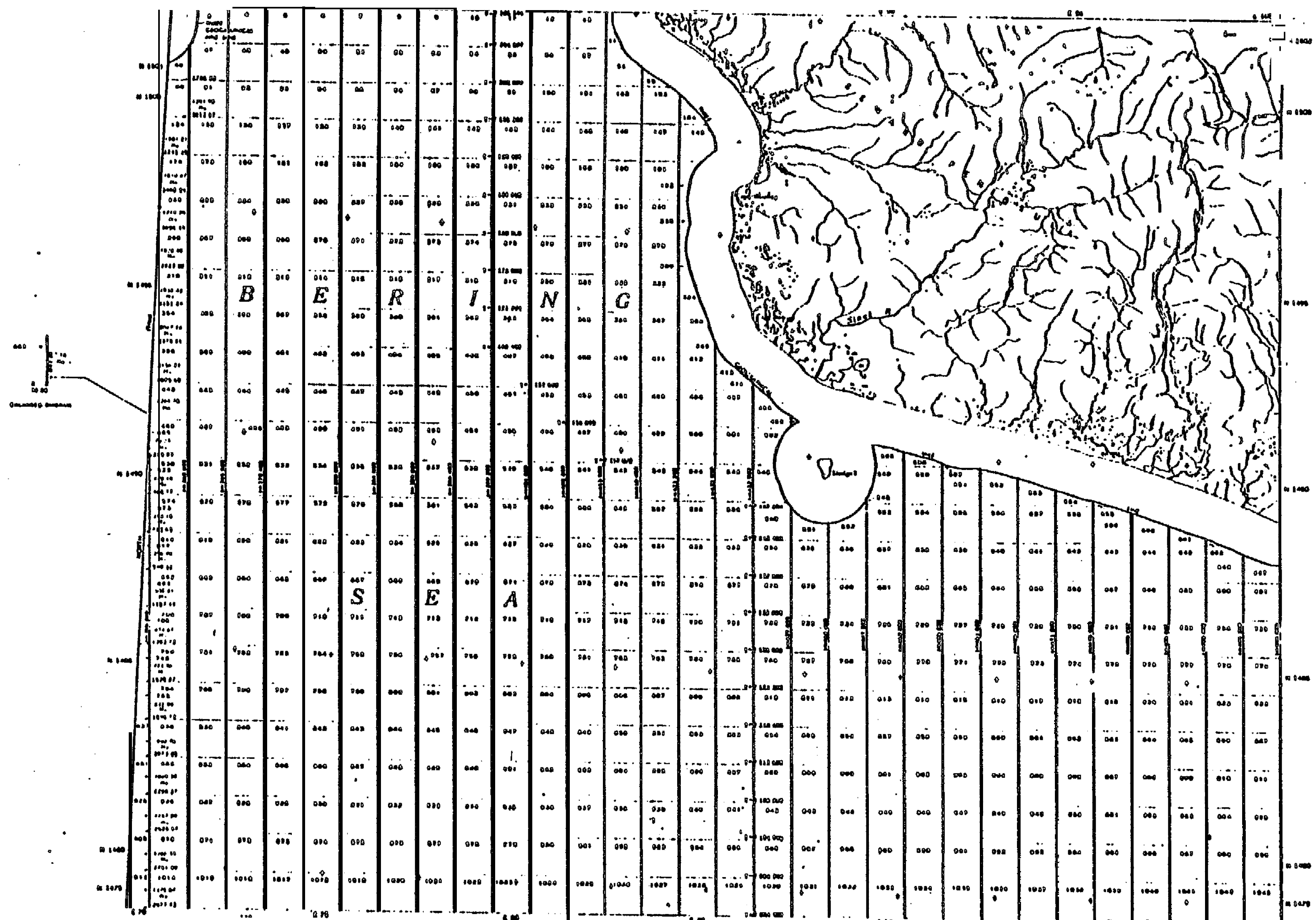
M Area of moderate potential
Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



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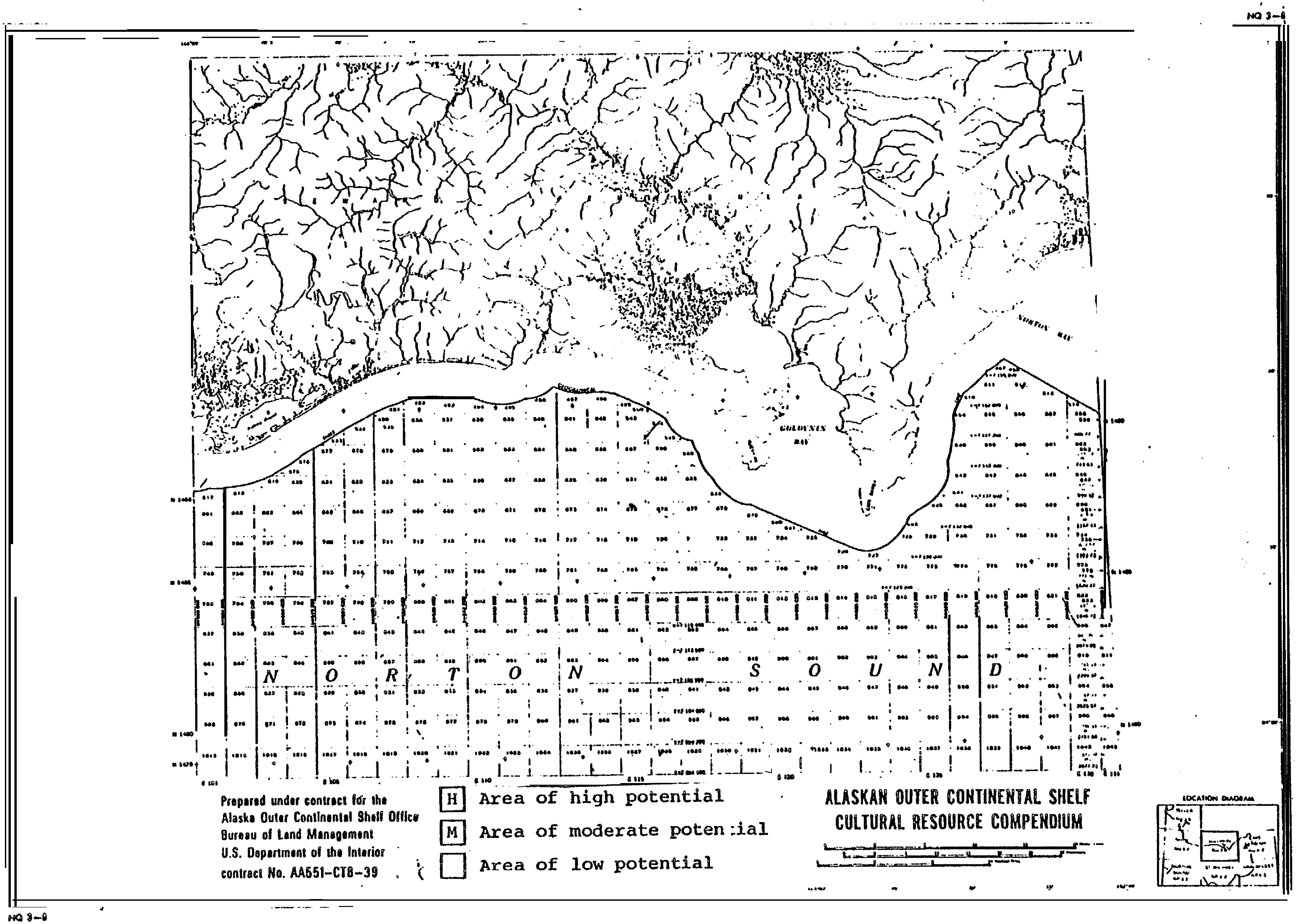
ALASKAN OUTER CONTINENTAL SHELF CULTURAL RESOURCE COMPENDIUM


NORTON SOUND
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ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM
LOCATION DIAGRAM
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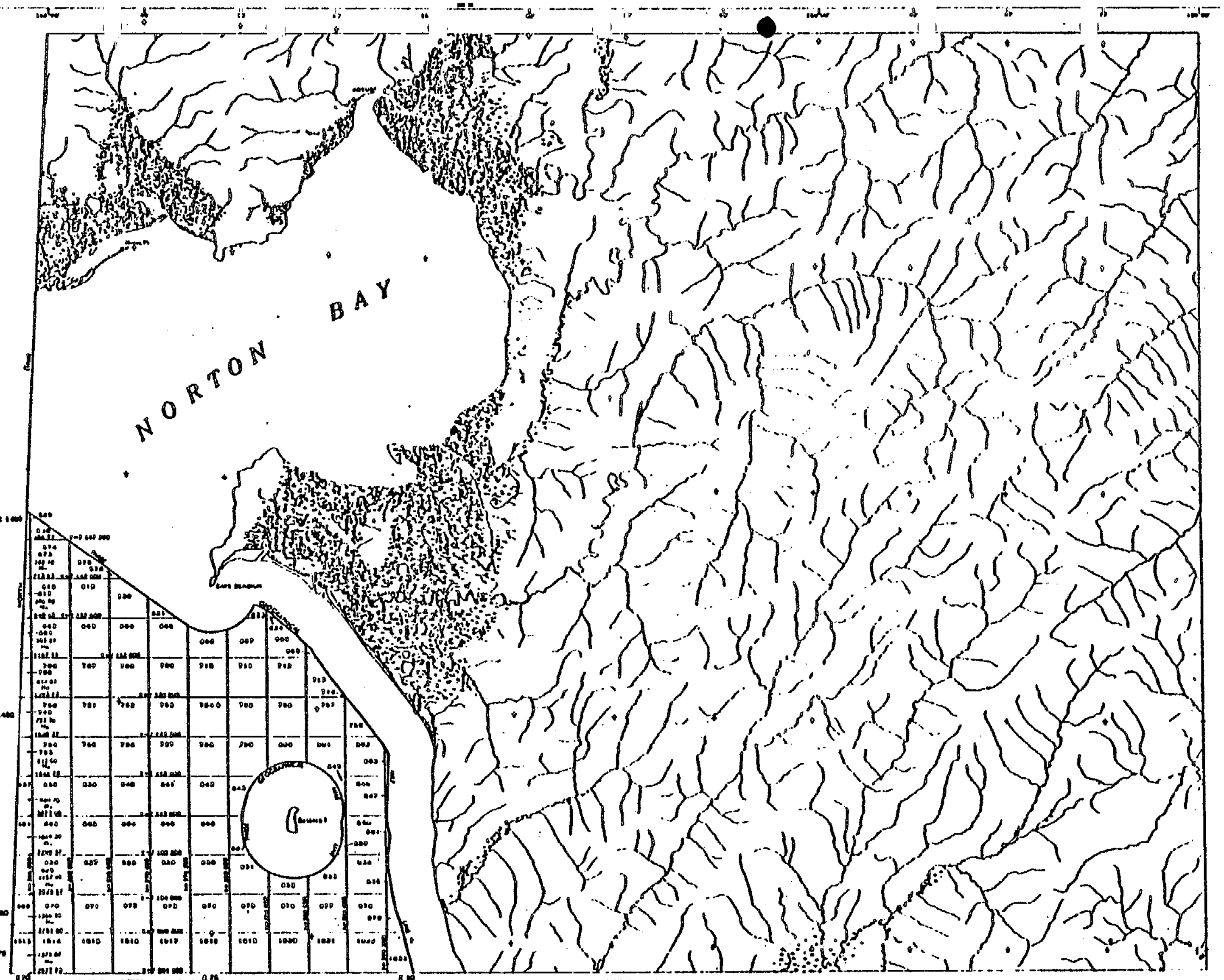

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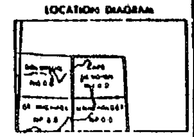
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

LOCATION DIAGRAM



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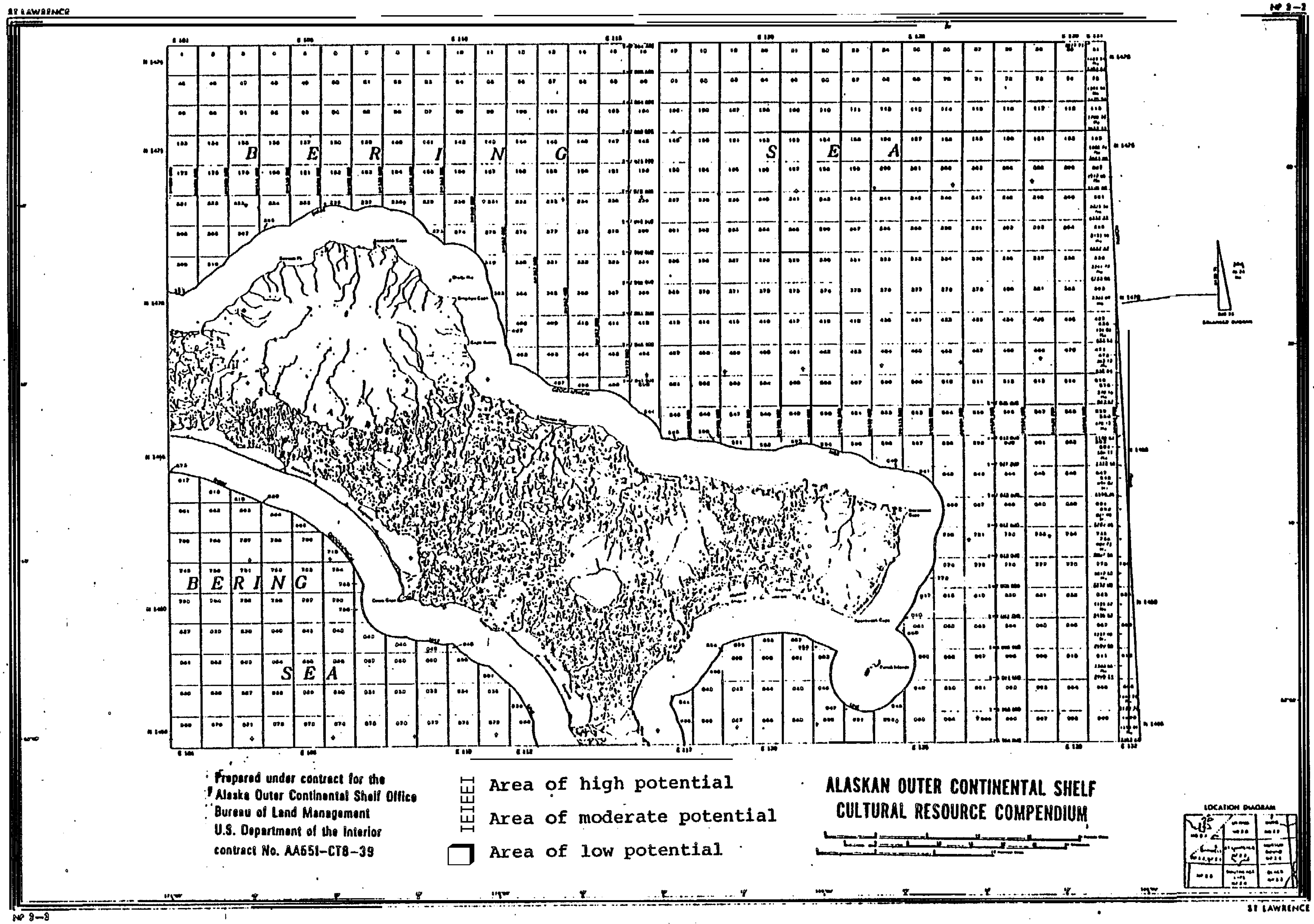

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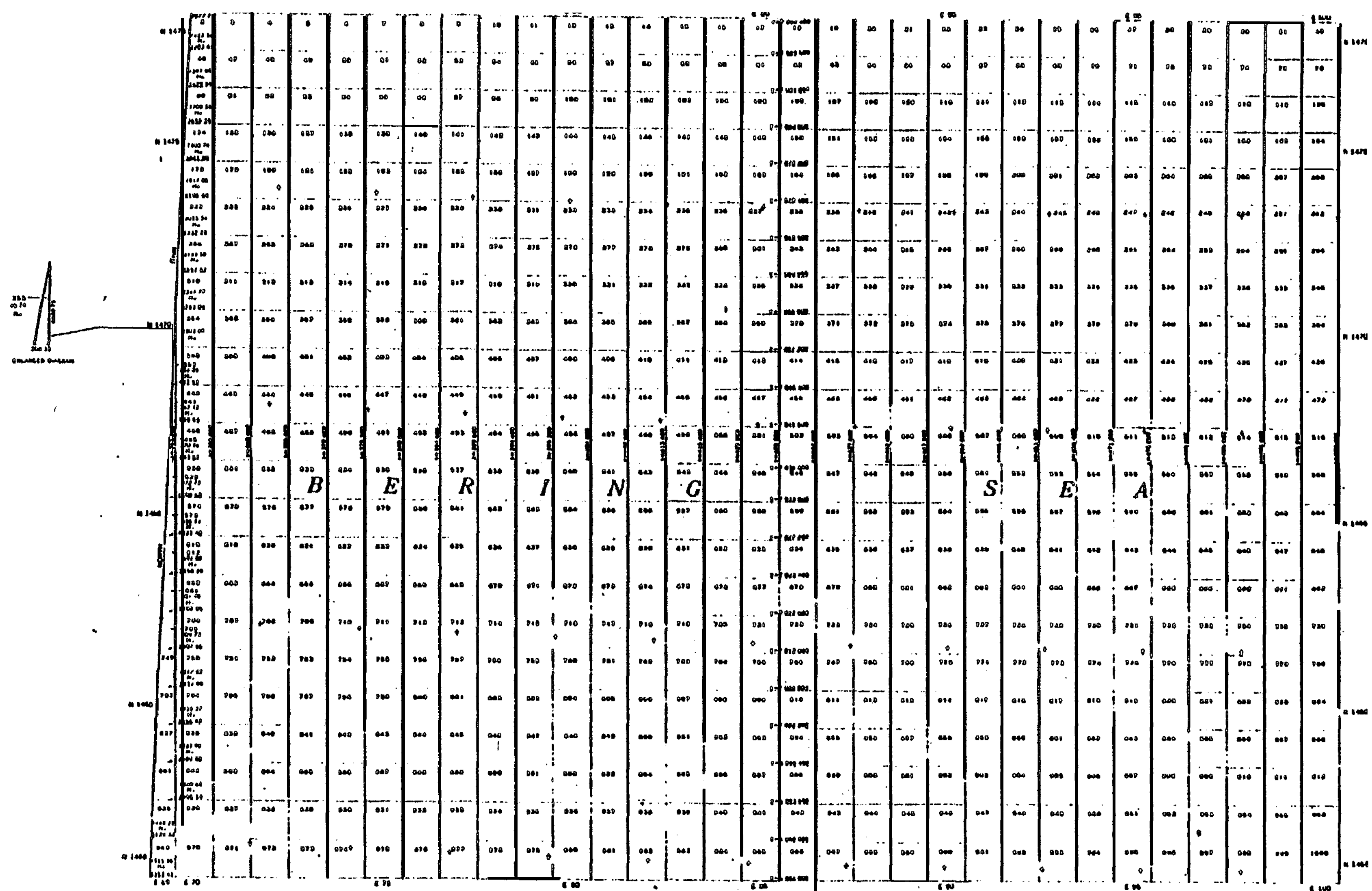

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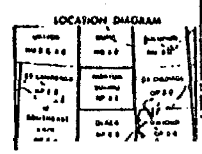

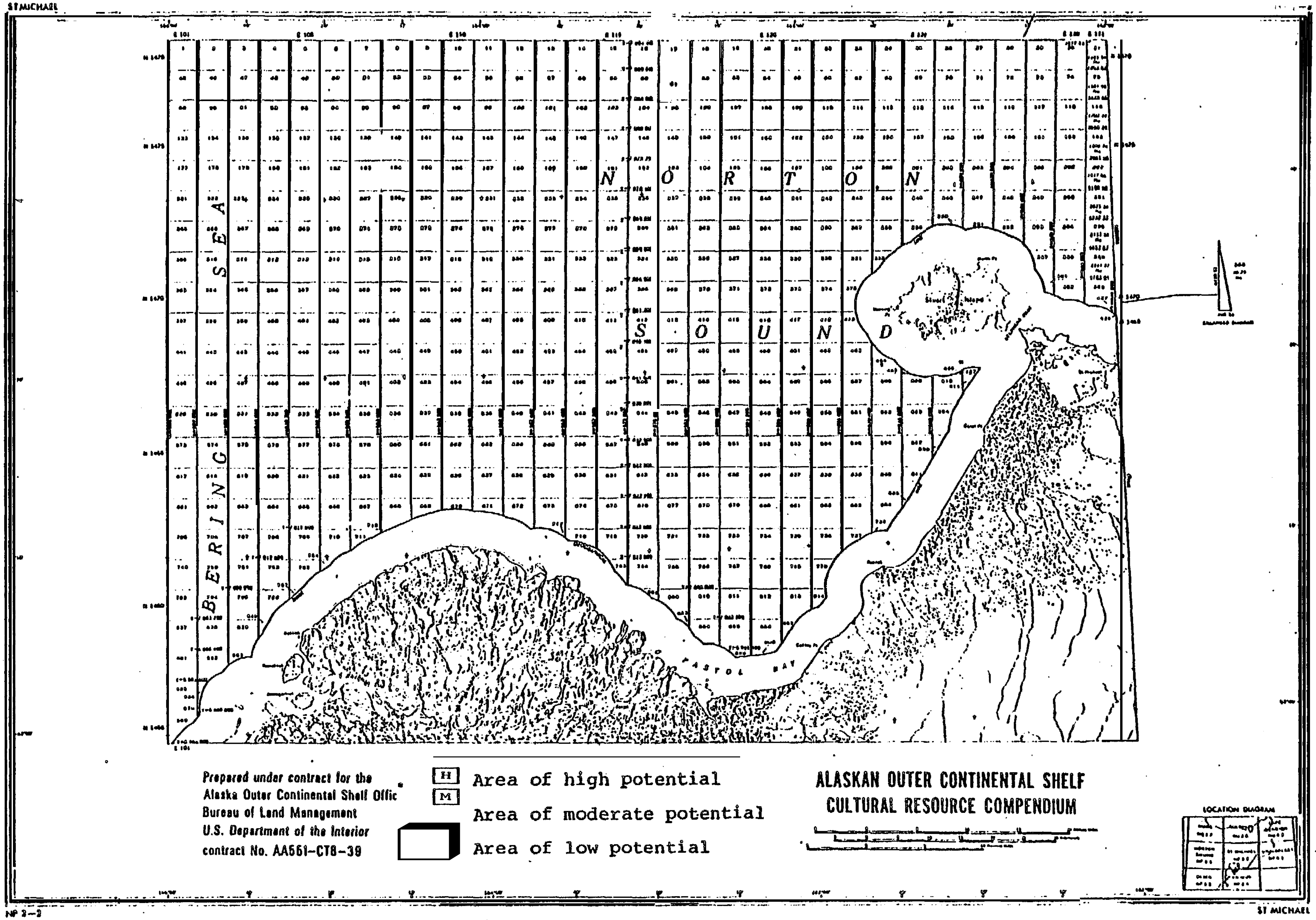

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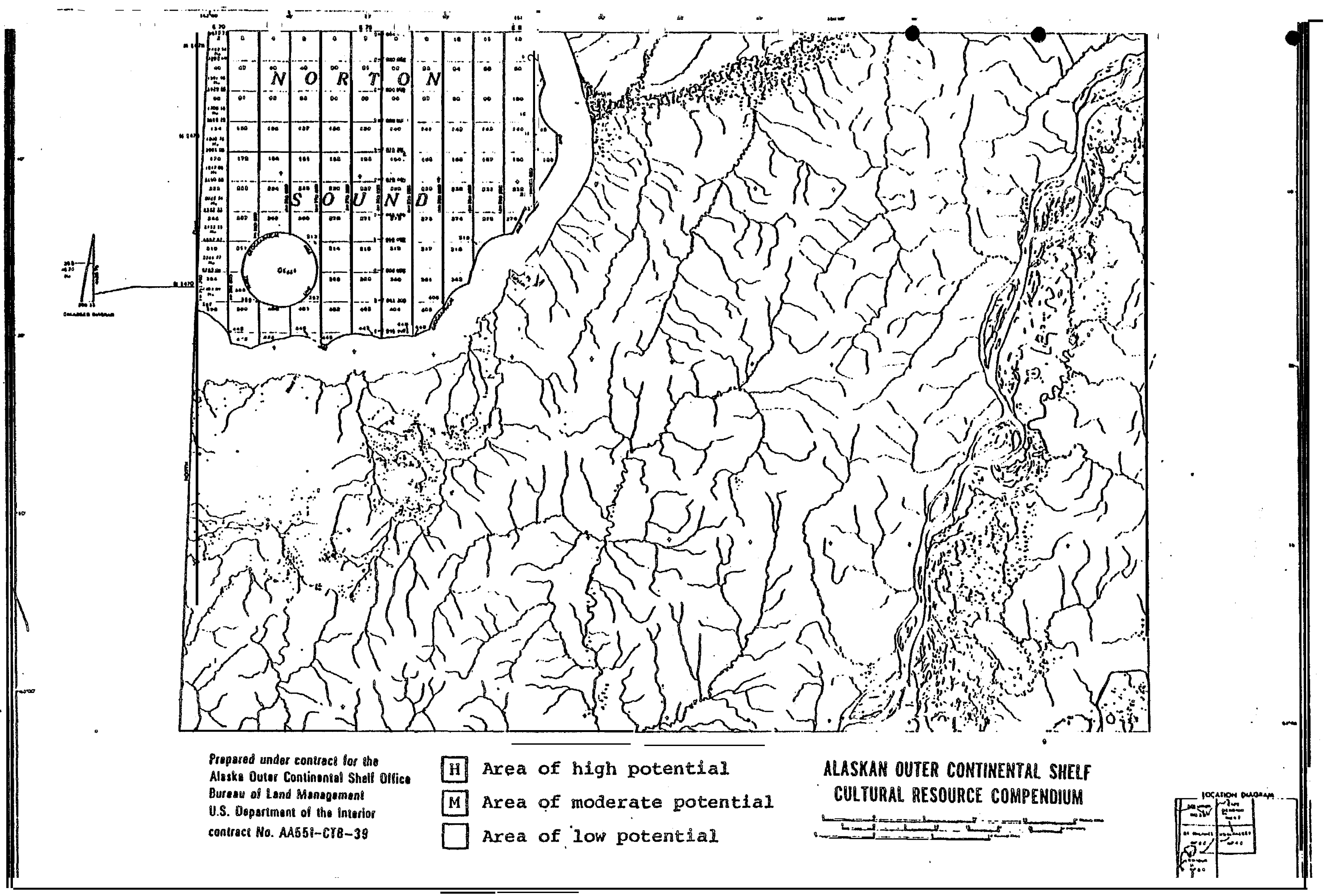
H Area of high potential

M Area of moderate potential

Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



Prepared under contract for the
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U.S. Department of the Interior
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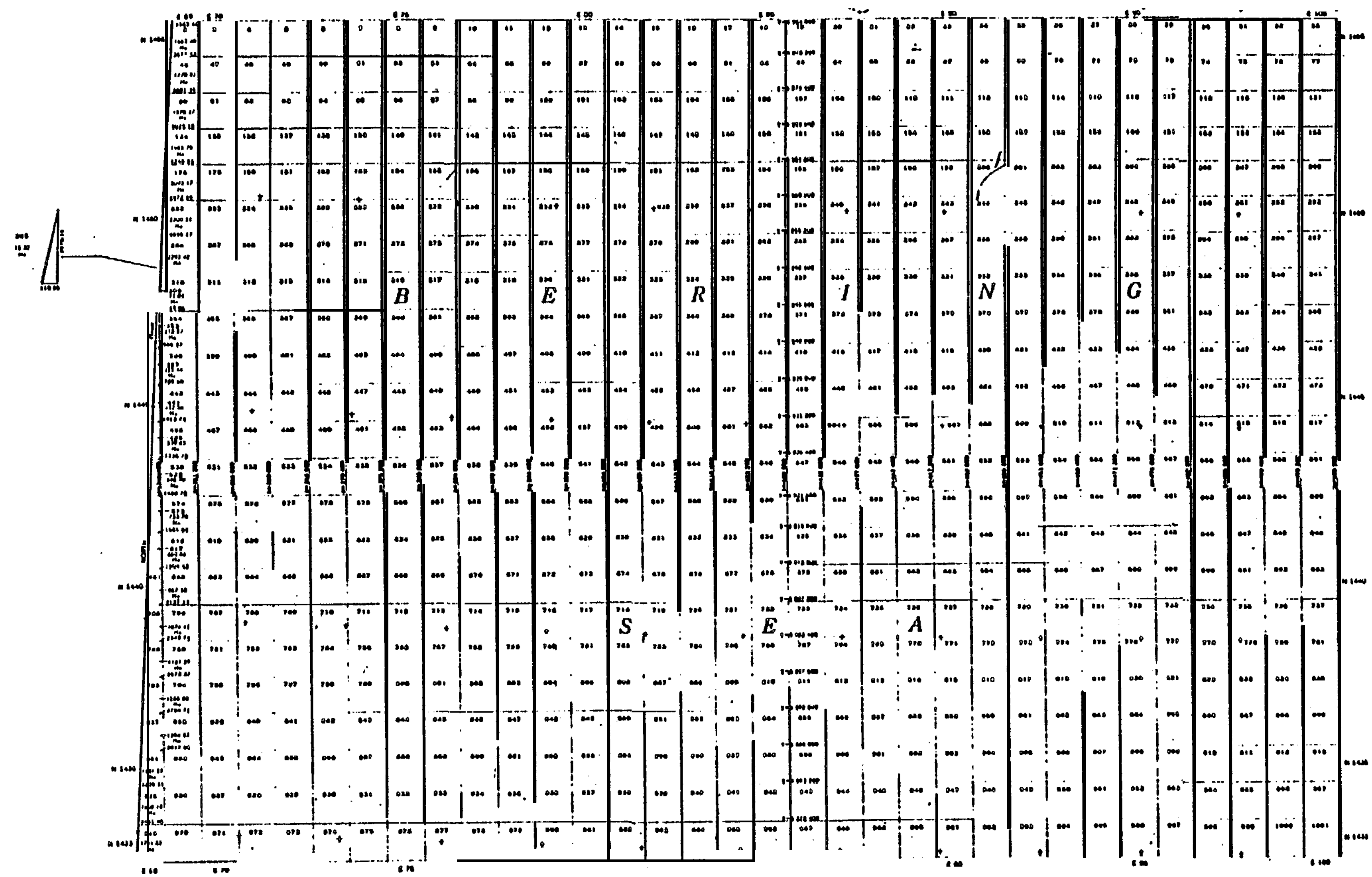
[M] Area of moderate potential

[ ] Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



Prepared under contract for the
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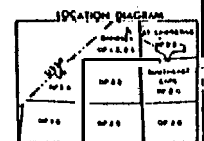
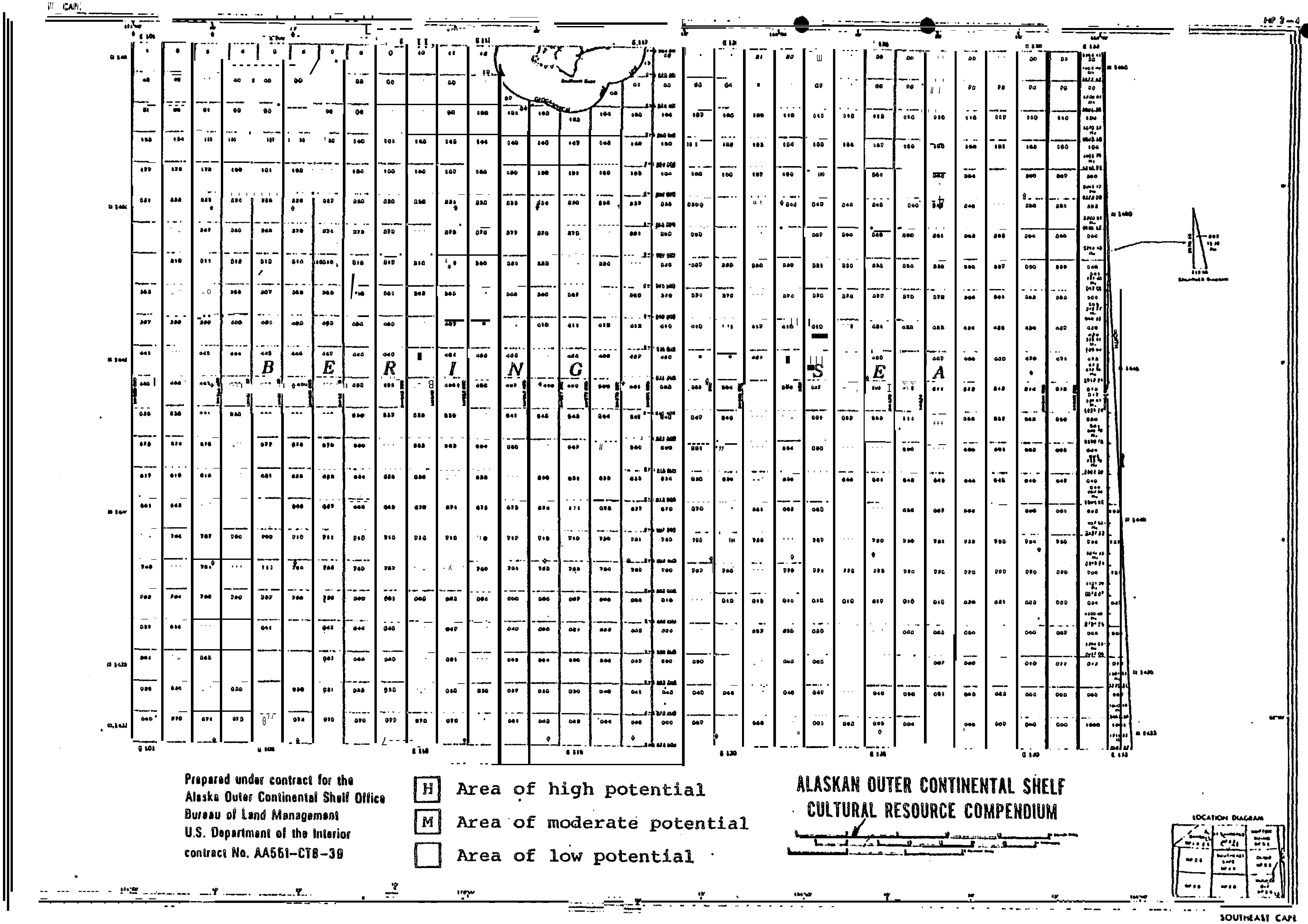
U.S. Department of the Interior
contract No. AA551-CT8-39

Area of high potential
Area of moderate potential
Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM





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U.S. Department of the Interior
contract No. AA551-CT8-39

[H] Area of high potential

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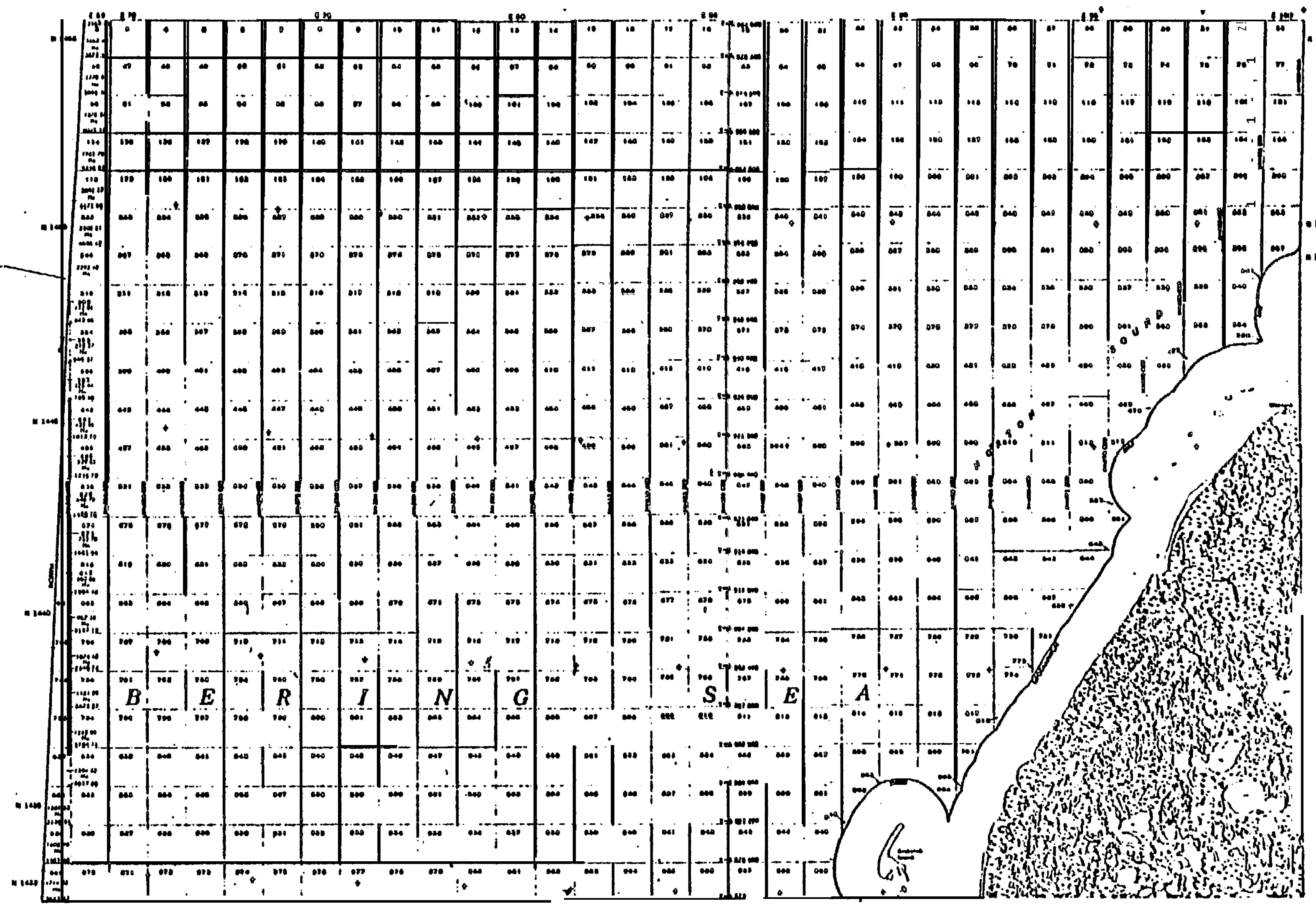
[ ] Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



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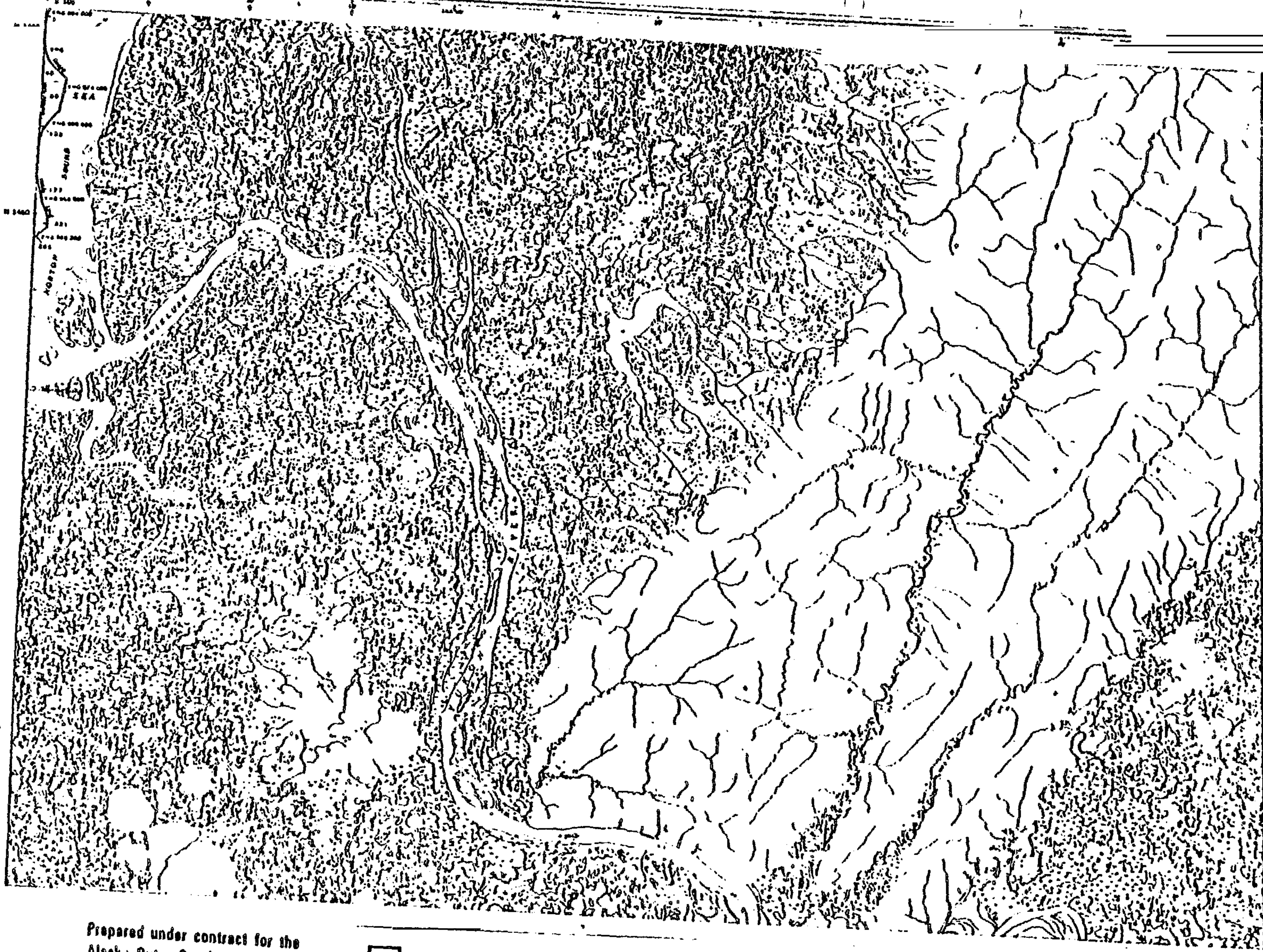
H Area of high potential

M Area of moderate potential

Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



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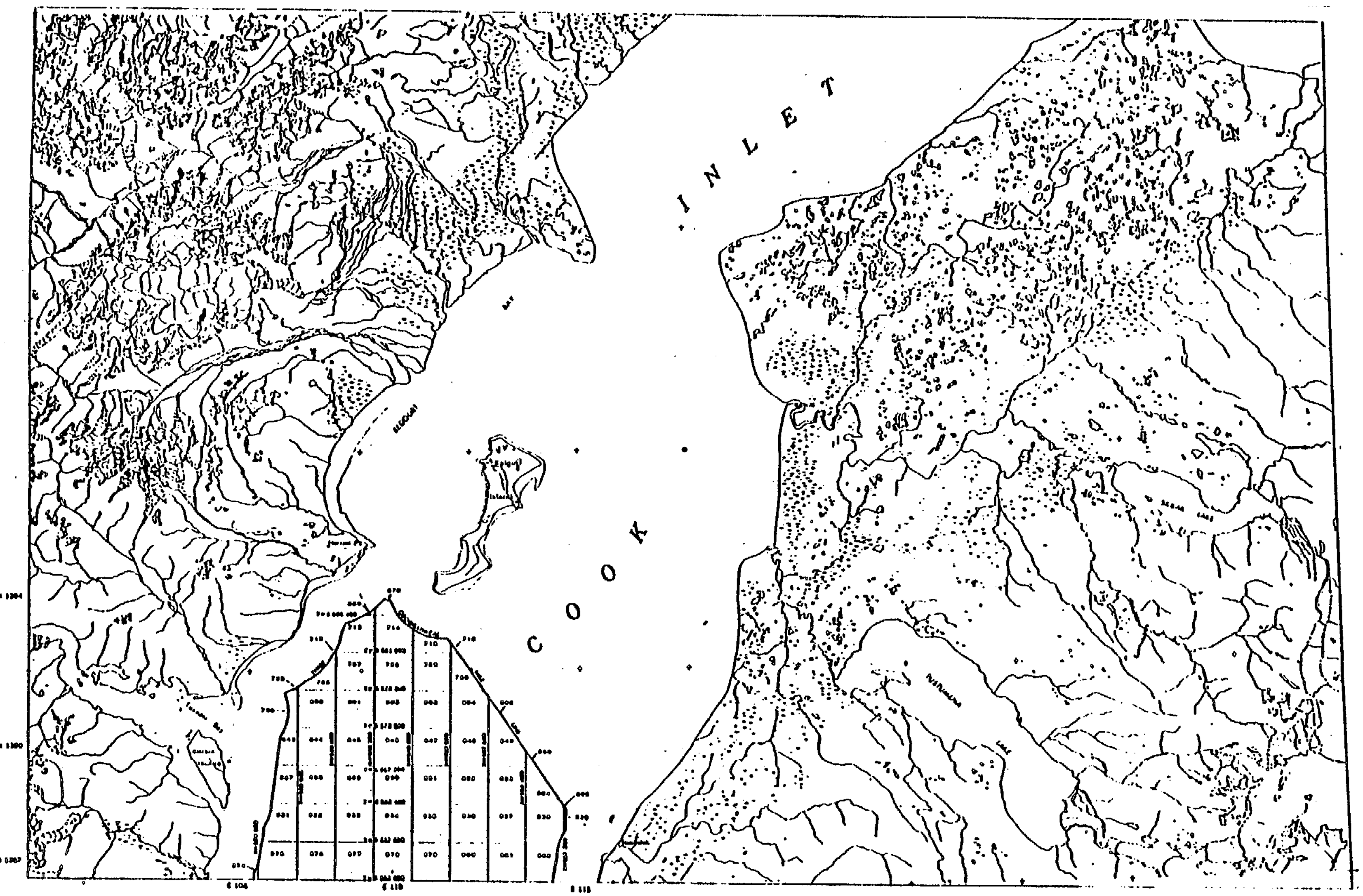
U.S. Department of the Interior
contract No. AA551-CT8-39

[H] Area of high potential
[M] Area of moderate potential
[ ] Area of low potential

**ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM**



Prepared under contract for the
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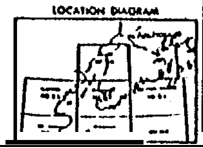
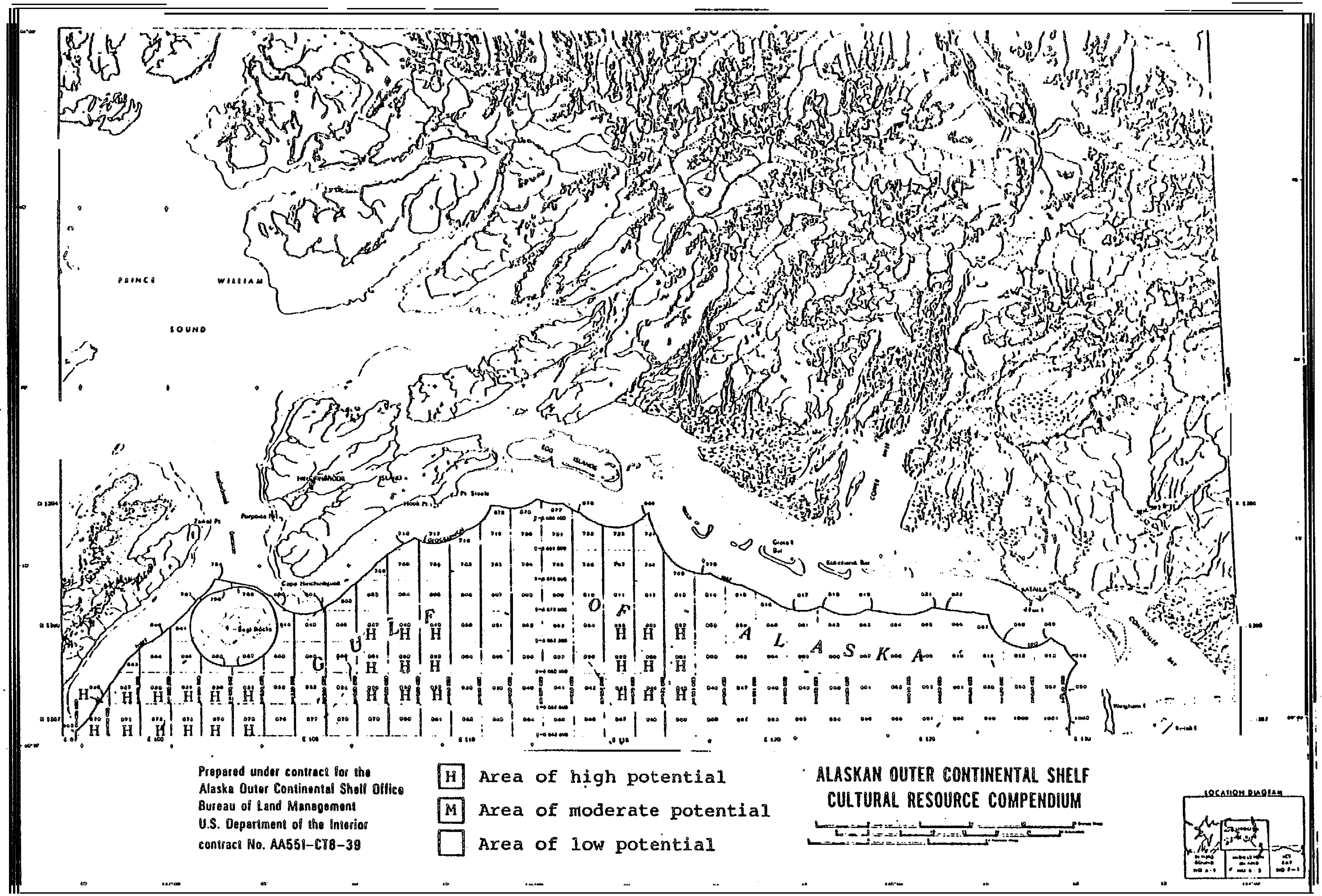
H Area of high potential

M Area of moderate potential

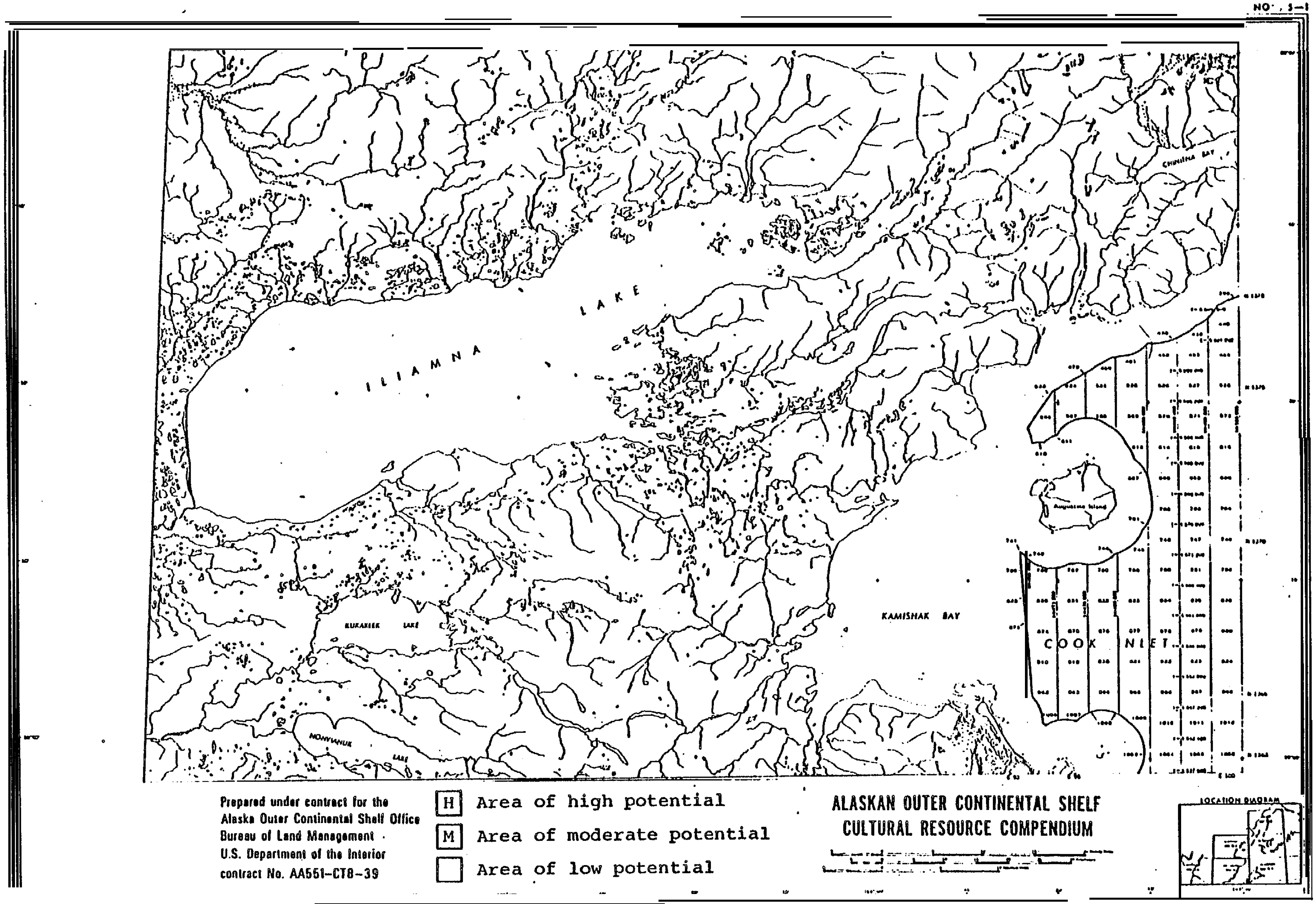
Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM





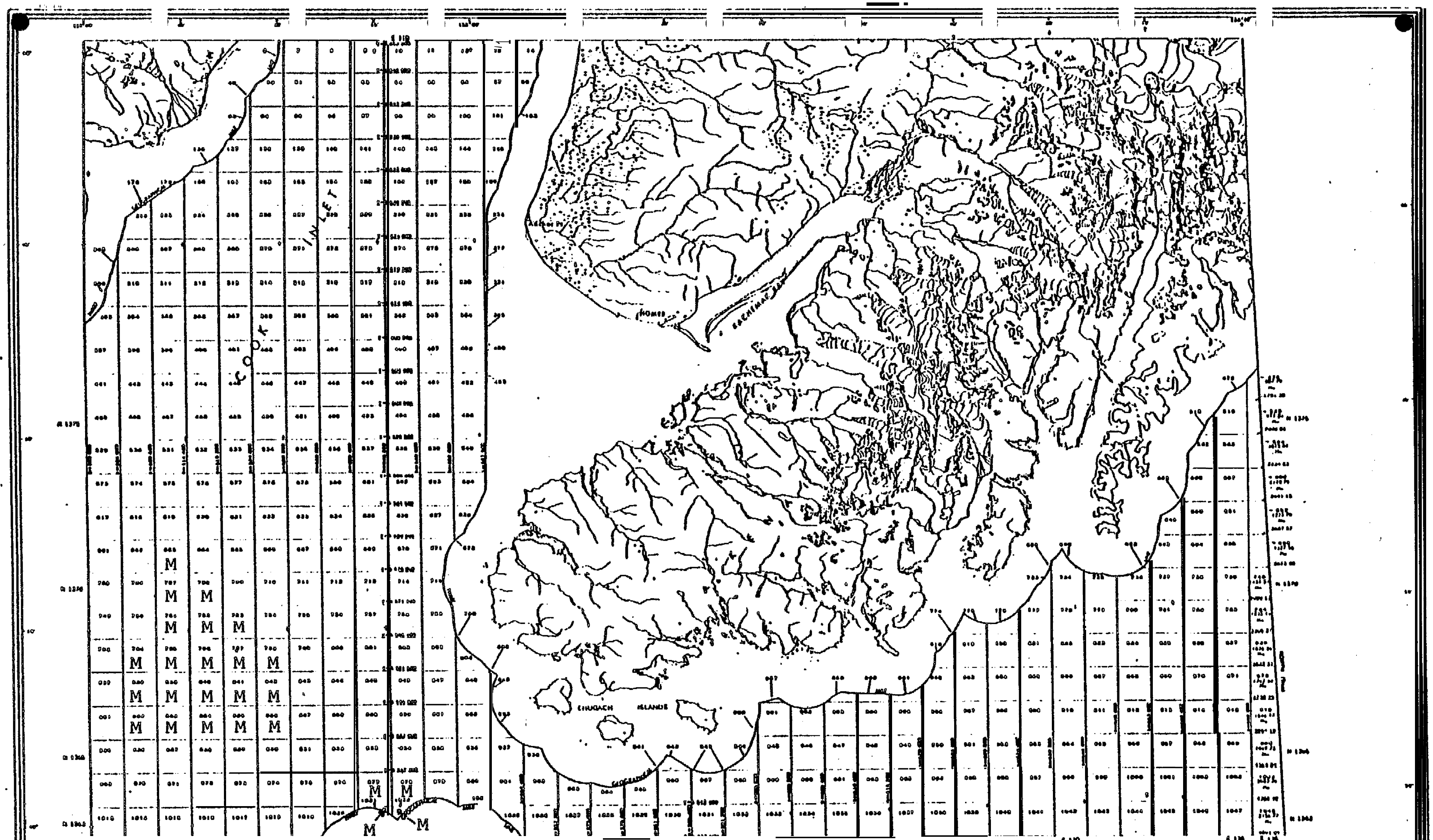
PRINCE
WILLIAM
SOUND
GULF OF ALASKA
Prepared under contract for the
Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-39
H Area of high potential
M Area of moderate potential
Area of low potential
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM
LOCATION DIAGRAM



ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

Prepared under contract for the Alaska Outer Continental Shelf Office Bureau of Land Management · U.S. Department of the Interior contract No. AA551-CT8-39

H Area of high potential
M Area of moderate potential
Area of low potential



Prepared under contract for the
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U.S. Department of the Interior
contract No. AA551-CT8-39

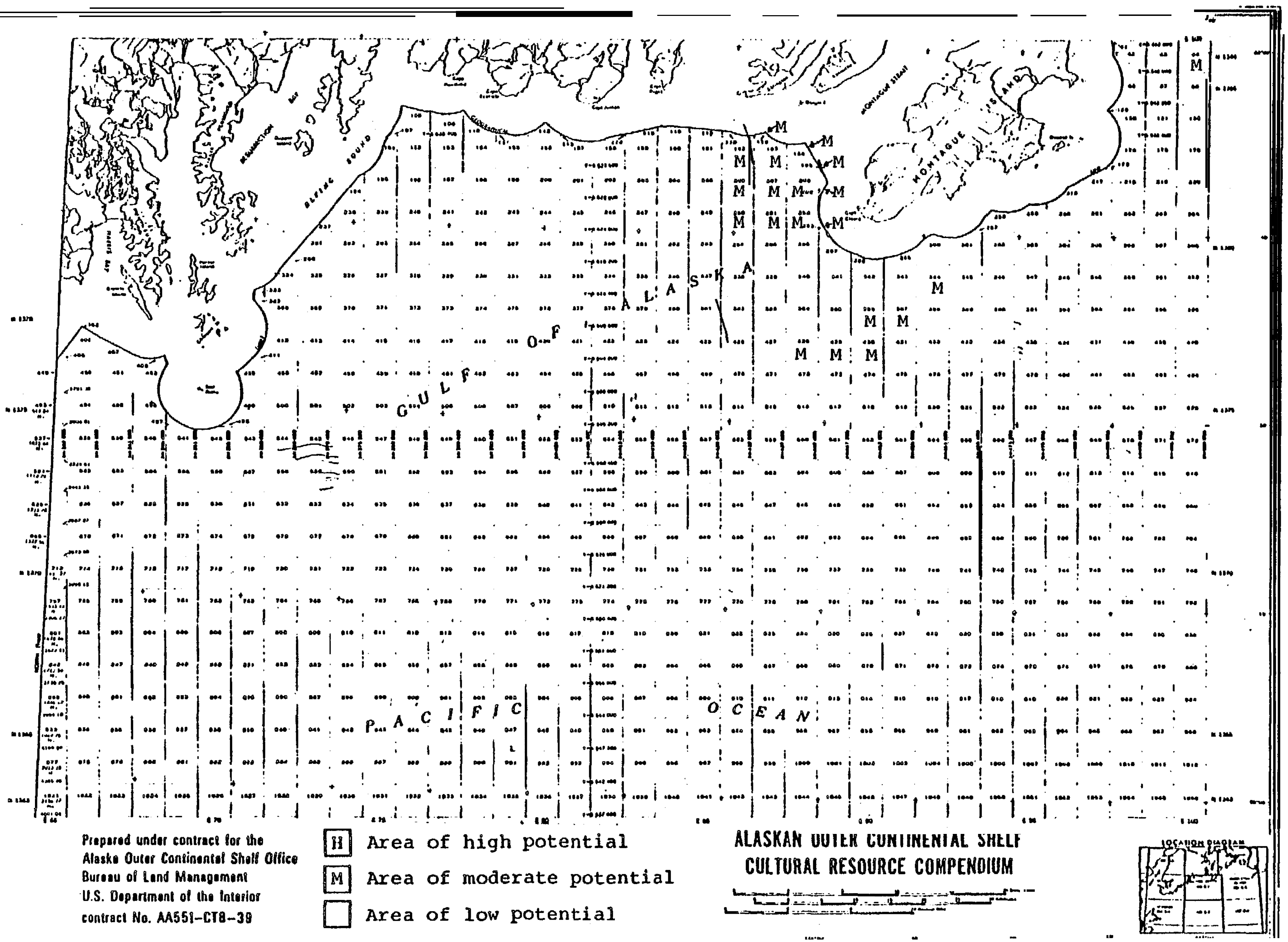
H Area of high potential

M Area of moderate potential

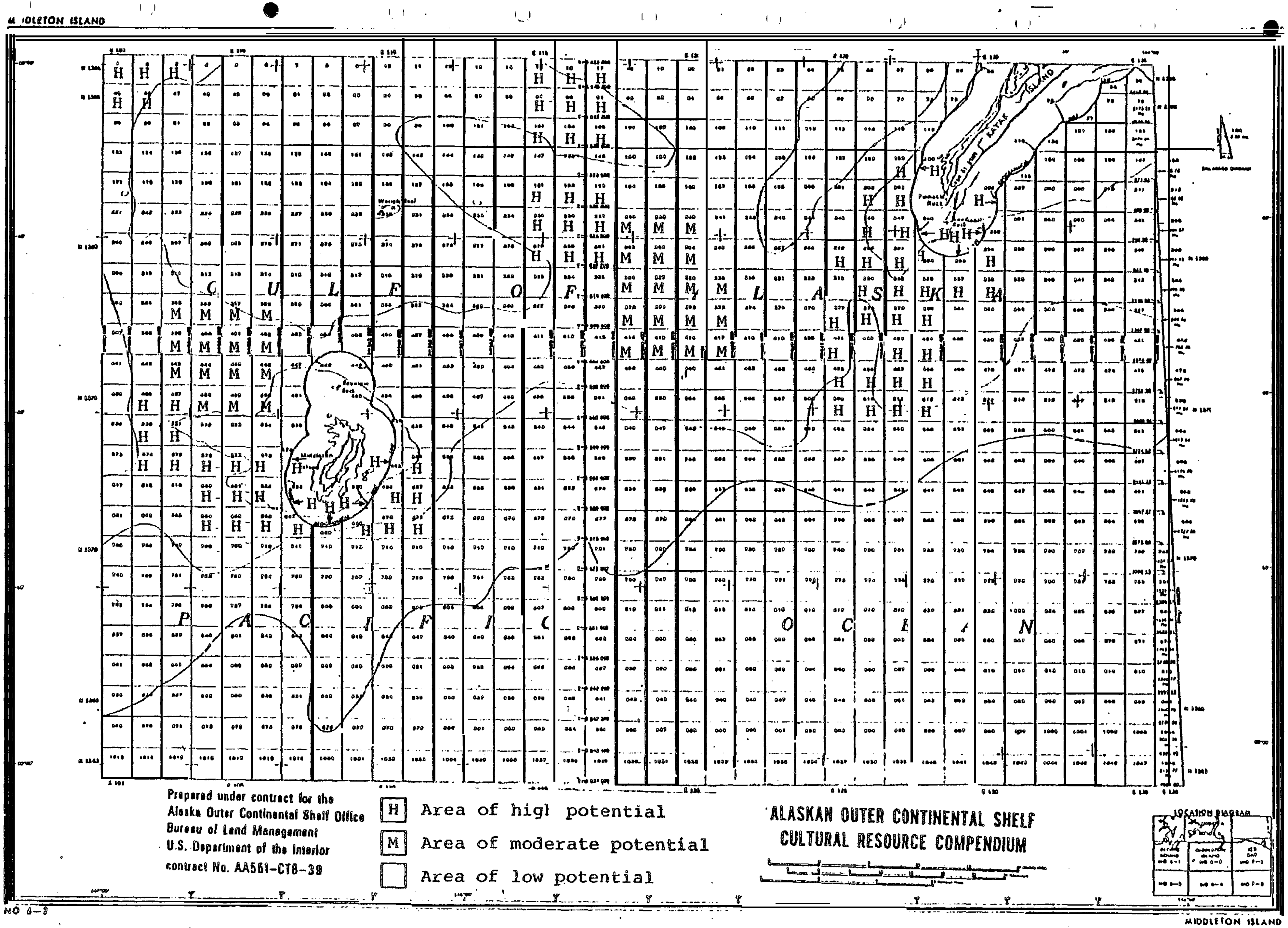
Area of low potential

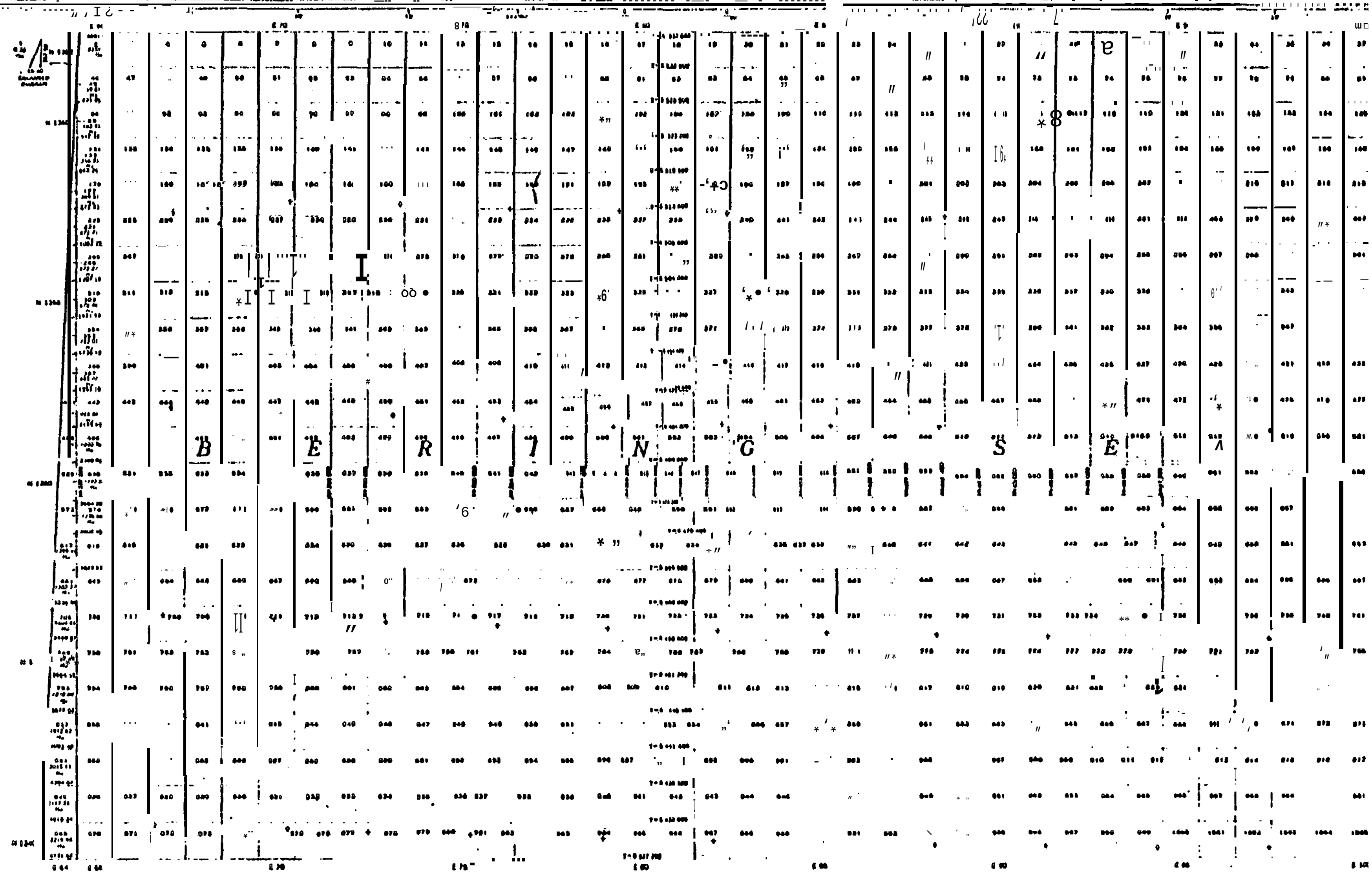
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

NO 5-2



GULF OF ALASKA
PACIFIC OCEAN
MONTAGUE ISLAND
MONTAGUE STRAIT
ELRING SOUND
RESURRECTION BAY
M
Prepared under contract for the
Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-39
H Area of high potential
M Area of moderate potential
Area of low potential
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM
LOCATION DIAGRAM
NO 6-1


MIDDLETON ISLAND
GULF OF ALASKA
PACIFIC OCEAN
KAYAK ISLAND
Middleton
Prepared under contract for the
Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-39
H Area of higl potential
M Area of moderate potential
Area of low potential
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM
LOCATION DIAGRAM
NO 6-8
MIDDLETON ISLAND



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U.S. Department of the Interior
contract No. AA551-CT8-39

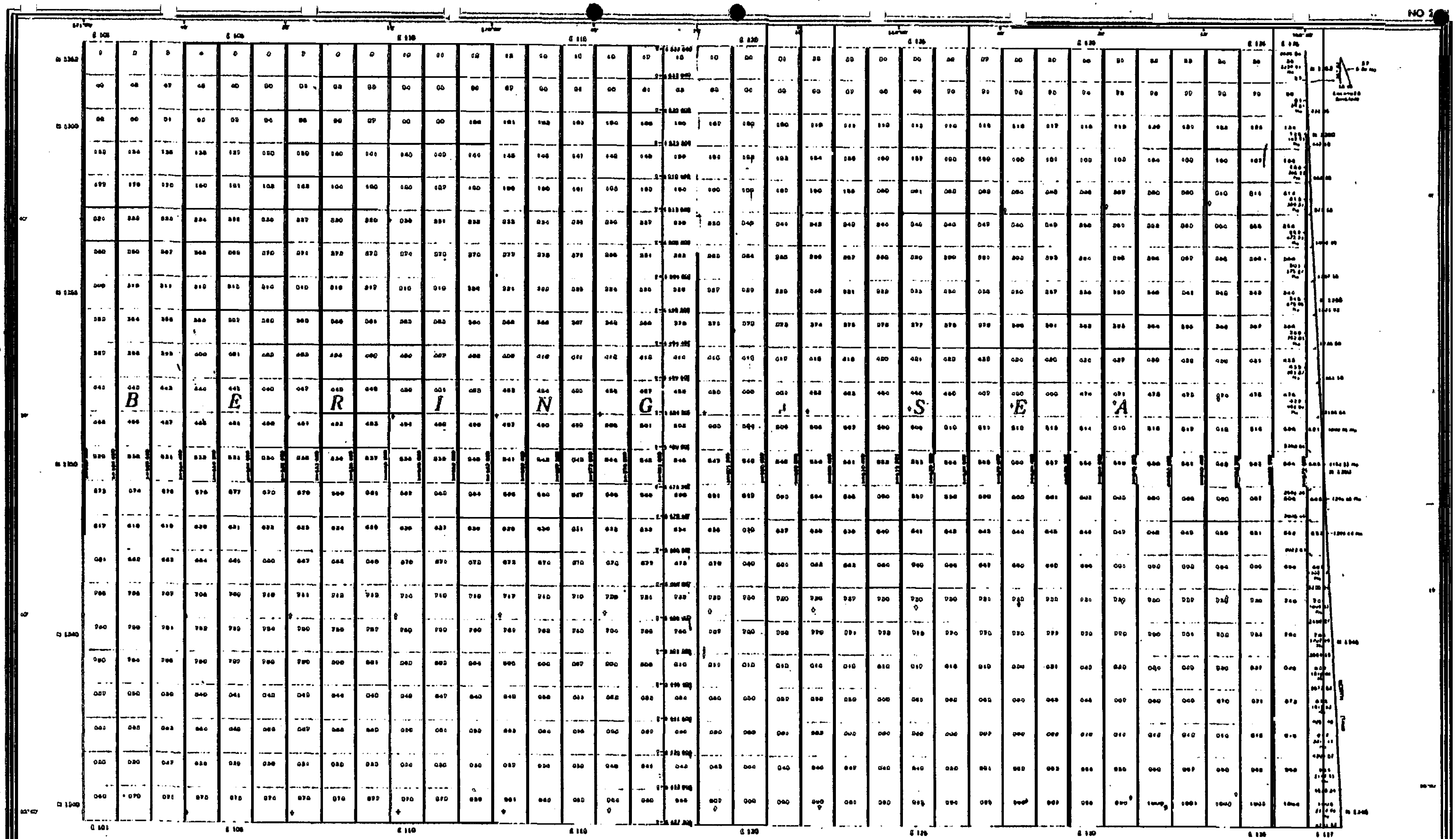
H Area of high potential

M Area of moderate potential

Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

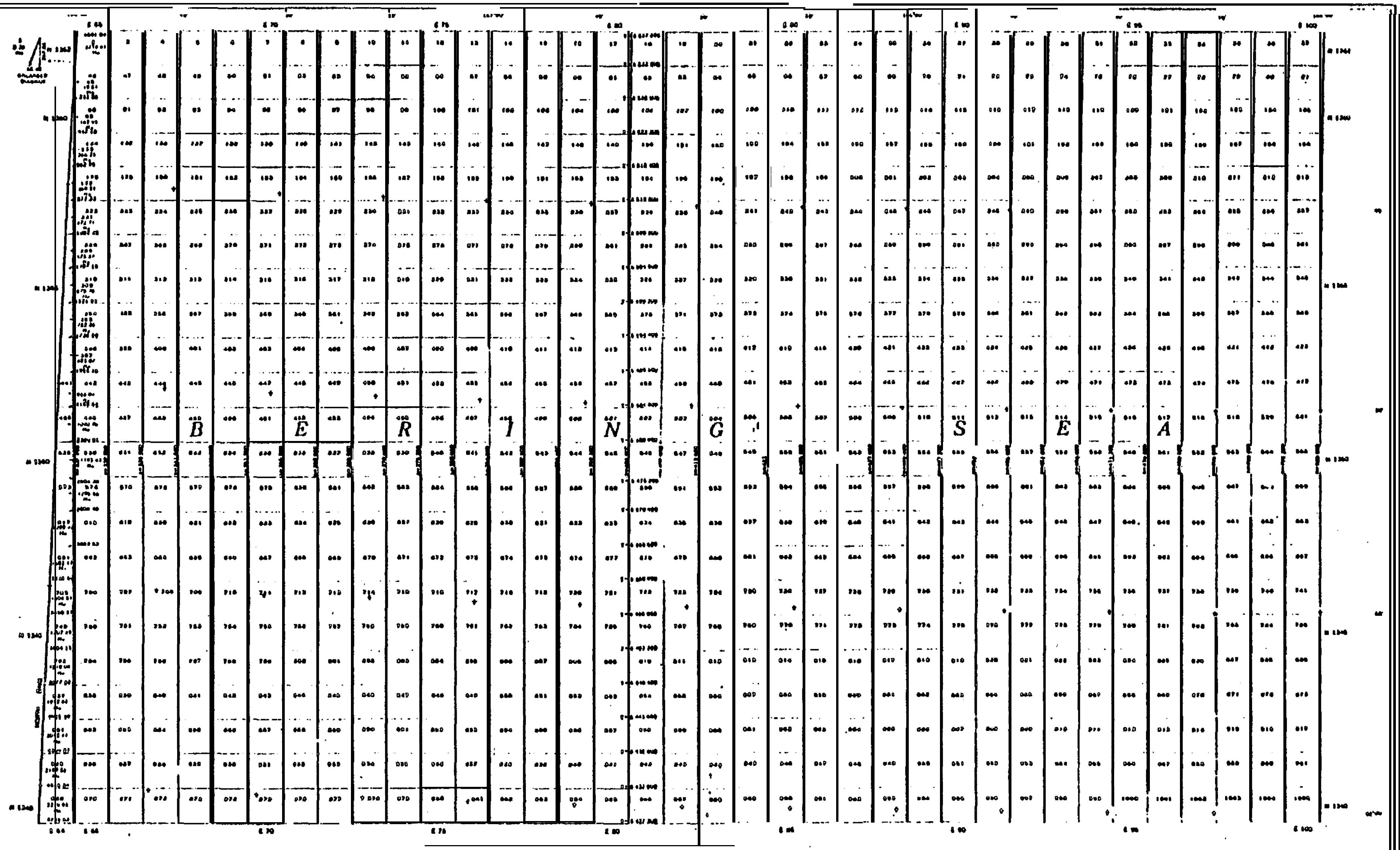
LOCATION DIAGRAM



Prepared under contract for the
Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-38

H	Area of high potential
M	Area of moderate potential
	Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



Prepared under contract for the
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U.S. Department of the Interior
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[H] Area of high potential

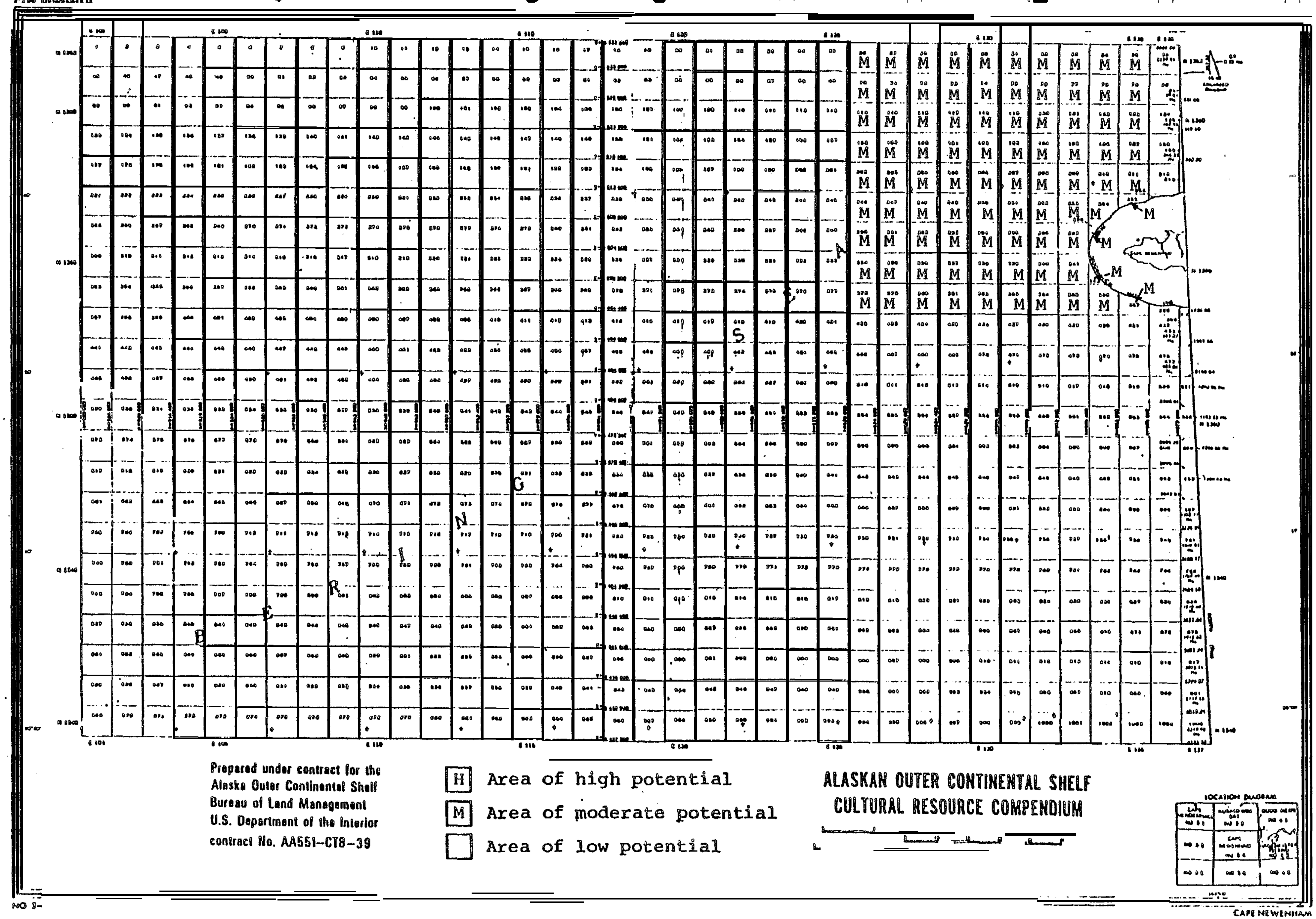
[M] Area of moderate potential

[ ] Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

LOCATION DIAGRAM

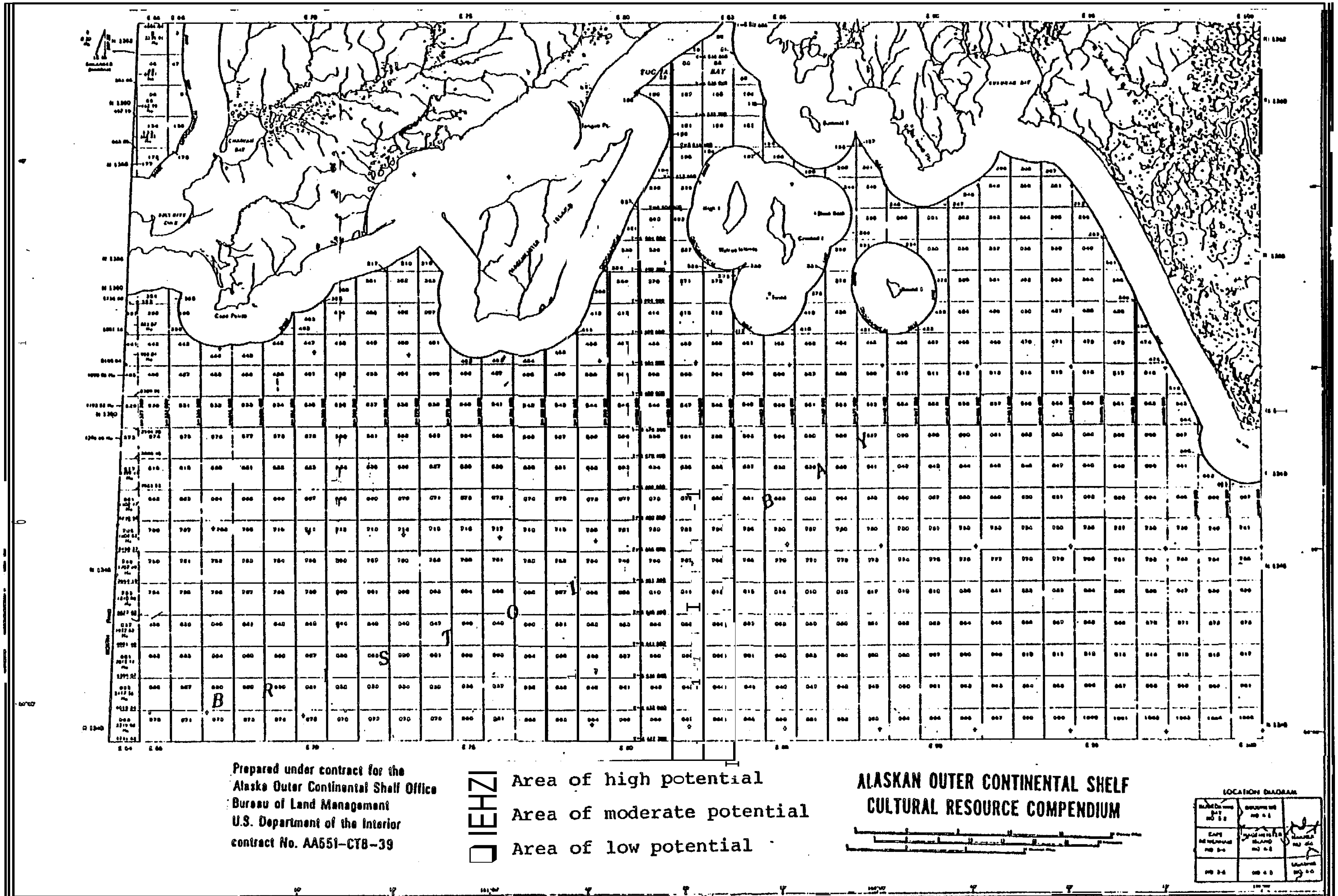
NO 3-3

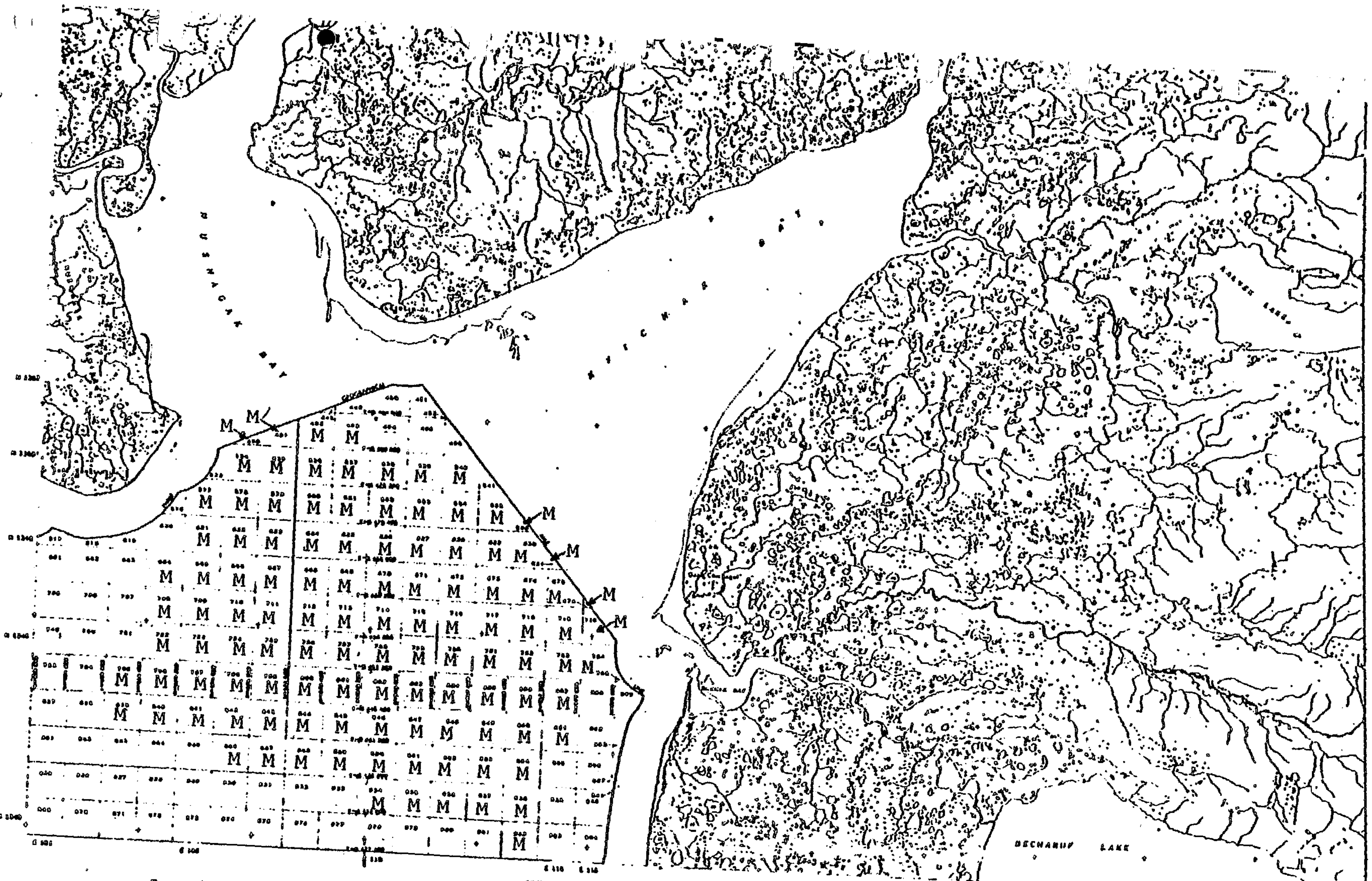


Prepared under contract for the Alaska Outer Continental Shelf Bureau of Land Management U.S. Department of the Interior contract No. AA551-CT8-39

H	Area of high potential
M	Area of moderate potential
	Area of low potential

ALASKAN OUTER CONTINENTAL SHELF CULTURAL RESOURCE COMPENDIUM


Prepared under contract for the
Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-39
Area of high potential
Area of moderate potential
Area of low potential
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM
LOCATION DIAGRAM



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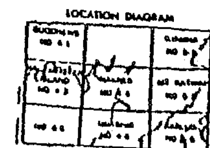
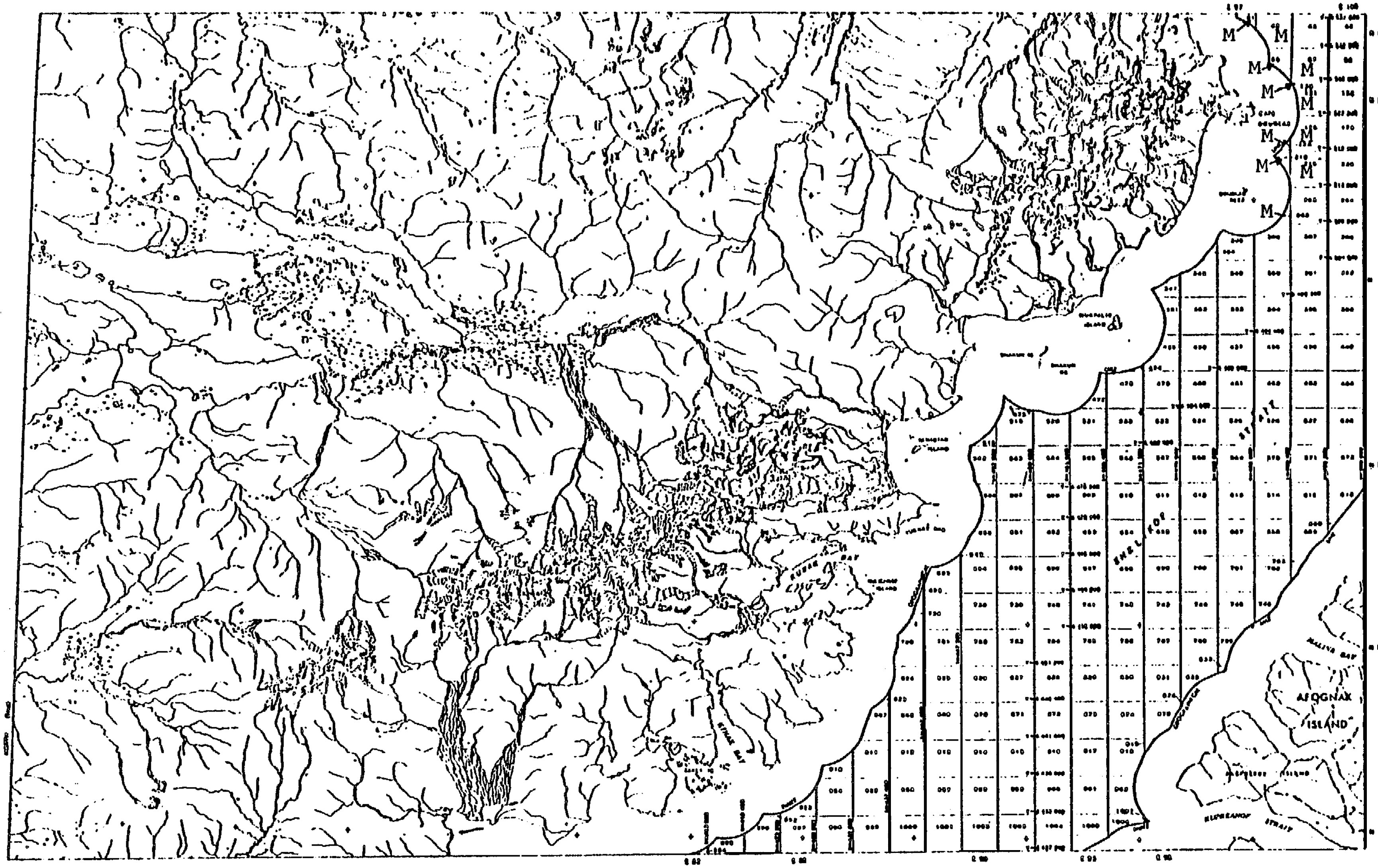
contract No. AA551-CT8-39

H Area of high potential
M Area of moderate potential
Area of low potential

ALASKAN OUTER CONTINENTAL SHELF CULTURAL RESOURCE COMPENDIUM



NAKNEK



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No. AA551-CT8-39

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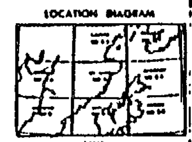
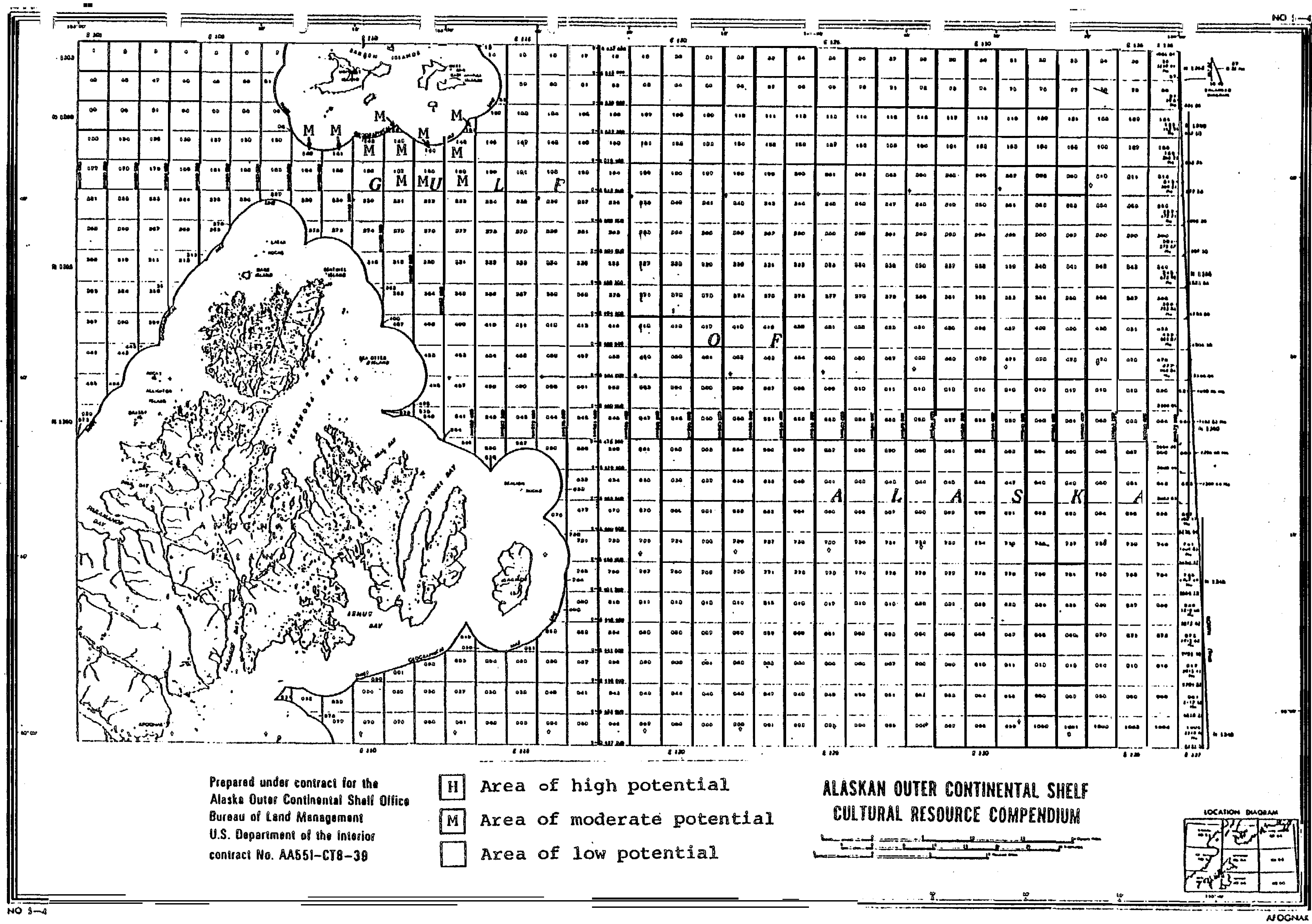
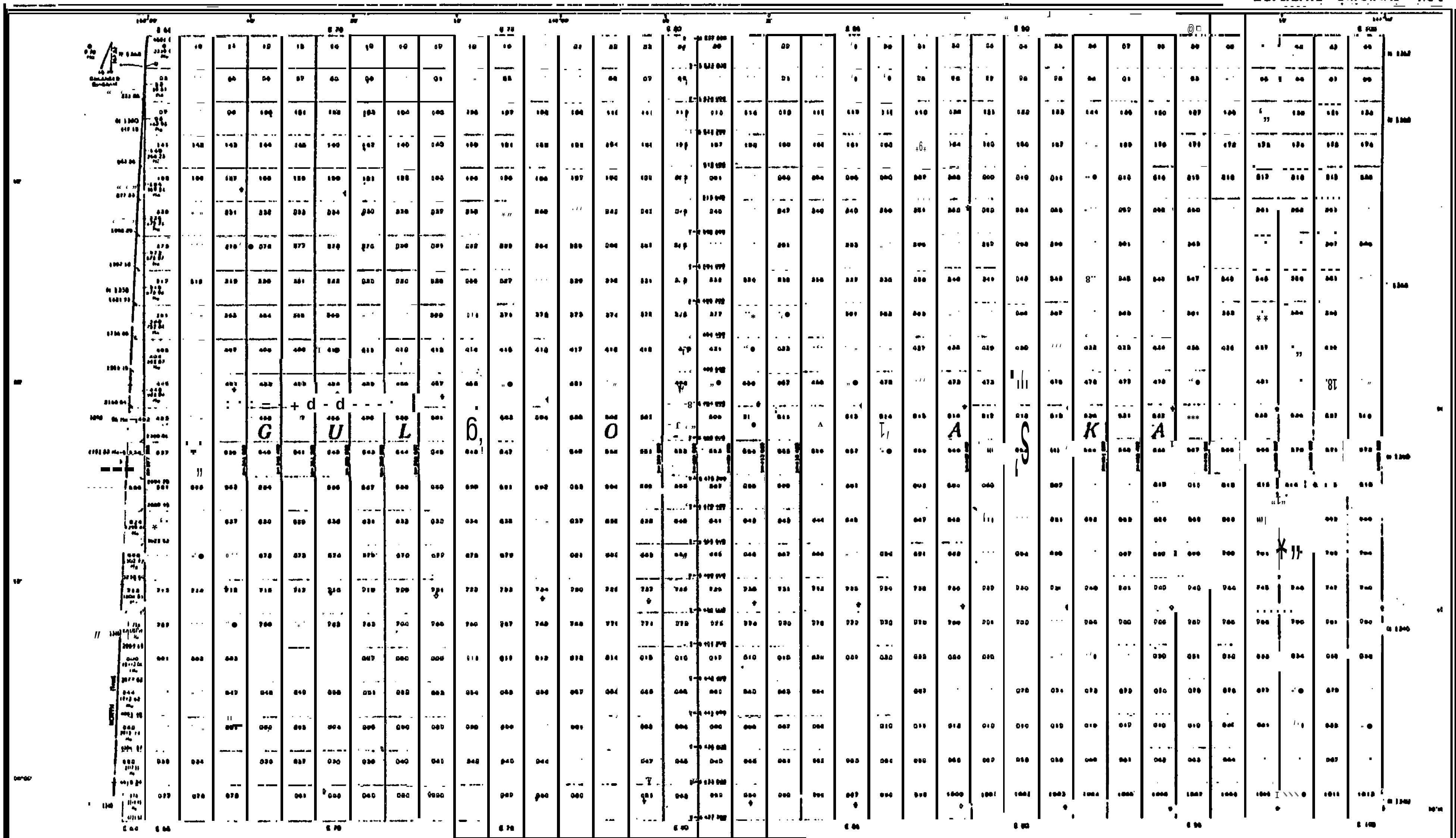
[ ] Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM




G U L F
O F
A L A S K A
Prepared under contract for the
Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-38
H Area of high potential
M Area of moderate potential
Area of low potential
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM
LOCATION DIAGRAM
NO 5-4
AFOGNAK



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U.S. Department of the Interior
contract No. AA551-CT8-39

H Area of high potential

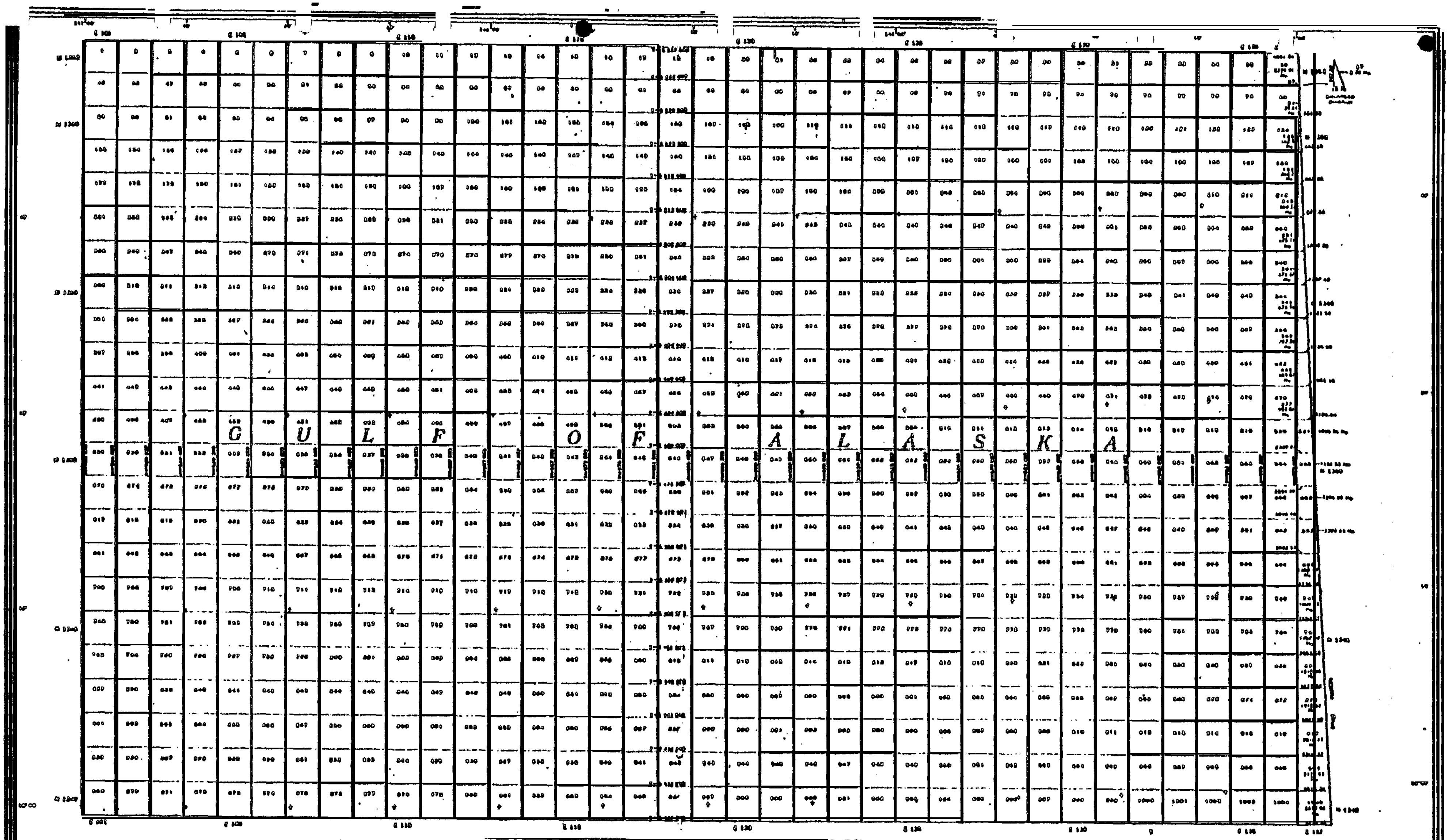
M Area of moderate potential

Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

LOCATION DIAGRAM

NO 4-3



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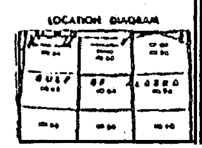
contract No. AA551-CT8-38

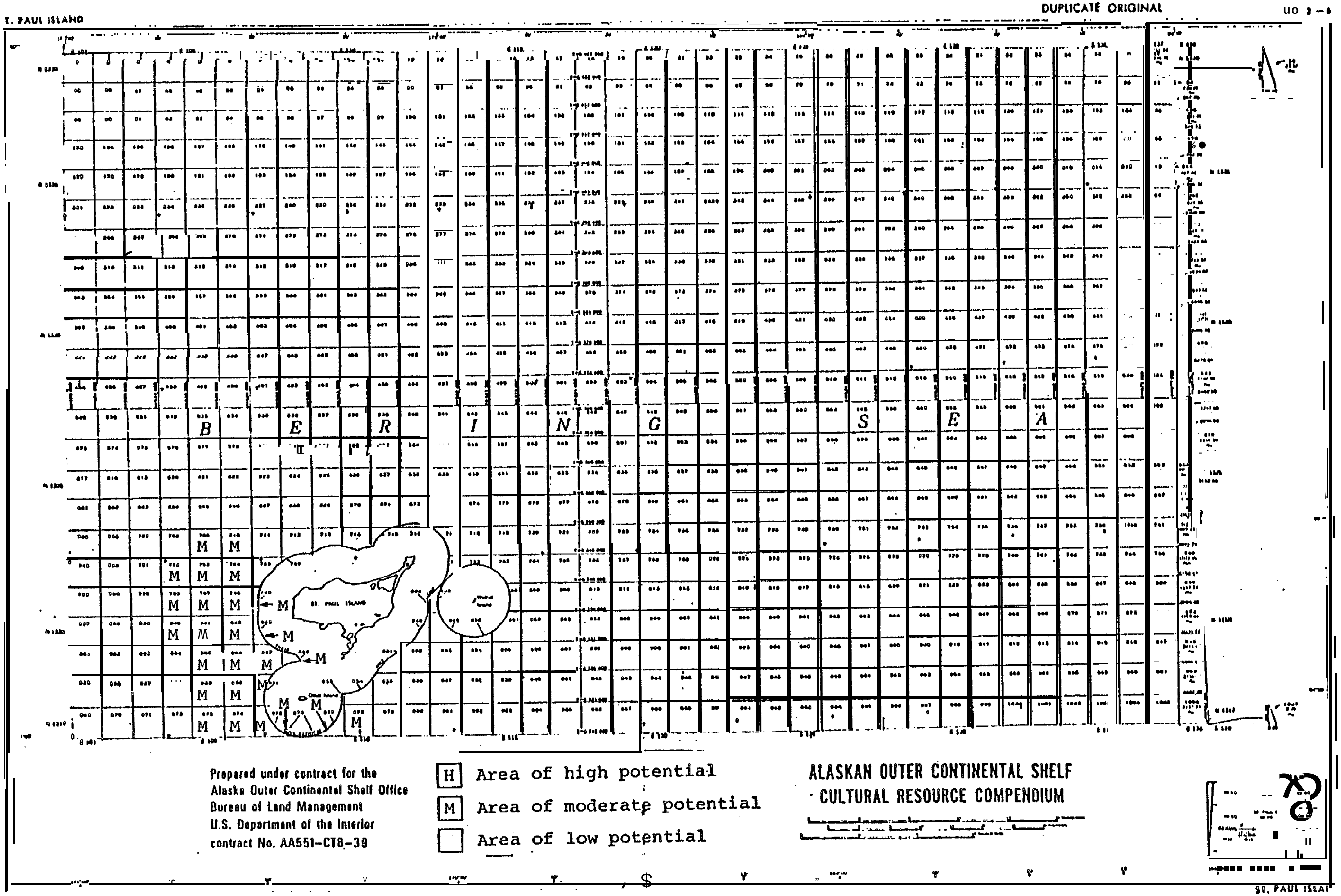
H Area of high potential

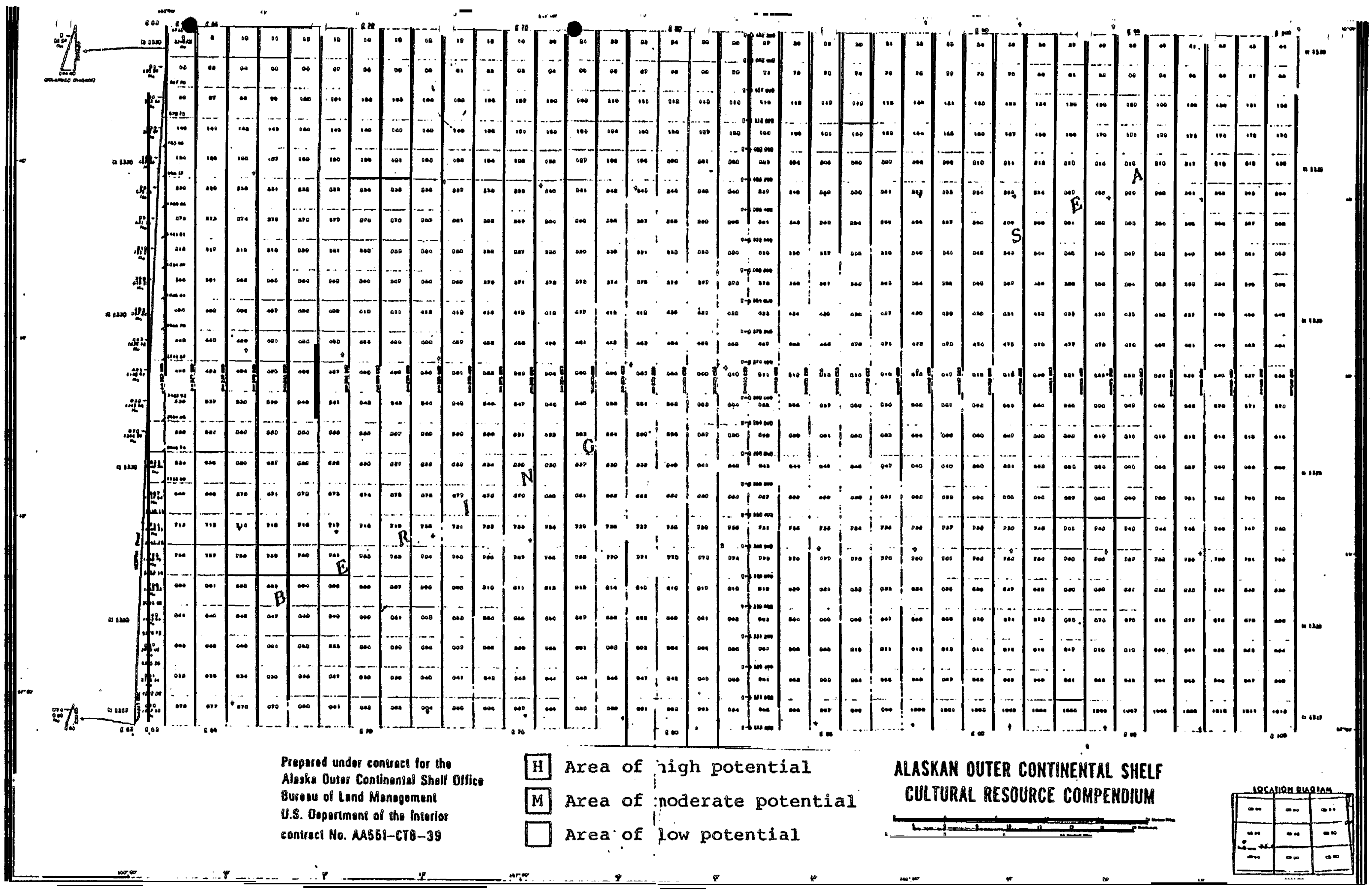
M Area of moderate potential

Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM




T. PAUL ISLAND
DUPLICATE ORIGINAL
UO 3-6
B E R I N G S E A
ST. PAUL ISLAND
Prepared under contract for the
Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-39
H Area of high potential
M Area of moderate potential
Area of low potential
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM
NO 3-6
ST. PAUL ISLAND



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- [H] Area of high potential
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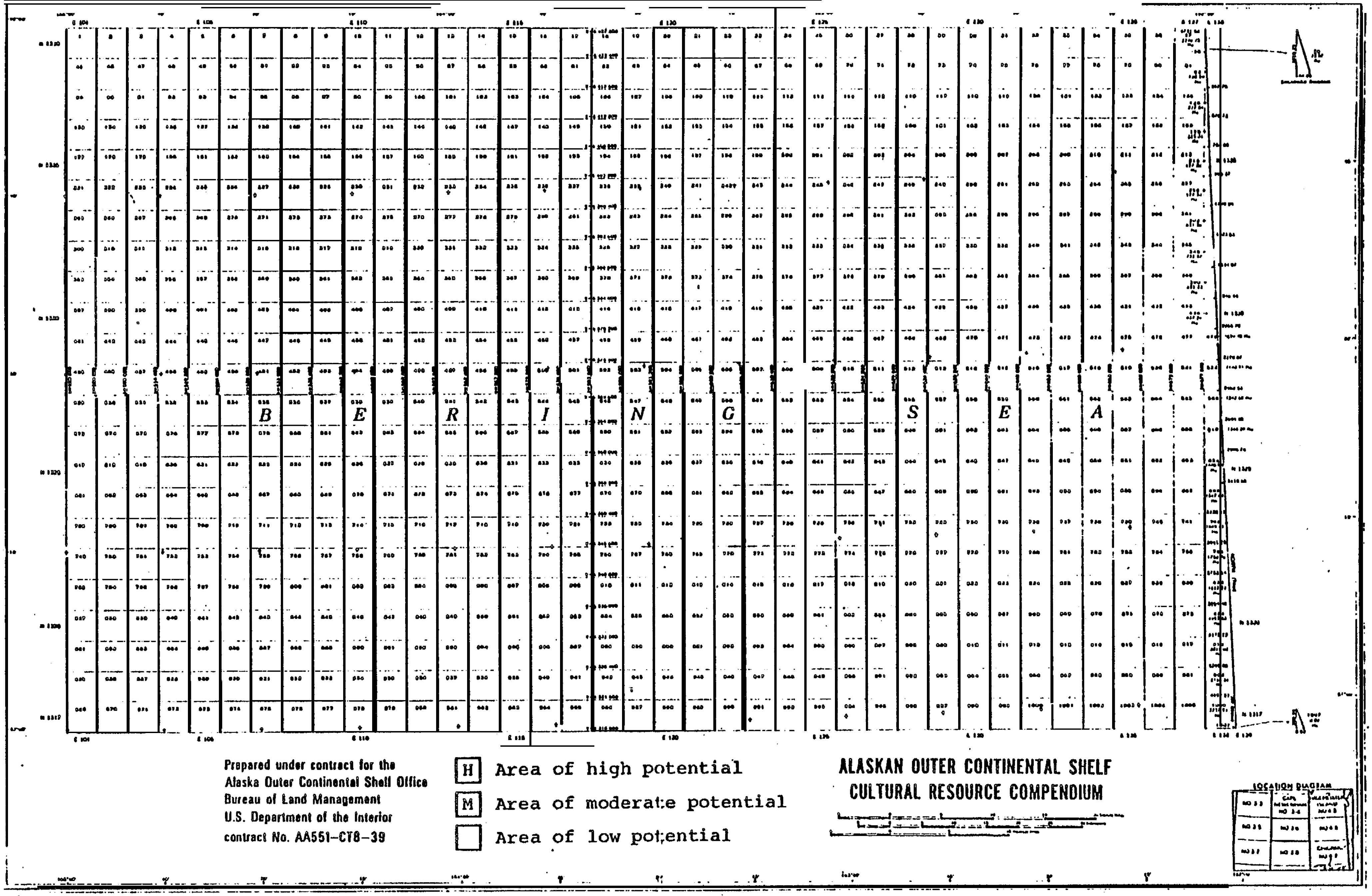
- [ ] Area of low potential

ALASKAN OUTER CONTINENTAL SHELF CULTURAL RESOURCE COMPENDIUM



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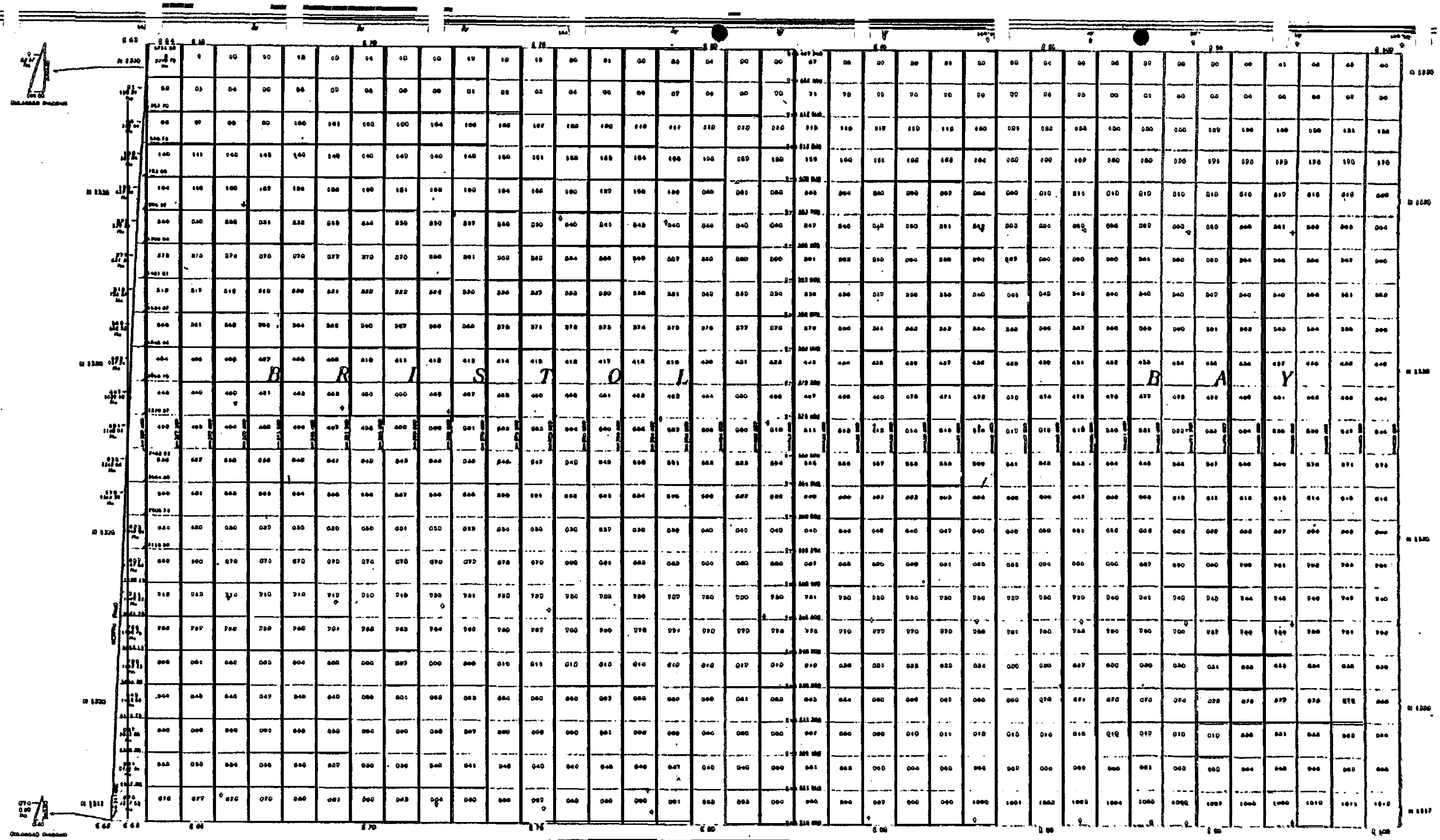
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



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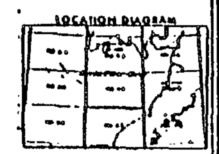
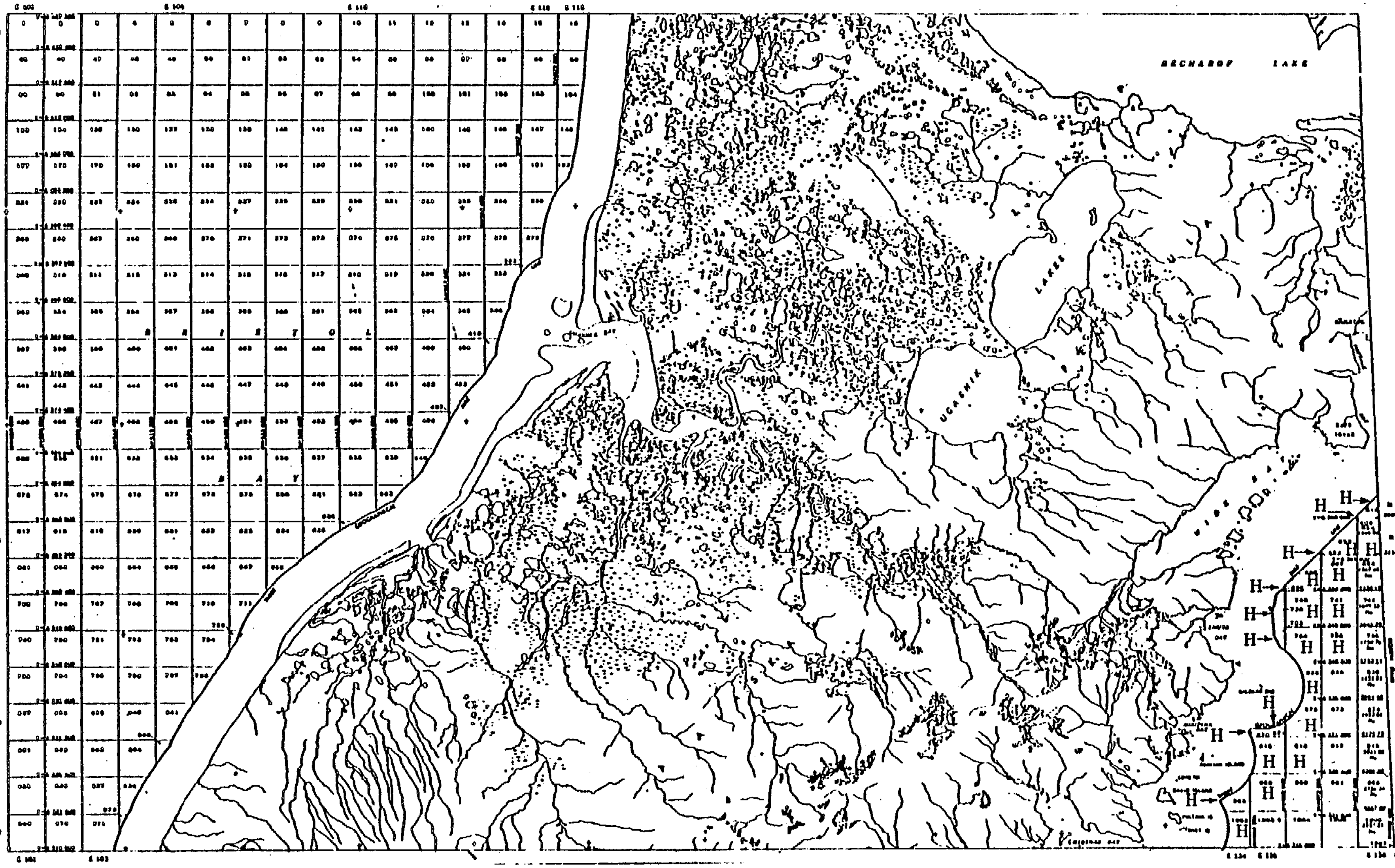
H	Area of high potential
M	Area of moderate potential
	Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



NO 4-9



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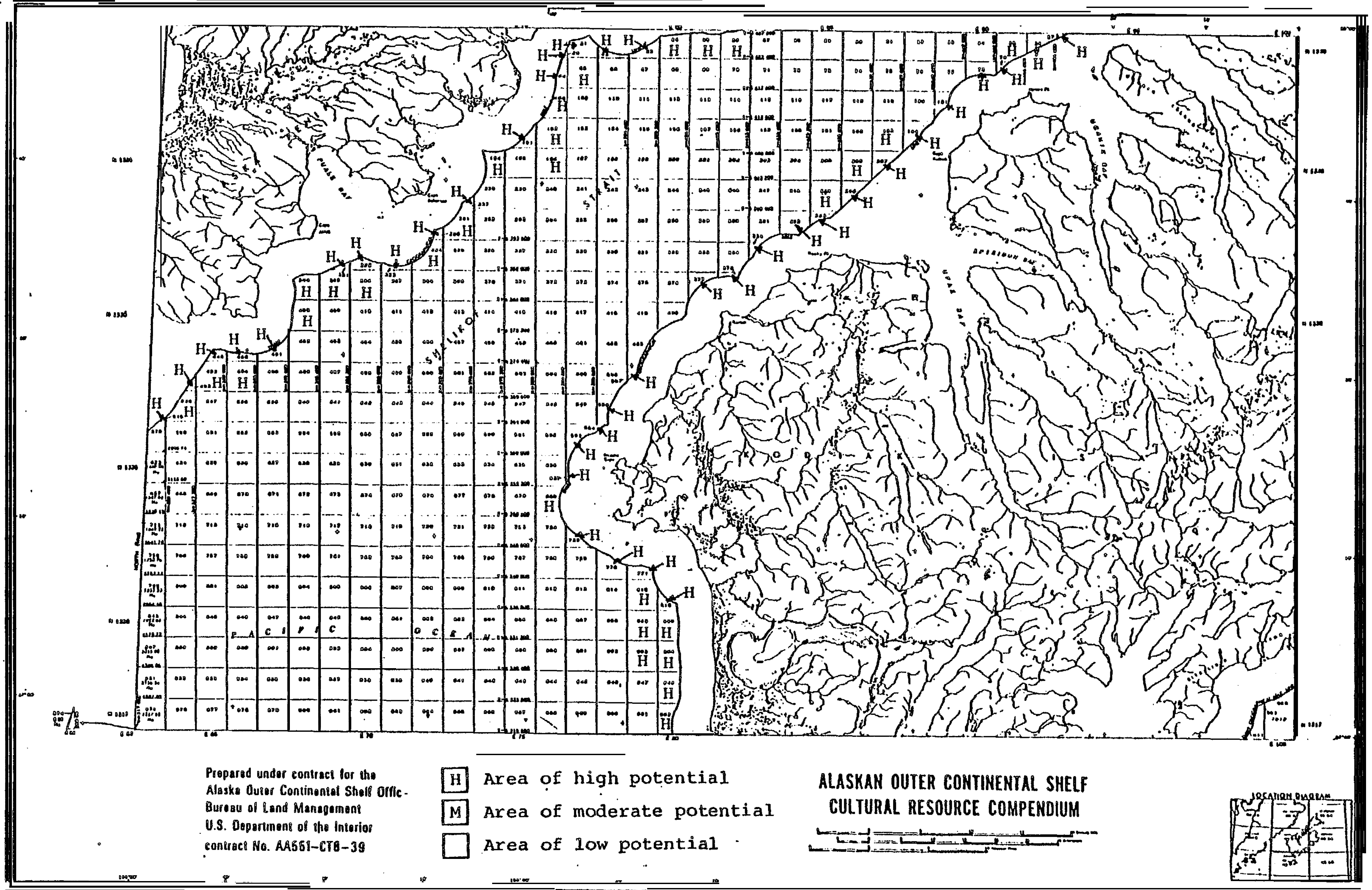
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-39

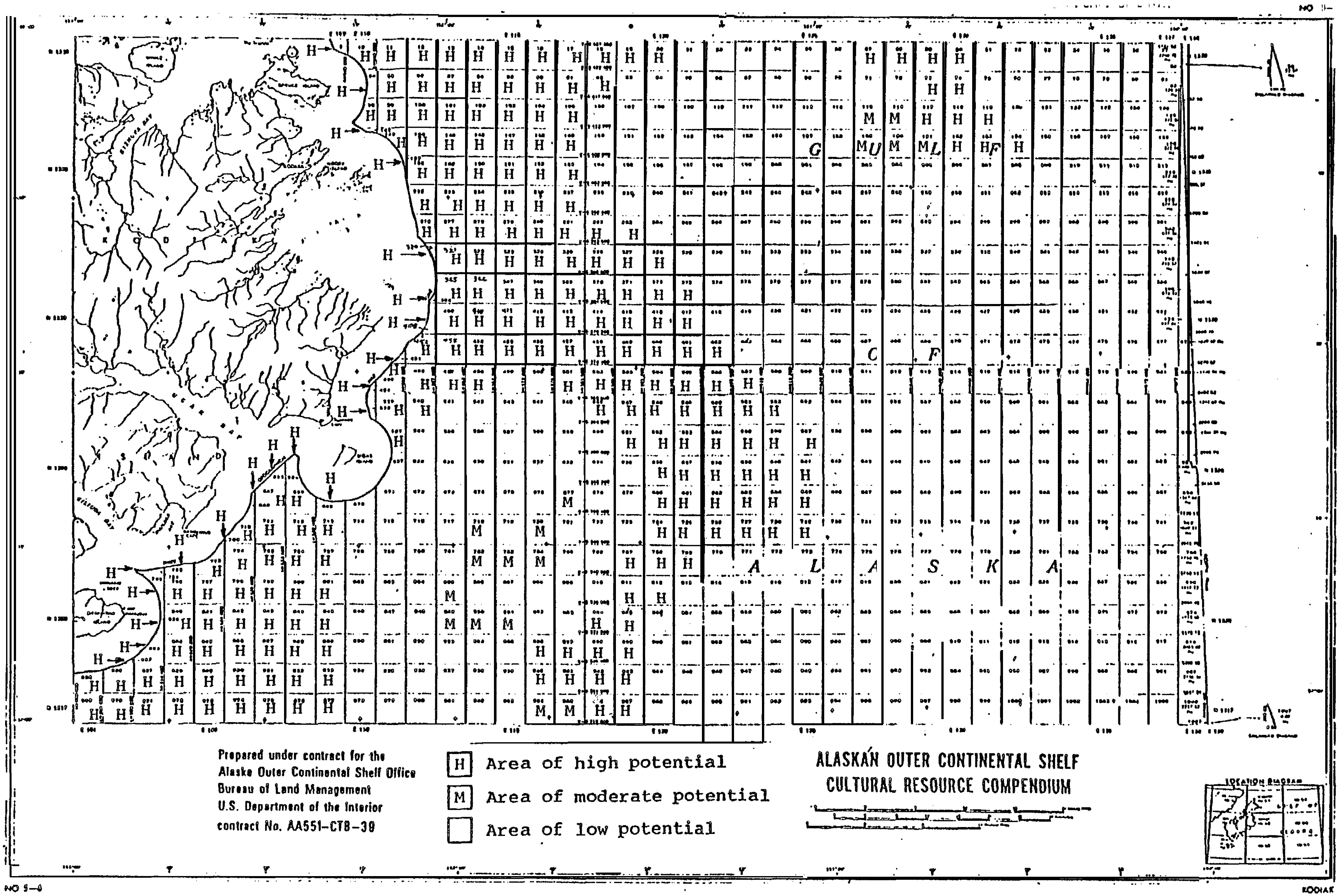
H Area of high potential

M Area of moderate potential

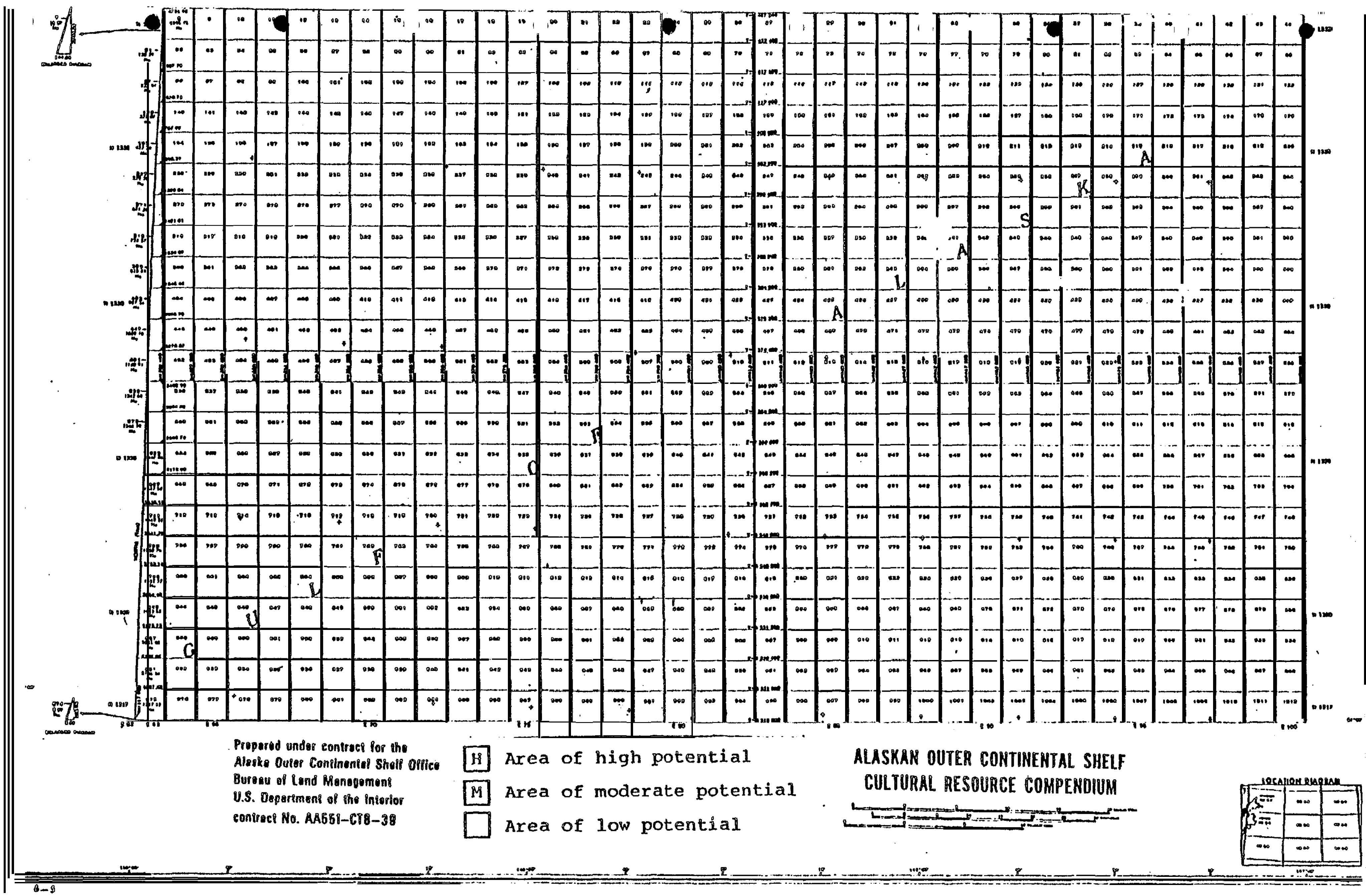
Area of low potential

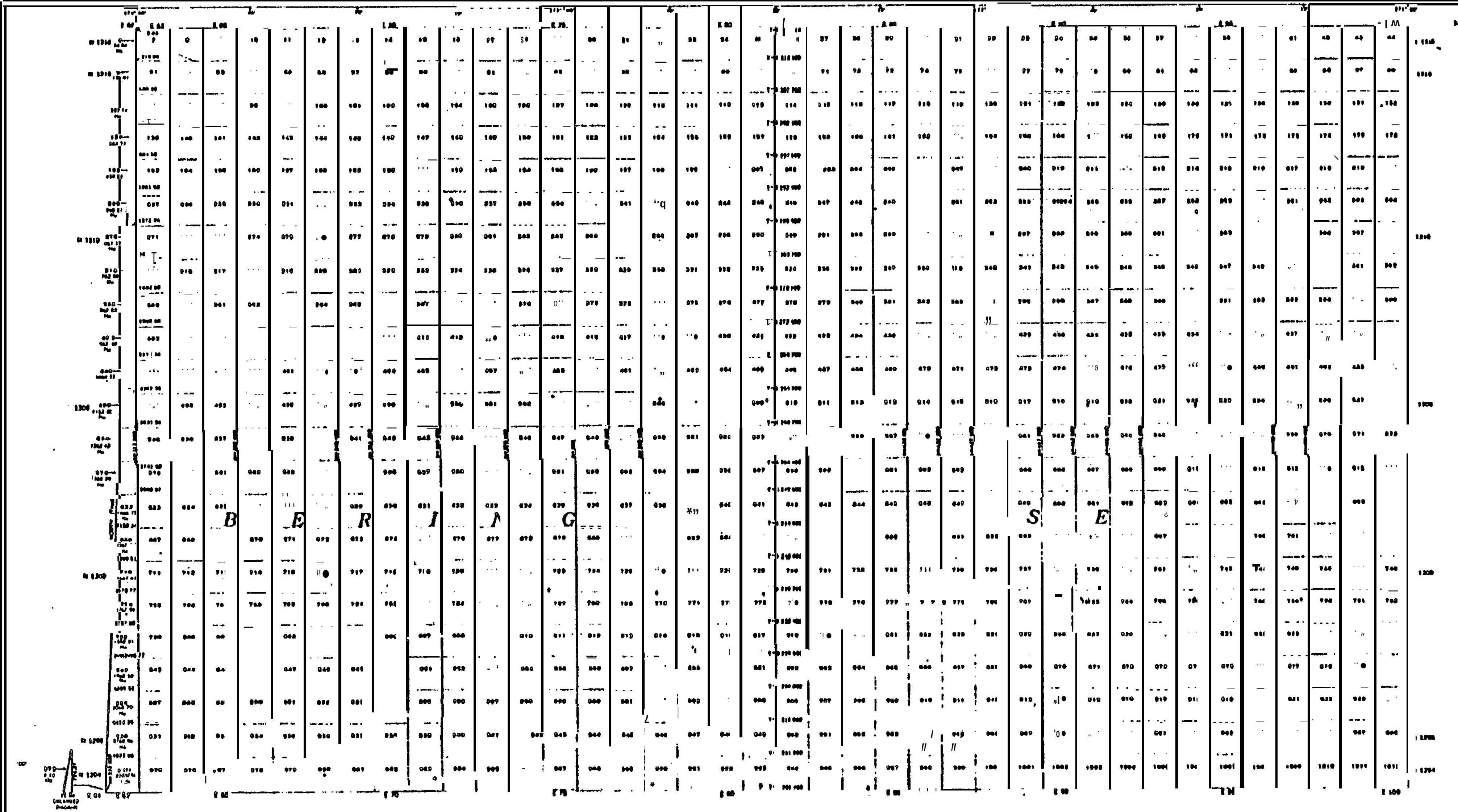
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM


PACIFIC OCEAN
SHELIKOF STRAIT
KODIAK
H
Area of high potential
M
Area of moderate potential
Area of low potential
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM
Prepared under contract for the
Alaska Outer Continental Shelf Offic-
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-39
LOCATION DIAGRAM



ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM
Prepared under contract for the
Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-39
H Area of high potential
M Area of moderate potential
Area of low potential
A L A S K A
KODIAK
NO 5-6


GULF OF ALASKA
Prepared under contract for the
Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-38
H Area of high potential
M Area of moderate potential
Area of low potential
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM
LOCATION DIAGRAM



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Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-39

[H] Area of high potential

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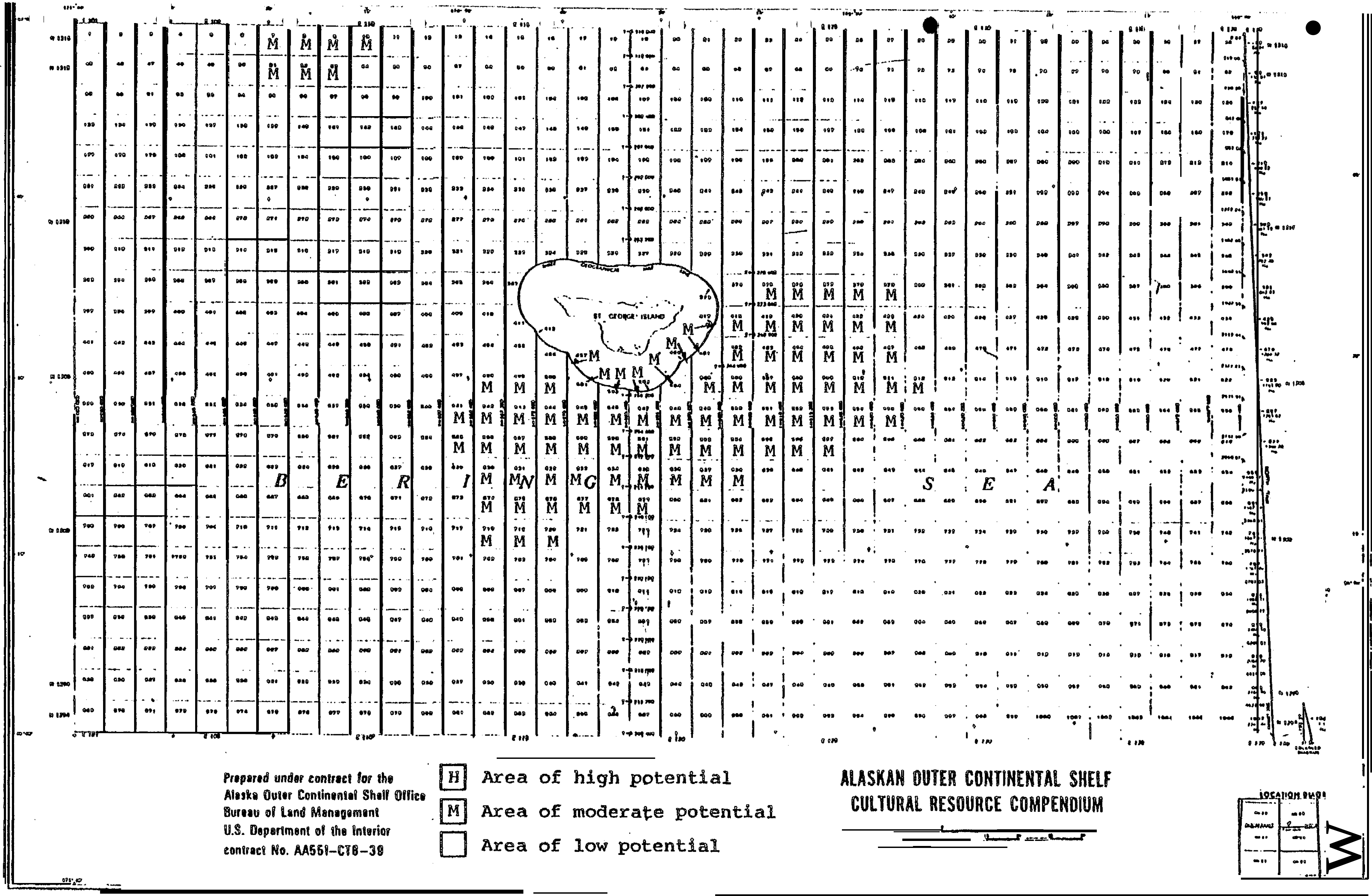
[ ] Area of low potential

ALASKAN OUTER CONTINENTAL SHELF CULTURAL RESOURCE COMPENDIUM

LOCATION DIAGRAM

NO 3-7

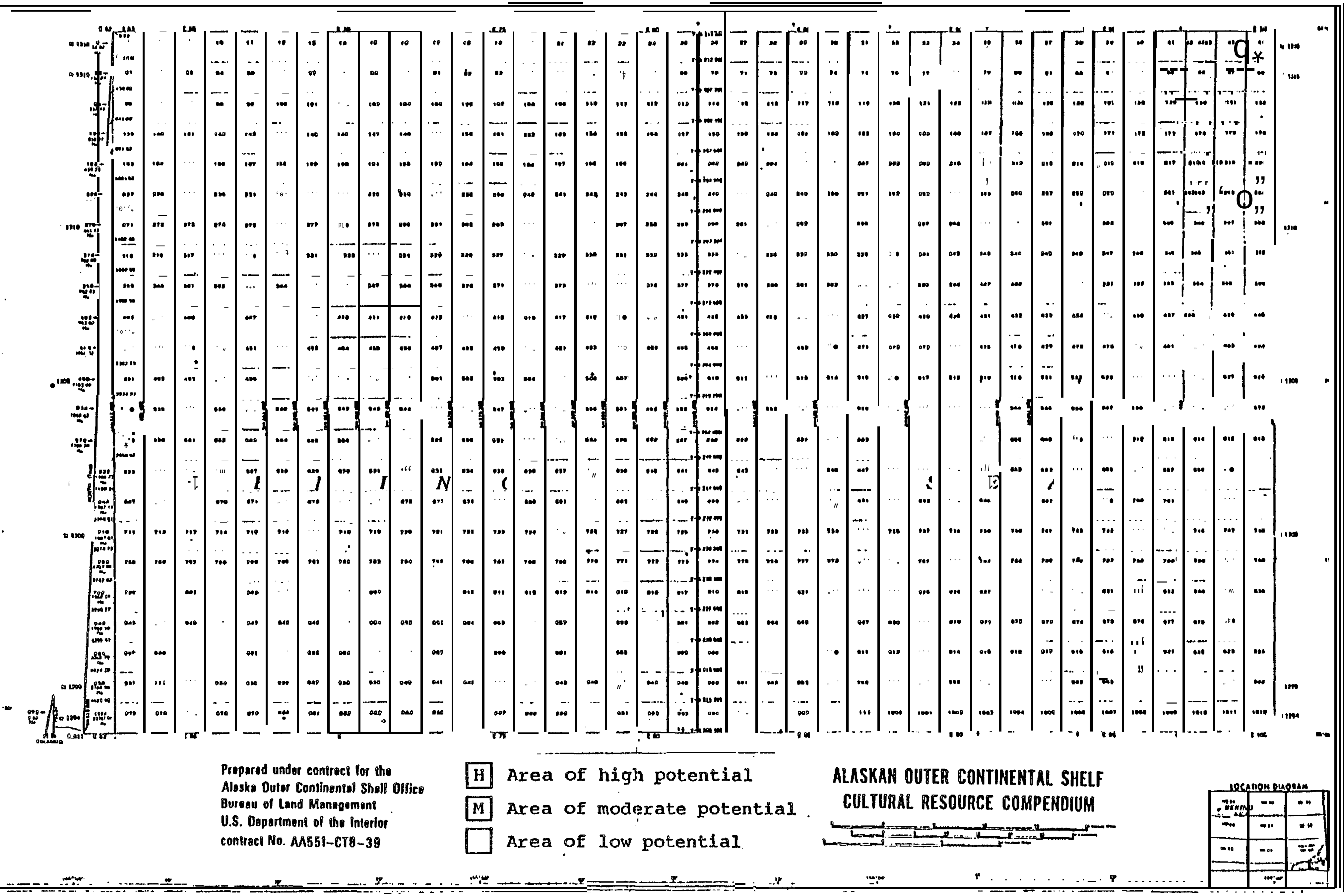


Prepared under contract for the
Alaska Outer Continental Shelf Office
Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-38

H Area of high potential
M Area of moderate potential
Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

ST. GEORGE ISLAND



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Bureau of Land Management
U.S. Department of the Interior
contract No. AA551-CT8-39

H Area of high potential

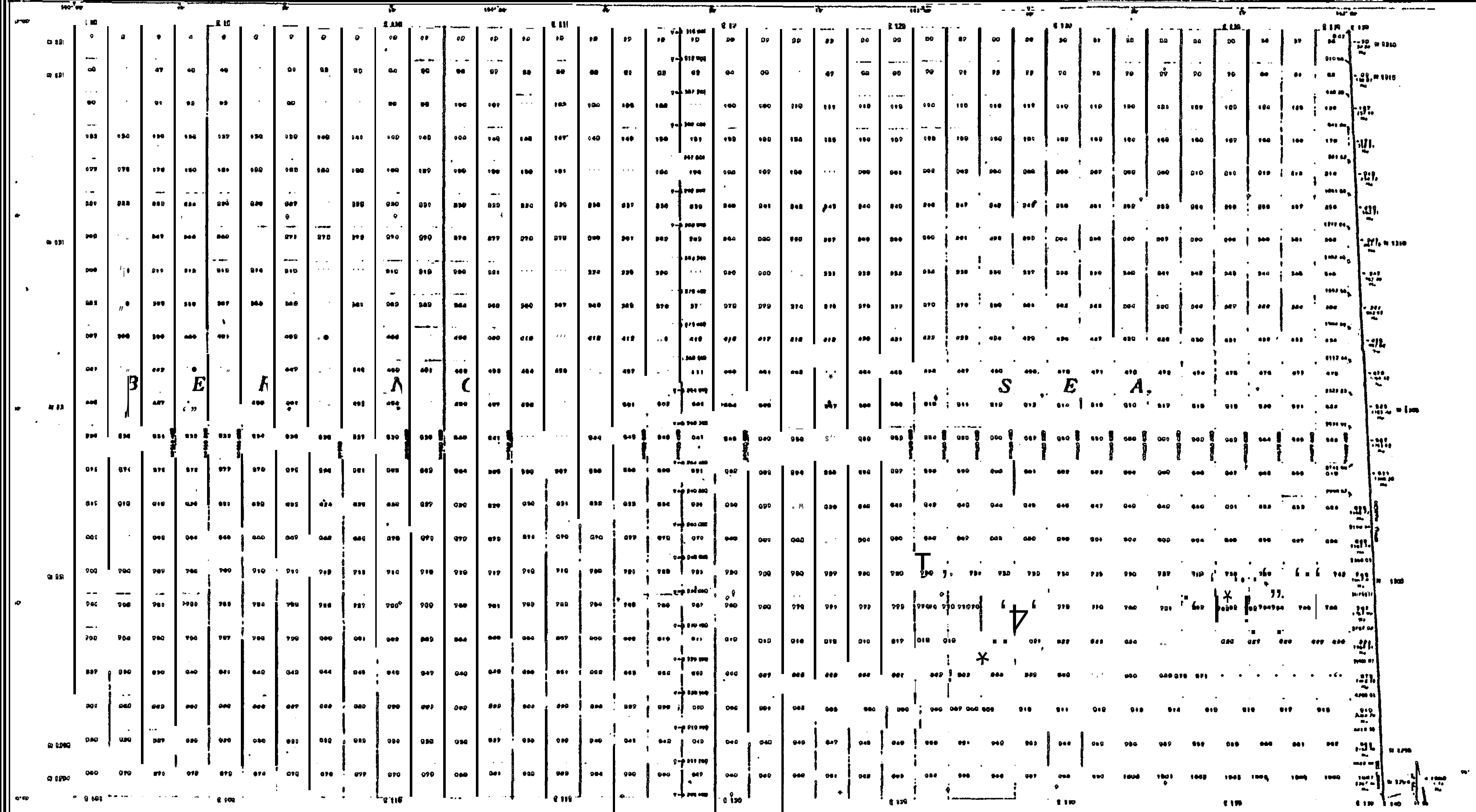
M Area of moderate potential

Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

3-7

DUPLICATE ORIGINAL



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contract No. AA551-CT8-39

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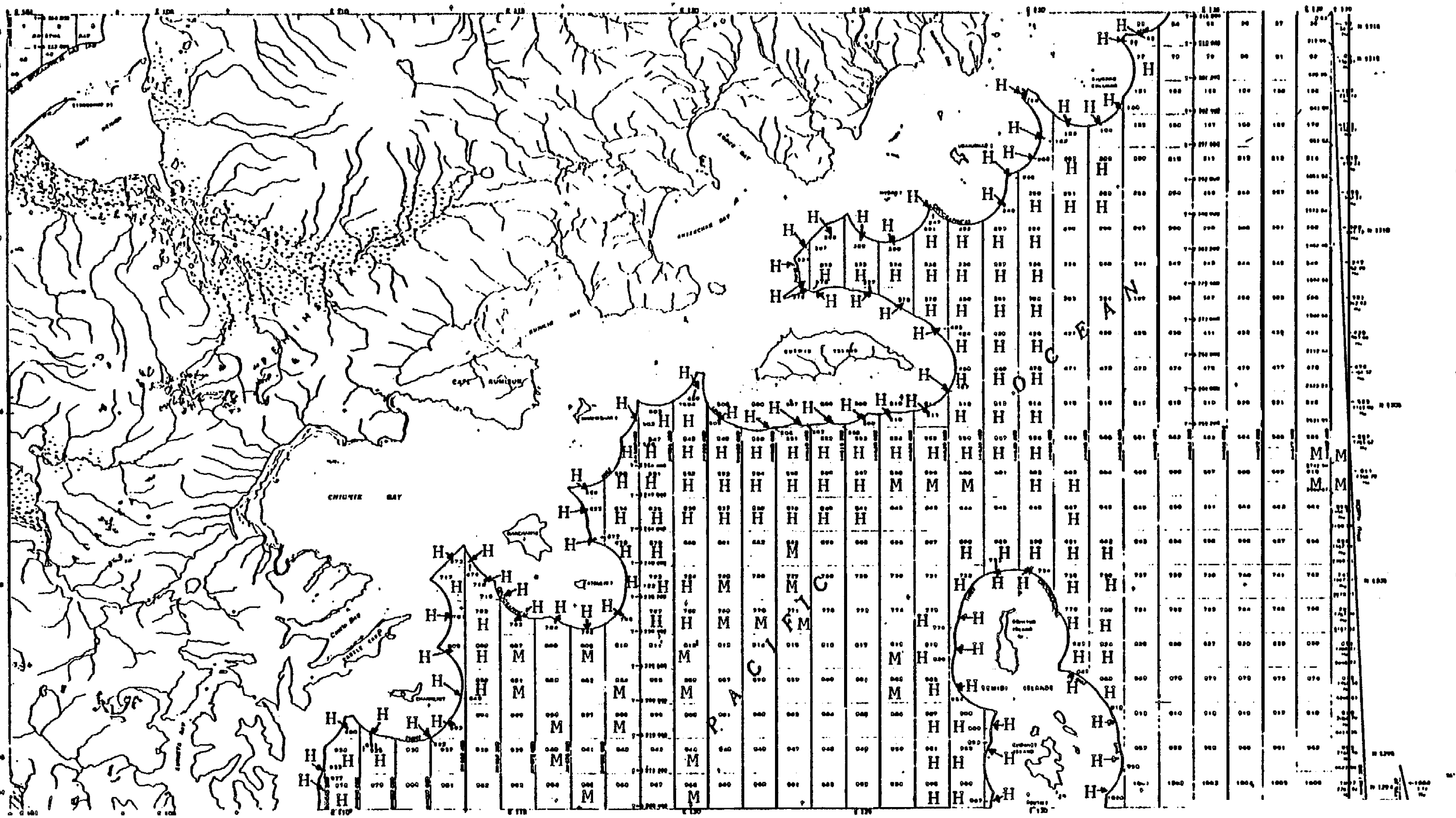
[ ] Area of low potential

ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



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[H] Area of high potential
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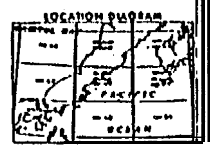
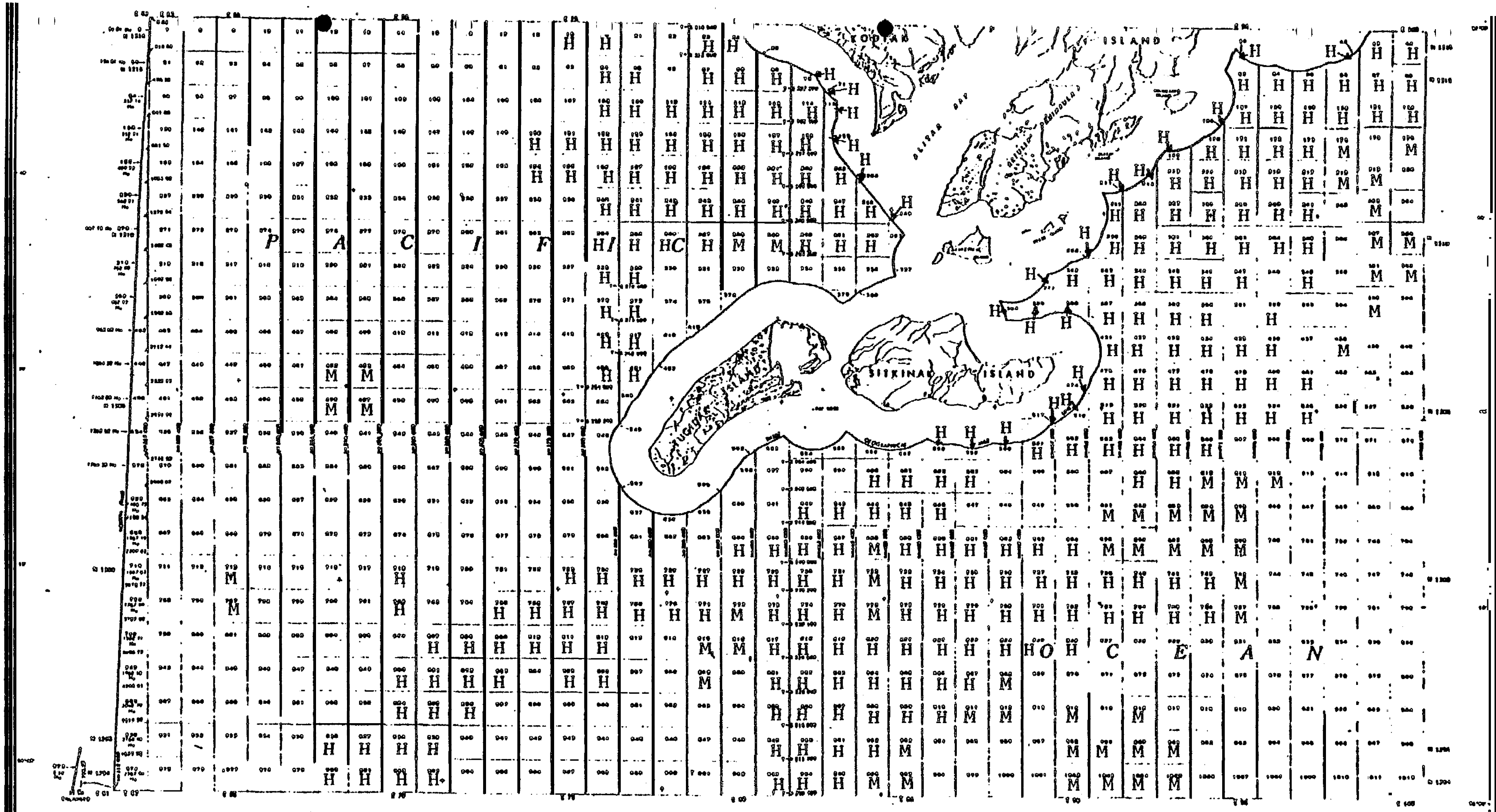
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM





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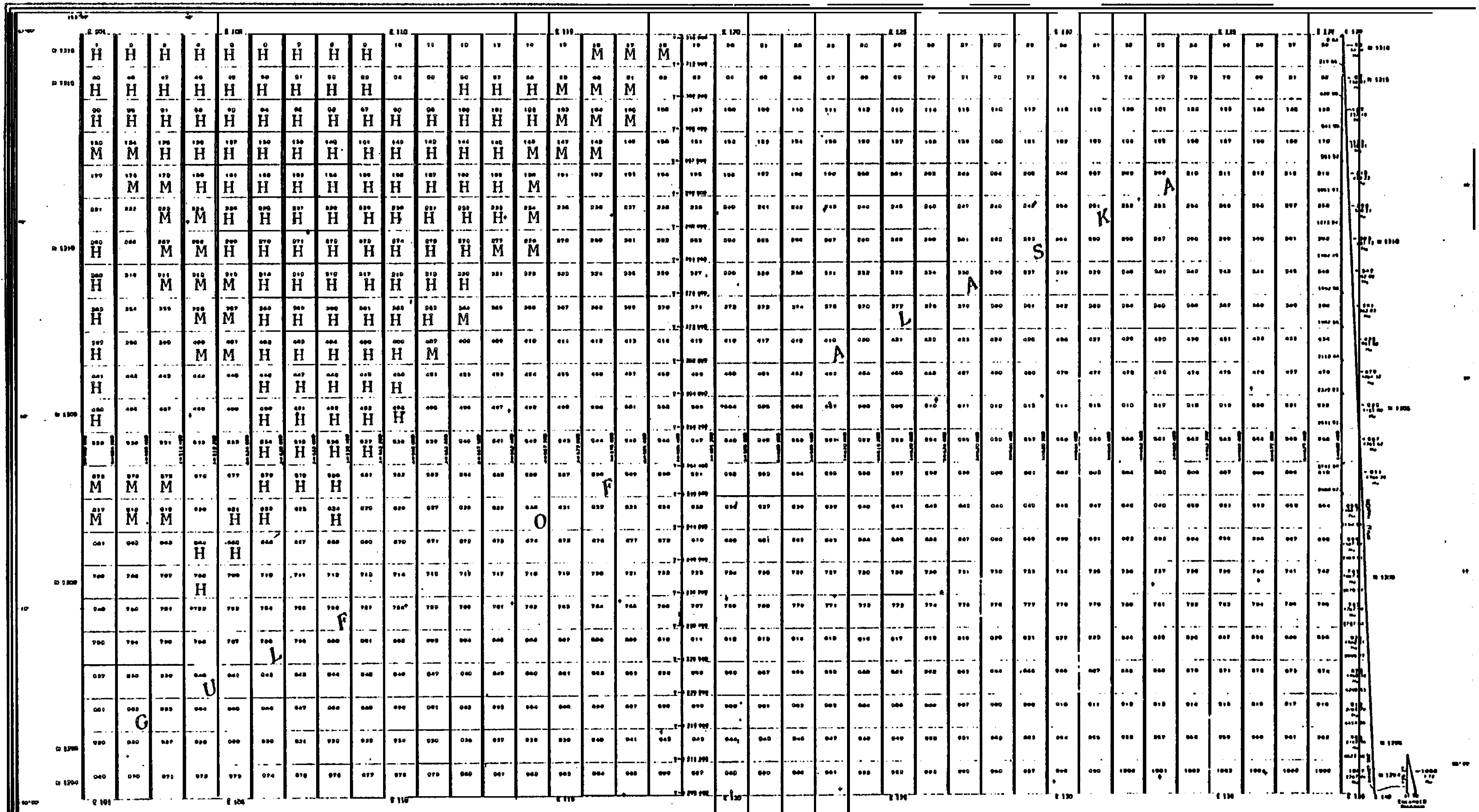
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



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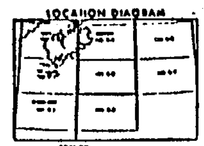
H	Area of high potential
M	Area of moderate potential
	Area of low potential

ALASKAN OUTER CONTINENTAL SHELF CULTURAL RESOURCE COMPENDIUM



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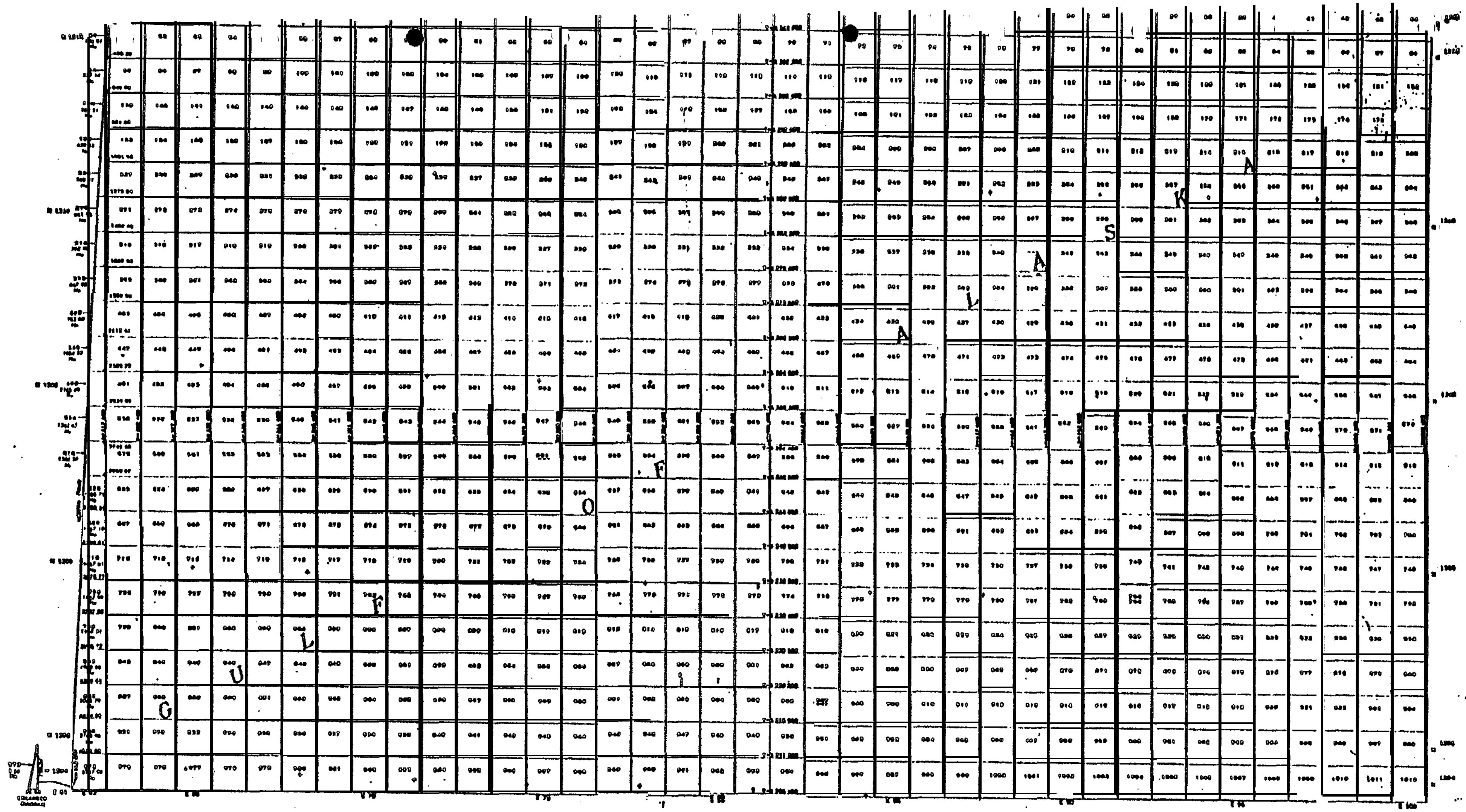

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ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

LOCATION DIAGRAM

NO 8-7

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ALASKAN OUTER CONTINENTAL SHELF
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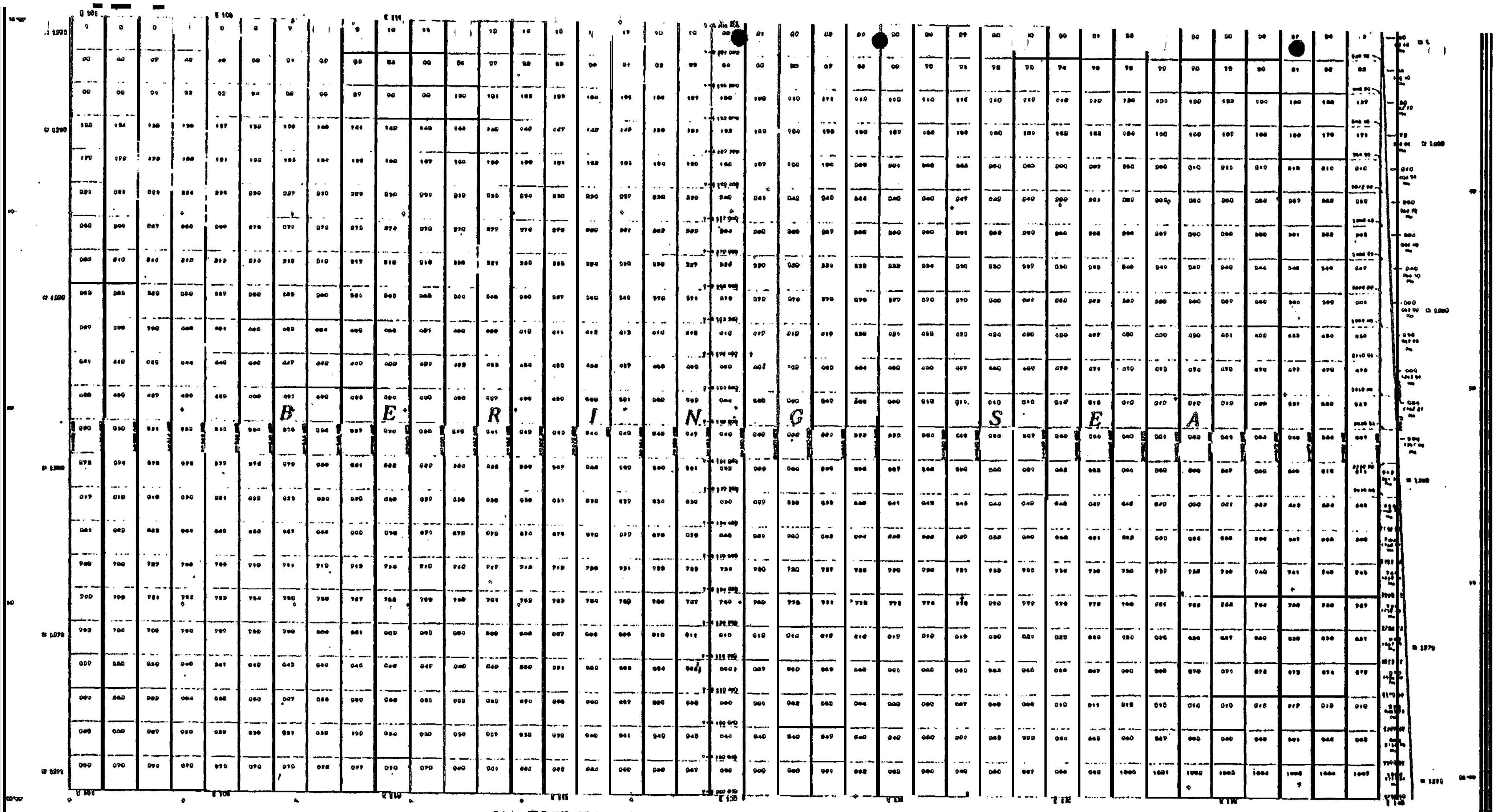

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ALASKAN OUTER CONTINENTAL SHELF
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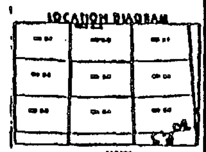

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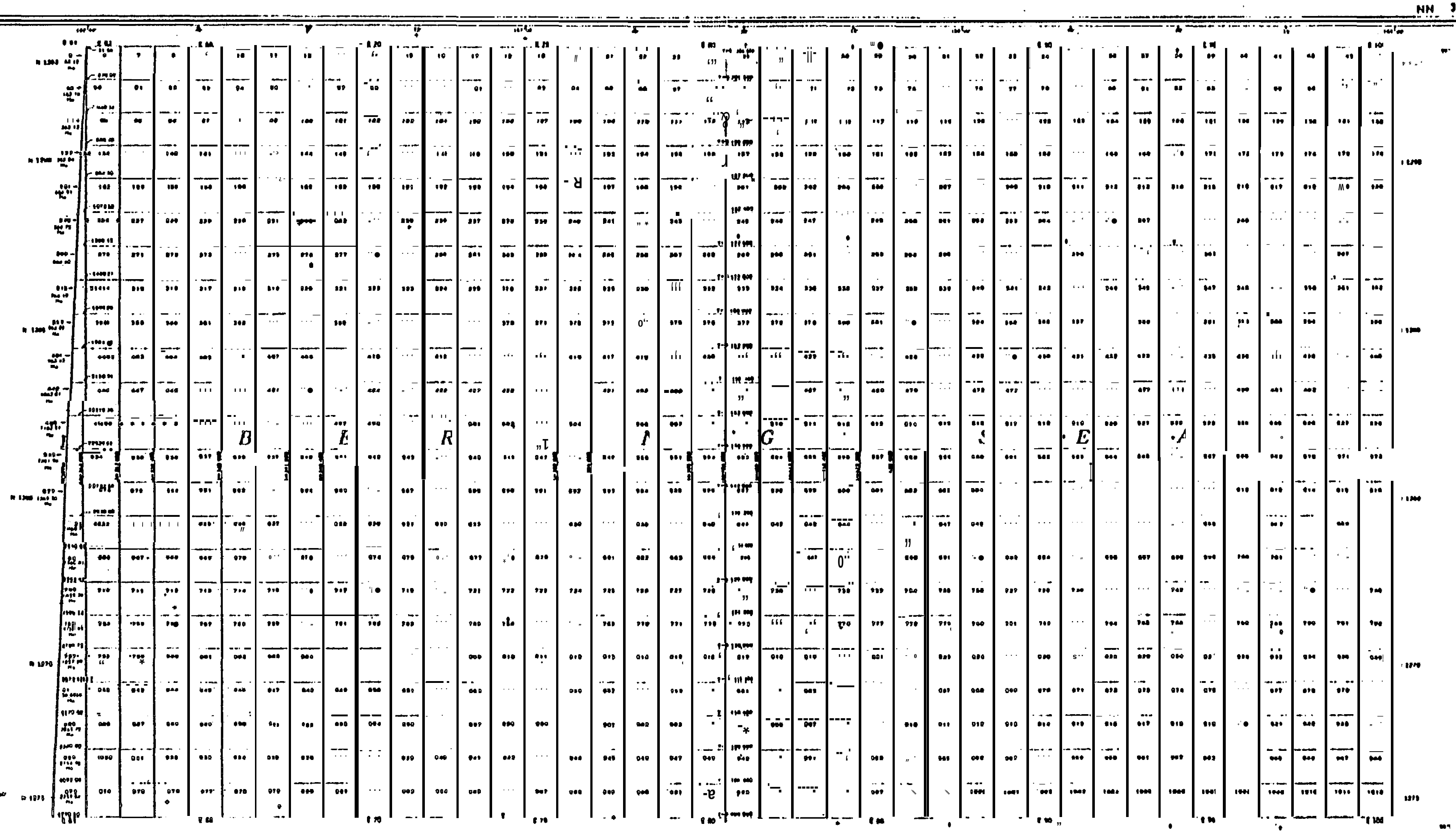

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ALASKAN OUTER CONTINENTAL SHELF
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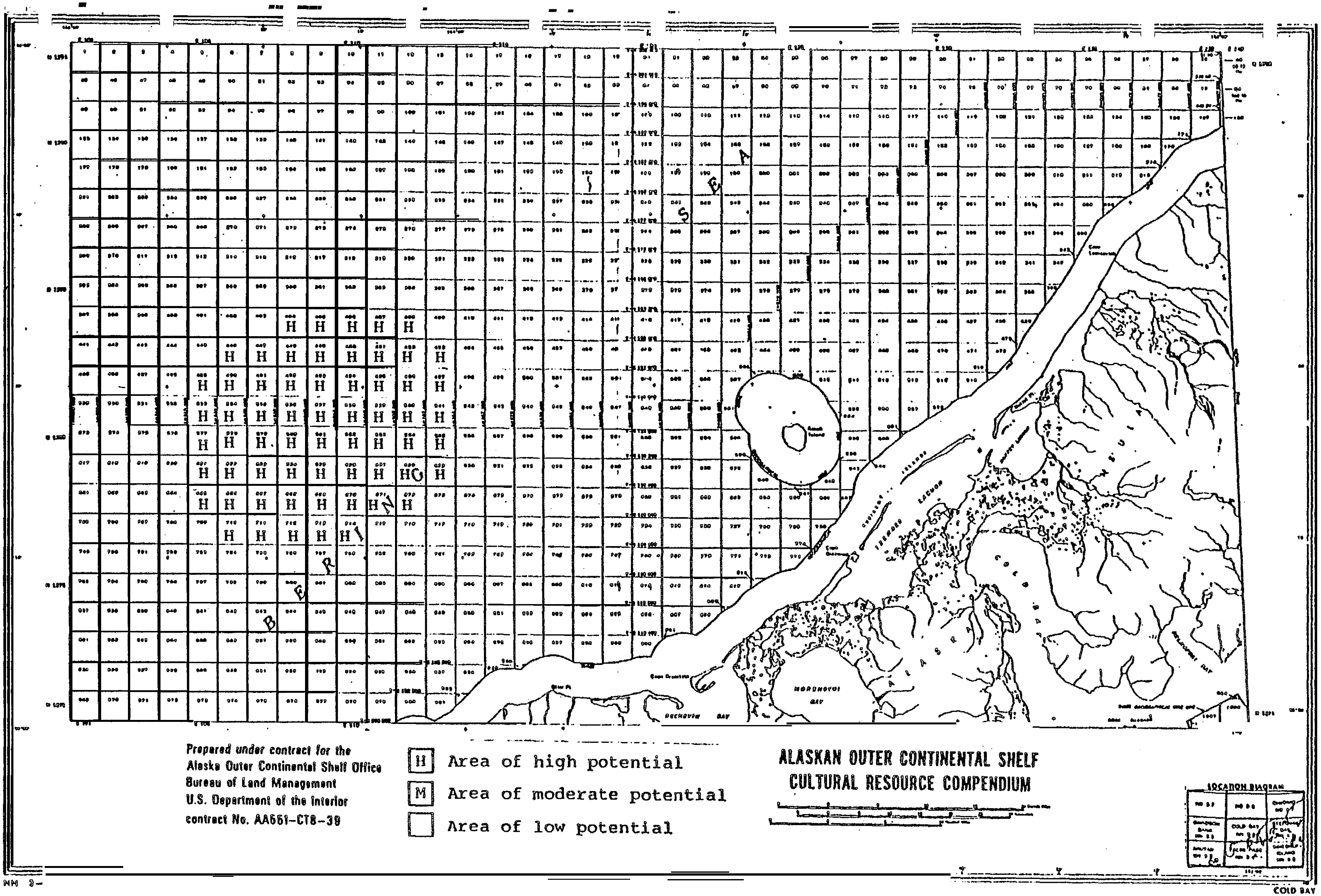
LOCATION DIAGRAM



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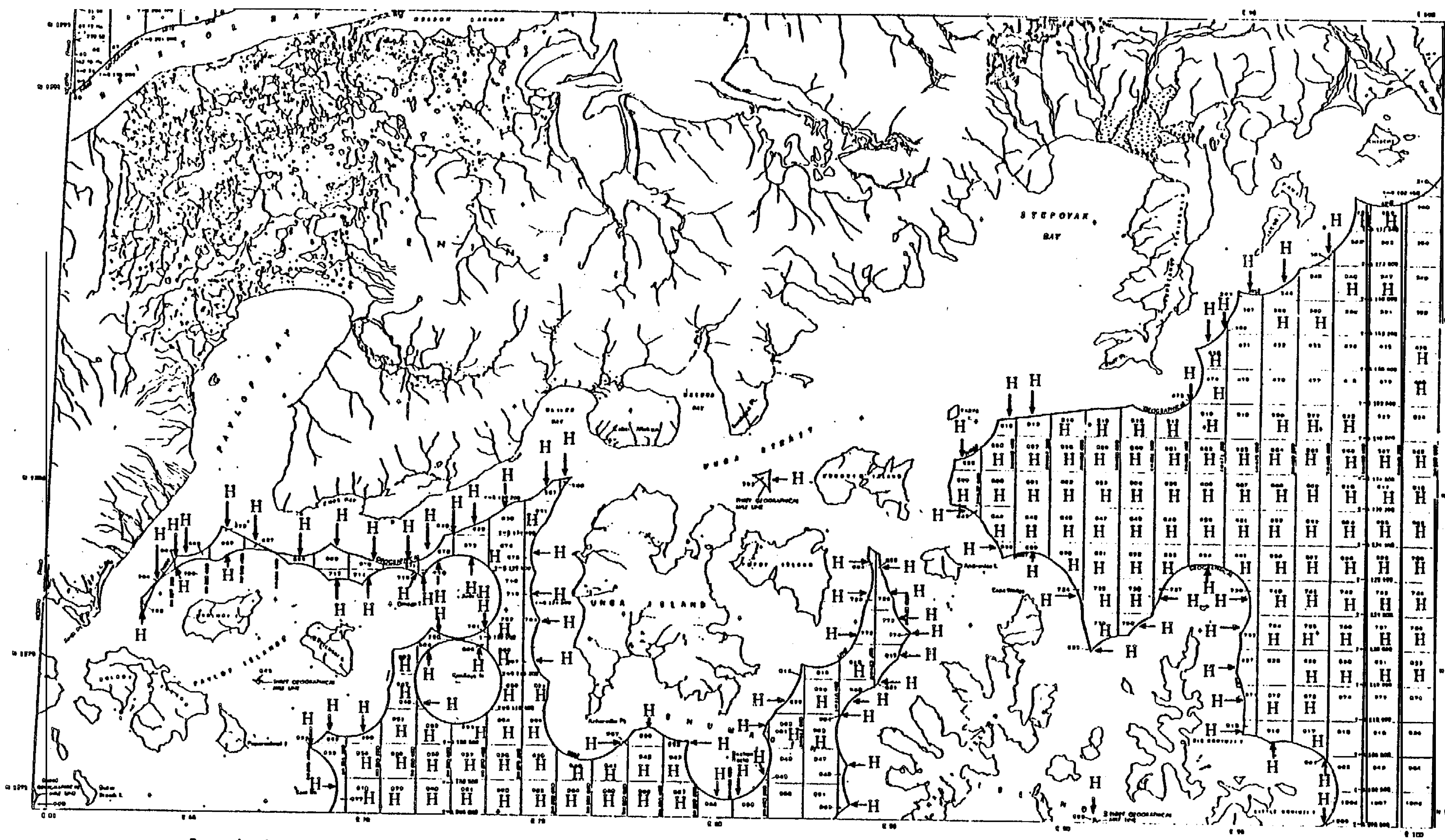

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ALASKAN OUTER CONTINENTAL SHELF
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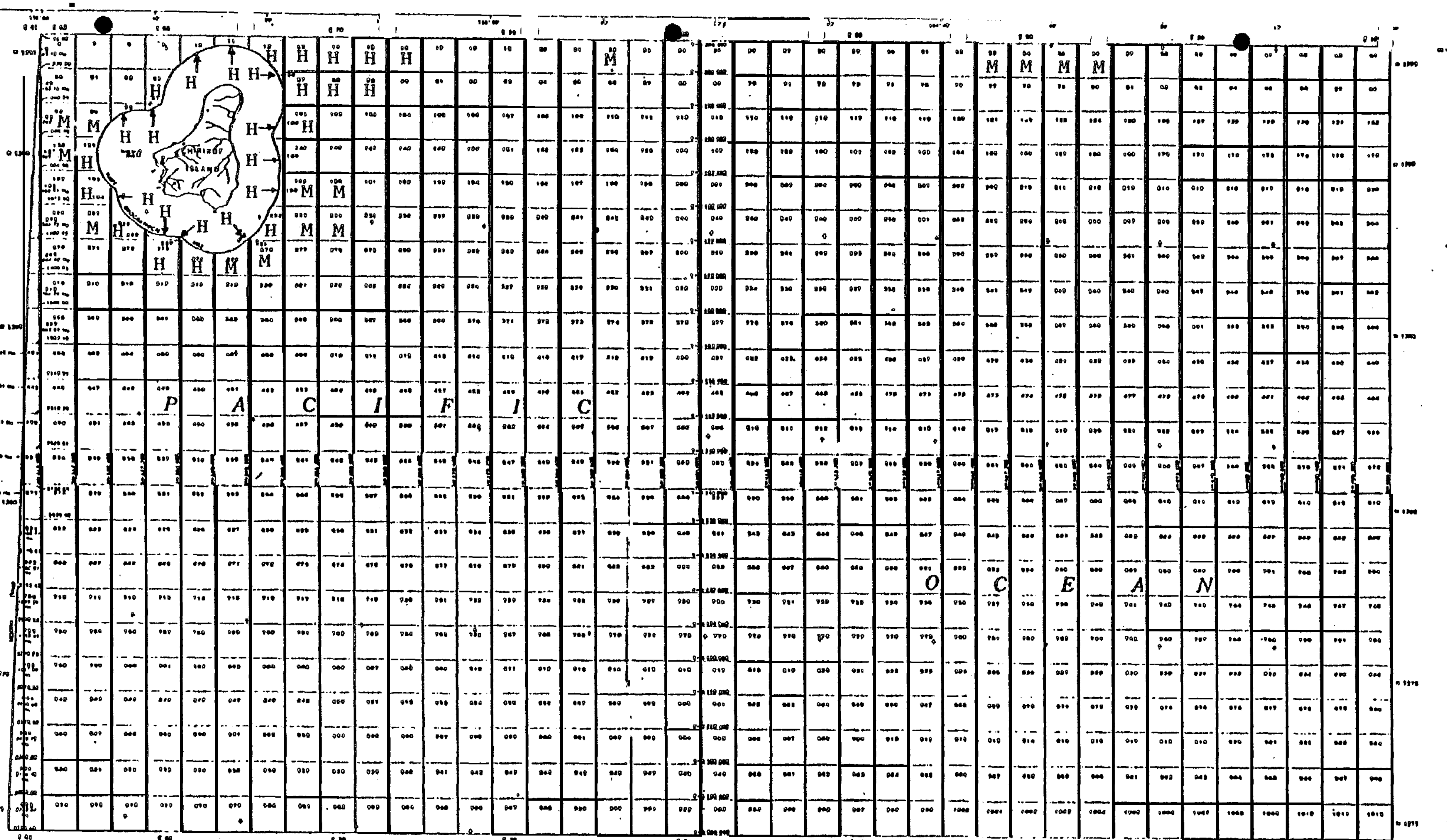

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ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

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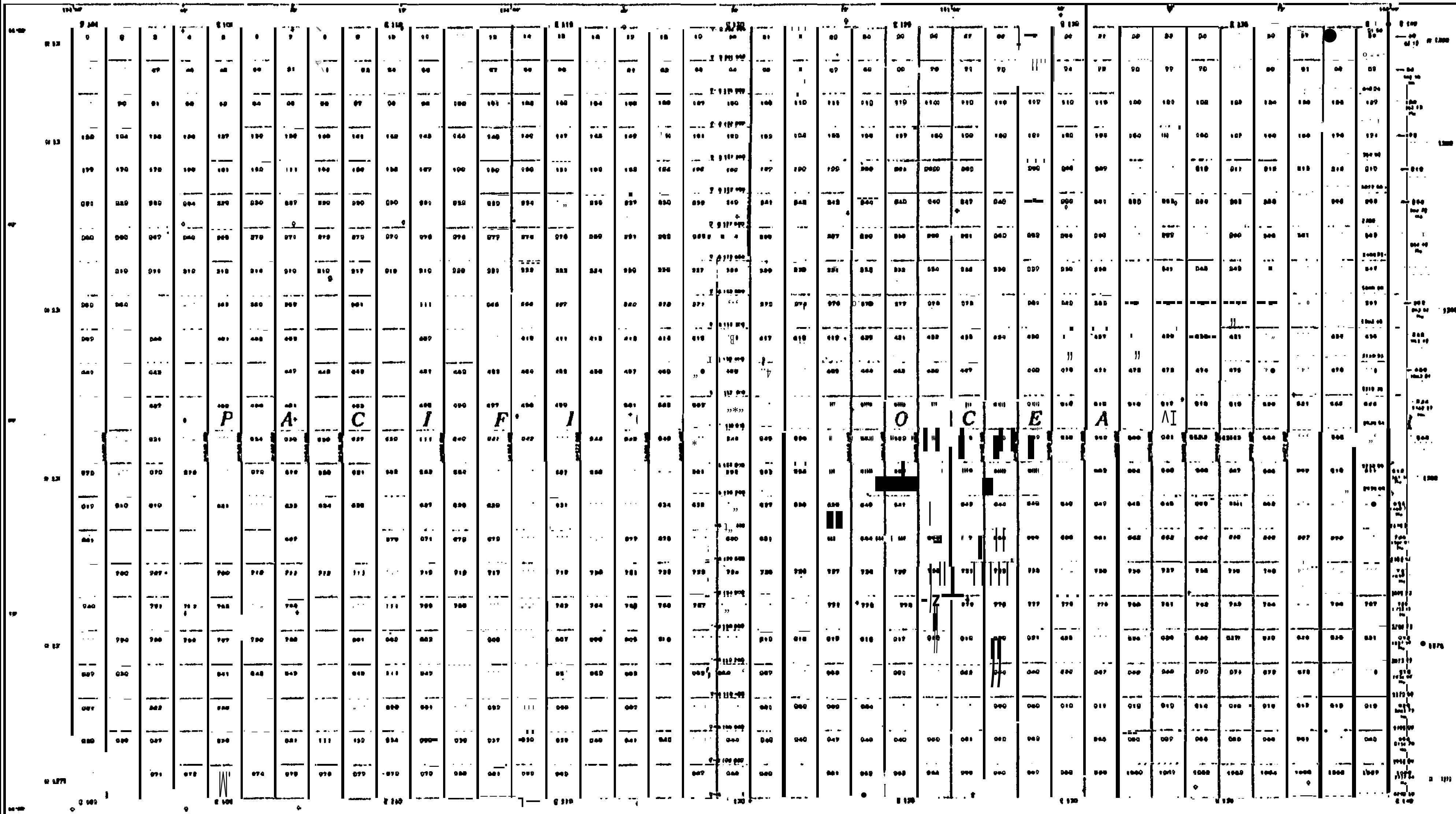

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ALASKAN OUTER CONTINENTAL SHELF
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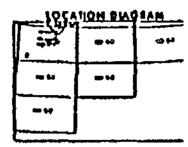

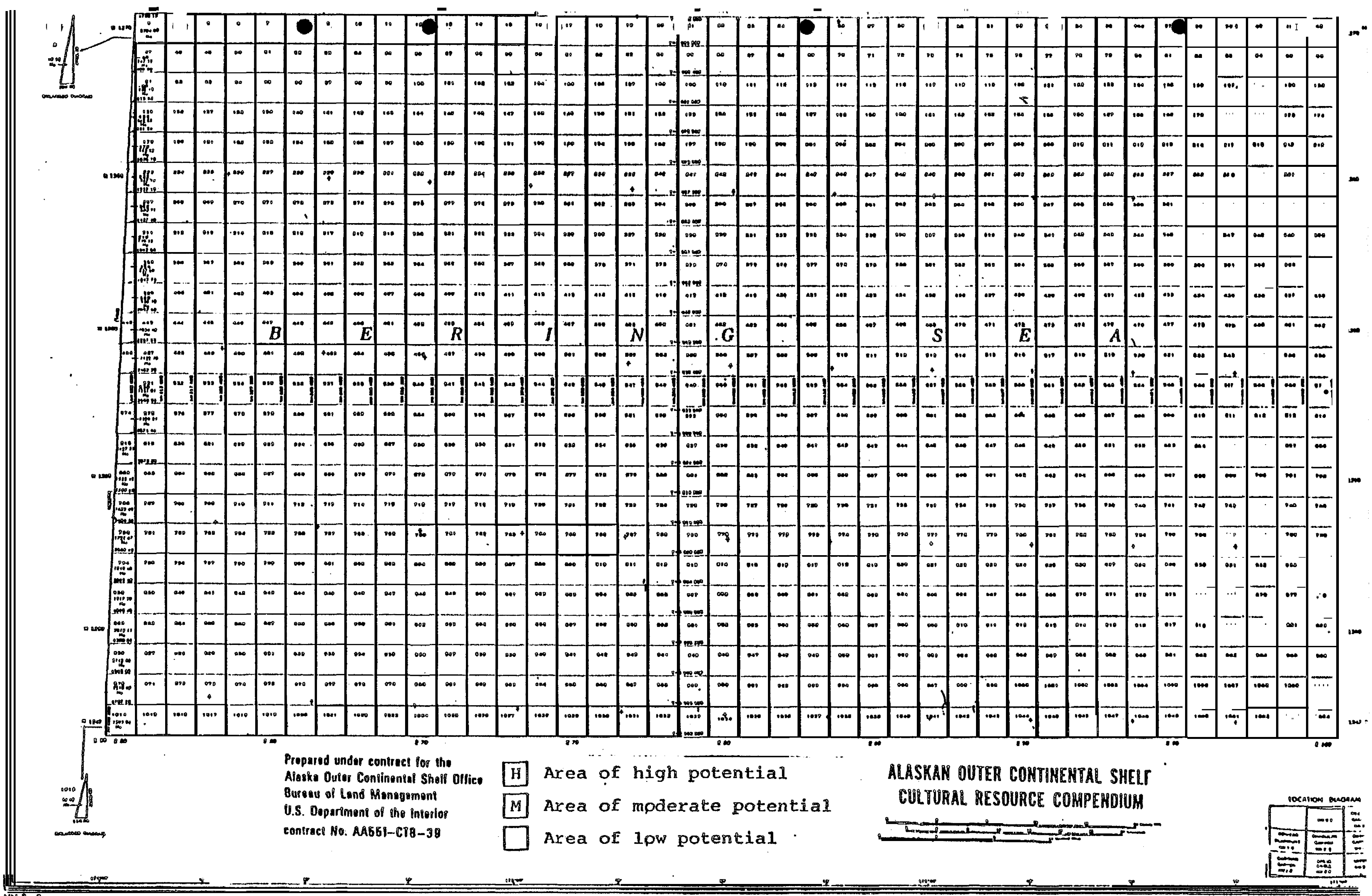

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ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

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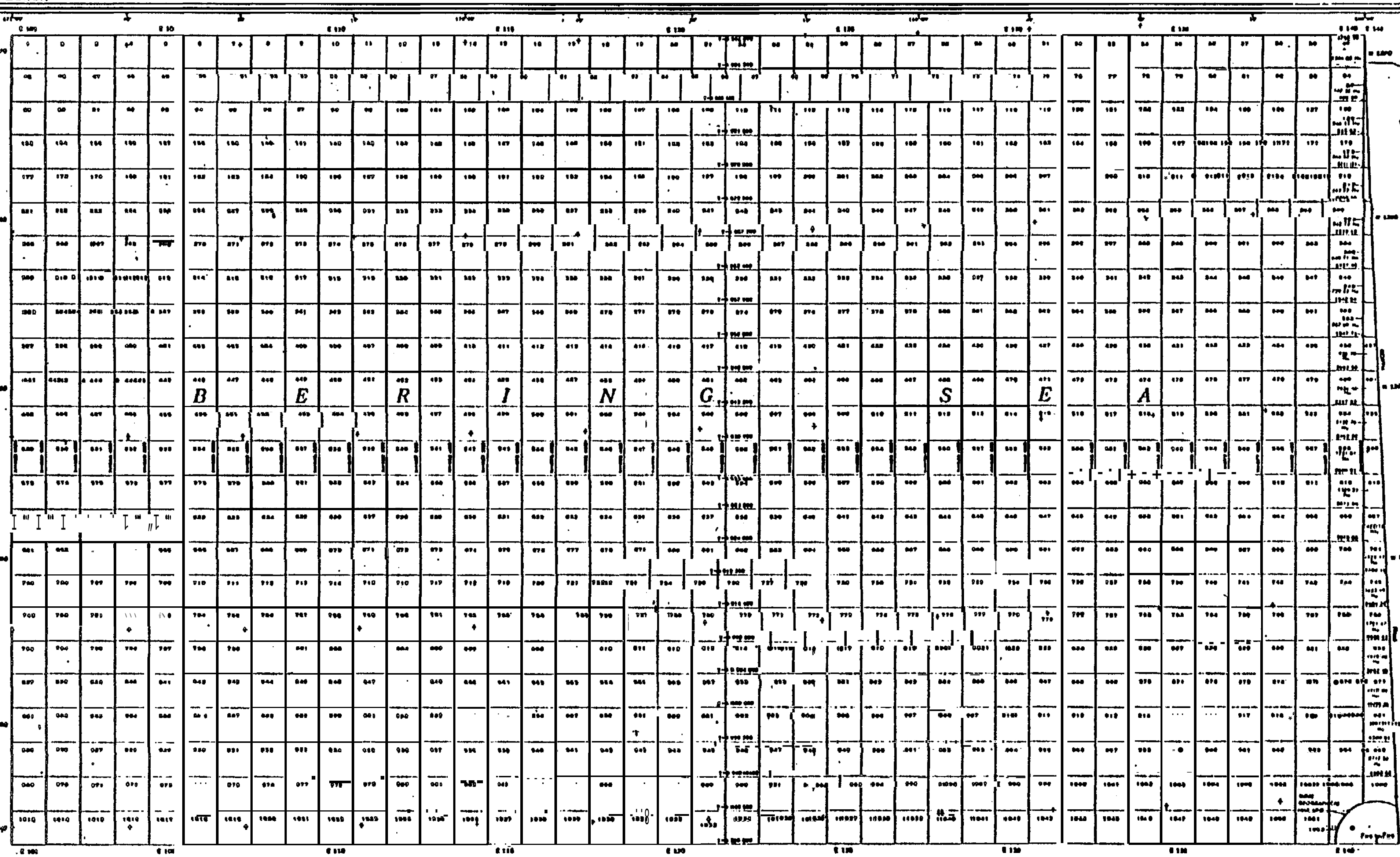

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ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

LOCATION DIAGRAM

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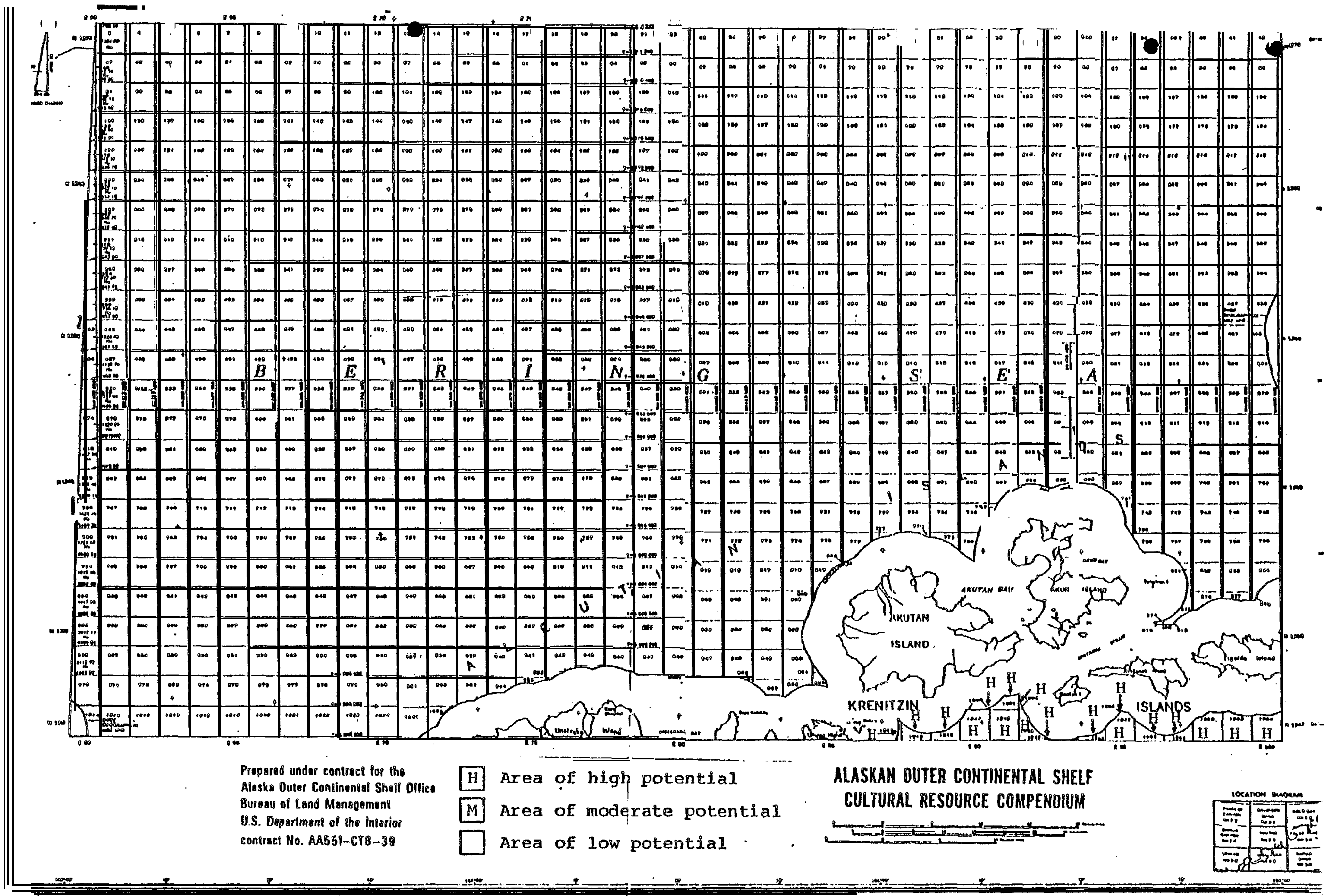

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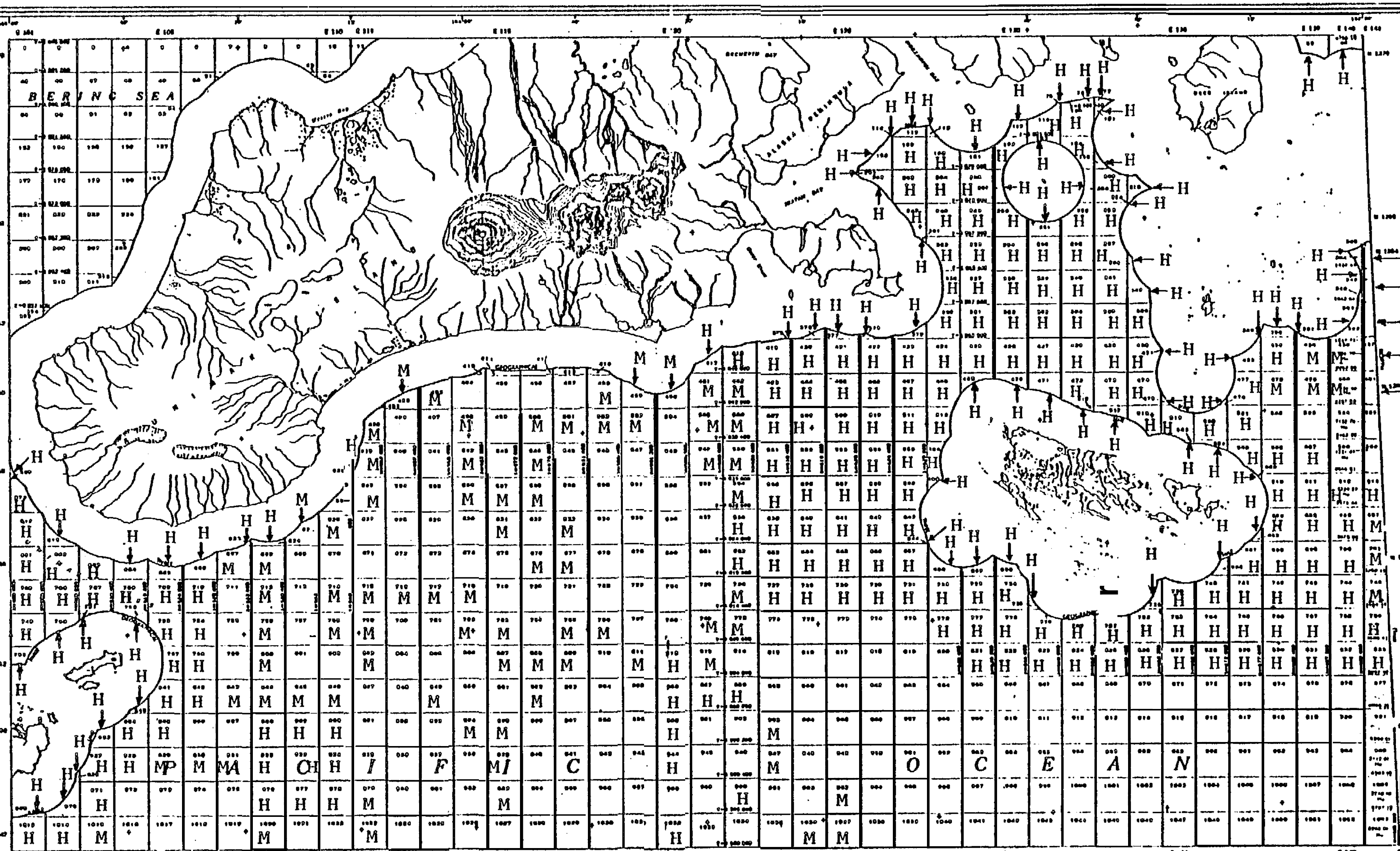
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



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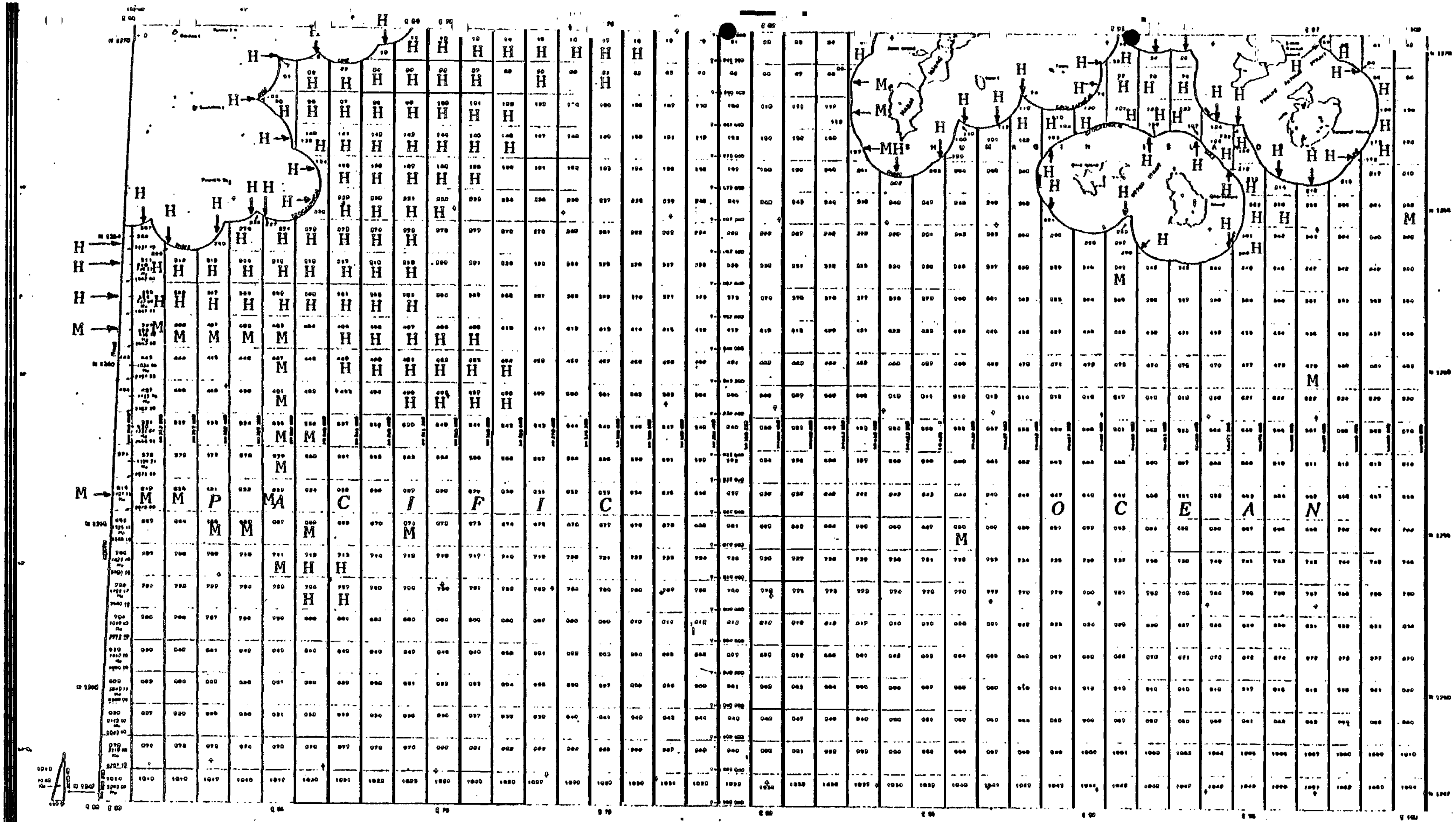
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM

LOCATION DIAGRAM



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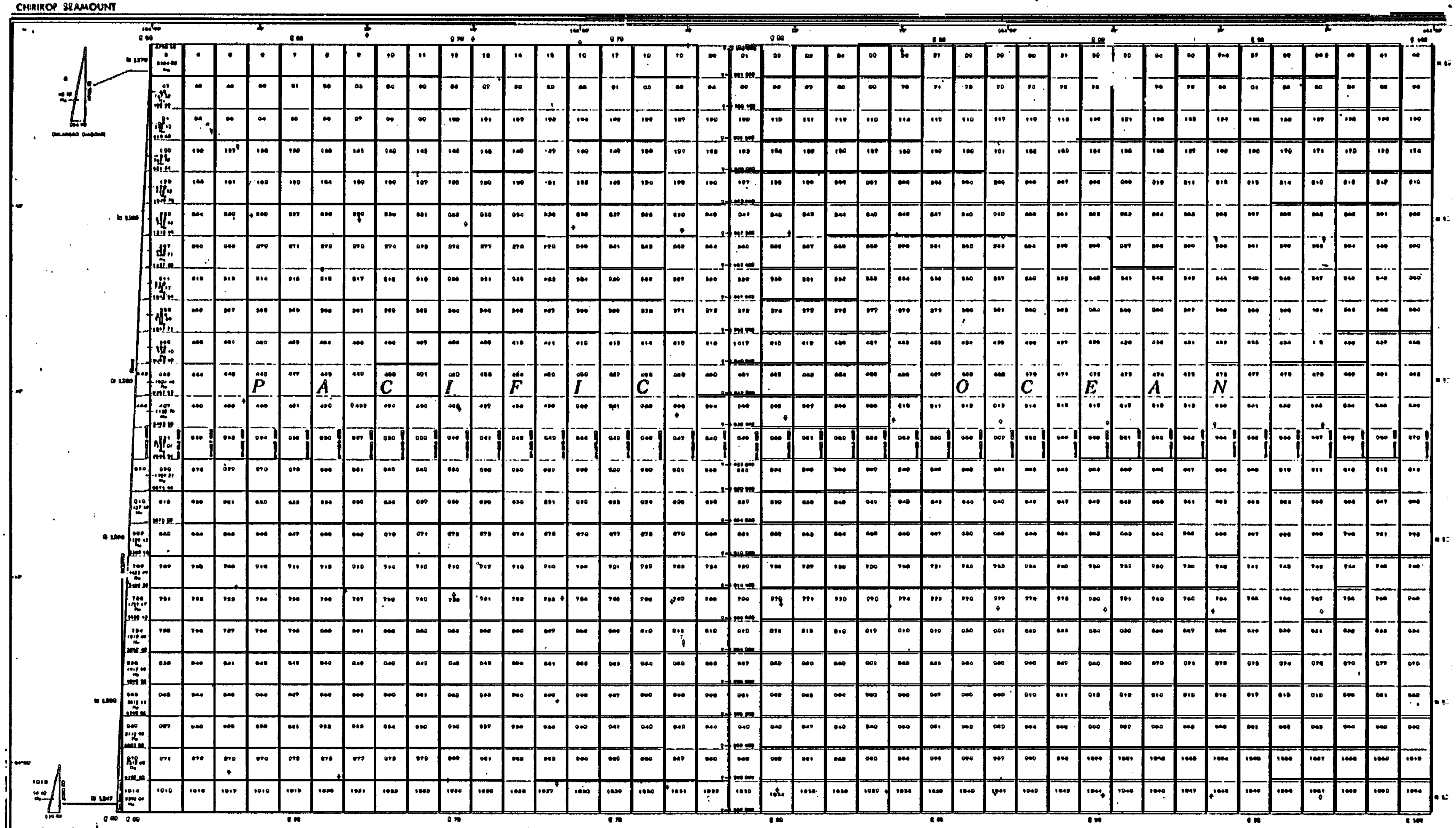
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



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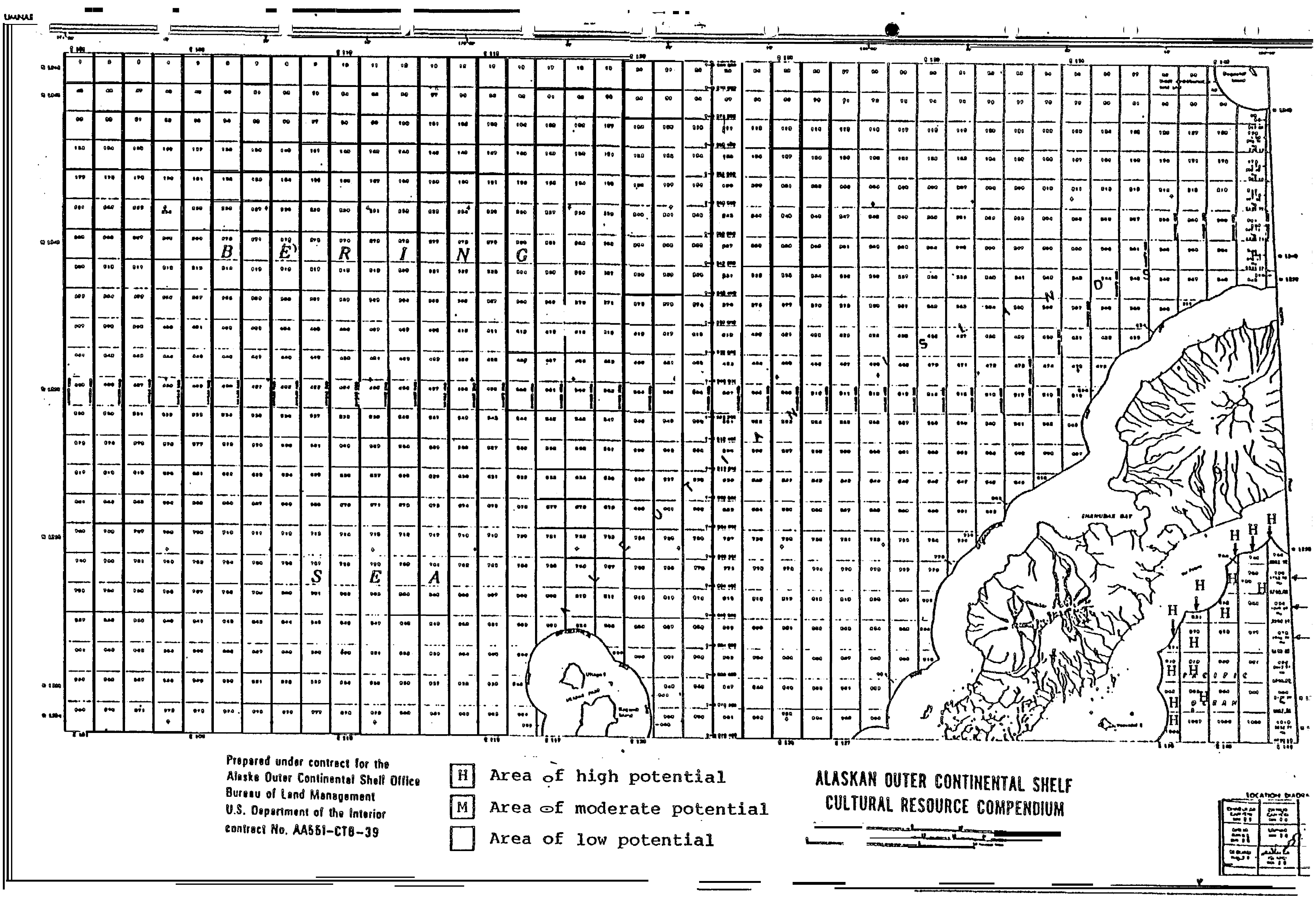
ALASKAN OUTER CONTINENTAL SHELF CULTURAL RESOURCE COMPENDIUM

LOCATION DIAGRAM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H Area of high potential
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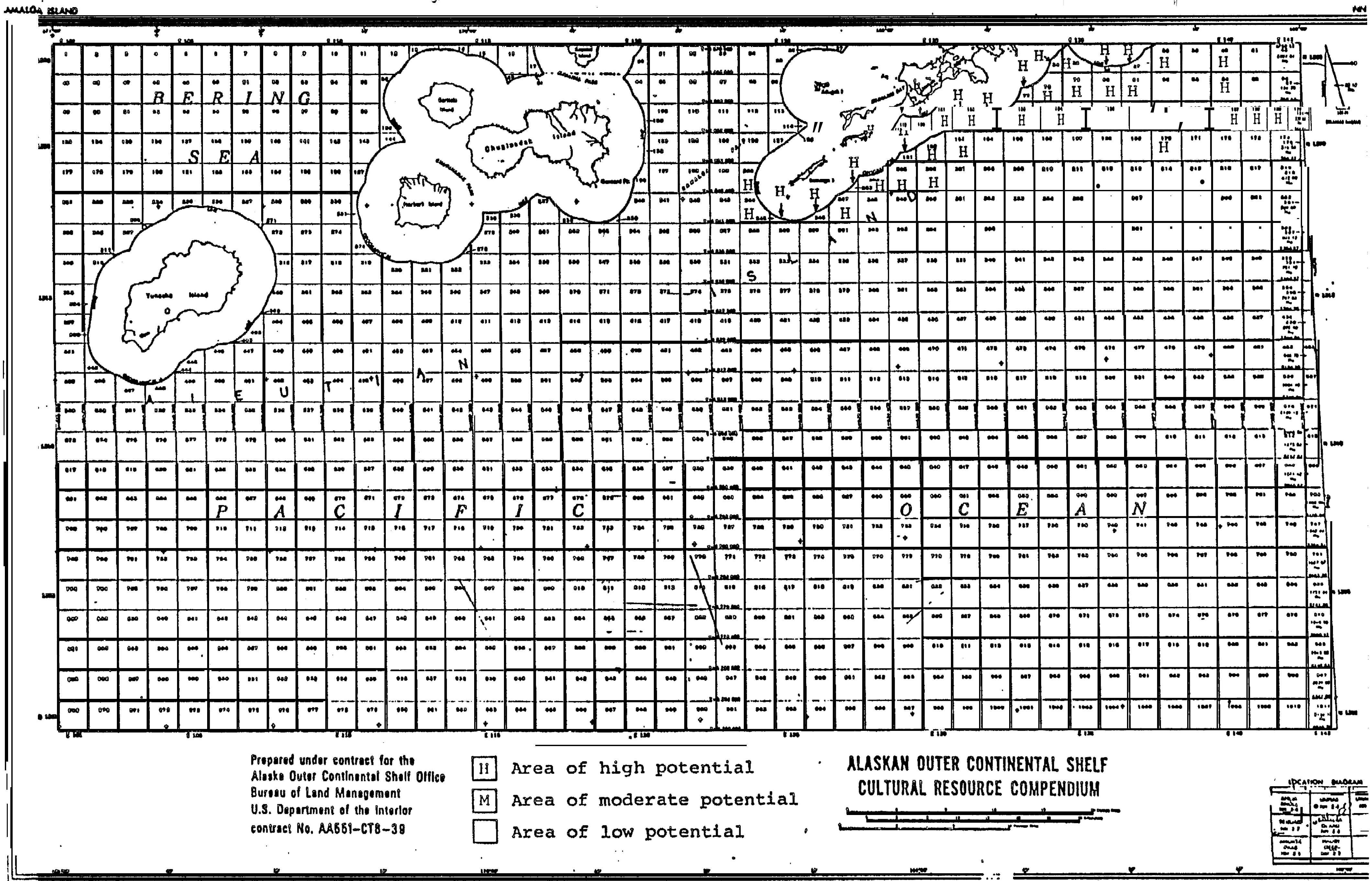
Area of low potential
ALASKAN OUTER CONTINENTAL SHELF
CULTURAL RESOURCE COMPENDIUM



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ALASKAN OUTER CONTINENTAL SHELF
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