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GEOLOGY AND PETROLEUM POTENTIAL OF HOPE AND SELAWIK BASINS

By

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HOPE BASIN STRATIGRAPHIC PROJECT

By Staff

ALASKA DIVISION OF MINING AND GEOLOGICAL AND GEOPHYSICAL SURVEYS

For

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DECEMBER 1986

TABLE OF CONTENTS

INTRODUCTION

This report is a summary of the geologic framework and petroleum potential of the Hope and Selawik basins in the southern Chukchi Sea-Kotzebue Sound region, adjacent to northwestern Alaska (figure 1). The report provides geologic information relevant to State of Alaska Lease Sale 45 in the Kotzebue Sound area, which was scheduled for May, 1989. The sale has now been deleted from the State's lease sale schedule. Information in this report may be relevant to possible future Federal lease sales in the Hope Basin. Data and information presented here were compiled from the following sources: 1) published literature, 2) logs and core from two on-shore petroleum test holes, 3) logs from several shallow coal exploration wells at Chicago Creek on northern Seward Peninsula, 4) field studies of Cretaceous outcrops north of Kotzebue Sound, 5) unpublished industry reports, and 6) conversations with industry and government geologists who have worked in the region. Funding for our survey of the published literature and for a 10-day field study of Cretaceous outcrops was provided by a grant from the "Studies Related to Continental Margins" program of the U.S. Department of the Interior, Minerals Management Service, and administered by the Bureau of Economic Geology, University of Texas at Austin. This report will serve as the final report for the "Hope Basin Stratigraphic Project" in

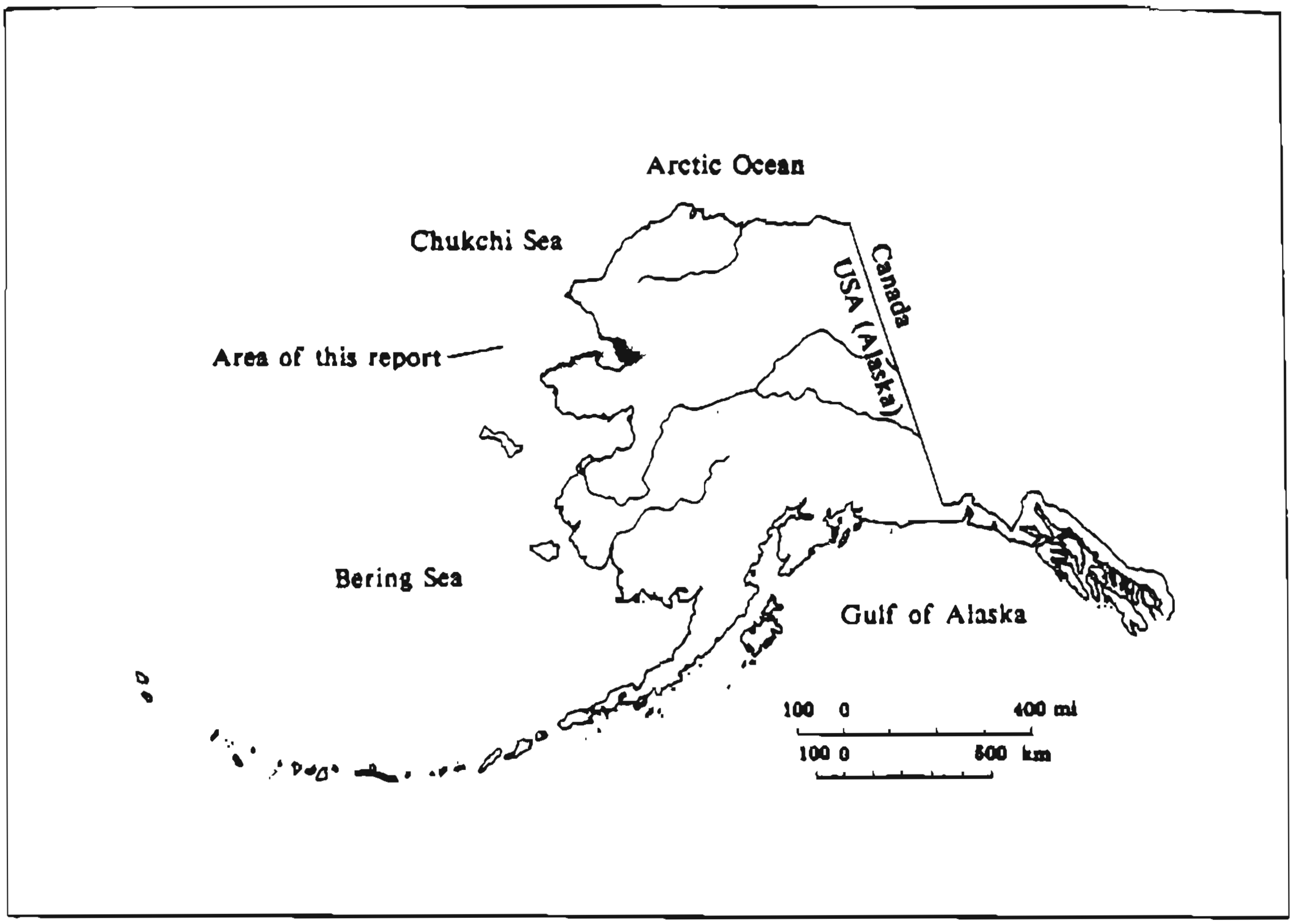


Figure 1. Location map of the area covered by this report.

accordance with the terms of the subagreement between the Alaska Division of Geological and Geophysical Surveys, and the University of Texas.

The field program was conducted by W.M. Lyle of the Alaska Division of Mining and Geological and Geophysical Surveys, and D.K. Thurston of the U.S. Minerals Management Service, between June 17, and June 27, 1985. Thermal maturity analyses were performed by Jacobson Consulting, Inc., Denver, Colorado; porosity and permeability analyses by Core Laboratories, Inc., Dallas, Texas; and hydrocarbon analyses by Chemical and Geological Laboratories of Alaska, Inc., Anchorage, Alaska. Discussions with geologists from the U.S. Geological Survey, U.S. Bureau of Land Management, U.S. Minerals Management Service, National Oceanic and Atmospheric Administration, Alaska Division of Oil and Gas, Alaska Division of Mining and Geological and Geophysical Surveys, Standard Alaska Production Co., ARCO Exploration Co., and Mobil Research and Development Co. were very helpful and were greatly appreciated. An early version of this report was written by Lyle; the final draft was written by John Decker and M.S. Robinson. J.G. Clough of the Alaska Division of Mining and Geological and Geophysical Surveys compiled the bibliography.

REGIONAL GEOLOGIC FRAMEWORK

LOCATION

The Hope and Selawik basins are predominantly off-shore depocenters of Tertiary age located in less than 50 meters of water in the epicontinental Chukchi Sea (figure 2). The portion of the Hope Basin which belongs to the United States lies between the Kotzebue Arch to the south, and the Cape Krusenstern-Cape Lisburne shoreline and Herald Arch to the northeast (figure 2). The Selawik Basin is located south of the Kotzebue Arch, entirely within Kotzebue Sound and adjacent on-shore lowlands (figure 2). Both the Hope and Selawik basins coincide with gravity lows which help to define the margins of the main depocenters (figure 3).

TERMINOLOGY

Grantz and others (1975; 1976), and Ehm (1983), include the Selawik Basin within their more broadly defined Hope Basin. Industry geologists, on the other hand, generally prefer that the basins have two separate names mainly because currently there is no pre-Quaternary stratigraphic

Figure 2. Location map of the Hope and Selawik Basin areas as used in this report, and major structural elements in the Hope Basin and adjacent areas (modified from Eittreim et al, 1979).

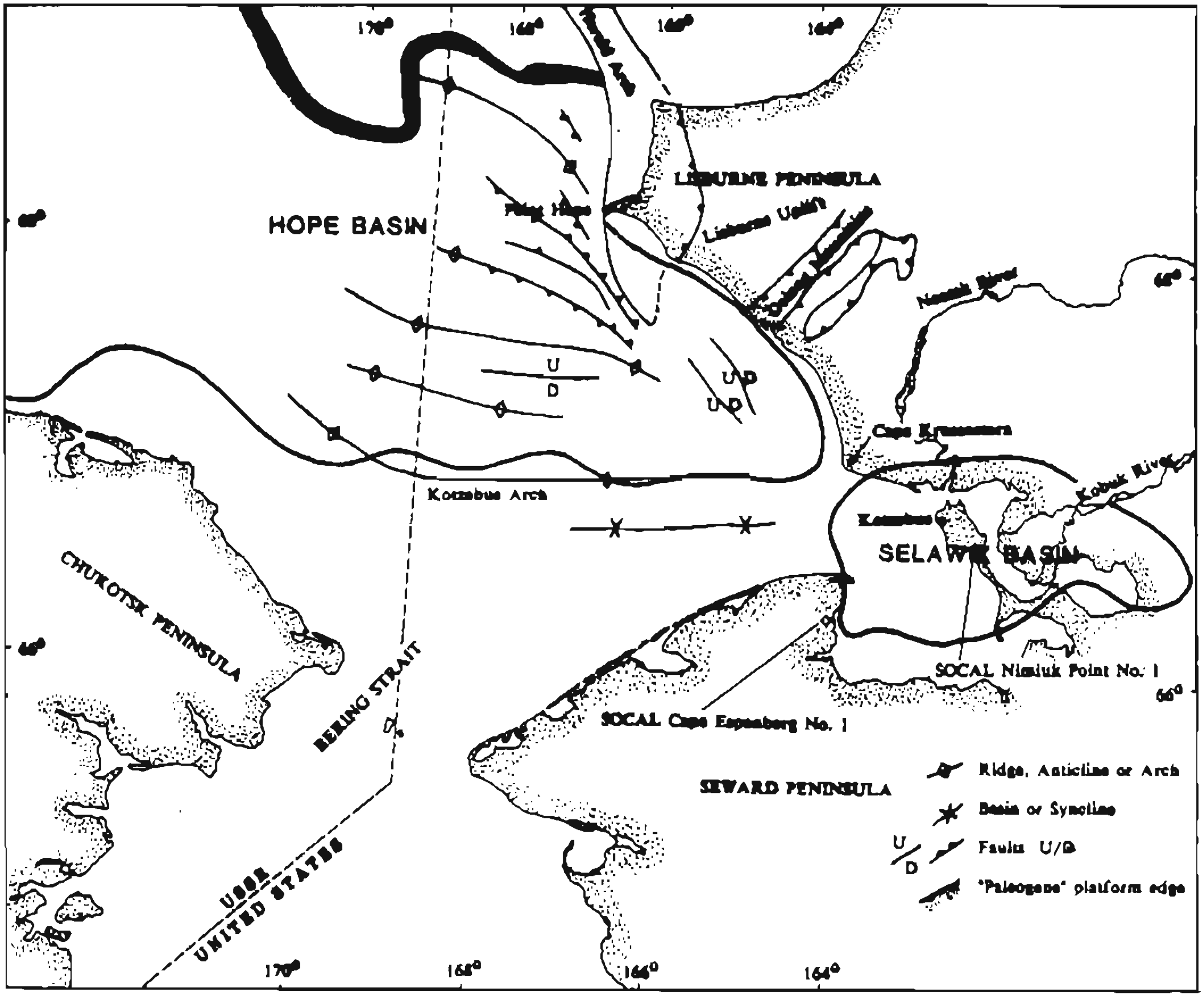
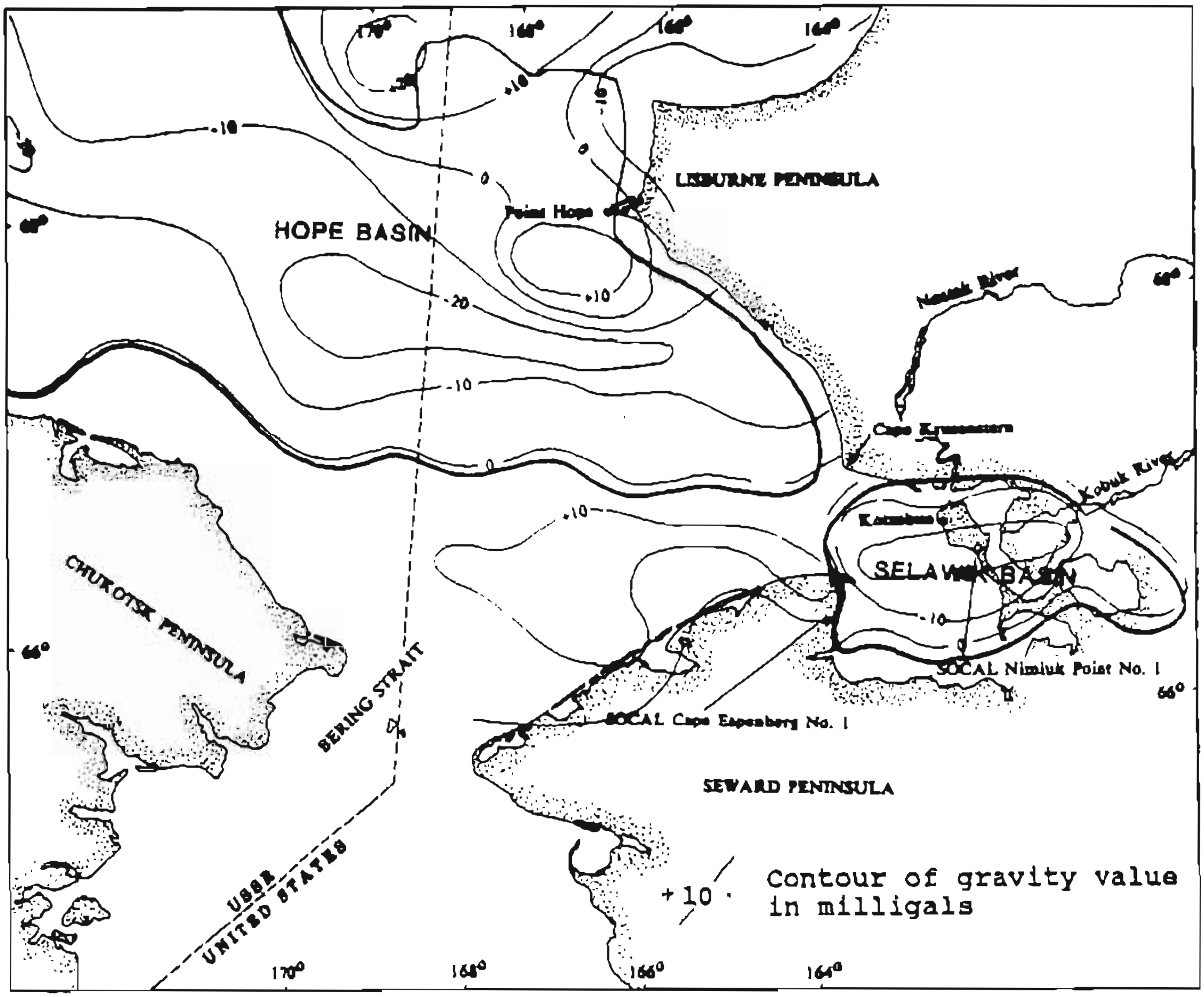


Figure 3. Free air gravity anomaly contour map of the Hope-Selawik Basin area (modified from Ostenso, 1968).



continuity between the Hope and Selawik depocenters, and because the petroleum potential of the two basins is considered to be quite different.

PLATE TECTONIC SETTING

In spite of their predominantly off-shore location, the Hope and Selawik basins occur entirely within continental crust. They probably formed in Tertiary time as relatively small within-plate crustal rift systems and would be classified as intracontinental basins by Dickinson (1974).

Several early plate tectonic reconstructions showed that the present boundary between the North American and Eurasian plates passed through the Bering Strait. These models suggested that Alaska and Siberia were on two separate lithospheric plates, and that a major crustal suture was located beneath the Bering and Chukchi Seas. Such models were originally postulated with little knowledge of Arctic geology, they were never widely accepted, and they are now generally considered to be highly unlikely.

Arctic geologists (for example, Churkin, 1969) believe that the major geologic terranes of Alaska and Siberia are continuous across the shallow Bering and Chukchi seas. Modern reconstructions indicate that the Chukchi Sea and eastern Siberia have been a coherent part of either the North American plate (Minster and Jordan, 1978) or the smaller Bering plate (Minster and others, 1974; Stone, 1983) since at least Jurassic time (figure 4).

STRATIGRAPHY

The nature of the basement upon which strata of the Hope and Selawik basins were deposited can be inferred by correlating Brooks Range and Seward Peninsula geology with off-shore seismic sequences, and sparse drill-hole and dredge-haul data. The Hope basin, from Kotzebue ridge to the north, probably is underlain by rocks typical of the Brooks Range. Whereas, rocks underlying the Selawik basin are more similar to rocks exposed on Seward Peninsula.

Brooks Range geology is best viewed in terms the of three stratigraphic sequences defined by Lerand (1973), and named the Franklinian, Ellesmerian, and Brookian sequences (figure 5).

The Franklinian sequence consists of upper Proterozic through Devonian clastic and carbonate sedimentary rocks with a northern provenance. These rocks are generally weakly metamorphosed and structurally disrupted. A major regional

Figure 4. N-polar projection of the earth showing the major conventional plate boundaries by shading. The dashed lines represent possible boundaries for the Bering plate as discussed in the text (modified from Stone, 1983).

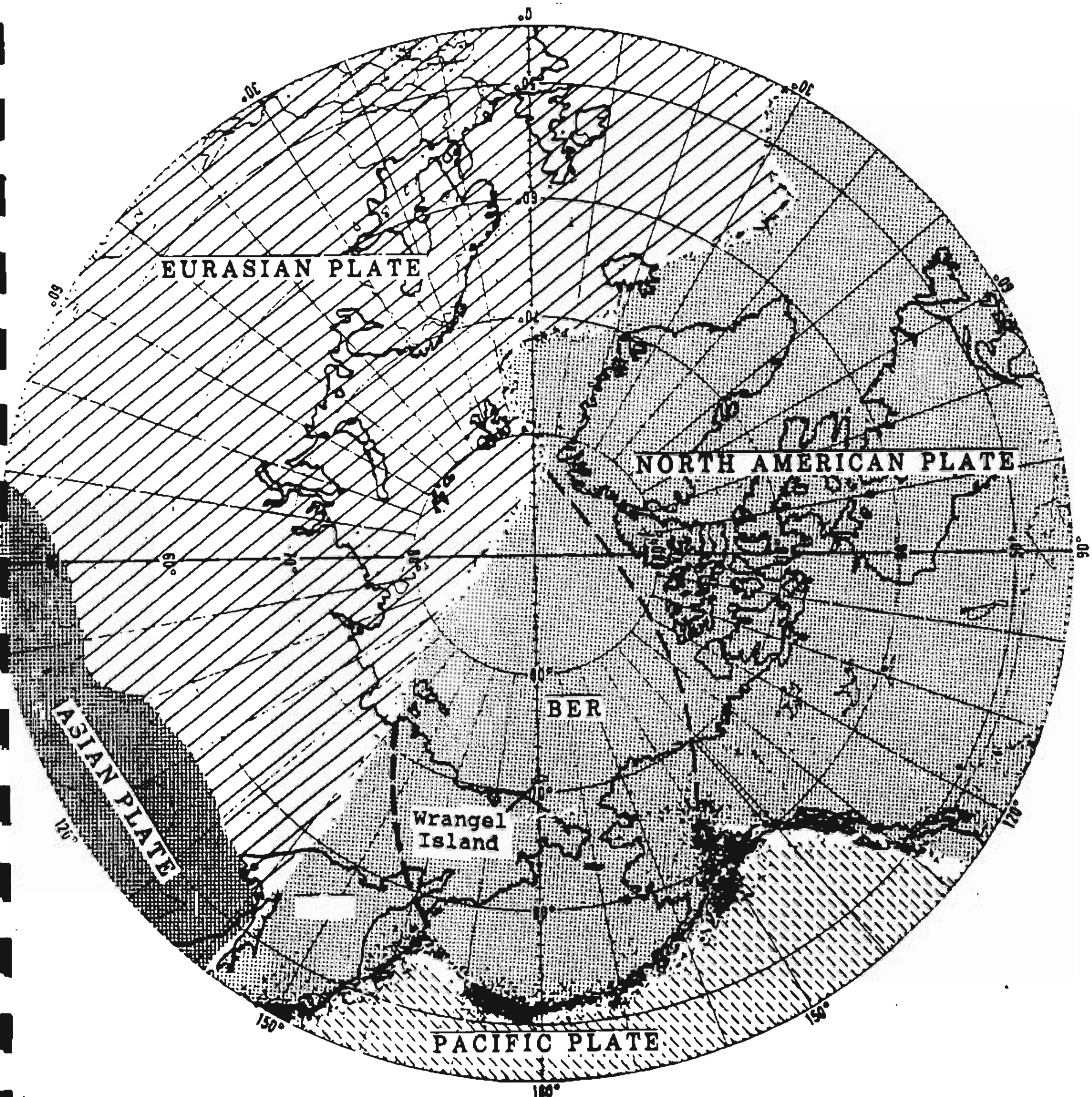


Figure 5.--Generalized stratigraphy of northern Alaska and adjacent continental shelves.

AGE			SEQUENCE	STRATIGRAPHY (South – North)	THICKNESS (m)	GENERALIZED LITHOLOGY	DEPOSITIONAL CHARACTERISTICS
CENOZOIC	QUATERNARY		BROOKIAN	GUBIK FORMATION	10-200	Marine sand, gravel, silt, and clay.	Sediment derived from the Brooks Range, the Arctic foothills, wave erosion of sea cliffs, and melting icebergs.
CENOZOIC	TERTIARY	NEOGENE / PALEOGENE	BROOKIAN	SAGAVANIRKTOK FM. (eastern North Slope only)	0-2,500 W - E	Poorly consolidated nonmarine and marine shale, sandstone, and conglomerate, with some carbonaceous shale, lignite, and bentonite.	Sediment mostly prograded northeastward from the Brooks Range into the southward-deepening Colville foredeep, an east-west-elongate trough created when the Arctic platform tilted southward, probably as a result of loading of Brooks Range thrust sheets and clastic sediment on the south part of the platform. When the Colville foredeep was filled, Cretaceous and Tertiary sediments overtopped the Barrow arch and prograded northward onto the western Beaufort shelf, where they thicken northward.
MESOZOIC	CRETACEOUS	UPPER	BROOKIAN	COLVILLE GROUP (central and eastern North Slope only)	0-3,600 W - E	Predominantly nonmarine, with coal in the west. Shallow- to deep-marine clastic rocks in the east.	
MESOZOIC	CRETACEOUS	LOWER	BROOKIAN	NANUSHUK GROUP (W. North Slope)	0-3,300+	Marine and nonmarine shale, siltstone, sandstone, coal, conglomerate, and bentonite.	
MESOZOIC	CRETACEOUS	LOWER	BROOKIAN	FORTRESS MT. FM. (W. North Slope); TOROK FORMATION	400-3,000; 1000-3,000; 200-1,200+	Marine shale, sandstone, and conglomerate. Marine shale, sandstone, and siltstone turbidites.	
MESOZOIC	CRETACEOUS	LOWER	ELLESMERIAN	PEBBLE SHALE UNIT, KONGAKUT FM., and KEMIK SANDSTONE	0-700	Shelf and basinal marine shale and siltstone containing rounded quartz grains and chert pebbles. Coquinoid to south; quartzose sandstone at base in east.	The Ellesmerian sequence on the Alaskan North Slope was derived from a northerly source terrane called Barrovia by Tailleur (1973). The constituent formations generally thin and coarsen northward, and onlap the uplifted northern Arctic platform in the crestal region of the Barrow Arch.
MESOZOIC	JURASSIC		ELLESMERIAN	KINGAK SHALE (locally includes KUPARUK RIVER SANDS at the top)	0-1,200+	Marine shale, siltstone, and chert, locally containing glauconitic sandstone (in the west). Shallower water facies are apparently the northerly ones.	
MESOZOIC	TRIASSIC		ELLESMERIAN	SHUBLIK FORMATION	0-225	To the north, marine shale, carbonate, and sandstone As shown, includes the Sag River Sandstone. To the south, shale, chert, limestone, and oil shale.	
PALEOZOIC	PERMIAN		ELLESMERIAN	SADLEROCHIT GROUP (and SIKSIKPUK FM. on western North Slope)	0-700+	Eastern North Slope: marine and nonmarine sandstone, shale, and conglomerate; marine sandstone, siltstone, and shale. Western North Slope: sandstone, conglomerate, and shale to the north; argillite, chert, and shale to the south.	
PALEOZOIC	PENNSYLVANIAN		ELLESMERIAN	LISBURNE GROUP	0-2,000+	Fossiliferous marine limestone and dolomite, with some chert, sandstone, siltstone, shale. Local volcanic rocks.	
PALEOZOIC	MISSISSIPPIAN		ELLESMERIAN	ENDICOTT GROUP	0-1,000+	Marine sandstone, mudstone, shale, conglomerate, interbedded limestone, coal, and conglomerate.	
PALEOZOIC	PRE-MISSISSIPPIAN		FRANKLINIAN	Marine sedimentary rocks (includes IVIAGIK GROUP of Martin (1970) on Lisburne Peninsula)	Thousands of meters	Eastern North Slope: argillite, graywacke, limestone, dolomite, chert, quartzose sandstone, shale, and metamorphic equivalents. Western North Slope: argillite and graywacke.	Deposited during Middle Cambrian to Late Devonian time in the Franklinian geosyncline, which trended generally parallel to the Arctic margin of North America. North and northwestern facies are mostly eugeoclinal, south and southeastern facies mostly miogeoclinal. Probably extends northward beneath the Beaufort and Chukchi shelves.

unconformity marks the top of the Franklinian sequence and the beginning of the Ellesmerian sequence.

The Ellesmerian sequence consists of Mississippian through Lower Cretaceous mature clastic and carbonate sedimentary rocks that were deposited on the Arctic Platform of deformed Franklinian basement. In general, the Ellesmerian strata coarsen and thin to the north against an inferred highland which was gradually lowered by erosion during late Paleozoic and early Mesozoic time and eventually tectonically removed during Late Jurassic and Early Cretaceous time. A reversal in drainage from north source to south source occurred progressively from west to east during Late Jurassic and Early Cretaceous time and marks the top of the Ellesmerian sequence and the beginning of the Brookian sequence.

The Brookian sequence consists of Upper Jurassic through Holocene immature clastic sedimentary rocks derived from a southern source. The southern source was created by the Brooks Range orogeny which resulted in north vergent thrusting of Franklinian and Ellesmerian strata, and the obduction of oceanic crust from the south. The clastic deposits of the Hope and Selawik basins are considered part of the Brookian sequence.

Seismic-reflection data and sonobuoy refraction profiles collected by the U.S. Coast Guard and the U.S. Geological Survey have been interpreted by Grantz and others (1976) to suggest that the stratigraphic sequences characteristic of the Brooks Range can be projected into the Chukchi Sea and traced at least as far west as Wrangel Island (see figure 4).

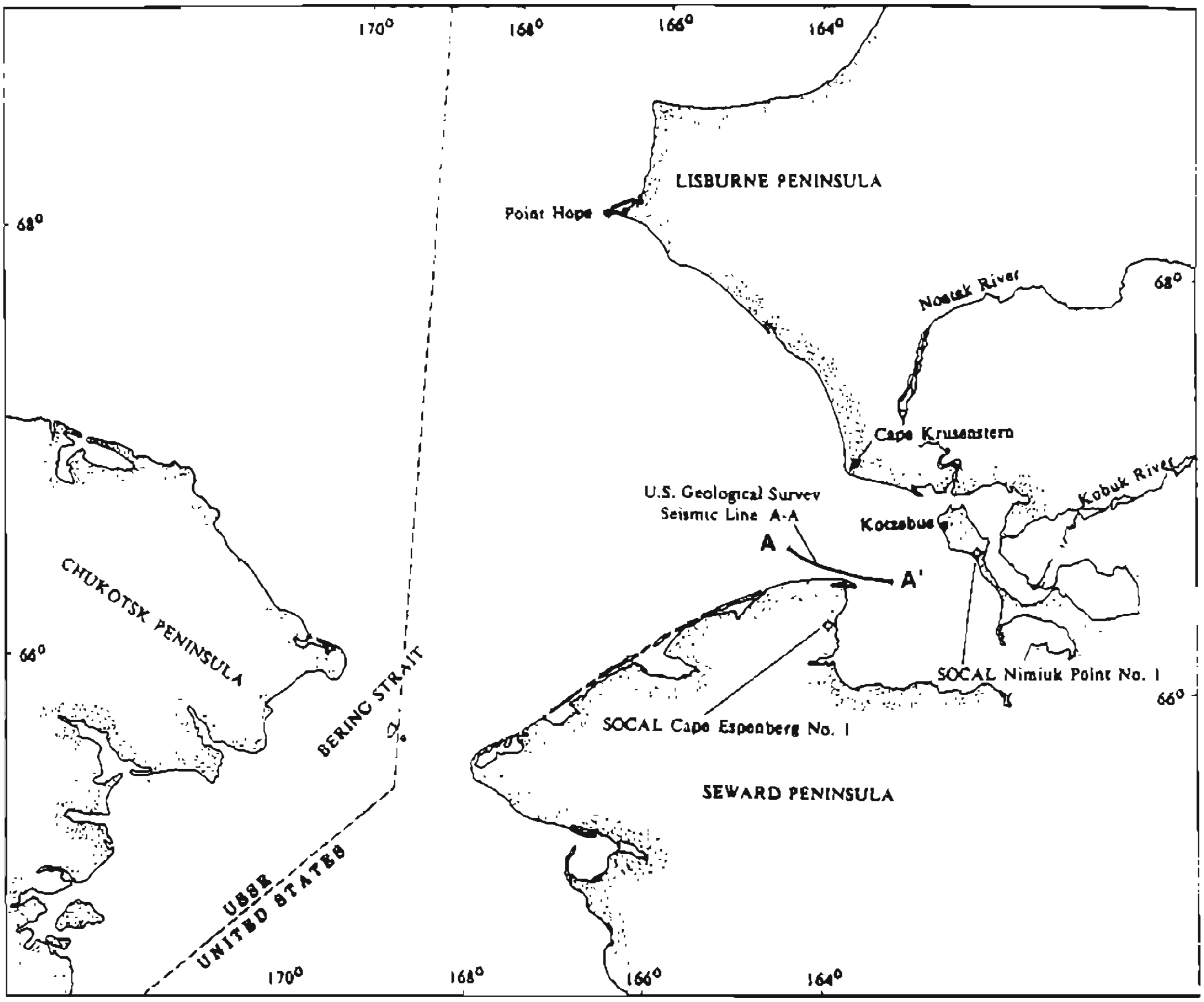
The basement strata of Seward Peninsula are the same age and their protoliths are similar to rocks of the Franklinian sequence of the Brooks Range and Arctic Slope. On northern Seward Peninsula, basement rocks consist of generally schistose metasedimentary rocks and marble. Drill-hole data indicate that Tertiary deposits of the Selawik Basin were deposited directly on this lower Paleozoic basement with no strata equivalent to the Ellesmerian or Mesozoic portion of the Brookian sequences present.

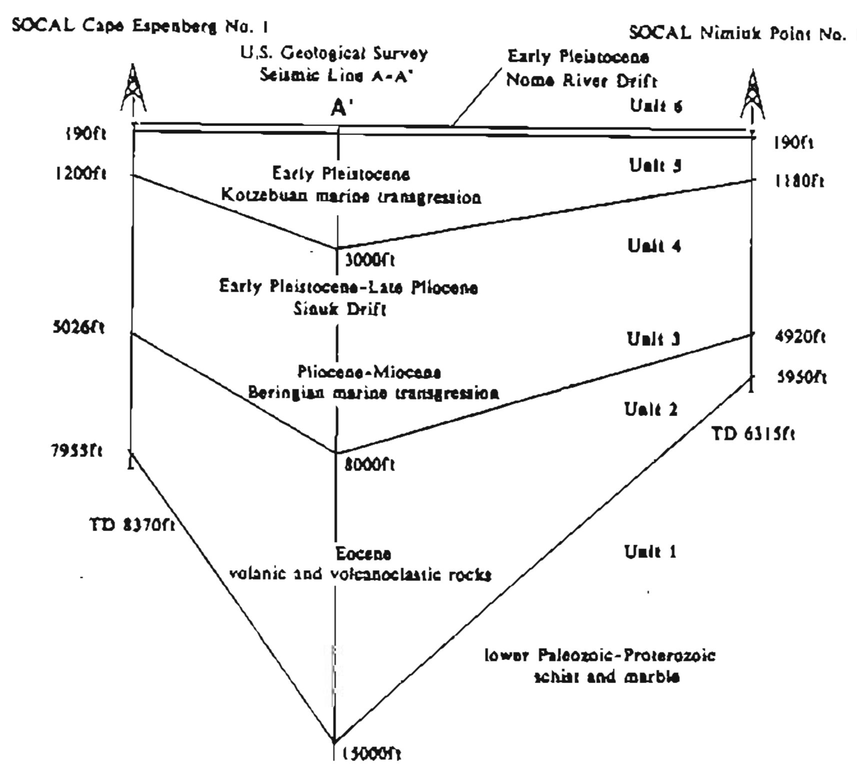
Selawik Basin

SOCAL Wells

The stratigraphic succession within the Selawik Basin is fairly well established from Standard Oil Company of California's (SOCAL) two petroleum test wells at Cape Espenberg on the northern Seward Peninsula and at Nimiuk Point on the Baldwin Peninsula near Kotzebue (figure 6). Six

Figure 6. Correlation diagram between the SOCAL Cape Espenberg No. 1 and the SOCAL Nimiuk Point No. 1 test wells, including correlations from U.S. Geological Survey seismic line A-A'.





stratigraphic units have been recognized by Turner and Olsen (1978) and are here numbered, from oldest to youngest, 1 through 6.

Unit 1 consists of schistose volcanogenic metasandstone, and light-gray microcrystalline marble with calcite veins. Unit 1 extends from 2472 m. to a T.D. of 2601 m. in the Cape Espenberg well, and from 1849 m. to a T.D. of 1962 m. in the Nimiuk Point well. These rocks are likely to correlate with pre-Mississippian schists and marble extensively exposed on the Seward Peninsula.

Unit 2 consists of lithic tuff, welded tuff, basalt and andesite porphyry, volcanogenic sandstone, volcanic conglomerate, and claystone. Unit 2 is 910 m. thick in the Cape Espenberg well and thins to 320 m. in the Nimiuk Point well. Unit 2 is bound above and below by unconformities. Potassium-Argon whole rock analysis of basalt samples from the two wells yield late Miocene ages (U.S. Bureau of Land Management (B.L.M.), unpublished data). From the Cape Espenberg well, basalt collected from the interval 1635 to 1653 m. produced an age of 40.7 +/- 2.0 m.y. According the the report submitted to the B.L.M. by Rodger E. Denison, consulting geologist from Dallas, Texas, "The original rock was composed of plagioclase, pyroxene, iron oxides and olivine. The olivine is now completely converted to micaceous material. The texture is mildly porphyritic with phenocrysts of plagioclase and former olivine. The plagioclase is generally fresh as is most pyroxene. . . . The determined age is a minimum due to the alteration but should be quite close to the age of crystallization. The age is late Eocene and it is doubtful, in my opinion, that the age is likely to be older than middle Eocene.

" From the Nimiuk Point well, basalt chips from the interval 1838 m. to 1846 m. produced an age of 42.3 +/- 10.2 m.y. According to Denison "The rock was originally composed of plagioclase, pyroxene, iron-oxides and olivine. Only plagioclase remains as a fresh mineral. The remainder has been altered to chloritic micas or replaced by carbonate minerals. Both calcite and siderite appear to be present. The plagioclase is generally fresh in most intervals. Calcite veins are common. . . . The problem in obtaining a satisfactory age centers on a lack of sample. The core chips are too small to obtain enough volume. The rock was treated to remove calcite and the intergranular micaceous material. The plagioclase was then concentrated. If a clean plagioclase separation could be made it is believed that a reliable age could be determined from the interval. . . . The age indicates the rock was probably crystallized in the Eocene." Basalt of confirmed Eocene age has also been reported to the east in the Yukon-Koyukuk Province (Harris, 1985), and on the southern Seward Peninsula (Tom Ager, U.S. Geological Survey, oral communication, Nov. 1986).

Unit 3 consists of interbedded sand and clay with local thin gravel beds, deposited in a marine environment. Unit 3 is 328 m. thick in the Cape Espenberg well and 277 m. thick in the Nimiuk Point well. Unit 3 unconformably overlies Unit 2 and apparently is conformable with Unit 4. Micropaleontological studies by U.S. Minerals Management Service of samples from the two wells indicates that the age of Unit 3 may range from Late Pliocene through middle late Miocene. This unit corresponds to the Beringian marine transgression of Pliocene age identified by Hopkins throughout the Bering Sea region.

Unit 4 consists predominantly of interbedded sand and gravel, with local clay-rich sections, and thin coal, lignite and wood-fragment horizons. This unit was probably deposited in a non-marine environment during an uncertain succession of glacial advances and retreats. Unit 4 is 861 m. thick in the Cape Espenberg well and 755 m. thick in the Nimiuk well. The contact with the marine deposits of Unit 3 is sharp but with no angular discordance or obvious break in sedimentation. Similarly, the upper contact of Unit 4 is sharp, but with no angular discordance and no apparent disconformity. Unit 4 underlies Lower Pleistocene deposits of units 5 and 6 (see discussion below), therefore, Unit 4 is Early Pleistocene or older. Turner and Olsen (1978) and Donald L. Olsen, U.S. Minerals Management Service, oral communication, Nov. 1986) maintain that, on the basis of diatom biostratigraphy, the base of Unit 4 can be no older than earliest Pleistocene. Based on its tremendous thickness, however, it seems logical to assume that Unit 4 contains both lower Pleistocene and upper Pliocene deposits. The unit probably correlates at least in part with the Sinuk glacial interval on Seward Peninsula (Kaufman and Hopkins, 1986) and the Gunsight Mountain glacial episode in the central Brooks Range (Hamilton, 1986), both of late Pliocene age.

Unit 5 consists of silt, and mud with common pyritized wood-fragments. The presence of marine shell fragments suggests that this unit was probably deposited in a shallow-marine environment. Unit 5 is 314 m. thick in the Cape Espenberg well and 308 m. thick in the Nimiuk Point well. The top and bottom contacts of Unit 5 appear conformable, but because of the poor age control, disconformities at these boundaries cannot be ruled-out. Deposits similar to Unit 5 occur locally on Baldwin Peninsula in the vicinity of the Nimiuk Point well, and are very likely to be correlative. These surface exposures were deposited during a interglacial high stand of sea level called the Kotzebuan transgression by Hopkins (1967). Amino acid dates suggests that deposits of the Kotzebuan transgression are about 500,000 years old (Hopkins, 1967). However, more recent age information (see discussion of Unit 6) indicates that the overlying unit is older than 790,000 years. On this basis, we consider Unit 5 to be of early Pleistocene age.

Unit 6 consists of sand, silt and clay with common wood fragments. This unit was probably deposited as nonmarine glacial outwash and flood plain deposits during a low stand of sea level. Unit 6 is 59 m. thick in both wells. It occurs extensively at the surface on Baldwin Peninsula and is referred to as drift of the Nome River glaciation (for example, Hopkins, 1967). The Nome River glaciation is correlative with the Anaktuvuk glaciation in the central Brooks Range (Hamilton, 1986). Normally magnetized Basalt dated at 810,000 +/- 80,000 years on Seward Peninsula (Kaufman and Hopkins, 1986) overlies drift that correlates with the Nome River deposits. The boundary between the Bruhnes Normal and the Matuyama Reversed Polarity Chrons is at 790,000 years (Johnson, 1982) which is here taken as the maximum age of the basalt, and the minimum age of the Nome River glaciation. The Nome River deposits and the entire section below therefore must be pre-late Pleistocene in age. An alternative, although unlikely, possibility is that the basalt actually overlies drift correlative with the older Sinuk glaciation and that the Nome River glaciation is therefore pre-790,000 years (David Hopkins, oral communication, Nov. 1986).

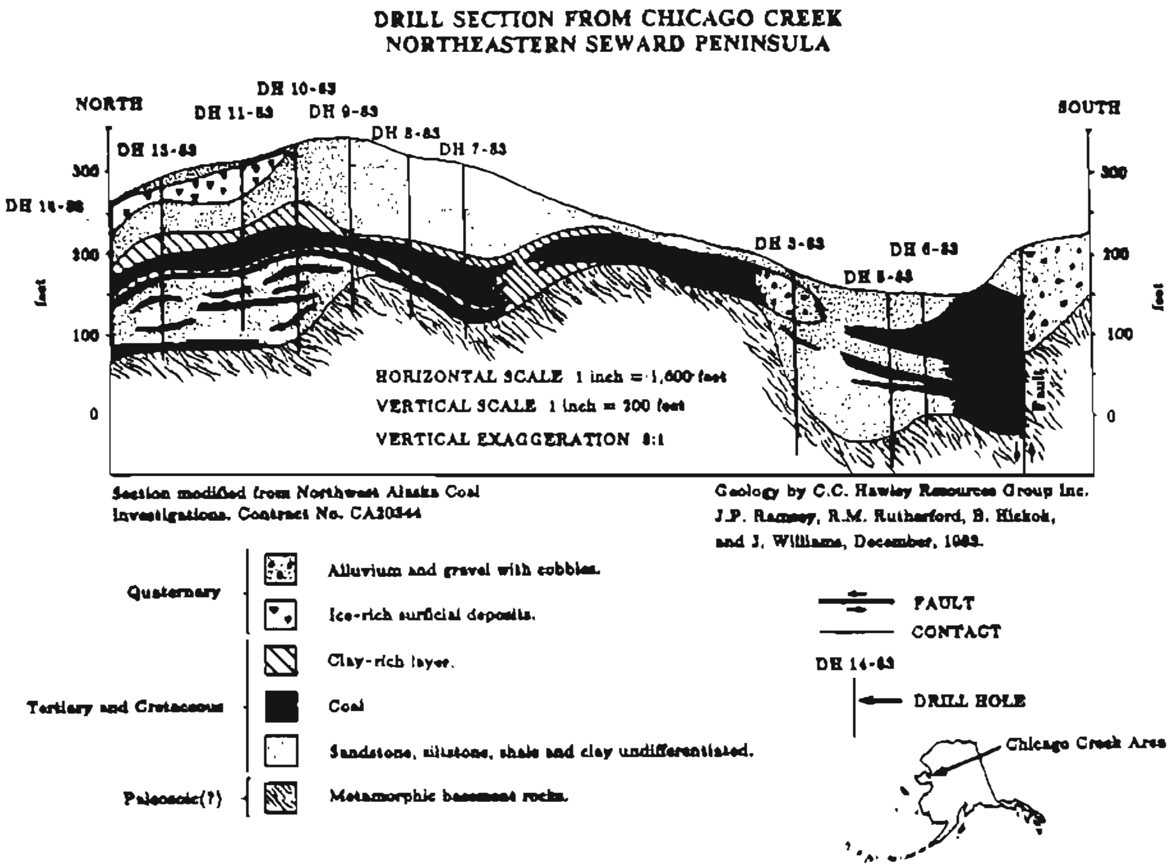
Our age assignments for the units in the two SOCAL wells are based primarily on the biostratigraphic work of Turner and Olsen (1978) modified only slightly where required by new data. The age assignments are substantially different from the interpretation of Eittreim and others (1977) who suggest that the Neogene-Paleogene boundary occurs at about the contact between units 4 and 5, or possibly within the upper part of unit 4.

Chicago Creek Coal-Bearing Strata

Tertiary strata missing beneath the Eocene volcanic rocks of Unit 2 in the SOCAL wells is present in an isolated graben along Chicago Creek on the northern Seward Peninsula (figure 9). Eleven coal exploratory wells were drilled under State of Alaska contract to determine the feasibility of mining the coal for the production of heat and electricity. All wells were less than 100 m deep, and all but one penetrated metamorphic basement.

In general, the Tertiary section at Chicago Creek consists of poorly consolidated conglomerate, sandstone, siltstone, mudstone, and coal, deposited in a non-marine environment. The Tertiary section unconformably overlies quartz-mica schist of lower Paleozoic or Proterozoic age, and is unconformably overlain by a thin Quaternary silt unit. The coal-bearing section contains a diagnostic assemblage of Paleocene polynomorphs (Tom Ager, U.S. Geological Survey, written communication, August, 1986)

Figure 7. Drill section of the coal-bearing sequence at Chicago Creek, northeastern Seward Peninsula (modified from Hawley et al, 1985).



Cretaceous Sections

Clastic sedimentary rocks of Cretaceous age occur throughout the Yukon-Koyukuk Province east of Seward Peninsula (Patton, 1973). The exposures of these rocks closest to Selawik Basin occur in the Waring Mountains, east of Kotzebue Sound. At this location, the rocks consist of marine conglomerate, volcanic and calcareous graywacke, and mudstone of Early Cretaceous age, overlain by nonmarine conglomerate, sandstone, mudstone, and coal of Late Cretaceous age (Patton and Miller, 1968). The total thickness of Cretaceous rocks in the Waring Mountains is about 5000 m. (Patton and Miller, 1968).

During the 1985 field season, W.M. Lyle and D.K. Thurston measured and collected sampled from four stratigraphic sections of the Lower Cretaceous rocks in the Waring Mountains (figure 8A-D). Upper Cretaceous rocks in the Waring Mountains are only moderately indurated and generally form poor exposures, not suitable for detailed measurement. Spot samples of the Upper Cretaceous rocks were collected from four locations (figure 8A-D).

Figure 8A. Measured section of Cretaceous rocks in the Waring Mountains.

SECTION 1 HACKLEY HILLS SECTION

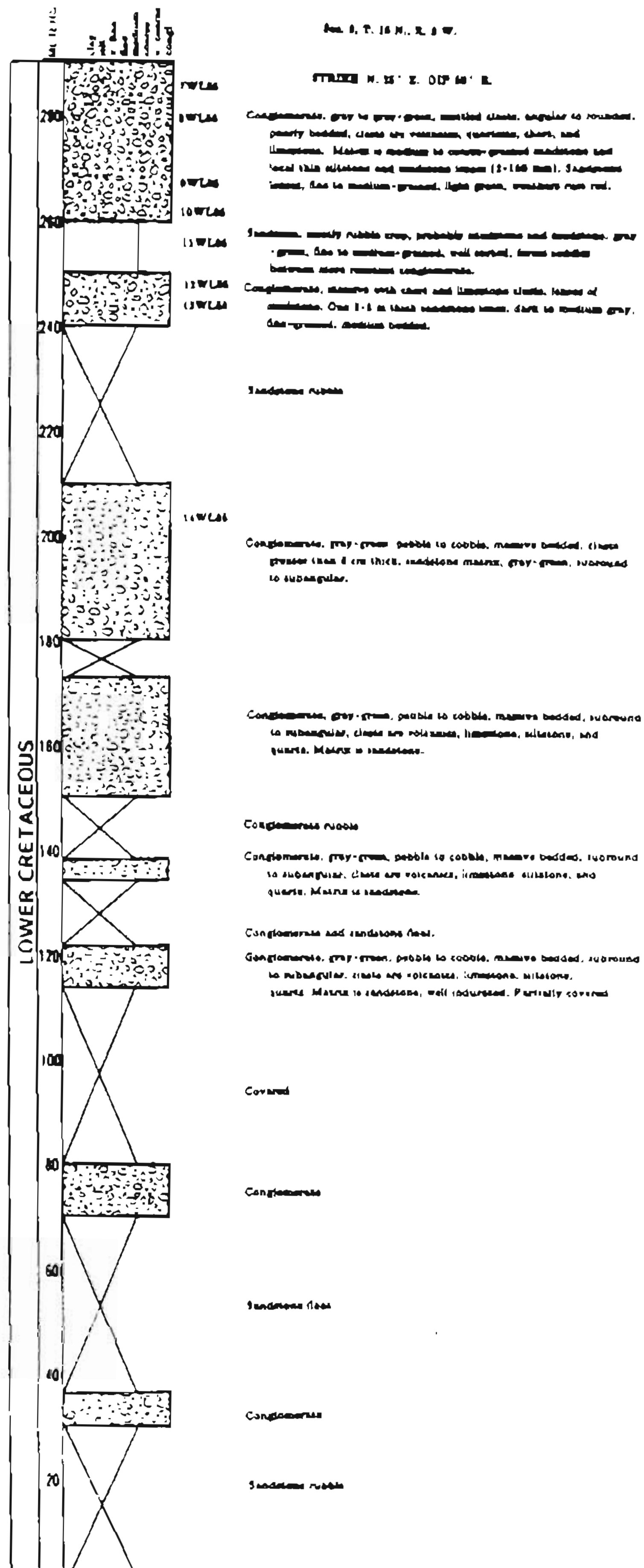


Figure 8B. Measured section of Cretaceous rocks in the Waring Mountains.

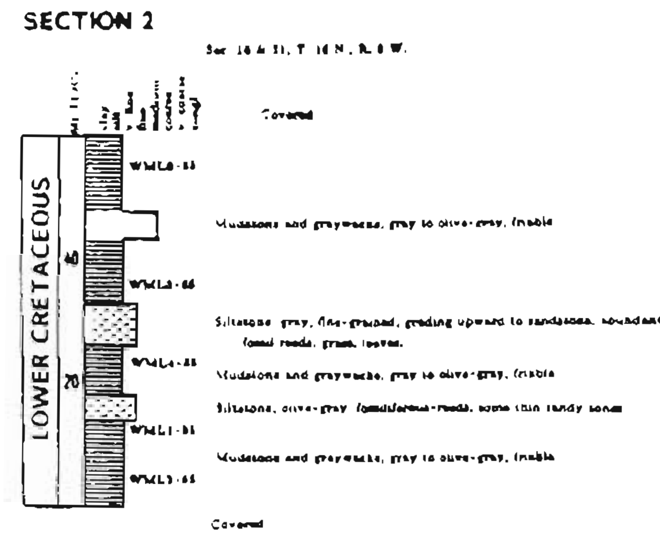


Figure 8C. Measured section of Cretaceous rocks in the Waring Mountains.

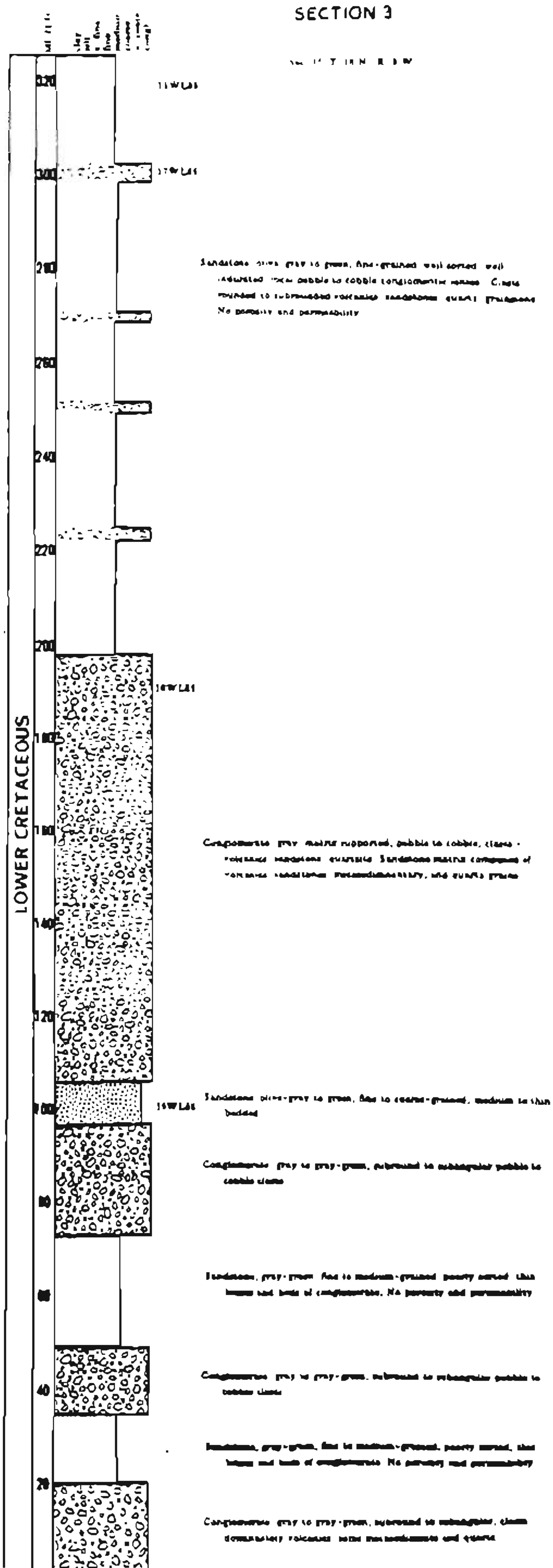
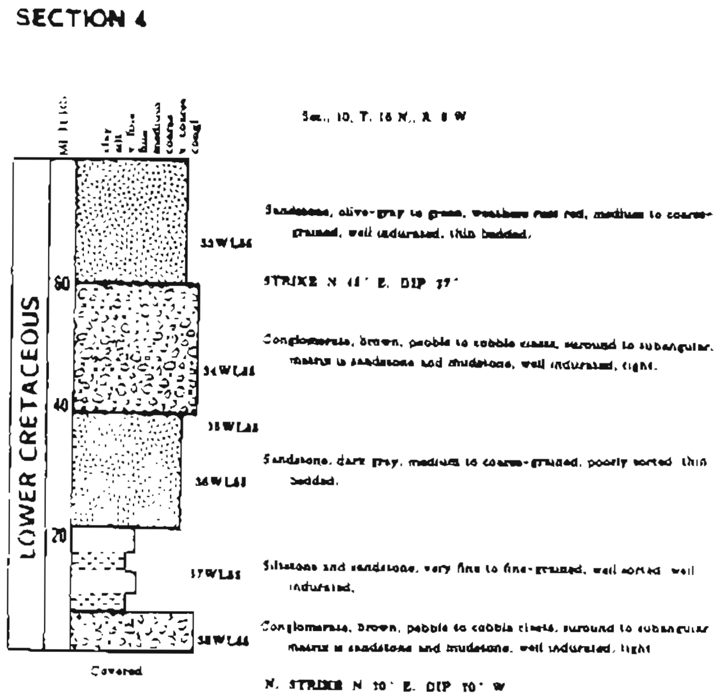
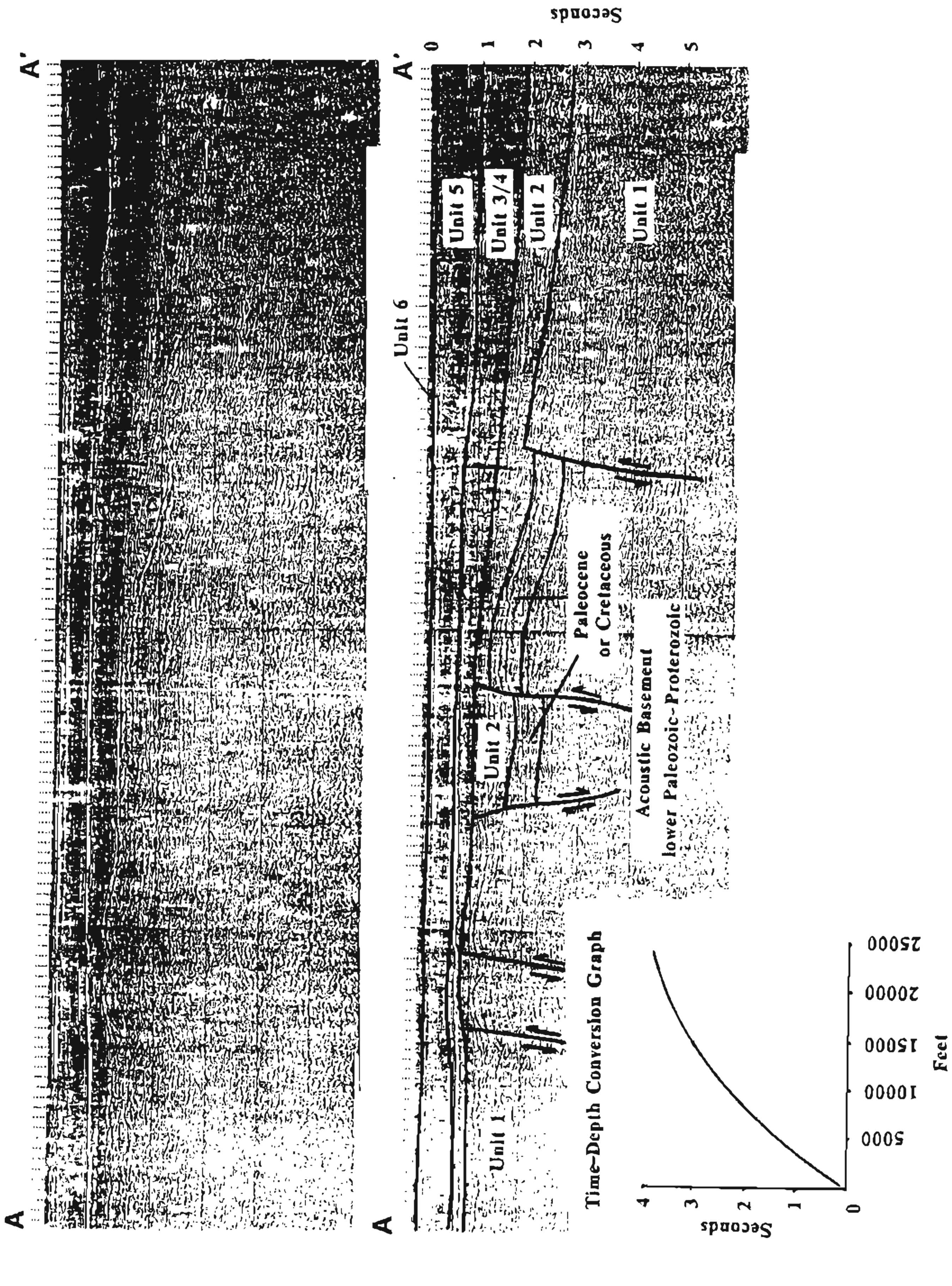


Figure 8D. Measured section of Cretaceous rocks in the Waring Mountains.



Seismic Profile

The U.S. Geological Survey seismic profile A-A' (figure 9) extends into Kotzebue Sound and intersects, at its eastern end, the straight line between the two SOCAL wells (figure 6). At the eastern end of the profile, three prominent reflectors occur equally spaced at about 1 sec., 2 sec., and 3 sec. The lowest reflector occurs at about 4640 m. and almost certainly represents the unconformity between lower Paleozoic or Proterozoic metamorphic basement (Unit 1) and Eocene volcanic and volcaniclastic rocks (Unit 2). The reflector at 2 sec. (about 2400 m.) probably is the unconformity at the top of Unit 2. We interpret the prominent reflector at 1 sec. (about 900 m.) to correspond to the change from marine muds of Unit 5 to the coarse clastic deposits of Unit 4. Apparently, units 3 and 4 cannot be distinguished seismically, and for simplicity, will be referred to as the Neogene interval. The 1 sec. reflector is referred to as reflector "K" by Eittreim and others (1977) and is easily recognizable throughout Hope and Selawik basins. The diagrammatic correlation diagram (figure 6) shows the relationships between the two SOCAL wells and profile A-A'. In general the basin thickens between the two wells from less than 2500 m. to over 4600 m. The majority of igure 9. Seismic profile and interpretation of U.S. Geological Survey seismic line A-A' (modified from Grantz et al, 1971).



the thickening takes place in Units 2, and to a lesser degree in Unit 5.

Profile A-A' shows the structure of Selawik basin to consist of pre-Neogene block faults which produced a horst and graben topography upon which the Neogene beds were unconformably deposited. Within the compound graben near the center of the profile, a bedded unit is preserved above acoustic basement and below the Eocene volcanic and volcaniclastic rocks. This unit is approximately 800 m. thick and most likely correlates with the Paleocene nonmarine rocks at Chicago Creek or, less likely, the Cretaceous rocks of the Waring Mountains.

The west side of profile A-A' shows the erosion of all pre-Neogene units above basement horsts of the Kotzebue Arch, and thinning of the Neogene strata over the Arch. Pleistocene deposits (Unit 5) are not influenced, at this location, by the existence of the buried arch.

HOPE BASIN

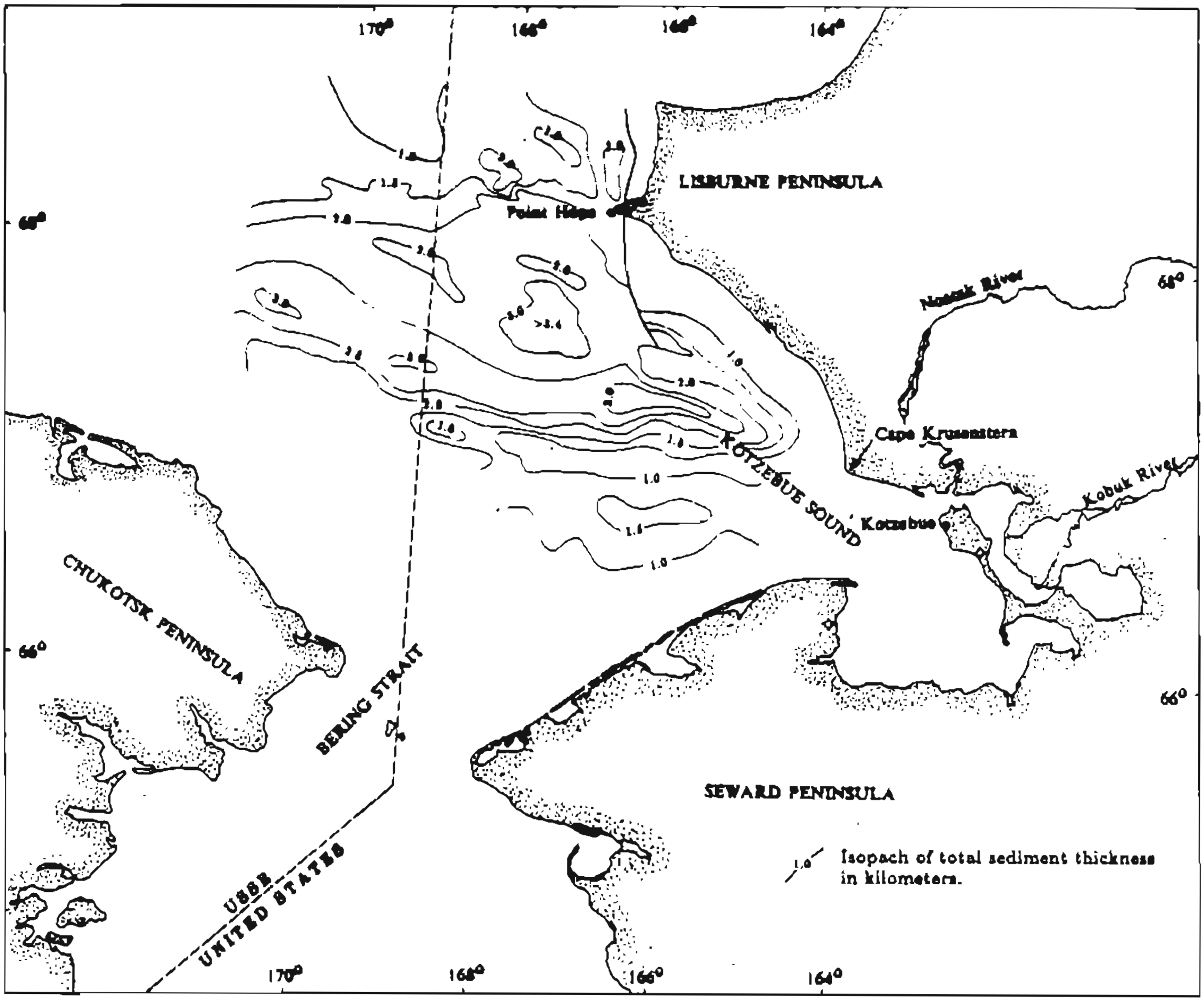
Seismic Profile Data

Interpretation of seismic data across Hope Basin reveals that the basin consists of over 3000 m. of stratified rock which unconformably overlie acoustic basement in several elongate east-west troughs north of

Kotzebue Ridge (figure 10). Seismic profiles across Hope Basin have been interpreted by Grantz and others (1976), and by Eittreim and others (1979). Grantz and others (1976) recognize three main acoustic reflection units. The lowest unit is 800 to 900 m. thick, has a seismic velocity of Vp= 3.1-3.3 km/sec., and is interpreted to be nonmarine deposits of Late Cretaceous or Paleogene age. The middle unit is about 1500 m. thick, has a seismic velocity of Vp=1.9-2.9 km/sec., and is interpreted to be marine clastic deposits of Paleogene age. The upper unit is about 750 m. thick, has a seismic velocity of Vp=1.7-1.9 km/sec., and is interpreted to be marine and nonmarine clastic deposits of Neogene age.

We suggest an alternative age interpretation of the seismic sequences identified by Grantz and others (1976) based on seismic correlations with the Selawik Basin. From Hope Basin, the upper unit thins to the south toward Kotzebue Ridge and, on some seismic profiles, pinches out beneath a Quaternary erosion surface which most likely represents the onset of the Nome River glaciation. On other profiles, the upper unit can be traced almost continuously from Hope Basin over Kotzebue Ridge into Selawik Basin (Eittreim and others, 1979) where it correlates with lower Pleistocene marine deposits of the Kotzebuan transgression (Unit 5). We suggest that the middle unit in Hope Basin correlates with the Neogene section (Units 3 and 4) in the Selawik basin, based on their similar stratigraphic position

Figure 10. Isopach map of the thickness of sediment above acoustic basement in Hope Basin (modified from Wiley, 1986).

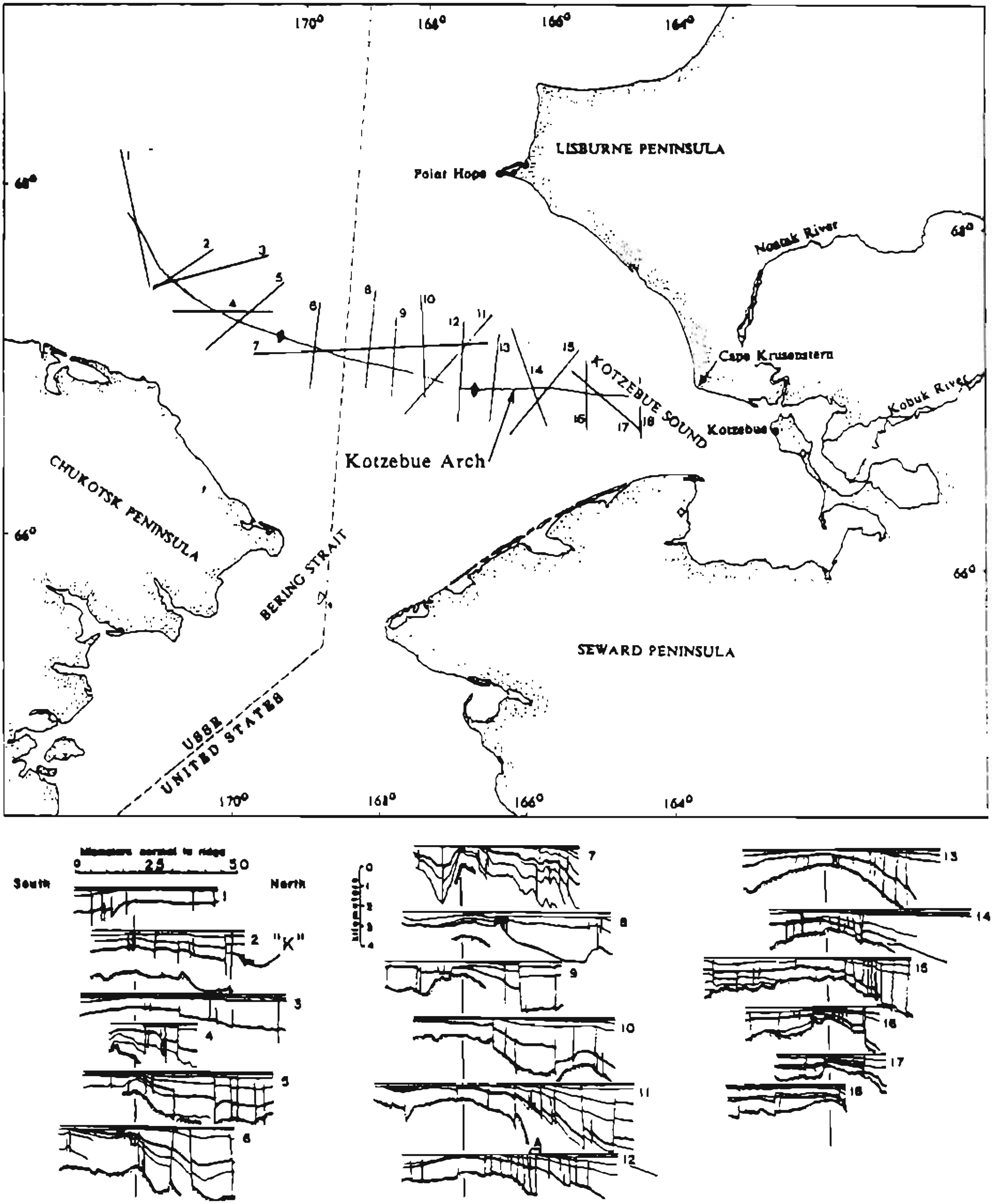


and seismic character. The age of the lower unit in the Hope Basin is still uncertain. The lower unit could correlate with the Eocene volcanic and volcaniclastic rocks (Unit 2) in the SOCAL wells, the Paleocene coal-bearing strata of Chicago Creek, or the Upper Cretaceous nonmarine conglomerate of the Waring Mountains.

The major difference between our interpretation and the interpretation of Grantz and others (1976) is that we believe that the upper reflector is the boundary between Pleistocene and Neogene, whereas they believe that the upper reflector is the boundary between Neogene and Paleogene.

Eittreim and others (1977) recognize two major sequences in Hope Basin, an upper sequence of Neogene age, and a lower sequence of Paleogene age. The two sequences are separated by a strong reverberant reflector called reflector "K" (figure 11). It is not at all clear how the three acoustic sequences recognized by Grantz and others (1976) correspond to the two sequences of Eittreim and others (1977). The average seismic velocity of Vp=1.72 for Eittreim's upper unit corresponds well with the velocity Vp=1.7 to 1.9 km/sec. of Grantz's upper unit, but the thicknesses of the upper units do not corrsepond. The thickness of Eittreim's upper unit (50 to 2600 m.) corresponds well with the combined thicknesses of the upper and middle units of Grantz (750 + 1500 = 2250 m.), but then

Figure 11. Seismic profiles in Hope Basin, across Kotzebue Arch (modified from Eittreim et al, 1977)



the velocities do not agree. Regardless of how these interpretations relate to one another, we agree that, reflector "K" marks the Neogene-Paleogene boundary in Hope Basin. The isopach map of sediment above reflector "K" (our units 3, 4, 5, and 6) shows the configuration of the Neogene basin (figure 12).

STRUCTURAL GEOLOGY

The structural development of the Hope and Selawik basins is primarily the result of regional north-south extension during Neogene time (figure 13). Pre-Neogene grabens preserve Cretaceous or Paleogene deposits at several locations, both on-land and off-shore, but the horst and graben topography was eroded to a smooth surface prior to deposition of the Neogene strata. During late Neogene through Quaternary time, regional north-south extension produced deep grabens in the Chukchi Sea, Norton Sound, and Kotzebue Sound; continental rifting and volcanism on Seward Peninsula (Turner and others, 1981); and extensive east-west normal faulting throughout the western Brooks Range (Susan Karl, oral communication, Nov. 1986).

Several types of hydrocarbon traps related to extensional tectonics have been suggested for the Norton Basin, south of Seward Peninsula (Fisher, 1982). Most of these traps (figure 14) can potentially occur in the Hope and Selawik basins.

Figure 12. Isopach map of the thickness of Neogene sediment in Hope Basin (modified from Chase et al, 1980).

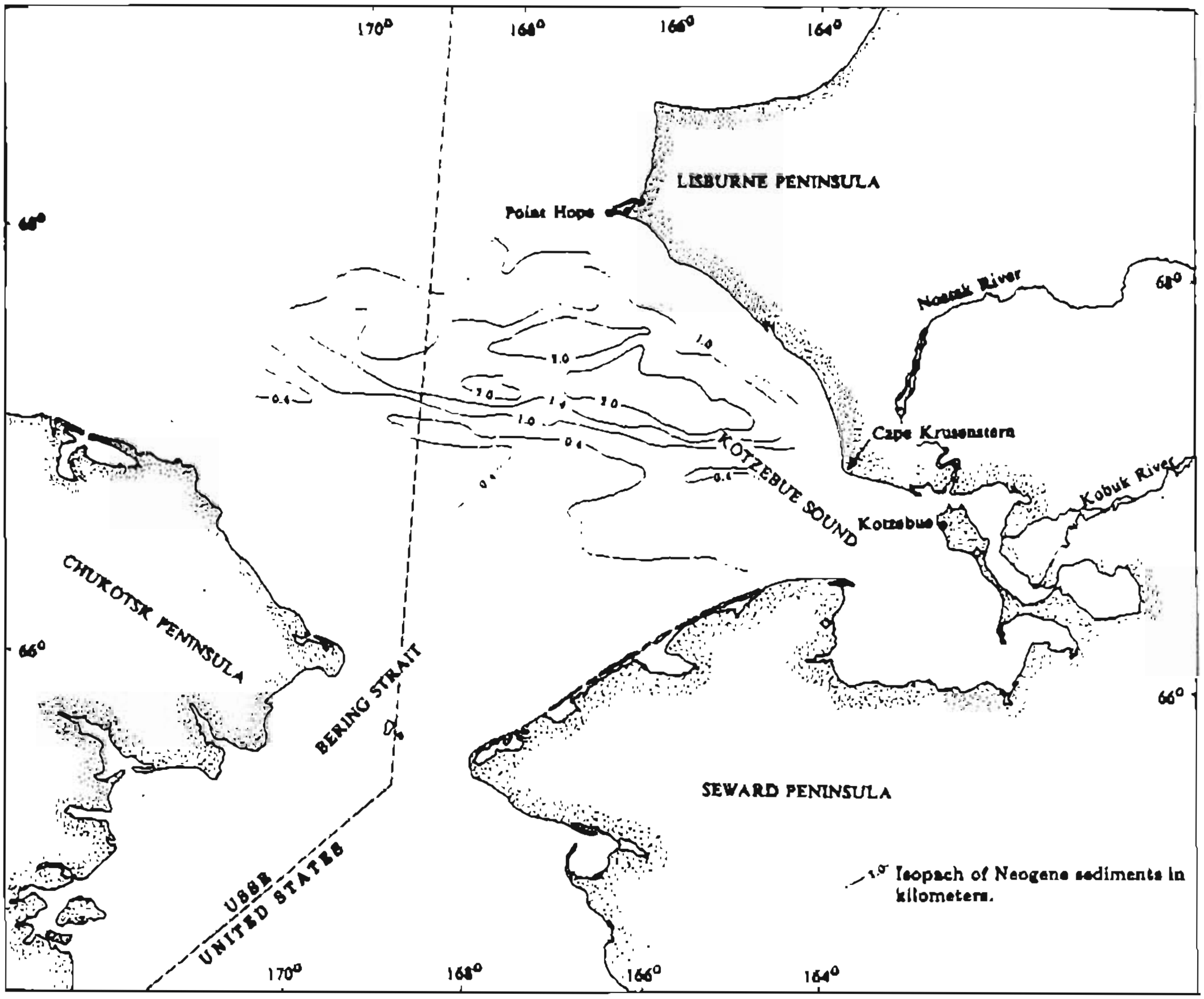


Figure 13. Map of the late Quaternary tectonic stress trajectories of the Aleutian Islands and Alaska (modified Minster et al, 1974 and Sykes and Sbar, 1974).

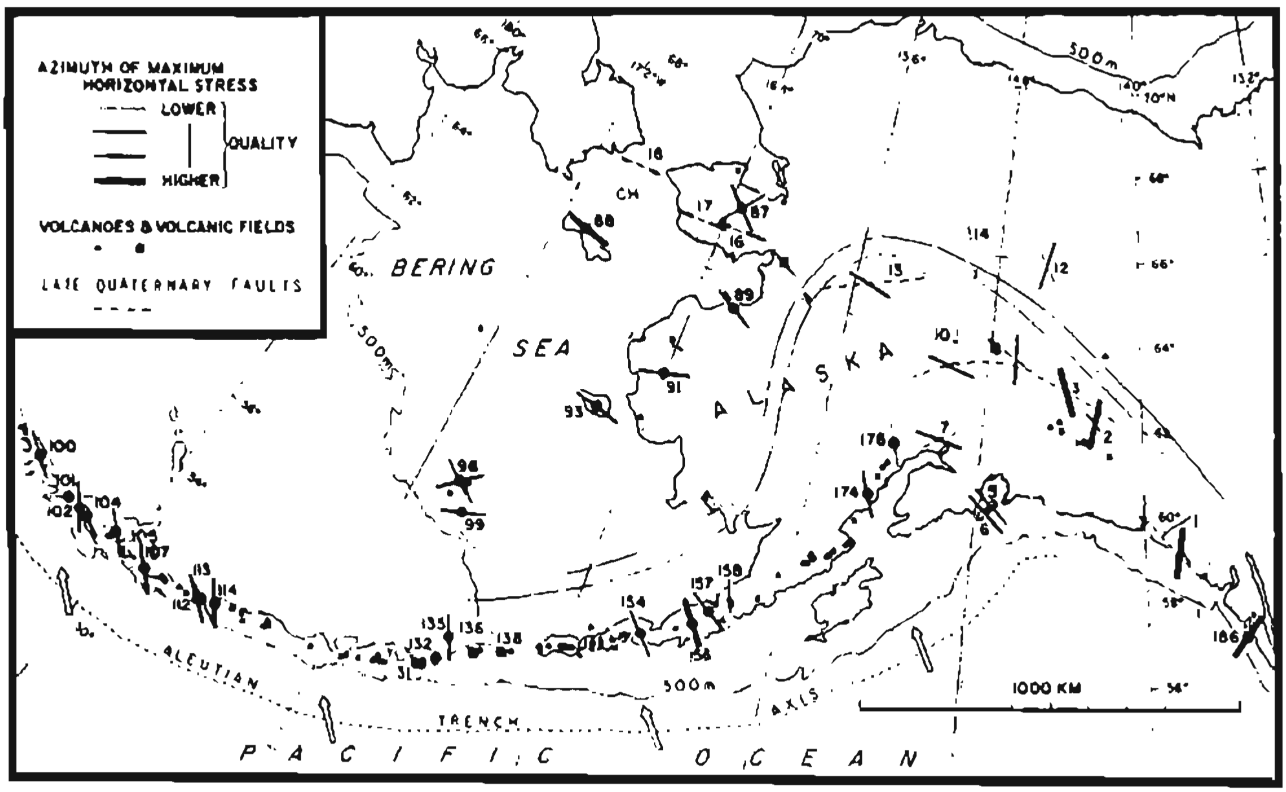
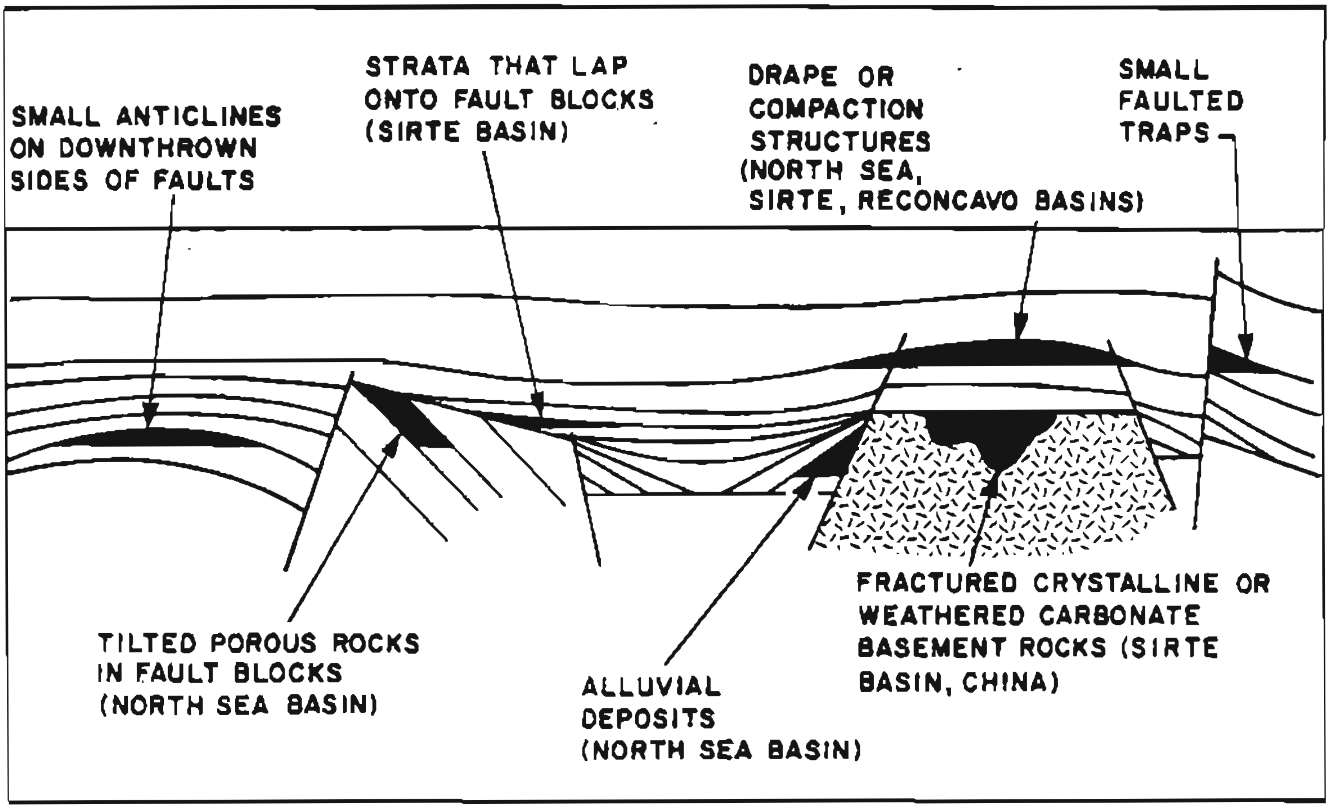


Figure 14. Types of hydrocarbon traps that may be present in the Hope and Selawik basins (modified from Fisher, 1982).



Fractured crystalline basement may occur within horsts of Paleozoic basement. Tilted porous rock may occur in pre-Neogene (Cretaceous or Paleogene) strata within both basins, but particularly associated with the Kotzebue Ridge. Small faulted traps are most likely to occur in the Neogene strata adjacent to growth faults that were active throughout Neogene deposition. Small anticlines within grabens, and drape structures and compaction traps above horsts can be expected to occur in both the Neogene and the Cretaceous or Paleogene strata. Stratigraphic traps can occur throughout the acoustic section.

PETROLEUM POTENTIAL

SOURCE ROCKS

The potential petroleum source rocks exposed around Hope and Selawik basins are very limited. Paleozoic metamorphic rocks are too thermally altered to be sources for hydrocarbons, and Neogene deposits are generally immature.

Samples from Upper and Lower Cretaceous strata in the Waring Mountains yield total organic carbon values that range from 0.04 percent to 0.32 percent, and average 0.14 percent. (figure 15). These values are an order of magnitude lower than typical values from hydrocarbon-rich basins. The thermal alteration index for these rocks ranges from 3+ to 4- (equivalent vitrinite reflectance values of 2.0 to 2.5), which is overmature and outside the oil and wet-gas windows.

Figure 15. Thermal alteration index (TAI), total petroleum hydrocarbons(TPH) and equivalent vitrinite reflectance (EVF) data for Cretaceous rocks from the Waring Mountains.

SAMPLE NO.	TPH (PERCENT)	TAI	EVF (PERCENT)
WL85-30	.00041		
WL85-32	.00190		
DT85-1	.00320		
DT85-2		3+ to 4-	2.0 to 2.5
DT85-3	.00140		
DT85-4			
DT85-5	.00030		
DT85-6		3+	2.0
DT85-7	.00014		
DT85-8		3+ to 4-	2.0 to 2.5
DT85-9	.00190		
DT85-10		3+ to 4-	2.0 to 2.5
DT85-11	.00160		
DT85-12		3+	2.0
DT85-13	.00170		
DT85-14		3+ to 4-	2.0 to 2.5
DT85-15	.00140		
DT85-16		3+ to 4-	2.0 to 2.5
DT85-17	.00160		
DT85-18		3+ to 4-	2.0 to 2.5
DT85-19		3+ to 4-	2.0 to 2.5

Samples from the SOCAL Nimiuk Point well analyzed for Mobil Oil Company, indicate that the entire section is generally low in organic carbon and is thermally immature (figure 16) Low-gray vitrinite reflectance values increase from 0.19 at 100 feet (31 m.) to 0.51 at 5770 feet (1793 m.). Total organic carbon values range from 0.06 percent to 8.34 percent and average 1.16 percent for eleven samples. If the anomalously high value is removed, the average for ten samples drops to 0.44 percent. The 8.34 percent value occurs as a depth of 1420 feet (441 m.), in a zone characterized by low-gray vitrinite reflectance values of 0.25 to 0.28. Visual kerogen analysis indicates that the Nimiuk Point section is dominated by cellulosic (gas-type) kerogens (figure 17). Similarly low vitrinite and organic carbon values, and predominantly cellulosic kerogen types were also obtained from the Cape Espenberg well (figure 18 and 19).

The corrected bottom-hole temperature for the Cape Espenberg well indicates a geothermal gradient of 48 deg. C/km. (Fisher, 1982), which is consistent with the vitrinite values from the two SOCAL wells. Using this geothermal gradient, oil window vitrinite reflectance values (Ro=0.65 to 1.30) can be predicted to occur at depths of 2500 m. to 3300 m. Tertiary section at these depths are expected near the depositional center of the Selawik and Hope basins.

Figure 16. Total organic carbon data from the SOCAL Nimiuk Point test well, Baldwin Peninsula (Page, M.M., 1981, unpublished).

TOTAL ORGANIC CARBON DATA
SOCAL NIMIUK PT. No. 1

Sample Interval (feet)	Depth (feet)	TOC (PERCENT)
100-220	160	0.19
730-850	790	1.61
1360-1480	1420	8.34
1990-2110	2050	0.31
2620-2740	2680	1.11
3250-3370	3310	0.57
3880-4000	3940	0.14
4510-4630	4570	0.12
5140-5260	5200	0.06
5770-5890	5830	0.12
6211-6310	6261	0.18
	AVERAGE	1.16
AVERAGE LESS 8.34 (high value)		0.44

Figure 17.

Thermal Maturation and Visual Kerogen Analyses
Socal Nimiuk Pt. No. 1, Kotzebue, Alaska

DEPTH OR SPL. NO.	LOW-GRAY Ro MEAN	% POP.	FIRST HIGH-GRAY Ro MEAN	% POP.	TAI	THERMAL MATURITY	KEROGEN TYPE	HYDROCARBON POTENTIAL/REMARKS
100'	0.19	18	0.36	37		Immature	Cellulosic	Gas type kerogen
460'	0.23	65	0.69	33		Immature	Cellulosic	Gas type kerogen
820'	0.25	85	1.64	15		Immature	Cellulosic	Gas type kerogen
1180'	0.28	36	0.58	37	2	Immature	Cellulosic	Gas type kerogen
1540'	0.25	69	0.99	31	2	Immature	Cellulosic	Gas type kerogen
1900'	0.25	74	1.10	26	1+	Immature	Cellulosic	Gas type kerogen
2260'	0.34	85	1.75	15		Immature	Cellulosic	Gas type kerogen
2530'	0.35	80	0.91	20		Immature	Cellulosic	Gas type kerogen
2890'	0.31	74	2.29	17		Immature	Cellulosic	Gas type kerogen
3250'	0.37	66	0.72	34		Immature	Cellulosic	Gas type kerogen
3650'	0.35	100	-	-		Immature	Cellulosic	Gas type kerogen
3970'	0.39	45	0.59	32		Immature	Cellulosic	Gas type kerogen
4330'	0.36	100	-	-		Immature	Cellulosic	Gas type kerogen
4690'	0.37	72	1.36	25		Immature	Cellulosic	Gas type kerogen
5050'	0.41	47	0.74	38		Immature	Cellulosic	Gas type kerogen
5410'	0.44	85	0.87	15	2	Immature	Cellulosic	Gas type kerogen
5770'	0.51	68	1.03	32	2,2+	Immature	Cellulosic	Gas type kerogen
6130'	-	-	-	-		-	-	Metamorphic rocks
6250'	-	-	-	-		-	-	Metamorphic rocks

Figure 18. Total organic carbon data from the SOCAL Cape Espenberg test well, Seward Peninsula (Page, M.M., 1981 unpublished).

TOTAL ORGANIC CARBON DATA
SOCAL CAPE ESPENBERG. No. 1

Sample Interval (feet)	Depth (feet)	TOC (PERCENT)
130-250	190	0.76
340-460	400	1.48
550-670	610	1.64
760-880	820	1.70
970-1090	1030	2.78
1180-1300	1240	2.32
1390-1510	1450	17.17
1600-1720	1660	0.59
1810-1930	1870	0.19
2020-2140	2080	1.33
2230-2350	2290	1.10
2440-2560	2500	1.04
2650-2770	2710	1.48
2860-2980	2920	1.20
3070-3190	3130	0.36
3280-3400	3340	0.37
3490-3610	3550	1.62
3700-3820	3755	0.55
3910-4030	3970	0.78
4540-4660	4600	1.44
5800-5920	5860	0.12
6430-6550	6490	0.04
7060-7180	7120	0.06
7690-7810	7750	0.13
	AVERAGE	1.65
	AVERAGE LESS 17.17 (high value)	0.93

Figure 19.

Thermal Maturation and Visual Kerogen Analyses
Socal Cape Espenberg No. 1, Kotzehue, Alaska

DEPTH OR SPL. NO.	LOW-GRAY Ro MEAN	% POP.	FIRST HIGH-GRAY Ro MEAN	% POP.	TAI	THERMAL MATURITY	KEROGEN TYPE	HYDROCARBON POTENTIAL/REMARKS
130'	0.22	28	0.81	48	2	Immature	Cellulosic	Gas type kerogen
490'	0.23	65	0.87	35	2	Immature	Cellulosic	Gas type kerogen
850'	0.22	73	0.93	26		Immature	Cellulosic	Gas type kerogen
1210'	0.25	92	0.76	8		Immature	Cellulosic	Gas type kerogen
1570'	0.26	75	1.13	24		Immature	Cellulosic	Gas type kerogen
1930'	0.27	89	1.28	11	2+	Immature	Cellulosic	Gas type kerogen
2380'	0.27	94	1.24	6		Immature	Cellulosic	Gas type kerogen
2740'	0.25	85	0.86	15		Immature	Cellulosic	Gas type kerogen
3110'	0.26	81	1.29	18		Immature	Cellulosic	Gas type kerogen
3460'	0.29	73	1.05	26		Immature	Cellulosic	Gas type kerogen
3820'	0.29	74	0.74	26		Immature	Cellulosic	Gas type kerogen
4180'	0.34	84	0.76	16	2+	Immature	Cellulosic	Gas type kerogen
4540'	0.40	92	1.13	8		Immature	Cellulosic	Gas type kerogen
4900'	0.43	74	0.97	26		Immature	Cellulosic	Gas type kerogen
5260'	-	-	-	-		-	-	Sample lost
5620'	0.49	100				Immature	Cellulosic	Basalt-caved vitrinite
5980'	0.49	100				Immature	Cellulosic	Welded tuff-caved vit.
6340'	-	-	-	-		-	-	Insufficient data
6670'	-	-	-	-		-	-	Insufficient data
7060'	-	-	-	-		-	-	Insufficient data
7420'	0.66	100				Immature	Cellulosic	Volcanic Agglomerate-Probable caved vit.
7780'	1.70	64				Overmature	Cellulosic	Volcanic Agglomerate
8140'	2.13	77				Overmature	Cellulosic	Gas-metasediments
8320'	2.33	89				Overmature	Cellulosic	Gas-metasediments
Cores								
5000'	0.40	65	1.09	28		Immature	Cellulosic	Gas type kerogen
5026'	0.34	100				Immature	Cellulosic	Basalt-caved vitrinit.
7705'	1.77	94				Overmature	Cellulosic	Volcanic Agglomerate
8361'	-	-	-	-		-	-	Insufficient data

RESERVOIR QUALITY

The reservoir properties of exposed rocks around Hope and Selawik basins and in the SOCAL wells are quite variable. Pre-Tertiary strata generally have porosities and permeabilities much lower than typical of petroleum reservoirs. The reservoir quality of Neogene deposits is good to very good, and of Paleogene deposits is moderate to poor.

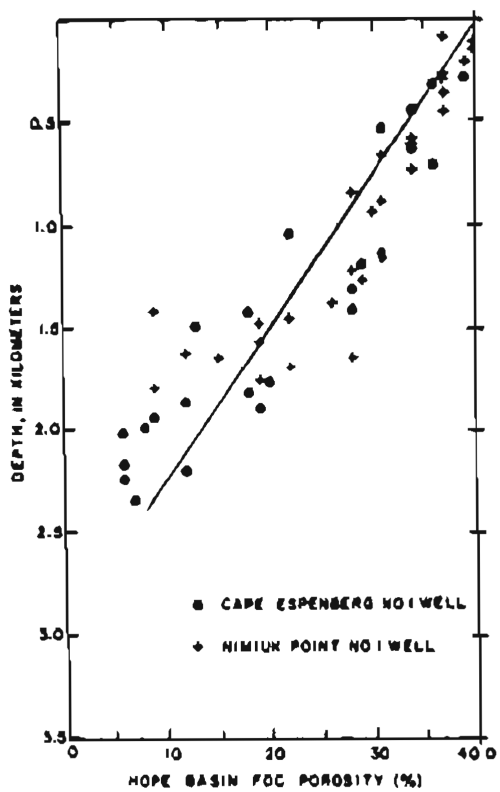
The porosity of field samples collected from Cretaceous outcrops in the Waring Mountains range from 1.0 to 14.5 percent, and average 4.7 percent for 39 samples (figure 20). Thirty-four of the 39 samples have permeabilities of less than 1.0 millidarcies (md). The highest values are from two conglomerate samples with porosities of 9.9 and 14.5 percent and permeabilities of 49 and 69 md. respectively.

Porosities determined from compensated gamma-gamma formation density logs from the two SOCAL wells range from 40 percent at the top of the wells to 5 percent at the bottom (Fisher, 1982; figure 21).

Figure 20. Porosity and permeability data for surface samples from the Selawik Basin area.

SAMPLE NO.	PERMEABILITY (millidarcy)	HE POROSITY (PERCENT)	DENSITY	SAMPLE DESCRIPTION
WL85-1	<0.01	4.1	2.61	PHYLLITE
WL85-2	<0.01	1.8	2.76	META-SANDSTONE
WL85-3	21.0	2.6	2.76	MUDSTONE
WL85-5	<0.01	0.9	2.78	MUDSTONE
WL85-6	7.1	6.8	2.64	MUDSTONE
WL-7	0.01	2.6	2.69	MICA SCHIST
WL85-7	69.0	14.5	2.83	CONGLOMERATE
WL85-8	0.04	9.5	2.73	META-SANDSTONE
WL85-11	<0.01	5.0	2.72	HORNFELS
WL85-13	0.01	1.0	2.72	HORNFELS
WL85-14	0.69	3.0	2.77	CONGLOMERATE
WL85-15	49.0	9.9	2.75	CONGLOMERATE
WL85-16	<0.01	3.3	2.71	MUDSTONE
WL85-17	0.25	7.2	2.73	META-SANDSTONE
WL85-20	<0.01	1.4	2.75	META-SANDSTONE
WL85-22	0.01	3.5	2.71	META-SANDSTONE
WL85-23	0.17	7.6	2.69	SANDSTONE
WL85-24	0.08	5.0	2.69	SANDSTONE
WL85-25	0.68	7.7	2.69	SANDSTONE
WL85-26	0.12	7.0	2.68	SANDSTONE
WL85-27	0.01	2.9	2.72	META-SANDSTONE
WL85-28	0.05	4.3	2.69	SANDSTONE
WL85-29	0.24	6.2	2.69	SANDSTONE
WL85-33	0.52	2.6	2.64	CONGLOMERATE
WL85-34	0.03	4.2	2.71	SANDSTONE
WL85-35	1.10	7.3	2.67	SANDSTONE
WL85-35B	0.16	2.3	2.74	SANDSTONE
WL85-36	0.41	7.7	2.67	SANDSTONE
WL85-37	<0.01	2.5	2.72	SANDSTONE
WL85-38	0.27	3.8	2.64	CONGLOMERATE
WL85-39	0.52	5.0	2.69	CONGLOMERATE
WL85-41	0.03	3.4	2.69	QUARTZITE
WL85-42	0.01	1.3	2.73	QUARTZITE
WL85-43	0.03	3.7	2.72	SANDSTONE
WL85-44	0.01	5.9	2.72	SANDSTONE
DT85-20	0.07	5.5	2.77	SANDSTONE
DT85-24	0.76	7.8	2.70	SANDSTONE
DT85-25	0.03	4.0	2.71	SANDSTONE
DT85-26	<0.01	2.3	2.74	HORNFELS

Figure 21. Porosity - depth data for the SOCAL Cape Espenberg No. 1 and the SOCAL Nimiuk Point No. 1 test wells (modified from Fisher, 1982).



SUMMARY

The most likely petroleum reservoir in the Hope and Selawik basins is the Neogene. Order of magnitude calculations indicate that Hope Basin contains about 70,000 cubic km., and Selawik Basin about 15,000 cubic km. of Neogene sediment with an estimated average porosity of about 15 percent. Thermal maturation levels within the oil window are predicted to occur in both basins between 2500 m. and 3300 m. Small- to moderate-size structural and stratigraphic traps can be expected in extensional basins of this type. However, the volume of high organic carbon source rock within the Neogene deposits is extremely low, and there is no evidence that oil or gas generation has ever occurred. Pre-Tertiary strata around Kotzebue Sound are over mature and probably have been since pre-Neogene time. Little is known about the source rock potential of Paleogene rocks. The Paleocene strata at Chicago Creek were deposited in a nonmarine environment and contain a high percentage of organic carbon in the form of coal. The coal is lignitic and has not reached the grade of sub-bituminous-C. Under the conditions in which Paleogene deposits are likely to occur, if at all, in Hope and Selawik basins, these deposits could produce gas or oil of the type found in Cook Inlet, Alaska.

BIBLIOGRAPHY AND REFERENCES CITED

American Stratigraphic Company, 1977, Log number A-299, Standard Oil of California, No. 1 Cape Espenberg: Denver, 1 sheet.

American Stratigraphic Company, 1977, Log number A-296, Standard Oil of California, No. 1 Nimiuk Point: Denver, 1 sheet.

Andreasen, G.E., 1960, Total intensity aeromagnetic profiles of Cape Espenberg, Alaska: U.S. Geological Open-file Report 192, 2 sheets.

Armstrong, A.K., Mamet, B.L., and Dutro, J.T., Jr., 1971, Lisburne Group, Cape Lewis-Niak Creek, northwestern Alaska, in Geological Survey research 1971: U.S. Geological Survey Professional Paper 750-B, p. B23-B34.

Barnes, D.F., 1971, Preliminary Bouguer anomaly and specific gravity maps of Seward Peninsula and Yukon Flats, Alaska: U.S. Geological Survey Open-file Report 467, 11 p.

Barnes, D.F., 1977, Bouguer gravity map of northern Alaska: U.S. Geological Survey Open-file Report 77-166A, 1 sheet, scale 1:1,000,000.

Berryhill, R.V., 1962, Reconnaissance sampling of beach and river mouth deposits, Norton Bay and Kotzebue Sound, Seward Peninsula, Alaska: U.S. Bureau of Mines Open-file Report, 13 p.

Cady, J.W., Ruppel, B.D., McHendrie, A.G., and Deas, H.S., 1973, Seismic, magnetic and gravity profiles -- Chukchi Sea and adjacent Arctic Ocean, 1972: Part 2, Magnetic and gravity profiles: U.S. Geological Survey Open-file Report 573, 29 sheets.

Campbell, R.H., 1960, Generalized stratigraphic section of the Lisburne Group in the Point Hope A-2 quadrangle, northwestern Alaska, in Geological Survey research 1960: U.S. Geological Survey Professional Paper 400-B, p. B337-B339.

Campbell, R.H., 1961, Thrust faults in the southern Lisburne Hills, northwest Alaska, in Geological Survey research 1961: U.S. Geological Survey Professional Paper 424-D, p. D194-D196.

Campbell, R.H., 1967, Areal geology in the vicinity of the Chariot site, Lisburne Peninsula, northwestern Alaska: U.S. Geological Survey Professional Paper 395, 71 p.

Chase, T.E., Miller, C.P., Thomas, J.A., Seekins, B.A., of sedimentary basins of offshore Alaska: U.S. Geological Survey Open-file Report 80-182, 1 sheet, scale 1:2,770,702 at latitude 62½.

Churkin, Michael, Jr., 1969, Paleozoic tectonic history of the Arctic Basin north of Alaska: Science, v. 165, p. 549-555.

Churkin, Michael, Jr., 1973, Paleozoic and Precambrian rocks of Alaska and their role in its structural evolution: U.S. Geological Survey Professional Paper 740, 64 p.

Cobb, E.H., 1972, Metallic mineral resources map of the Kotzebue quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-421, 1 sheet, scale 1:250,000.

Cobb, E.H., 1975, Summary of mineral occurrances (other than mineral fuels and construction materials) in five quadrangles in west-central Alaska (Hughes, Kotzebue, Melozitna, Selawik, Shungnak): U.S. Geological Survey Open-file Report 75-627, 57 p.

Cobb, E.H., and Miller, T.F., 1981, Summaries of data on and lists of references to metallic and selected nonmetallic mineral occurrences in the Hughes, Kotzebue, Melozitna, Selawik and Shungnak quadrangles, west-central Alaska; Supplement to Open-file Report 75-627: Part A, Summaries of data to January 1, 1981: U.S. Geological Survey, Open-file Report 81-847A, 14 p.

Cobb, E.H., and Miller, T.P., 1981, Summaries of data on and lists of references to metallic and nonmetallic mineral occurrences in the Hughes, Kotzebue, Melozitna, Selawik, and Shungnak quadrangles, west-central Alaska; Supplement to Open-file Report 75-627: Part B, Lists of references to January 1, 1981: U.S. Geological Survey Open-file Report 81-84 7B, 13 p.

Collier, A.J., 1905, Coal fields of the Cape Lisburne region: U.S. Geological Survey Bulletin 259, p. 172-185.

Decker, John, and Karl, Susan, 1977, Preliminary aeromagnetic map of Seward Peninsula, Alaska: U.S. Geological Survey Open-file Report 77-796E, 1 sheet, scale 1:1,000,000.

Decker, John, and Karl, Susan, 1977, Aeromagnetic profiles of Seward Peninsula, Alaska: U.S. Geological Survey Open-file Report 77-796F, 1 sheet.

Dickinson, W.R., 1974, Plate tectonics and sedimentation, in Dickinson, W.R., ed., Tectonics and sedimentation: Society of Economic Paleontologists and Mineralogists Special Publication No. 22, p. 1-27.

Eittreim, Steven, Grantz, Arthur, and Whitney, O.T., 1977, Tectonic imprints on sedimentary deposits in the Hope basin, in Blean, K.M., ed., The United States Geological Survey in Alaska: accomplishments during 1976: U.S. Geological Survey Circular 751-B, p. B100-B103.

Eittreim, Steven, Grantz, Arthur, and Whitney, O.T., 1978, Isopach maps of Tertiary sediments, Hope Basin, southern Chukchi Sea, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-906, 1 sheet, scale 1:1,000,000.

Eittreim, Steven, Grantz, Arthur, and Whitney, O.T., 1979, Cenozoic sedimentation and tectonics of Hope Basin, Southern Chukchi Sea: in Sisson, A., ed., The relationship of plate tectonics to Alaskan geology and resources, Alaska Geological Society, Anchorage, p. B1-B11.

Ehm, Arlen, 1983, Oil and gas basins map of Alaska: Alaska Division of Geological and Geophysical Surveys Special Report 32, scale 1:2,500,000, 1 sheet.

Fisher, M.A., 1982, Petroleum Geology of Norton Basin, Alaska: American Association of Petroleum Geologists Bulletin, v. 66, p. 286-301.

Fisher, M.A., Patton, W.W., Jr., and Holmes, M.A., 1981, Geology and petroleum potential of the Norton basin area, Alaska: U.S. Geological Survey Open-file Report 81-1316, 51 p. + 5 tables, 29 figures.

Fujita, K., Dretzka, E.E., and Grantz, A., 1982, Bibliography of northeast Siberian geology and geophysics (Second Edition): U.S. Geological Survey Open-file Report 82-616, 80 p.

Gates, G.O., Grantz, Arthur, and Patton, W.W., Jr., 1968, Geology and natural gas and oil resources of Alaska: in Beebe, B.W., ed., Natural Gases of North America, American Association of Petroleum Geologists, memoir 9, vol. 1, p. 3 - 48.

Grantz, Arthur, Dinter, David A., Hill, Edwin, Chase, T.E., 1982, Map showing tracklines of high-resolution uniboom seismic-reflection profiles collected August 31 through September 21, 1980, in the Chukchi Sea, Alaska: U.S. Geological Survey Open-file Report 82-527, scale 1:1,000,000.

Grantz, Arthur, and Greenberg, Jonathan, 1981, Map showing tracklines of high resolution Uniboom seismic reflection profiles collected August 26 through September 19, 1978, in the Chukchi Sea: U.S. Geological Survey Open-file Report 81-33, scale 1:1,000,000.

Grantz, Arthur, Hanna, W.F., and Wallace, S.L., 1971, Chukchi Sea seismic reflection profiles and magnetic data, 1970, between northern Alaska and Herald Island: U.S. Geological Survey Open-file Report 71-125, 32 sheets seismic profiles, 2 sheets magnetic data, 1 location map.

Grantz, Arthur, Hanna, W.F., and Wallace, S.L., 1972, Chukchi Sea seismic reflection and magnetic profiles, 1971, between northern Alaska and Herald Island: U.S. Geological Survey Open-file Report 72-137, 38 sheets seismic profiles, 2 sheets magnetic profiles, 2 location maps and index map, 1969-1971.

Grantz, Arthur, Holmes, M.L. and Kososki, B.A., 1975, Geologic framework of the Alaskan continental terrace in the Chukchi and Beaufort Seas: U.S. Geological Survey Open-file Report 75-124, 68 p.

Grantz, Arthur, Holmes, M.L., and Kososki, B.A., 1976, Geologic framework of the Alaskan continental terrace in the Chukchi and Beaufort Seas, in Yorath, C.J., Parker, E.R., and Gelass, D.J., eds., Canada's continental margins and offshore D.J., eds., Canada's continental margins and offshore petroleum exploration: Canadian Society of Petroleum Geologists Memoir 4, p. 669-700.

Grantz, Arthur, Holmes, M.L. Riley, D.C., and Wallace, S.L., 1972, Seismic, magnetic and gravity profiles -- Chukchi Sea and adjacent Arctic Ocean, 1972: Part 1, Seismic reflection profiles: U.S. Geological Survey Open-file report 551, 21 sheets.

Grantz, Arthur, Mann, Dennis M., and May, Steven D., 1982, Tracklines and multichannel seismic-reflection data collected by the USGS in the Beaufort and Chukchi Seas in 1977 for which profiles and stack tapes are available: U.S. Geological Survey Open-file Report 82-735, 1 sheet.

Grantz, Arthur, and May, S.D., 1983, Geologic framework and petroleum potential of United States Chukchi Shelf north of Point Hope [abs]: American Association of Petroleum Geologists Bulletin v. 67, no. 3, p. 474.

Grantz, Arthur, and May, S.D., 1984, Summary geologic report for Barrow Arch, Outer Continental Shelf (OCS), Planning Area, Chukchi Sea, Alaska: U.S. Geological Survey Open-file Report 84-395, 40 p.

Grantz, Arthur, McHendrie, A.G., Nilsen, T.H., and Yorath, C.J., 1974, Seismic reflection profiles on the continental shelf and slope between Bering Strait and Barrow, Alaska, and Mackenzie Bay, Canada: U.S. Geological Survey Open-file Report 585, 51 sheets.

Grantz, Arthur, McHendrie, A.G., Nilsen, T.H., Yorath, C.J., and Phillips, J.D., 1974, Digital magnetic tapes of single channel seismic reflection profiles on the continental shelf and slope between Bering Strait and Barrow, Alaska, and MacKenzie Bay, Canada: National Technical Information Service PB-232 344, 12 p.

Hamilton, T.D., 1986, Late Cenozoic glaciation of the central Brooks Range, in Hamilton, T.D., and others, eds., Claciation in Alaska--The geologic record: Alaska Geological Society, p. 9-50.

Hanna, W.F., Ruppel, D.B., McHendrie, A.G., and Sikora, R.F., 1974, Residual magnetic anomaly and free-air gravity anomaly profiles, 1973, on continental shelf and slope between Bering Strait and Barrow, Alaska, and MacKenzie Bay, Canada: U.S. Geological Survey Open-file Report 74-6, 6 sheets.

Harris, Anita, ed., 1983, Thermal maturation values (conodont color alteration indices) for Paleozoic and Triassic rocks, Chandler Lake, De Long Mountains, Howard Pass, Killik River, Misheguk Mountain, and Point Hope Quads, Northwest Alaska and subsurface NPRA: U.S. Geological Survey Open-file Report 83-505.

Harris, Ronald, 1985, Paleomagnetism of the Yukon-Koyukuk Province, Alaska: unpublished University of Alaska Master of Science thesis, Fairbanks, Alaska.

Holmes, M.L., and Creager, J.S., 1981, The role of the Kaltag and Kobuk faults in the tectonic evolution of the Bering Strait region: in Hood, D.W., and Calder, J.A., eds., The eastern Bering Sea Shelf Oceanography and Resources: U.S. Department of Commerce, NOAA, Office of Marine Pollution Assessment, p. 293-302.

Hopkins, David M.(editor), 1967, The Bering Land Bridge: Stanford University Press, Stanford, California.

Hudson, Travis, 1977, Geologic map of Seward Peninsula, Alaska: U.S. Geological Survey Open-file Report 77-796.

Jansons, Uldis, 1981, Preliminary evaluation of sample data from the proposed Chukchi Imuruk National Reserve (now Bering Land Bridge National Preserve), Alaska: U.S. Bureau of Mines Open-file Report 28-81, 8 p.

Johnson, R.G., 1982, Bruhnes-Matuyama magnetic reversal dated at 790,000 yr B.P. by marine-astronomical correlations: Quaternary Research, v. 17, p. 135-147.

Kachadoorian, Reuben, Lachenbruch, A.H., Moore, G.W., and Waller, R.M., 1960, Supplementary report on geologic investigations in support of Phase II, Project Chariot in the vicinity of Cape Thompson, northwestern Alaska: U.S. Geological Survey Open-file Report 197, 30 p.

Kaufman, D.S., and Hopkins, D.M., 1986, Glacial history of the Seward Peninsula, in Hamilton, T.D., and others, eds., Claciation in Alaska--The geologic record: Alaska Geological Society, p. 51-78.

Lerand, Monti, 1973, Beaufort Sea, in McCrossan, ed., The Future Petroleum Provinces of Canada: Canada Society of Petroleum Geologists Memoir No. 1, p. 315-386.

May, S.D., and Grantz, Arthur, 1985, Digital marine gravity data collected in the Chukchi Sea in 1978: U.S. Geological Survey Open-file Report 85-602, 4 p.

May, S.D., and Grantz, Arthur, 1985, Digital marine gravity data collected in the southern Chukchi Sea in 1980: U.S. Geological Survey Open-file Report 85-603, 4 p.

May, S.D., and Grantz, Arthur, 1985, Digital marine gravity data collected in the Chukchi Sea in 1982: U.S. Geological Survey Open-file Report 85-742, 4 p.

May, S.D., Ruppel, B.D., and Grantz, Arthur, 1985, Digital marine gravity data collected in the southern Chukchi Sea in 1976: U.S. Geological Survey Open-file Report 85-600, 4 p.

May, S.D., Ruppel, B.D., and Grantz, Arthur, 1985, Digital marine gravity data collected in the Beaufort and Chukchi Seas in 1977: U.S. Geological Survey Open-file Report 85-601, 4 p.

Mendenhall, W.C., 1902, Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers: U.S. Geological Survey Professional Paper 10, 68 p.

Miller, D.J., Payne, T.G., and Gryc, George, 1959, Geology of possible petroleum provinces in Alaska, with an annotated bibliography by E.H. Cobb: U.S. Geological Survey Bulletin 1094, 131 p.

Minster, J.B. and Jordan, T.H., 1978, Present-day plate motions, Journal of Geophysical Research, v. 83, p. 1065-1077.

Minster, J.B., Jordan, T.H., Molnar, Peter, Haines, E., 1974, Numerical modelling of instantaneous plate tectonics: Geophysical Journal of the Royal Astronomical Society, v. 36, p. 541-576.

Moore, G.W., 1960, Recent eustatic sea-level fluctuations recorded by arctic beach ridges, in Geological Survey research 1960: U.S. Geological Survey Professional Paper 400-B, p. B335-B337.

Moore, G.W., 1961, Sorting of beach sediment, northwestern Alaska, in Geological Survey research 1961: U.S.

Geological Survey Professional Paper 424-C, p. C198-C200.

Nakamura, Kazuaki, Plafker, George, Jacob, K.H., and Davies, J.N., 1980, A tectonic stress trajectory map of Alaska using information from volcanoes and faults: Bulletin of the Earthquake Research Institute, v. 55, p. 89-100.

Nelson, C.H., and Creager, J.S., 1976, Displacement of Yukon-derived sediment from the northern Bering Sea to southern Chukchi Sea during the Holocene, in Cobb, E.H., ed., The United States Geological Survey in Alaska: accomplishments during 1975: U.S. Geological Survey Circ. 733, p. 10-11.

Ostenso, N.A., 1968, A gravity survey of the Chukchi Sea region, and its bearing on westward extension of structure in northern Alaska: Geological Society of America Bulletin, v. 79, no. 2, p. 241-254.

Patton, W.W., Jr., 1973, Reconnaissance geology of the northern Yukon-Koyukuk Province, Alaska: U.S. Geological Survey Professional Paper 774-A, p. A1-A17.

Patton, W.W., Jr., and Miller, T.P., 1968, Regional geologic map of the Selawik and southeastern Baird Mountains quadrangles, Alaska: U.S. Geological Survey Miscellaneous Geological Investigations Map I-530, 1 sheet, scale 1:250,000.

Pewe, T.L., Hopkins, D.M., and Lachenbruch, A.H., 1959, Engineering geology bearing on harbor selection along the northwest coast of Alaska from Nome to Point Barrow: U.S. Geological Survey Open-file report 173, 57 p.

Reiss, Thomas, Phillips, R. Lawrence, Hunter, Ralph, and Barnes, Peter W., 1983, Summary of marine geologic studies on the inner shelf of the Chukchi Sea, Alaska, 1975 and 1981: U.S. Geological Survey Open-file Report 83-71, 11 p.

Ruppel, B.D., and McHendrie, Craig, 1975, Free air gravity anomaly profiles from the Chukchi Sea: U.S. Geological Survey Open-file Report 75-343, 2 maps, 9 profiles.

Ruppel, B.D., and McHendrie, A.G., 1976, Free air gravity anomaly map of the eastern Chukchi and southern Beaufort Seas: U.S. Geological Survey Miscellaneous Field Studies Map MF-785, scale 1:2,000,000.

Sainsbury, C.L., 1972, Geologic map of the Teller quadrangle, western Seward Peninsula, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-685, scale 1:250,000.

Sainsbury, C.L., 1975, Geology, ore deposits, and mineral

Mines Open-file Report 73-75, 108 p. (Also available as National Technical Information Services PB 247 099/AS).

Scholl, D.W., and Sainsbury, C.L., 1960, Marine geology and bathymetry of the nearshore shelf of the Chukchi Sea, Ogotoruk Creek area, northwest Alaska: U.S. Geological Survey Open-file Report 187, 68 p.

Schumacher, G.M., 1976, Bathymetric maps of Chukchi Sea and Arctic Ocean: U.S. Geological Survey Open-file Report 76-823, 2 sheets, scale 1:2,500,000.

Semenovich, V.N., Gramberg, I.S., and Nesterov, I.I., 1973, Oil and Gas Possibilities in the Soviet Arctic: American Association of Petroleum Geologists Memoir 19, p. 194-203.

Staff, Alaska Field Operations Center, 1979, Mineral appraisal of the proposed Selawik National Wildlife Refuge, Alaska: A preliminary comment: U.S. Bureau of Mines Open-file Report 22-79, 7 p.

Stone, D.B., 1983, Present day plate boundaries in Alaska and the Arctic: Journal of the Alaska Geological Society, v. 3, p. 1-14.

Tailleur, I.L., 1965, Low-volatile bituminous coal of Mississippian age on the Lisburne Peninsula, northwestern Alaska, in Geological Survey research 1965: U.S. Geological Survey Professional Paper 525-B, p. B34-B38.

Toimil, L.G., 1978, Ice-gouged microrelief on the floor of the eastern Chukchi Sea, Alaska: a reconnaissance survey: U.S. Geological Survey Open-file Report 78-693, 94 p.

Turner, D.L., Swanson, S.E., and Wescott, Eugene, 1981, Continental rifting--A new tectonic model for geoghermal exploration of the central Seward Peninsula, Alaska: Geothermal Resources Council, Transactions, v. 5., p. 213-216.

Turner, R.F., Martin, G.C., Risley, D.E., Steffy, D.A., Flett, T.O., and Lynch, M.B., 1986, Geologic Report for the Norton Basin Planning Area, Bering Sea, Alaska: U.S. Department of the Interior, Minerals Management Service, 179 p.

Turner, R.F., and Olsen, D.L., 1978, Preliminary paleontology report, Standard Oil Company of California, Cape Espenberg No. 1 well and Nimiuk Point No. 1 well, Kotzebue Sound--Selawik Basin Area: U.S. Minerals Management Service internal report.

Wiley, Thomas J., Sedimentary basins of offshore Alaska and adjacent regions: U.S. Geological Survey Open-file

Winters, W.J., and Lee, H.J., 1985, Geotechnical properties of samples from borings obtained in the Chukchi Sea, Alaska: U.S. Geological Survey Open-file Report 85-23, 55 p.

APPENDIX

Figure 22 Sample and station location map.

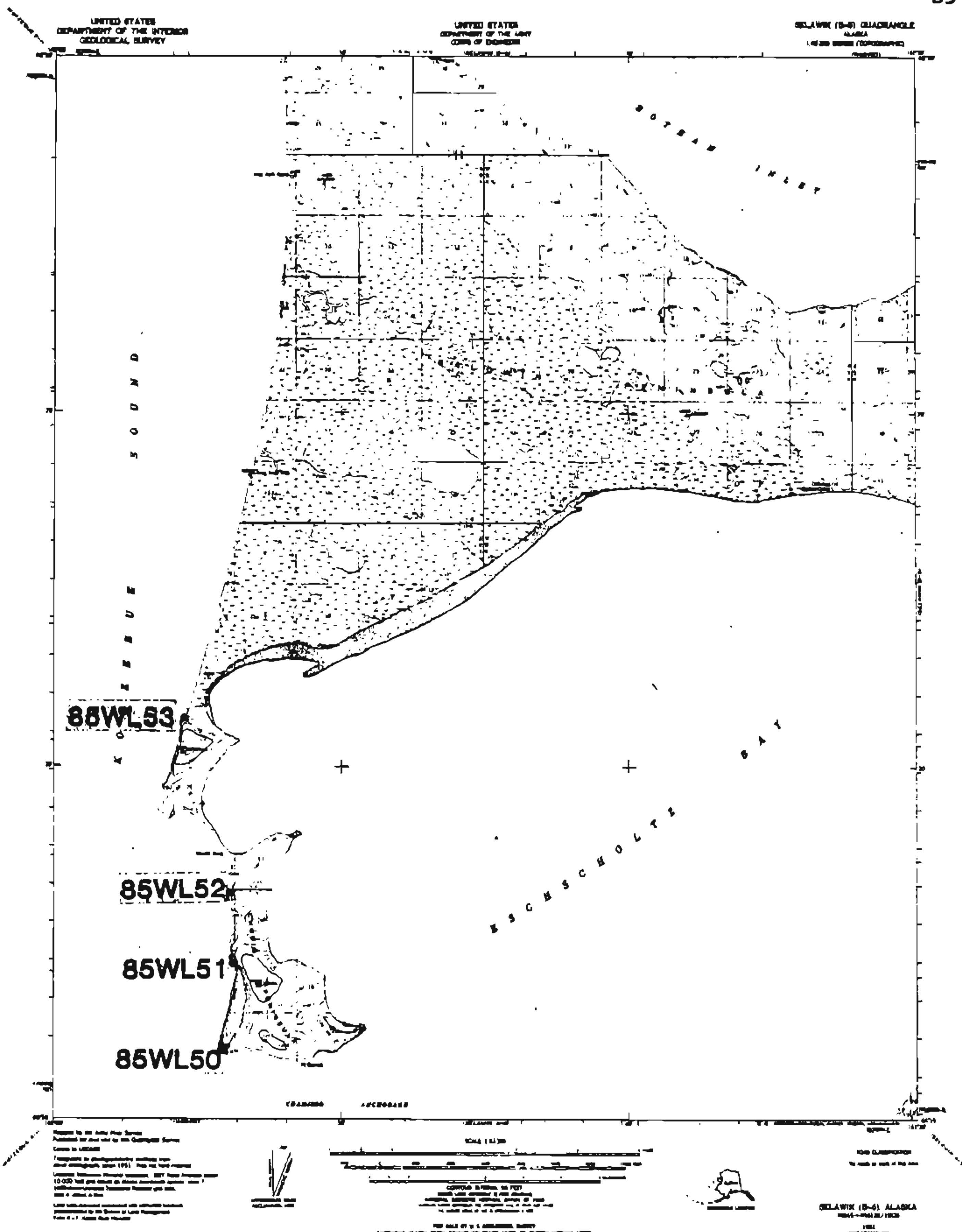


Figure 23 Sample and station location map.

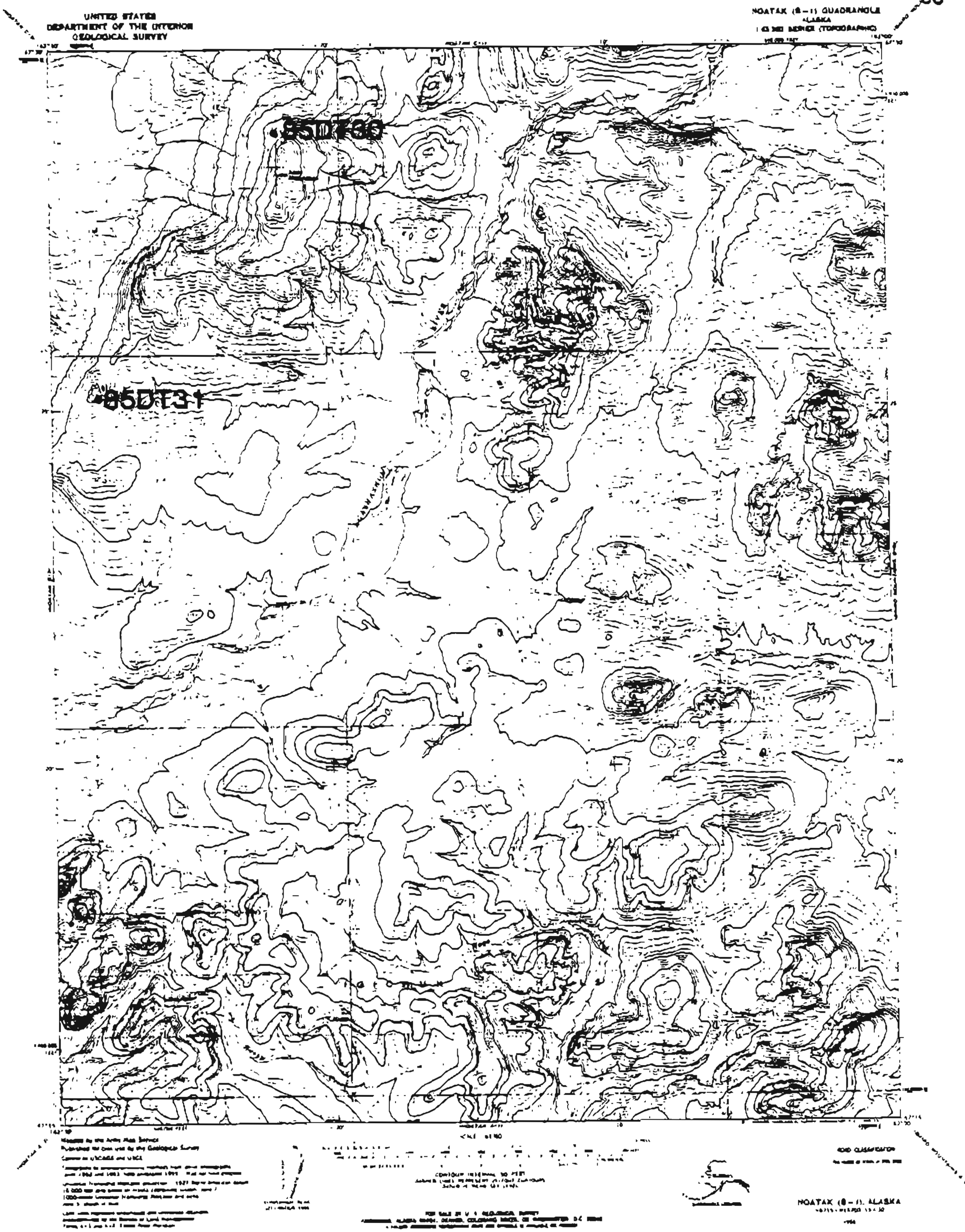


Figure 24. Sample and station location map.

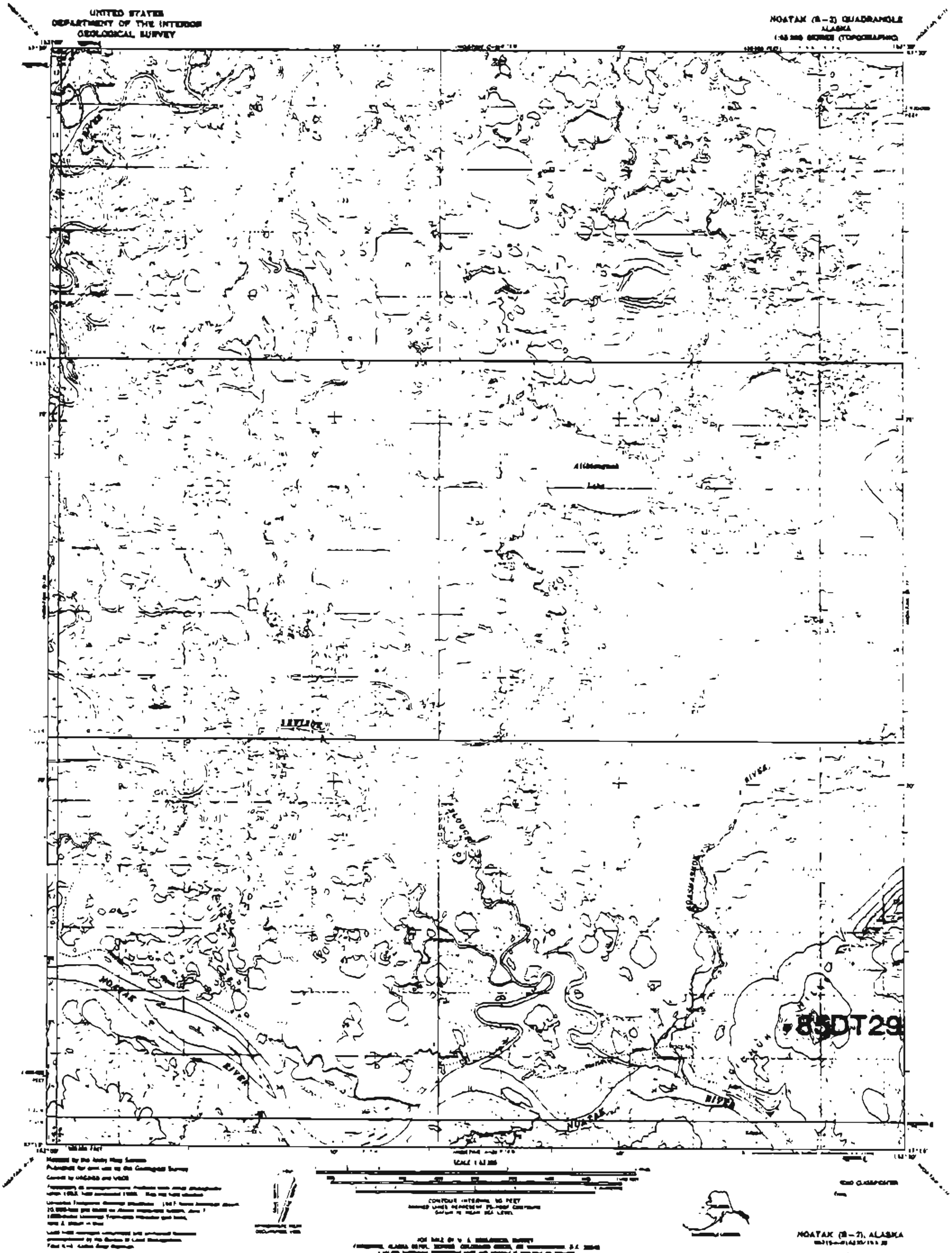


Figure 25. Sample and station location map.

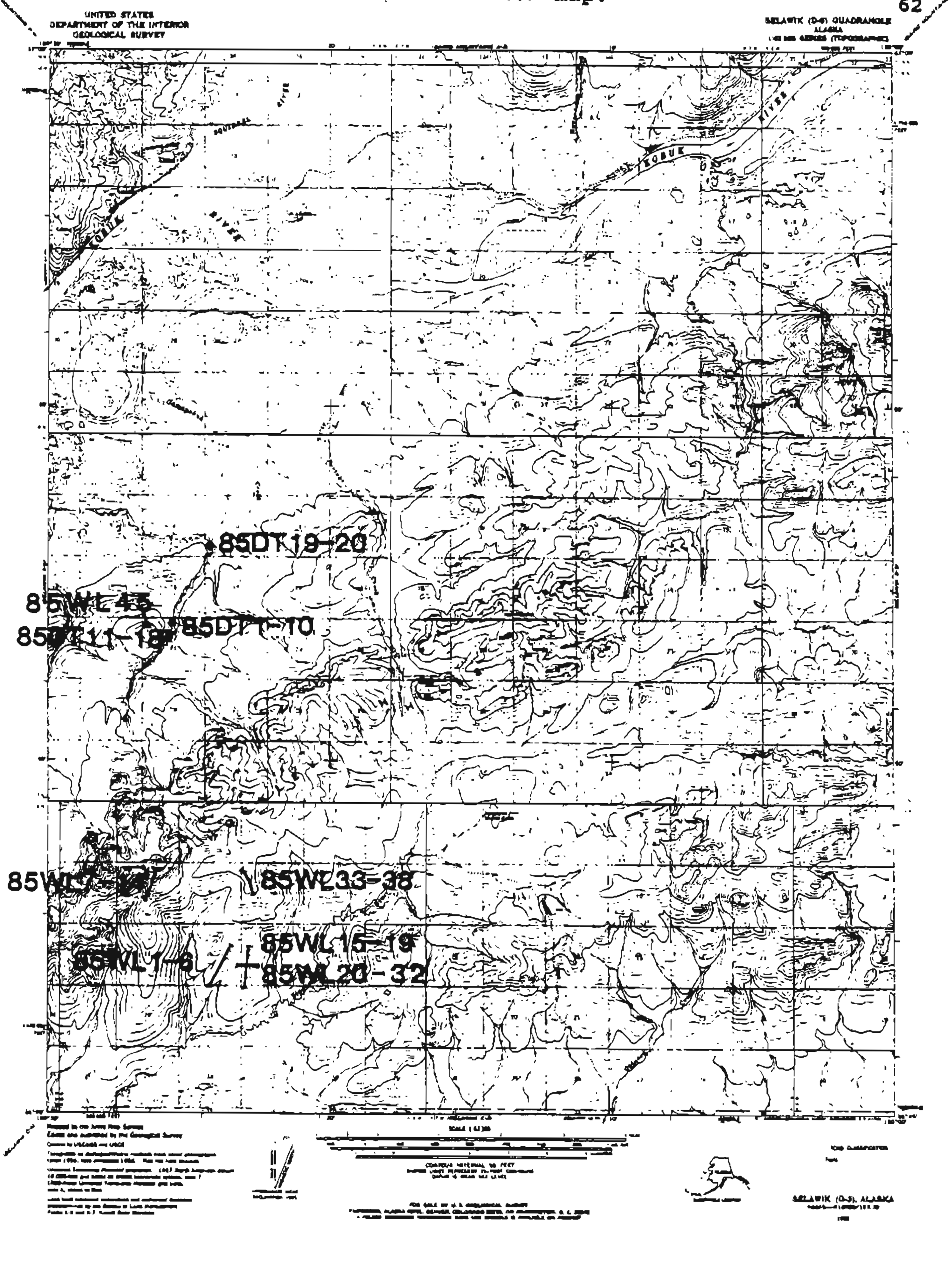


Figure 26. Sample and station location map.