UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

SUMMARY GEOLOGIC REPORT FOR BARROW ARCH OUTER CONTINENTAL SHELF (OCS) PLANNING AREA, CHUKCHI SEA, ALASKA

By

Arthur Grantz and Steven D. May

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This report is preliminary and has not been reviewed
for conformity with U.S. Geological Survey editorial standards
or stratigraphic nomenclature. Any use of trade names is
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Introduction

This summary report is a partial revision of U.S. Geological Survey Open-File Report 82-1053 (Grantz and others, 1982). That report synthesized for the Minerals Management Service information available to the U.S. Geological Survey (USGS) as of 1982 on the geologic framework, petroleum geology and regional geologic hazards of the Barrow arch planning area in the Chukchi Sea. The planning area covers the northern part of the Alaskan Chukchi shelf east of the U.S.-Russia convention line of 1867 (fig. 1). New geologic data and interpretations have made it desirable to revise those sections of Open-File Report 82-1053 dealing with the geologic framework and petroleum potential of the Barrow arch planning area, and these revised sections constitute the present report. Additional revisions will be made when seismic data gathered in 1982, and processed in late 1983 and early 1984, are interpreted. These revisions will be incorporated in a more complete report on the geology of the Chukchi Sea that is now in preparation. No significant changes are as yet required in the section of Open-File Report 82-1053 dealing with regional geologic hazards. The reader is referred to that report (Grantz and others, 1982) for a synthesis of present USGS information on geologic hazards in the planning area.

There is no discussion of hard minerals in either the 1982 report or the present one with the exception of a brief discussion of the distribution of sand and gravel on the Chukchi Shelf (Grantz and others, 1982, p. 43-44). There are no known potentially economic deposits of other hard minerals in the planning area. Large potentially economic deposits of coal do occur, however, in Cretaceous strata of coastal northwest Alaska north of Cape Lisburne (Barnes, 1967) and in Mississippian strata on the Lisburne Peninsula (Conwell and Triplehorn, 1976). Our seismic data suggest that both the Cretaceous and the Mississippian coals extend offshore but we have no data from which to judge their thickness, extent or quality in the planning area.

The Barrow arch planning area (fig. 1) is an extensive frontier terrain that is prospective for petroleum but is, as of this date (1984), incompletely explored and entirely untested. The area is in most places underlain by a thick section of sedimentary rocks prospective for oil and gas and contains diverse geologic structures and stratigraphic features that may have trapped hydrocarbon fluids. The prospective sedimentary section includes every geologic system from the Devonian(?) or Mississippian to the Tertiary, and includes a number of formations that contain petroleum deposits or strong shows of oil or gas on the North Slope of Alaska. These formations have proved disappointing, however, where tested in a few exploratory wells in the western part of the National Petroleum Reserve in Alaska, which lies adjacent to the Chukchi shelf.

Petroleum exploration and development in the Barrow arch planning area will be hindered by the Arctic climate, polar ice pack, winter darkness, absence of harbors in Alaska north of the Aleutian Islands, and remoteness from exploration support facilities and supplies. Pack ice entirely covers the area from the months of October or November to June, and part of it is ice free for a short time in late summer only in favorable ice years (fig. 2). The bathymetry, however, is favorable for exploration because most of the planning area is less than 60 m (200 ft) below sea level (fig. 3). The National Petroleum Council (1981, p. 5) estimates that "Proven technology and sufficient information and technical expertise for advanced design work is available for the industry to proceed confidently with operations in water as deep as 650 feet in the southern Bering Sea and to about 200 feet in the more severely ice-covered areas of the northern Bering, Chukchi, and Beaufort Seas." Thus, essentially all of the planning area is thought by the National Petroleum Council to be technologically accessible to petroleum exploration and development at the present time.

The Chukchi shelf and the Barrow arch planning area lie adjacent to the North Slope of Alaska which, in spite of its remoteness, is extensively explored for petroleum. The National Petroleum Reserve in Alaska (NPRA) occupies the western part of the North Slope (Fig. 1), but the main areas of oil and gas development lie east of the mouth of the Colville River (151° W. long). The principal logistic base for petroleum exploration on the North Slope is in the Prudhoe Bay area, about 350 km east of the Chukchi shelf.

The Trans-Alaska Pipeline System (TAPS), a common carrier, would provide an outlet for Barrow arch planning area oil brought to its northern terminus near Prudhoe Bay. If the proposed Alaska Natural Gas Transportation System, a pipeline with a terminus near Prudhoe Bay, is also built it would presumably provide the means for carrying planning area natural gas to market. These pipelines are 400-600 km across the topographically subdued North Slope from the most likely sites for shoreline terminals of pipelines that might bring Chukchi Sea oil and gas onshore. TAPS and the proposed gas pipeline, if it is built, favorably affect the economics of developing oil and gas deposits in the Barrow arch planning area because the feasibility of economically transporting large volumes of oil or gas by ice-breaking tankers year-round from the Chukchi Sea has yet to be demonstrated.

Our data base consists mainly of the U.S. Geological Survey multichannel seismic-reflection profiles and accompanying high-resolution seismic-reflection profiles shown in figure 1 and some additional Geological Survey single channel seismic-reflection profiles, sonobuoy refraction measurements, side scan sonograms, sea bed samples and bathymetric data. The multichannel seismic profiles, which are the main basis for the interpretations presented, are not evenly distributed. Ice conditions during periods of data acquisition were such that profile coverage in the northern part of the planning area is sparse (fig. 1). Elsewhere, the multichannel profiles are mostly 30 to 90 km apart, with typical line spacing being 40 to 50 km. Because of the wide spacing and irregular distribution of the profiles, and because the profiles are only partially processed, the interpretation of the geologic framework and petroleum potential presented in this report are only preliminary. Strong artifacts on some of the profiles, particularly in the southwestern part of the planning area, further limit the usefulness of the affected profiles for geologic interpretation and resource assessment.

Bathymetry and physiography

The sea bed in the Barrow arch planning area (fig. 3) is remarkably flat and most of it lies between the 30 and 60 m isobaths. Water more than 60 m deep is found in the planning area at the head of Barrow sea valley and in two other broad sea valleys that extend a short distance into the planning area north of Hanna Shoal. Except for the nearshore areas and the large sand ridges at Blossom Shoals, off Icy Cape, the shallowest part of the planning area is at Hanna Shoal, near 72° N. lat, 162° W. long. A small area of the sea bed there is less than 25 m below sea level. The bathymetric and other base maps used in the illustrations are compiled on a polar stereographic projection.

Geologic framework

The Barrow arch planning area encompasses parts of seven major structural provinces having more or less distinct geologic character and petroleum potential. These provinces are enumerated, and their locations are shown, in figures 4 and 15. The general stratigraphy and lithology of the region is summarized in figure 5 and a cross section based on correlated test wells in the adjacent onshore is presented in figure 6. The offshore geologic data are mostly new, but some material was taken from Eittreim and others(1978, 1979) and Grantz and others (1981). Onshore data are mainly from Alaska Geological Society (1981), Lathram (1965), Miller and others (1979), Guldenzopf and others (1980), and Tetra Tech, Inc. (1982).

Depth to seismic horizons, and commonly the thickness of seismic-stratigraphic units in this report are given in seconds of two-way seismic reflection travel time. An approximate conversion of travel-time to km can be made through the graphs in figure 7, which represent the average regional velocity structure. The curve for the North Chukchi basin also approximates conditions in northern Hope basin and the young sedimentary sequence in the Tertiary canyon fill (fig. 4). The curve for the Chukchi shelf has been biased by the Tertiary canyon fill; its use will give depths that are somewhat shallower than actual where the fill is not present.

Stratigraphy

The sedimentary strata of northern Alaska and the United States Chukchi shelf, including the Barrow arch planning area, can be conveniently grouped into three regionally extensive sequences of contrasting lithology, tectonic character and hydrocarbon potential: the Franklinian, Ellesmerian, and Brookian (fig. 5). The Franklinian sequence (Cambrian to Devonian), which regionally consists of slightly to strongly metamorphosed sedimentary and some volcanic rocks, is inferred to constitute economic basement for the planning area. Following mild metamorphism and regional deformation, an extensive platform was cut across the Franklinian rocks in Late Devonian and Early Mississippian time. This, the Arctic platform, is a low-gradient surface that has remained remarkably stable beneath the North Slope of Alaska and the Chukchi shelf, and is the foundation for the potentially petroliferous strata of the Chukchi shelf. A lithologically diverse suite of clastic and carbonate sedimentary rocks, the Ellesmerian sequence, was deposited on the Arctic platform. This sequence contains both marine and nonmarine beds, including stratigraphically condensed organic-rich shale, texturally mature sandstone and conglomerate, and some dolomitized limestone. Clastic components were derived from a northerly sourceland that lay beneath and north of the outer part of the present continental shelf of the Beaufort and northeast Chukchi Seas. In a following section on the Hanna trough it is suggested that the Chukchi platform of the west-central Chukchi Sea (fig. 10) may also have been a western sourceland for the Ellesmerian clastic strata of the United States Chukchi shelf. In the Chukchi shelf the main Ellesmerian sequence as developed on the western North Slope appears to be underlain, beneath a mild angular unconformity, by a thick sedimentary unit that filled in structurally low areas of the Arctic Platform. This unit is called the Eo-Ellesmerian sequence in this report.

Eo-Ellesmerian sequence: Structural sags and faulted depressions in the angular unconformity (the Arctic platform) at the top of the Franklinian sequence beneath the Chukchi shelf are filled with sedimentary prisms that coalesce at their edges to form a regional stratigraphic sequence of irregular outline and marked local variations in thickness. Figure 9, a structural contour map in isochrons of the base of this sequence, shows the distribution of the sequence and the local structural subbasins in which it lies. The deepest of these subbasins, located about 50 km west of Icy Cape, contains as much as 5 km of section on one seismic profile. These beds are closely related to the Ellesmerian sequence because they produce coherent seismic reflections over a large area and are only slightly more deformed than that sequence. However there is commonly a low angle, but pronounced, angular unconformity between these rocks and the Ellesmerian beds, and in places fault-bounded prisms of these sediments appear to be overstepped by Ellesmerian strata. These strata are called Eo-Ellesmerian because of their structurally close, but unconformable relationship with the overlying Ellesmerian sequence.

The character of the Eo-Ellesmerian beds can only be inferred because they cannot be definitively correlated with rocks observed in outcrops or wells onshore. Further, they lie at subsurface depths that in places exceed 15 km, and they generally have only fair to poor seismic expression. Comparison with onshore seismic-stratigraphic and subsurface units recognized in the exploration of NPRA (Guldenzopf and others, 1980, Alaska Geological Society, 1981, and Tetra Tech,Inc., 1982) suggests, however, that the Eo-Ellesmerian beds belong to the Endicott Group (fig. 5), which has a somewhat sporadic distribution in NPRA. Where encountered in the subsurface or interpreted from seismic-reflection profiles in NPRA, the Endicott consists of a thick sequence of pre-Lisburne Mississippian and perhaps Upper Devonian clastics, mainly nonmarine and in part coal-bearing. Its principal development is in the northwest-elongate, compound Ikpikpuk-Umiat basin of east-central NPRA, but seismic-reflection profiles suggest (C. E. Kirschner, unpub. data, 1984) that a wedge of Endicott clastics may also occur in Meade basin, which underlies western NPRA between about 158^{o} and 159^{o} W. long, and 69^{o}30' and 70^{o}30' N. lat. The areal extent of the inferred Endicott beds in Meade basin is much smaller than in the larger Ikpikpuk-Umiat basin to the east.

Several characteristics suggest correlation of the Eo-Ellesmerian seismic-stratigraphic sequence with the subsurface Endicott Group of NPRA. Chief of these is the stratigraphic position of the Eo-Ellesmerian beds beneath a mild angular unconformity and a seismic-stratigraphic unit that correlates with the Lisburne Group and overlying beds of the Ellesmerian sequence in western NPRA. The shape of the Eo-Ellesmerian prism (fig. 9) also closely resembles that of the Endicott Group. Both consist of coalesced, locally thick subbasins that in aggregate are less extensive and less uniform in thickness than the overlying Ellesmerian sequence (figs. 10 and 11). Both also have significant structural relief at the base and considerable local thickness. Maximum observed thickness of the Eo-Ellesmrian prism is 5 km, and of the Endicott prism in the subsurface of NPRA more than 3 km (C. E. Kirschner, unpub. data, 1984). Although the seismic-stratigraphic correlation of the Eo-Ellesmerian sequence with the Endicott Group of NPRA appears well supported, it should be noted that these prisms are not contiguous. The principal development of the Endicott Group is in the Ikpikpuk-Umiat Basin in eastern NPRA, which lies more than 200 km east of the Eo-Ellesmerian prism of the Chukchi shelf. The smaller Endicott Group prism in the Meade basin of west-central NPRA is at least 100 km east of the Eo-Ellesmerian prism, and no pre-Lisburne Endicott rocks have been reported to date from the westernmost North Slope.

Ellesmerian sequence: The dominantly clastic Ellesmerian sequence of the western North Slope (figs. 5 and 6), which was derived from a northerly sourceland, extends offshore and underlies most, but not all, of the proposed planning area. Its structure and thickness in this area is shown in figures 10 and 11. Beneath the eastern part of the planning area the sequence rests unconformably on the south-sloping Arctic platform and has the same general west strike, south dip, and southward increase in thickness that characterize it on the North Slope. In this area the sequence thickens from 0.1 sec (about 100-150 m) at a depth of about 1 sec (1 km) on the Barrow arch to about 2 sec (5 km) at a depth of 3 to 5 sec (6 to 11 km) in a southeast-striking structural low off Point Lay (fig. 11). This structural low merges with the Hanna trough, a north-striking structural low and sedimentary thick near 164^{o} W. long. The base of the Ellesmerian sequence (top of Eo-Ellesmerian sequence) is more than 4.85 sec (10 km) deep, and the sequence is more than 3.0 sec (7.7 km) thick near 71^{o}15' N. lat. A northward-deepening structural low north of 71^{o}30" N. lat near 162^{o} W. long contains a similar or greater thickness of Ellesmerian strata that is probably genetically related to Hanna trough. West of Hanna trough the Ellesmerian sequence becomes progressively shallower and thinner. Beyond 167^{o} W. long it is generally less than 0.5 sec (1.3 km) thick, and in places beyond about 168^{o} W. lat in the western part of the planning area it appears to be entirely absent (fig. 11). The decrease in thickness is due to stratal thinning and to erosional truncation and overlap, which suggests the possibility that a platform or sourceland lay to the west. On the other hand, sections of tentatively identified Ellesmerian rocks as thick as 2 sec (5.5 km) are preserved in fault blocks near Cape Lisburne, and these sections appear to extend west of the 0.5 sec isopach of Ellesmerian rocks of the region to the north of the fault blocks. A strong seismic reflector of regional extent is interpreted to mark the top of the Ellesmerian sequence and the base of the overlying Brookian sequence (fig. 12).

In the eastern part of the planning area the reflectors correlated with the Ellesmerian sequence consist of an upper unit of relatively weak, less continuous reflectors and a lower unit that contains a number of strong reflectors of considerable lateral extent. A strong reflector, which typically lies one third to one half way below the top of the Ellesmerian reflector packet on the seismic profiles, marks the top of the lower unit in the eastern part of the planning area. The relative thickness of the units changes markedly to the west, however, and in places one or both are entirely absent. Comparison of our seismic-stratigraphic units with those of western NPRA, as shown in Tetra Tech, Inc. (1982) in the area between Icy Cape and Barrow arch, suggests that the upper unit consists of the Lower Cretaceous Pebble shale unit and the Jurassic-Lower Cretaceous Kingak Shale. North of Icy Cape, however, the interpreted Kingak interval contains a few stronger reflectors in its lower part that may represent sandstone beds. The lower Ellesmerian unit is thought to represent the Lisburne Group (Pennsylvanian and Permian in western NPRA), the Permian and Triassic Sadlerochit Group, and the Triassic Shublik Formation and Sag River Sandstone (fig. 6). According to the regional time-depth function of figure 7, the upper unit (Kingak Shale and

Pebble shale unit) is relatively thinner, and the lower unit relatively thicker offshore than beneath the western North Slope. The northern limits of key stratigraphic components of the Ellesmerian sequence in western NPRA (taken from Guldenzopf and others, 1980, and Tetra Tech, Inc., 1982), where there is a progressive south to north overlap of older by younger stratigraphic units, are shown in figures 10 and 11. Seismic data indicate that the same progressive overlap occurs beneath the eastern part of the planning area.

Lower Brookian sequence: The lower part of the Brookian sequence of the planning area consists of a thick succession of seismic reflectors of weak to moderate strength that are interpreted to represent Cretaceous marine and nonmarine clastic sedimentary rocks of the Colville foredeep (fig. 4). Structural contours drawn at the base of the Brookian sequence in the planning area are shown in figures 12 and 13. The sequence rests, typically by downlap, on a strong regional seismic reflector that is thought to mark the top of the Pebble shale unit (Neocomian), at the top of the Ellesmerian sequence (fig. 6). Comparison with onshore data (C. M. Molenaar, unpub. data, 1984; and Tetra Tech,Inc., 1982) suggests that the lower Brookian sequence of the planning area consists of marine prodelta clastic deposits of the intertonguing Fortress Mountain and Torok Formations and nonmarine and shallow marine intradelta deposits of the Nanushuk Group (figs. 5 and 6). The age of these units is Aptian(?), Albian, and possibly lowest Upper Cretaceous (Cenomanian). Paleocurrent data (C. M. Molenaar, unpub. data, 1984) suggest that these beds were derived from a sourceland that lay to the southwest. Near latitude 70° N. on the North Slope, and possibly in places in the western and northern parts of the Chukchi shelf, the Albian beds are overlain by nonmarine and shallow marine intradelta deposits of the Colville Group (Upper Cretaceous). The Colville Group is interpreted to intertongue north and northeastward into marine prodelta deposits beneath the northern Chukchi and Beaufort shelves.

The lower Brookian sequence thickens north and south from a minimum of 0.25 to 0.67 sec (0.25 to 0.7 km) on the Barrow arch. North of the arch, the base of the sequence deepens gradually to about 1.5 to 2 sec (2 to 3 km) at the faulted tectonic hingeline (figs. 1, 4, and 12) that is thought to have formed during opening of the Canada Basin by sea floor spreading in late Neocomian time (see Grantz and May, 1983). At the hingeline the slope increases markedly, and the base lies more than 12 km below sea level beneath the outer continental shelf. The overlying sedimentary prism, the Nuwuk basin (figs 1, 4, and 12), may extend beneath the northeastern corner of the planning area where we lack multichannel seismic coverage. The basin is progradational and it is probable that near the shelf break it steps from the continental basement of the Arctic platform onto transitional or oceanic crust of the Arctic basin. It contains both foreset and topset beds, and numerous large erosional channels and channel fills. Structurally it is dominated by large, multi-strand, down-to-the-north growth faults that preliminary studies suggest were active since Late Cretaceous or early Tertiary time. The faults appear to be restricted to the Brookian sequence and to curve into, but not displace, the upper surface of pre-Brookian bedrock.

Southward from Barrow arch, beneath the eastern Chukchi shelf and the planning area, the lower Brookian sequence thickens rather uniformly to a maximum of 3.7 sec (about 7.5 km) beneath the axis of the Colville foredeep between Icy Cape and Point Lay. From this structural low and sedimentary thick the axis of the foredeep plunges southeastward beneath the foothills of the Brooks Range. Up-plunge, the axis merges with the north-trending Hanna trough in which the base of the Brookian sequence lies 2.4 to 3.0 sec (about 4 to 5.5 km) below sea level. The thickness of the lower Brookian beds in the trough is reduced, however, by a buried canyon filled with a thick upper Brookian ("Tertiary") sedimentary prism (figs. 4 and 14). West of Hanna trough and south of 71°30' N. lat, the Lower Brookian sedimentary sequence thins to less than 1.0 sec (about 1 km), but noise artifacts in the data, caused by high velocity rocks near the surface in the area northwest of Cape Lisburne preclude determining whether or not it wedges out entirely. Northwest of Hanna trough, in the northwestern corner of the planning area, the lower Brookian sequence thickens sharply as it drops into the eastern part of the North Chukchi basin, where the sequence is extensively deformed by listric normal faults of large displacement. The base of the unit lies more than 6 sec (about 12 km) below sea level, and is 4.5 km to perhaps 8.5 km or more thick, in this basin.

The lower Brookian sequence of the North Slope and eastern Chukchi Sea was derived from a sourceland that lay to the southwest and filled the Colville foredeep by progressive downlap on the top of the Ellesmerian sequence and by onlap against the Barrow arch to the northeast. The lower Brookian rocks also thicken into Hanna trough, which has somewhat less structural relief at the base of the Brookian than at the base of the underlying Ellesmerian rocks. The suggested, incompletely documented, westward reduction in the thickness of the lower Brookian sequence west of Hanna trough by stratal thinning and erosional truncation suggests that a sourceland, or at least a structurally positive area, also lay to the west of the trough in early Brookian time.

Upper Brookian sequence: An irregularly shaped body of young sedimentary rocks underlie the north half of the Barrow arch planning area. Structural contours at the base of these rocks, which are called the Upper Brookian sequence in this report, are shown in figure 14. They overlie the lower Brookian rocks with angular unconformity, have relatively low seismic-reflection velocities, and constitute the youngest bedrock stratigraphic unit in the planning area. From their stratigraphic position and relatively low seismic velocities we infer that they are largely or entirely Tertiary. While much of the section in the upper Brookian sequence can be traced into Tertiary beds of the Beaufort shelf and North Slope east of Harrison Bay, the basal contact or unconformity has not been tied to the Cretaceous-Tertiary boundary. For convenience we consider these rocks to be Tertiary in this report, but recognize that they may not include the lowest part of the Tertiary or, alternatively, that the lowest beds may be uppermost Cretaceous. Because the upper Brookian rocks are the highest stratigraphic sequence in the area and their upper beds lie at or close to the floor of the shallow Chukchi Sea, the structural contours on the base of the sequence in figure 14 are essentially isopachs.

The upper Brookian rocks are as much as 2.0 sec (2.2 km) thick in the subbasin that overlies Hanna trough, 1.5 to 1.9 sec (1.6 to 2.1 km) thick in a filled channel that connects the subbasin with the North Chukchi basin, more than 1.5 sec (1.6 km) thick in Nuwuk basin, and more than 3.6 sec (5.6 km) thick in the North Chukchi basin itself. The morphology of the subbasin that overlies Hanna trough, and the fact that the subbasin is linked to the deep North Chukchi basin by a buried channel (fig. 14), suggest that it is a submarine canyon that was tributary to the North Chukchi basin before both were filled by Tertiary sedimentary rocks. In morphology and size the postulated submarine canyon resembles the modern Navarin and Zhemchug canyons of the outer Bering shelf.

The low seismic velocities, the character of the Tertiary strata on the North Slope, and the geometry of the seismic reflectors suggest that the upper Brookian sequence in the planning area is composed of clastic sediments. On the east side of the subbasin overlying Hanna trough the seismic reflectors are conformable with the basal unconformity. On the more steeply sloping west side of the basin, however, reflectors within the subbasin buttress against the basal unconformity and underlying basin slope. Because the height of the west wall of the subbasin, and the thickness of the buttressing beds, is at least 1.25 sec (about 1.75 km), it is likely that much of the section in the subbasin is marine. The even thicker section in the North Chukchi basin presumably is also dominantly marine. As on the North Slope and Beaufort shelf, such marine beds would probably grade southward into nonmarine beds.

A sequence of sedimentary rocks that are correlative with the upper Brookian sequence of the northern part of the planning area, but occupy a separate basin 70 km to the south, onlaps Herald arch near Point Hope in the southern part of the planning area. These rocks occur in Hope basin (Eittreim and others, 1978 and 1979) which contains more than 3 sec (4.1 km) of strata with low to moderate seismic velocities near Point Hope (fig. 14). The seismic velocities, the character and age of sedimentary rocks exposed in the lowlands south and southeast of Hope basin, and the character of the seismic reflections (Eittreim and others, 1979) suggest that the basin is filled with nonmarine, and probably some estuarine and marine strata of Tertiary age. A lack of subsurface data leaves open the possibility that in places some Upper Cretaceous sedimentary rocks may also be present.

Structural provinces

Most of the Barrow arch planning area is underlain by the Arctic platform (see section on "Stratigraphy", above), which has been remarkably stable since its development in Late Devonian-Early Mississippian time. The platform has been tilted and warped, but high-gradient folds have not been recognized and faults of significant displacement are common only in the Chukchi platform of the western part of the planning area. Although structural gradients in the tilted and warped areas of the platform are very low, the affected areas are extensive and consequently the amplitude of the resultant deformation is large. Most of the major structural provinces of the shelf, which are shown in figure 15, are recorded in the morphology of the Arctic and Chukchi platforms.

Barrow arch and Arctic platform: Structurally the northern part of the Arctic platform, which lies east of Hanna Shoal, is dominated by Barrow arch (figs. 4 and 10-14). The arch underlies a small area in the northeast part of the planning area. Franklinian basement lies within 0.25 sec (0.3 km) of the sea surface in one locality along the broad crest of the arch, and flank dips are very low. The south-sloping Arctic platform forms the south flank of the arch. The crest and north flank is also underlain by the Arctic platform, but the platform in these areas was modified by uplift and erosion adjacent to the late Neocomian rift that created the continental margin and Canada basin north of Alaska (Grantz and May, 1983) and by subsequent sedimentary loading of the margin north of the tectonic hinge line (figs. 8-12, 14 and 15). The tectonic hinge line that lies north of the arch, a feature thought to have resulted from the rifting process, is the north boundary of Barrow arch and of the Arctic platform province in offshore northern Alaska.

The Arctic platform slopes uniformly south-southwest, with a gradient of about 2.5^{o}, from the crest of Barrow arch to the present structural axis of the Colville foredeep near Point Lay (fig. 4). The sedimentary section on the platform near Point Lay consists of about 5.5 km of Ellesmerian clastic and carbonate strata and about 7.5 km of lower Brookian marine and nonmarine strata. Off Icy Cape a local basin of northeast strike contains about 1.7 sec (5 km) of Eo-Ellesmerian strata (fig. 9). The northeast limit of these beds is uncertain. The Ellesmerian sequence thins northward by stratal thinning and progressive northward overlap of older by younger formations (figs. 6, 9 and 10) and it is only 0 to 100 or 200 m thick on the crest of Barrow arch. The lower Brookian sequence thins northward by the progressive northward downlap of foreset beds on its substrate and by erosion at the present land surface following Tertiary uplift along Barrow arch (fig. 6). The foresets formed in a prograding prodelta that filled the Colville foredeep from the southwest. The sequence consists of the marine Torok Formation and the marine and nonmarine Nanushuk Group. In places less than 0.25 sec (about 0.3 km) of these very thick units remain on Barrow arch.

Barrow arch, as expressed at the base of the Brookian sequence (fig. 12), dies out at Hanna trough near 163^{o} W. long. A large fault near 162^{o} W. long may be an important component of the boundary between the inferred thick Ellesmerian section in Hanna trough and its northern extension and the thin Ellesmerian section on Barrow arch. The fault was observed on only one multichannel profile and we are therefore uncertain of its strike and structural significance, but it appears to die out on the south near 71^{o} N. lat. Other than Barrow arch and the south tilt of strata south of the arch, the only significant deformational structures on the Arctic platform are the detachment folds of the foreland fold belt structural province (fig. 13).

Hanna trough: Downwarping and downfaulting of the Arctic platform from depths as shallow as 0.25 sec (0.3 km) on Barrow arch to depths as great as 4.85 sec (about 10 km) in the vicinity of 164^{o} W. long, created the east flank of Hanna trough (fig. 10). The change in structural level was largely accomplished by downwarping, but the major north-striking fault near 162^{o} N. long forms the boundary of a northeast extension or subbasin of the trough near 71^{o}40' N. lat. Except for the large north-striking fault, and a broad arch that separates the trough from its northeast extension, the Arctic platform beneath the east flank of Hanna trough is almost lacking in secondary structures. In contrast to the east flank, Franklinian basement beneath the axial region of the trough and the Chukchi platform west of it are in places warped or folded and broken by many faults. On the south, the trough loses its identity where its trend changes from north-south to northwest-southeast off Point Lay and it merges with the Ellesmerian basin of the North Slope. The north end lies beyond our multichannel profiles, but gravity data suggest that the trough or a related subbasin extends to the north-northeast.

At least 0.4 sec (1 km) of Eo-Ellesmerian strata and more than 3 sec (7 to 8 km) of Ellesmerian strata were deposited in the deepest parts of Hanna trough and its northeast extension, or subbasin (fig. 11). The Eo-Ellesmerian beds were deposited in structural downwarps, in places faulted, in the Arctic platform. The overlying Ellesmerian strata of the trough are areally more extensive, and less variable in thickness. As noted above, Ellesmerian strata in the west flank of Hanna trough thin westward by stratal thinning and by erosional thinning and overlap, suggesting that the Chukchi platform was a structural high, and perhaps a sourceland for Ellesmerian clastics. As the Ellesmerian strata on the Arctic platform also thin toward a sourceland, which lay to the north, the Hanna trough may be a depositional basin as well as a structural trough (fig. 11).

Hanna trough is also expressed in the thickness of the Brookian sequence and the structure of its basal contact (fig. 12), but its flanks have very low gradients in these rocks and the structural relief is less than in the underlying Ellesmerian rocks. About 2.5 sec (4 km) of Brookian strata underlie the trough from the area where it becomes a north-trending feature west of Icy Cape to its junction with the North Chukchi basin near 72° N. lat. It is not known from present data whether or not an extension or subbasin of the trough, as expressed in Brookian rocks, also continues to the north-northeast, as is inferred from the Ellesmerian rocks. The lower Brookian sedimentary thick in Hanna trough formed in part by infilling an existing broad sag, and in part by post-depositional faulting and downwarping. Crustal loading by the underlying Ellesmerian sedimentary thick, Cretaceous uplift of Barrow arch and of the Chukchi platform, and perhaps some differential compaction in Ellesmerian rocks may have all contributed to the structural relief of lower Brookian rocks in Hanna trough.

Upper Brookian strata filling a postulated submarine canyon constitute the uppermost sedimentary sequence in Hanna trough. The axis of the canyon fill and the channel connecting it to North Chukchi basin essentially coincide with the axis of the trough as defined by the base of the lower Brookian sequence (fig. 12) even though these prisms are thought to have quite different origins. The coincidence suggests that the canyon began as a consequent drainage that followed a structurally generated topographic low along the axis of the Hanna trough after lower Brookian deposition ceased. It also suggests that the branch canyon that trends northeast from the junction of the channel and the main canyon fill may likewise overlie a structural low in lower Brookian rocks. There are no multichannel profiles in this area, however, and the single channel profiles do not reveal whether a branch of Hanna trough indeed underlies the northeast branch of the canyon fill.

The maximum height of the west wall of the filled canyon is at least 1.25 sec (about 1.75 km), and the total thickness of the upper Brookian section is 2 sec (about 2.5 km). Thus most of the relief at the base of these rocks is due to erosion and canyon filling, but some downwarping of strata into the basin added a small structural component to the present depth of the infilled canyon. Structural deformation may also have created the sill in the buried channel that appears to connect the filled canyon with North Chukchi basin. The top of the sill is 0.5 sec (about 0.75 km) higher than the deepest part of the filled canyon on our profiles, and creates an obvious difficulty for the canyon-fill hypothesis. The sill may be partly explained, however, by the large north-northeast-trending graben that obliquely crosses the channel near its junction with the North Chukchi basin. Isochrons on the base of the upper Brookian sequence (fig. 14) indicate that the basal surface has been tilted east in the footwall of the fault bounding the east side of the graben. The tilt is interpreted to represent actual, as well as relative uplift of the footwall, and this uplift is thought to have contributed to the elevation of the adjacent sill. Additional relief on the sill was created by the syn- and post-upper Brookian downwarping of the canyon-fill subbasin that is recorded in post-canyon-fill strata.

Chukchi platform: Westward shallowing of the top of pre-Franklinian basement, westward overlap of older by younger Ellesmerian beds, westward stratal thinning within the Ellesmerian and lower Brookian sequences, and extensive high angle normal faulting characterize Chukchi platform, which underlies the planning area west of Hanna trough (figs. 10 to 12). The platform (top of Franklinian basement) shallows from depths of 4.5 to 5.5 sec (about 9 to 12 km) at the axis of Hanna trough and Colville foredeep to less than 1 sec (about 1.0 to 1.25 km) in places near the western margin of the planning area. As noted in a previous section, the westward overlap of older by younger Ellesmerian units against the westward-shallowing Chukchi platform indicates that an Ellesmerian structural high and perhaps a sourceland lay to the west. In places the Ellesmerian rocks wedge out entirely in the western part of the planning area (fig. 11) and the lower Brookian rocks thin to less than 1 km. The numerous normal faults west of Hanna trough are young features because they offset Brookian as well as Ellesmerian rocks and the underlying Chukchi platform.

Upper Brookian rocks on the Chukchi platform constitute a gently northward-dipping and -thickening sedimentary wedge that is broken by some large high angle normal faults (fig. 14). Southward, these rocks wedge out near 71°30' N. lat. Northward, they thicken to about 2 sec (2.3 km) at the hinge line that separates the platform from the North Chukchi basin. The Brookian rocks are sufficiently shallow in many places to be mapped from single channel profiles. Accordingly, many structural features are shown in these rocks in figure 14 that could not be delineated in older sequences. The large, north-northeast-striking graben near 166° W. long is one such feature. It has as much as 1.2 sec (about 1.4 km) of structural relief and a total sedimentary section that is 2 sec (about 2.3 km) thick. The graben is alined with the east end of North Chukchi basin and is possibly related to the opening of that basin.

Foreland fold belt of Colville foredeep: Large, high-amplitude detachment folds and thrust folds characterize the planning area between Icy Cape on the northeast and Cape Lisburne and Herald arch on the southwest (fig. 13). The folds have flank dips of 1° to 15°, amplitudes of up to 1.2 km, wavelengths generally in the range of 10 to 30 km, and strike lengths of 10 to more than 120 km. They are the continuation of the foreland fold province of the north side of the Brooks Range, where they involve mainly lower Brookian, but apparently also Ellesmerian beds. The folds swing in strike from east-west on the western North Slope to west-northwest and northwest offshore. They die out about 70 km off Icy Cape and about 140 km off Cape Lisburne. Offshore, the folds appear to be restricted to the lower Brookian sequence and to die out abruptly at the top of the Ellesmerian sequence, probably in the Pebble shale unit of Neocomian age. Their geometry indicates that they are detachment folds in an allochthonous plate of a regional low-angle detachment fault system. Immediately above the detachment zone the cores of the folds contain thickened wedges of poorly reflective sediment, presumably tectonically mobilized shale. The folds become progressively more complex toward Herald arch, and near the arch they are thrust folds with cores that are appressed and contain upward steepening listric thrust faults that rise in a northeasterly direction from the detachment fault to the seabed. Northeast vergence and the southwest increase in structural complexity indicate that the folds and the upper plate of the detachment fault moved relatively to the northeast. The folds appear to die out to the northwest by a decrease of displacement and shortening in the upper plate, rather than by extension of the basal detachment fault to the surface or its transformation into tear faults. However, some of our multichannel profiles in the fold belt are incompletely processed, and these conclusions are only tentative.

The faulted, folded, and therefore structurally thickened lower Brookian prism is 2 sec to more than 3.6 sec (about 2.8 to 7.3 km) thick in the fold belt. Beneath this prism and its basal detachment fault lies 0.5 to more than 2 sec (about 1 to more than 5 km) of Ellesmerian section (figs. 10 and 11). Near Cape Lisburne, tentatively identified Ellesmerian and older rocks are broken by a system of large normal faults whose trends and structural effects are presented conjecturally in figures 10 and 11. These faults, and the faulted blocks of Ellesmerian(?) and older rocks, terminate upward at the low-dipping detachment surface at the base of the folded Brookian sequence. The Ellesmerian(?) rocks in the fault blocks appear to range in thickness from a feather edge between Franklinian and Brookian rocks near Cape Lisburne to a little more than 2 sec (about 5.5 km) in the next fault block to the north.

Herald arch overthrust: A belt of perched acoustic basement underlies the southwest part of the planning area. It trends northwest from Cape Lisburne and has been named Herald arch (Grantz and others, 1975). The belt of acoustic basement lies between the folded lower Brookian rocks of the Colville foredeep to the northeast, which it overlies structurally, and the young sedimentary rocks of Hope basin, which overlie it depositionally. The fault plane at the base of the perched acoustic basement was not recognized on the seismic profiles but a reflector inferred to represent the detachment fault at the base of the folded lower Brookian rocks can be traced at least 60 km southwest of Cape Lisburne, generally down the inferred dip of the fault plane.

The perched acoustic basement is tentatively interpreted to be the upper, allochthonous plate of a large overthrust fault system that dips southwest at a low angle from the north side of Herald arch. The folded lower Brookian rocks below the overthrust fault are thought to form a lower allochthonous plate that in turn rests on the detachment fault discussed in the preceding section. The lower Brookian rocks extend southwest at least 15 km beneath the acoustic basement of the upper allochthonous plate. It is possible that a significant area and thickness of Ellesmerian rocks also underlies the lower allochthonous plate and its basal detachment fault. The sole faults underlying the upper and lower allochthons appear to merge west of the Lisburne Peninsula. The Tertiary Hope basin, which overlies the upper allochthonous plate west and south of Cape Lisburne, is thought to post-date the thrust faulting because it unconformably overlies an interpreted extension of the Herald arch and fault zone south of Point Hope.

Shallow seismic refraction measurements obtained with a multichannel streamer permit the perched acoustic basement of Herald arch to be divided into two domains of shallow bedrock (0 to 0.5 km deep) that have contrasting ranges of compressional wave seismic velocities (Vp) (see figs. 8, 12 and 13). In the northern domain Vp ranges from 3.1 to 4.0 km/sec; in the southern domain it ranges from 3.7 to 7.3 km/sec. These velocities, a few dredge and dart core samples, and projection of onshore geologic boundaries from the Lisburne Peninsula (Martin, 1970) suggest that the domain of shallow bedrock with lower Vp consists mainly of strongly deformed lower Brookian and perhaps upper Ellesmerian (post-Lisburne) sedimentary rocks. They also suggest that the domain of shallow bedrock with higher Vp consists, in places, of Lisburne Group, Endicott Group and Franklinian sequence rocks and that Ellesmerian and Franklinian sequence rocks may be more common in this domain than Brookian rocks.

Hope basin: A Tertiary sedimentary prism characterized by irregular basement topography, broad tectonic warps, and high angle normal and a few high angle reverse faults, but lacking compressional folds, underlies the southwestern corner of the planning area (fig. 14). The prism occupies Hope basin, which contains mainly or entirely Tertiary sedimentary rocks. Tectonic warping in mid-Tertiary time created two sedimentary subsequences within the basin. Both subsequences are irregular in thickness due to strong basement relief, faulting, and warping. The older, "Paleogene" subsequence is more uniform in regional distribution, and has a greater volume than the younger, "Neogene" sequence. Each sequence has a maximum thickness of more than 2 km, but the "Neogene" beds are present in significant thickness only in a triangular subbasin south of Point Hope.

Economically significant thicknesses of Hope basin sediment, about 1 km or more, underlie the planning area west and southwest of a large normal fault zone off Cape Lisburne and Point Hope. As much as 3 sec (about 4.4 km) of sedimentary rocks are present in the basin near Point Hope, and the section thickens southward to a maximum thickness of 3.5 sec (about 5.6 km) south of Point Hope. The area of relatively thick Hope basin section near Point Hope consists mainly of the "Paleogene" subsequence. The "Neogene" subsequence there is a sedimentary wedge that is generally less than 0.5 km, and in a small area a little more than 1 km thick that onlaps Herald arch to the north.

North Chukchi basin: A tectonic hinge line at which the dip of Ellesmerian and Brookian beds, and the thickness of the lower Brookian sequence increase to the north and west marks the south and east boundaries of North Chukchi basin in the northwest corner of the planning area (figs. 4, 10, 12, and 14). The position of the hinge line is imperfectly defined by three multichannel profiles (fig. 1). The profiles demonstrate that the northwest part of the planning area is underlain by the North Chukchi basin but they do not adequately relate the hinge line to the lower Brookian isochrons (fig. 12).

The base of the Brookian sequence deepens, and the sequence thickens, from 2 to 3.5 sec (about 2.5 to 5.5 km) on the Chukchi platform near the hinge line to more than 6 sec (12 km) on our northernmost multichannel lines in the basin. Most of the increase in thickness is in the lower Brookian sequence but some of it, especially in the east end of the basin, is in upper Brookian rocks. The former attains a thickness of at least 7 km, and the latter of at least 5 km in the basin. Near the eastern margin of the basin 2.5 km or more of Ellesmerian rocks appear in places to underlie the lower Brookian beds.

Contrasting structural deformation in the tentatively identified lower and upper Brookian sequences of North Chukchi basin suggests that the basin formed in two stages of rifting. The first stage is recorded in the tectonic hinge line and the basinward thickening of the lower Brookian beds. It presumably correlates with the late Neocomian rifting event (Grantz and May, 1983) that produced Canada Basin and the continental margin of the Alaskan Beaufort Sea. The second stage is recorded by numerous listric normal faults in the lower Brookian rocks in the eastern part of the North Chukchi basin. These faults are commonly antithetic, bound rotated fault blocks, and in places appear to extend into pre-Brookian rocks at moderate angles of dip. In other places, however, these faults extend no deeper than the upper surface of the Ellesmerian sequence, which they appear to follow downdip. The faulting and rotation produced a structurally and paleomorphologically complex seabed surface that was smoothed soon after deformation by sedimentary infilling of the structurally produced low spots. The smoothed seabed was then covered by the only slightly faulted basin fill sequence contoured in figure 14. Both the infilling sedimentary rocks and the subsequent basin fill are thought to belong to the upper Brookian sequence If our correlation of the youngest sedimentary sequences of North Chukchi basin as lower and upper Brookian is correct, the second stage of rifting originated in latest Cretaceous or earliest Tertiary time.

Crustal stretching related to the initial stages of a sea floor spreading event according to the model of Montadert and others (1979), as observed in the Bay of Biscay, is thought to have induced the second stage of rifting observed in the eastern part of the North Chukchi basin. Stretching, expressed in the upper crust as listric normal faulting and rotated fault blocks, resulted in crustal thinning, subsidence of the sea floor over the thinned crust, and deepening of the basin. Initiation of the second stage of basin subsidence coincided with development of the listric faults in post-lower Brookian, pre-upper Brookian time. Faulting was in part older than, and in part coeval with deposition of the basal upper Brookian lenticular sedimentary sequence that smoothed the block-faulted sea floor.

Several diapirs observed on single channel seismic-reflection profiles intrude the sedimentary rocks within or adjacent to North Chukchi basin. Two of the diapirs were actually traversed, and two others are inferred from localized upturns in otherwise flat-lying upper Brookian beds (Grantz and others, 1975 and 1981). The upturns resemble drag peripheral to diapirs. The diapirs are piercement structures that rise to within 100 m of the sea bed. The best-studied diapir, located near 73^{o} N. lat, 163^{o} W. long (fig. 14), is about 2 km in diameter and extends downward at least 3 km beneath the sea bed. Low compressional velocities, apparent lack of strong gravity or magnetic anomalies, and regional stratigraphy suggest that the diapirs are probably shale rather than salt, gypsum or igneous rock. On the basis of single channel data the diapirs are tentatively interpreted to originate in the lower Brookian or possibly the upper Ellesmerian sequence.

Petroleum potential

Assessment of the petroleum potential of an extensive frontier area such as that comprising the Barrow arch planning area on the basis of a reconnaissance seismic-reflection network and a few dredge samples, but no subsurface information, must necessarily be generalized, speculative and incomplete. Nevertheless the seismic data, augmented by the extrapolation of the results of geologic and petroleum exploration in NPRA and the North Slope, permit a preliminary evaluation of the petroleum potential and relative prospectivity of various parts of the planning area. The assessment is relatively more objective in the eastern part of the shelf, which lies near the western part of the partially explored NPRA, than elsewhere. The potential of areas like Hanna trough and North Chukchi basin, which have no close analogs onshore, is highly speculative. A synopsis of general lithologic conditions relevant to the petroleum potential of the western North Slope, taken mainly from K. J. Bird (oral commun., 1982), C. E. Kirschner (unpub. data, 1984), Bird (1981), Bird and Andrews (1979), Carter and others (1977), Guldenzopf and others (1980), and Tetra Tech, Inc. (1982), is presented below as a necessary first step in evaluating the potential of the Chukchi shelf.

A preliminary petroleum prospectivity map of the Barrow arch planning area is presented in figure 15. For convenience in discussion, the structural provinces of the area are also shown. Most of the area is considered prospective because it can be inferred from seismic data to be underlain by a significant thickness of Ellesmerian and Brookian sedimentary rocks. Additional areas are probably underlain by a significant thickness of these rocks, but the seismic data are inadequate to demonstrate this. Small areas near the west margin of the planning area and on the crest of Barrow arch, incompletely outlined by our reconnaissance seismic network, are considered not prospective because the sedimentary section in these areas is too thin. The minimum thickness of sedimentary rock that is prospective is estimated to be 1 km. This thickness was chosen because it was judged that, barring truly exceptional discoveries, oil and gas pools at shallower depths would require too many costly production platforms for development to be economically viable. Prospectivity in figure 15 is based on sedimentary thickness alone because our data are inadequate to classify the area on the basis of quality of source and reservoir rocks, reservoir seals, and stratigraphic traps, let alone thermal history and timing and pathways of hydrocarbon migration.

Western North Slope

Strata: The general subsurface stratigraphy and structure and the location and stratigraphic position of oil and gas pools and shows in test wells and seeps in NPRA west of Dease Inlet (fig. 3) are shown in figures 1, 6 and 16. The mid- and Upper Permian Echooka Formation (basal Sadlerochit) and all formations from the Shublik (Middle Triassic) to the Nanushuk (Albian and Cenomanian(?)) have yielded shows of oil or gas in test wells. However, neither the Lisburne Group (Pennsylvanian and Permian in the western North Slope) nor the Lower Triassic Ivishak Formation (upper Sadlerochit), penetrated in fewer wells than the younger Mesozoic rocks, have as yet yielded oil or gas in test wells west of Dease Inlet. These stratigraphic units do, however, produce oil or gas shows in test wells east of Dease Inlet and they contain the major oil and gas accumulations at Prudhoe Bay. The hydrocarbon occurrences west of Dease Inlet include structurally trapped, subeconomic gas pools in Lower Jurassic sandstones in the South Barrow and East Barrow fields, which lie 15 to 20 km south of Point Barrow, and it is believed that additional small accumulations of similar type are likely to occur in the vicinity (Lantz, 1981). Sands of Early Cretaceous (Pebble shale) age may also form pools in combination stratigraphic-structural traps at the Iko Bay-1 and Walakpa-1 and -2 wells, 30 to 40 km southeast and southwest of Point Barrow, but these occurrences have not been adequately evaluated (Bird, 1981; C. E. Kirschner, unpub. data, 1984). Pre-Lisburne (Endicott Group) and post-Nanushuk (Colville Group and Sagavanirktok Formation) sedimentary strata have not been encountered in test wells west of Dease Inlet even though many of the wells were drilled to basement.

In general, reservoir quality is better in the Ellesmerian shelf and shelf basin deposits than in the Brookian sequence. The Ellesmerian sandstones become thicker, coarser in grain size and cleaner to the north, toward their sourceland, and most of them shale out southward in an east-trending zone across central NPRA. Reservoir quality in the Brookian rocks is harder to characterize. The Brookian sequence consists of thick deltaic and prodeltaic deposits that filled a foredeep and were deposited much more rapidly than the Ellesmerian rocks. The best reservoirs may be expected in the paralic and shallow marine facies of the intradelta, and in submarine fan turbidites at the base of the prodelta slope.

Geochemical studies at the Prudhoe Bay field (Seifert and others, 1979) indicate that the oil there was derived from the Shublik Formation, Kingak Shale and Pebble shale unit, which correlates well with the occurrence of oil and gas shows in western NPRA (fig. 16). The lack of oil and gas shows in the Lisburne rocks of western NPRA may be because permeability pathways have not connected them with petroleum source beds, or because they consist of the non-dolomitic light-colored Wahoo Limestone rather than the vuggy, dolomitic zones in the dark-colored and shaly Alapah Limestone that contains the major Lisburne reservoirs at Prudhoe Bay. It is not certain, however, that the prospects drilled in western NPRA are traps at the Lisburne level. Thermal alteration studies on the Inigok-1 well, in eastern NPRA, indicate that the Endicott and Lisburne Group rocks are apt to be post-mature and gas prone below 3,600 m on the Arctic platform (Magoon and Claypool, 1982). These rocks lie at similar or greater depths in western NPRA where the thermal maturity of the surface formations, as estimated from vitrinite reflectance studies (L. B. Magoon and G. E. Claypool, unpub. data, 1984), tends to be even higher than at Inigok-1.

The Lower Triassic Ivishak Sandstone of the Sadlerochit Group, the main reservoir at Prudhoe Bay, is represented by lutite in NPRA west of about 157° W. long (Guldenzopf and others, 1980). The only significant sandstone in the Sadlerochit Group of western NPRA occurs in a 30-km-wide band in the Upper Permian Ikiakpaurak Member of the Echooka Formation (Guldenzopf and others, 1980). This sandstone produced minor gas shows in the Peard-1 well. It is about 50 to 60 m thick in the Peard-1 and Kugrua-1 wells and extends from a seismically mapped pinchout about 10 km north of Wainwright to a shaleout several kilometers north of the Tunalik-1 well (fig. 6). It is separated from the source rocks of the Shublik Formation by the Kavik Shale and the lutite facies that constitutes the Ivishak Sandstone in western NPRA. Therefore the gas shows may have originated in the adjacent shales of the Sadlerochit Group.

The Middle and Upper Triassic Shublik Formation and Sag River Sandstone, which are reservoirs for oil and gas at Prudhoe Bay, are possibly more prospective than the Sadlerochit in western NPRA and the eastern part of the planning area. These units produce oil and gas shows in test wells west of Dease Inlet and they contain sandstones that are in contact with the Shublik Formation and Kingak Shale, which contain petroleum source rocks. Sandstone in the Shublik occurs in a west-southwest-striking belt 40 or more km wide that onlaps Barrow arch on the north and shales out a few kilometers north of the Kugrua-1 and Tunalik-1 wells (fig. 6). Sand-shale ratios in the Shublik are highest in western NPRA, and reach values of 5.0 and 5.1 in the Walakpa-1 and Peard-1 wells (fig. 6), where the formation is about 90 m thick. The overlying Sag River Sandstone, mainly a lutite in western NPRA, is 30 to 40 m thick and contains sandy bar-like complexes of unknown extent at the Peard-1 and Kugrua-1 wells (Guldenzopf and others, 1980). Good prospects may also be found in the Kingak Shale, a westerly thickening Jurassic and Neocomian lutite that ranges in thickness from 500 m to more than 1,000 m in western NPRA. The Kingak, a source rock at Prudhoe Bay, contains several sandstone units west of Dease Inlet, and some of these contain subeconomic or incompletely evaluated gas pools at the South Barrow and East Barrow fields and the Tunalik-1 test well. The sandstones, which may include transgressive nearshore and offshore bar-like deposits and deep water turbidites (Guldenzopf and others, 1980), appear to have been derived from northerly and northwesterly sources, and in general become more abundant to the west, toward the planning area. In western NPRA the Kingak is truncated by the unconformity at the base of the upper Neocomian Pebble shale unit, which could serve as both a source rock and reservoir seal for hydrocarbon deposits in Kingak sandstones that might be in contact with the unconformity. In addition to serving as a possible source rock and seal, several thin sand bodies in the Pebble shale unit may also have reservoir potential. One such sand body in the Peard-1 well (fig. 6), where the Pebble shale unit is 116 m thick, is inferred to extend into the Chukchi shelf north of Icy Cape (Guldenzopf and others, 1980).

The Brookian rocks encountered in test wells in western NPRA were derived from source lands that lay to the south and southwest. They fill the Colville foredeep and consist of the interfingering Fortress Mountain and Torok Formations and the partly interfingering, partly overlying Nanushuk Group of Albian and Cenomanian age. The mainly intradeltaic Nanushuk and the prodeltaic Torok both yield shows of oil and gas in western NPRA. The shows in the Torok west of Dease Inlet are from foreset and bottomset turbidite and submarine fan deposits (C. E. Kirschner, unpub. data, 1984). The Nanushuk Group contains several small oil and gas fields in eastern NPRA. Gas and oil shows are common in the Nanushuk, and it contains a small gas field (Meade) west of Dease Inlet. South of Point Lay the Nanushuk is dominantly nonmarine and contains thick coal beds. However, it thins and becomes increasingly paralic and shallow marine to the northeast (Chapman and Sable, 1960; and Ahlbrandt, 1979), and these conditions should improve reservoir quality in that direction. Accordingly, the Nanushuk is expected to be gas-prone and contain less capable reservoirs to the southwest, and to be more likely to contain oil and have more capable reservoirs to the north or northeast. An oil seep from Nanushuk rocks at Skull Cliff, about 50 km southwest of Barrow (McKinnery and others, 1959), supports this contention. The Chevron Oil Company's Akulik-1 test well, located 8 km inland between western NPRA and the Chukchi Sea 110 km east of Cape Lisburne, tested the Nanushuk intradelta facies and perhaps the Torok-Fortress Mountain Formations. Projections from offshore (fig. 12) and NPRA (Bird and Andrews, 1979) suggest that at total depth (5,190 m) the well was still in these lower Brookian (Albian) rocks.

The results of this test and of another Chevron well (Eagle Creek-1, T.D. 3,650 m) 50 km to the southeast have not been announced, but both wells were plugged and abandoned. The Union Oil Company Tungak Creek-1 well, which tested the same rocks 35 km northeast of Point Lay, was suspended in March, 1982, at a depth of 2,503 m.

Thermal maturation: Vitrinite reflectance data and the rank of coal in test wells and outcrops provide some insight into the thermal history and possible stage of hydrocarbon generation and preservation in the sedimentary rocks of western NPRA, but they do not reveal whether the affected rocks actually generated oil or gas. The vitrinite reflectance data are reported by Magoon and Claypool (1979, 1982; and unpub. data, 1984), and we are grateful to them for access to their unpublished data. Data on coal rank were taken from Barnes (1967) and Conwell and Triplehorn (1976). Relation of coal rank to stages of hydrocarbon generation is from Hèroux and others (1979), but we follow Magoon and Claypool (1982) in using vitrinite reflectance values of 0.6 and 2.0 for the top and base of the liquid window--the zone of oil and gas condensate generation.

Vitrinite reflectance data indicate that equivalent stages of thermal maturation become shallower from eastern and central to western NPRA, suggesting more uplift on the west (Magoon and Claypool, 1979). The data also suggest that the top of the liquid window (the highest rocks that have experienced a thermal history capable of generating oil) lies about 0.3 to 1.0 km below the surface in western NPRA between the latitude of Point Lay and the Peard-1 well (fig. 1). The rank of outcropping Albian coal beds in this area is subbituminous, which corresponds to the zone of wet gas generation above the liquid window. North of Peard-1, the deepest prospective strata on basement are at the top of, or above the liquid window, in the overlying zone of wet gas generation. The base of the liquid window between the latitudes of Point Lay and Peard-1 in western NPRA, as interpreted from vitrinite reflectance measurements, lies 2.3 to 3.4 km below the surface in the three wells that reached the underlying zone of overmature rocks. One test well and the rank of outcropping Albian coal suggest that surface rocks in the foothills of the Brooks Range south of the latitude of Point Lay are in the liquid window, and that the base of the liquid window lies about 2.0 km below the surface. The rank of Endicott Group coal on the Lisburne Peninsula suggests that the Paleozoic rocks of the western Brooks Range and the upper allochthon of Herald arch are overmature for oil and gas condensate, and that former hydrocarbon liquids in these beds would now be dry gas. The vitrinite reflectance values also suggest that in the eastern half of the planning area upper Paleozoic and Triassic strata are overmature from Icy Cape or Wainwright south, and that the lower part of the lower Brookian sequence and older strata are overmature from the general latitude of Point Lay south.

Barrow arch planning area

Barrow arch and Arctic platform: The petroleum potential of the Arctic platform structural province in the planning area (area 1 in table 1 and fig. 15) is much like that of western NPRA, which it adjoins. Offshore seismic data and projection of onshore stratigraphy and thermal maturation data suggest that in area 1 sandstones from the Permian and Triassic Sadlerochit Group to the lower part of the Albian Nanushuk Group may be in contact with adequate source rocks and could contain significant pools of oil and, especially, gas. To date, only some subeconomic or inadequately evaluated gas deposits have been found in the adjacent onshore. Subsurface data (Guldenzopf and others, 1980; and C. E. Kirschner, unpub. data, 1984) suggest, however, that sandstone beds in the Middle Triassic to Lower Cretaceous Shublik, Sag River, Kingak and Pebble shale units, which locally attain significant thickness in western NPRA, may be thicker, more numerous and perhaps better reservoirs in area 1. If structural traps exist in this area, they have very low amplitude and have not been recognized on our reconnaissance seismic network. Stratigraphic traps caused by permeability gradients or shale oversteps at one of several unconformities in the section possibly occur. If present, such traps could be very large because of the uniform but low regional dip. Eo-Ellesmerian and Lisburne strata in area 1 are probably overmature and at best would contain dry gas. A large but incompletely defined area on the crest of Barrow arch is underlain by less than 1 km of post-Franklinian sedimentary rock, and is therefore considered to be nonprospective.

Hanna trough: Economically significant oil and gas deposits could be present in Hanna trough (area 2 in table 1 and fig. 15) because the trough contains a very thick section of sedimentary rocks with possible oil traps in some large basement-involved folds and locally numerous faults and rotated fault blocks. In addition to the area shown in figure 15, the trough may extend north of 72^{0} N. lat, but we have no multichannel seismic reflection data in that part of the planning area.

If the thermal history of the sedimentary rocks in Hanna trough is similar to that found in Tunalik-1 well (fig. 6), the Eo-Ellesmerian and most of the Ellesmerian section is overmature and could only contain dry gas. Ellesmerian and Brookian strata thicken into Hanna trough (figs. 9-12), but the nature of any accompanying facies changes is conjectural. The marked thickening of Ellesmerian beds into the trough (fig. 11) suggests that it may there be a basinal facies, perhaps dominated by lutite and possibly containing turbidite beds. Although these thickened deposits are probably themselves now overmature they could have generated oil or gas at an earlier time that migrated out of the trough into possible reservoirs on the flanks, where subsequent thermal alteration was less intense.

The presence of westward-increasing amounts of sandstone of north and northwest provenance in the Shublik-Pebble shale interval in western NPRA suggests that the broad crestal region of the present Barrow arch east of Hanna trough was formerly part of a more extensive sourceland for detrital sediment through late Ellesmerian time. This sourceland might also have furnished reservoir sands to the upper Ellesmerian section of Hanna trough. Most of the upper Ellesmerian rocks are probably in the liquid window in most parts of Hanna trough.

The thickening of the lower and upper Brookian sequences into Hanna trough (figs. 12 and 14) may have also created conditions favorable for the generation and entrapment of oil and gas. Free-wheeling extrapolation of thermal conditions and facies patterns from western NPRA suggests that at least part of the lower Brookian sequence in Hanna trough is in the liquid window and that in places the section probably contains paralic and shallow marine beds that could include winnowed sands. In addition, the deeper parts of the fill in the upper Brookian canyon (fig. 14) might also be in the upper part of the liquid window, but we have no thermal data from which to judge whether this is indeed the case. The upper Brookian canyon fill and the adjacent wall rocks could contain hydrocarbon traps where reservoir sands or sealing shale beds of the fill are in contact with source beds or sands of the lower Brookian sequence in the canyon walls. An analogous feature appears to have localized the subeconomic Simpson oil field (Bird, 1981), 85 km east of Barrow, where oil in the Nanushuk Group is trapped at an up-dip seal formed by Upper Cretaceous sedimentary rocks in Simpson canyon (C. E. Kirschner, unpub. data, 1984). Faults and rotated fault blocks, which are locally numerous in the canyon fill and adjacent wall rocks, may have created structural traps in both the lower and upper Brookian beds.

Chukchi platform: The westward thinning and shallowing of Ellesmerian and Brookian strata in area 3, part of the Chukchi platform (table 1 and fig. 15), in the western part of the planning area, suggest that a structural high or former sediment sourceland lay to the west. If it did, these rocks could contain good reservoir beds analogous to the north-sourced sandstone and conglomerate beds that are productive at Prudhoe Bay and elsewhere on the North Slope. Hydrocarbon fluids could have entered these beds from interlayered source beds or migrated into them from shales that might lie downdip, in Hanna trough. It is probable that much of the Ellesmerian and lower Brookian section in the eastern part of area 3 is in the liquid window, but extrapolating thermal conditions this far offshore from data points on the North Slope is speculative at best. If source and reservoir beds are present in area 3, the presence of numerous normal faults, some folds and possibly up-dip pinchouts may provide traps, but our seismic lines are too widely spaced to demonstrate whether closed structures are present. The eastern and central parts of area 3 are more prospective than the western part, where the total post-Franklinian sedimentary section thins to less than 1 km.

Foreland fold belt: Extrapolation of thermal maturation data from the western North Slope indicates that the top of the liquid window in the foreland fold belt in the south-central part of the planning area (area 4 in table 1 and fig. 15) is at the surface, or has been removed by erosion, from approximately the latitude of Point Lay south. North of Point Lay, the top of the window deepens to about 1 km opposite the northern part of area 4. Data from the Tunalik-1 well (fig. 6) and the Awuna-1 well 106 miles to the southeast (L. B. Magoon and G. E. Claypool, unpub. data, 1984) indicate that the vertical height of the liquid window at the latitude of area 4 is about 2.0 to 2.5 km. These data suggest that most of the Ellesmerian sequence and in places the lower part of the lower Brookian sequence in the broad structural low off Point Lay are overmature and could now contain only dry gas. All or most of the lower Brookian sequence, on the other hand, appears to lie within the liquid window and could have generated and preserved oil and gas condensate.

Broad folds and fault blocks in the Ellesmerian strata below the detachment fault that underlies area 4 offer possible structural traps for gas, but the extrapolation of stratigraphic trends from western NPRA suggest that adequate reservoirs may be absent. The numerous large detachment folds and thrust folds in the lower Brookian rocks that constitute the upper plate, above the detachment fault, are probably the most prospective structures in area 4. Thrust faults, however, disrupt the cores of many of the folds in the central and southern parts of area 4 and may reduce their capacity to hold hydrocarbon fluids. The folds may also be largely within the Nanushuk intradelta and have relatively poorer prospects for oil and for winnowed sandstones of paralic and neritic facies than eastern and north central NPRA, where the Nanushuk contains several small oil and gas fields.

Herald arch overthrust: Brookian rocks in the Herald arch overthrust belt in the southern part of the planning area (area 5 in table 1 and fig. 15) are probably too strongly deformed by listric thrusts and thrust folds, related to the underlying detachment fault zone, to have significant petroleum potential. Extrapolation of onshore data indicates that both the perched Ellesmerian rocks in the overthrust and those that underlie the detachment fault are overmature for hydrocarbon liquids in the southeastern part of area 5, and the overlying Ellesmerian rocks are in addition probably too strongly thrust-faulted to be prospective. If Ellesmerian rocks are present beneath the detachment fault zone in the northwest part of area 5, where the Brookian sequence is thinner, they may have escaped deep burial and overmaturation and might be comparable in potential to the Ellesmerian rocks of area 3, the Chukchi platform.

Hope basin: Thermal maturation in Hope basin in the southwestern corner of the planning area (area 6 in table 1 and fig. 15) is not known, but an estimate for the geologically analogous Norton basin by Fisher (1982) suggests that the liquid window in Hope Basin may lie between about 2.5 or 3.0 km and 5.0 km below the seabed. As Hope basin is as deep as 4.4 km near Point Hope, and locally as deep as 5.6 km farther south, the lower third of the basin fill may be within the liquid window. Adequate structural traps and reservoir sands may well be present in Hope basin, but the quality of source rocks is problematical. Meager marginal outcrops and two test wells at the head of Kotzebue Sound suggest that nonmarine rocks are prominent, possibly dominant, in the basin. Marine facies can be inferred for the center of the basin, but their presence has yet to be demonstrated. In light of the youthfulness of the basin (much of the fill is interpreted to be Neogene), and the nonmarine character of the marginal outcrops, Hope basin may be gas prone. However, the possibility that oil was also generated cannot be discounted.

North Chukchi basin: It is inferred that both the lower and upper Brookian sequences of the North Chukchi basin in the northwestern corner of the planning area (area 7 in table 1 and fig. 15) contain a substantial or dominant component of marine sedimentary rock, and therefore source beds for oil and gas are likely to be present. Strong reflectors in both sequences suggest further that many sandstone and perhaps conglomerate beds that could serve as reservoirs may also be present. This interpretation is supported by the observed westward thinning of Brookian sedimentary units on the Chukchi platform. A sourceland in that direction would have been much closer to the North Chukchi basin than the Brooks Range sourceland was to the Brookian clastics of the North Slope, and could have resulted in the delivery of coarser detritus to the basin. The numerous listric normal faults and rotated fault blocks that characterize the lower Brookian sequence in the eastern part of the North Chukchi basin may form large structural traps. Their prospectivity may be enhanced by the locally thick, early post-faulting infilling sedimentary unit that unconformably overlies it. The infilling unit has weaker seismic reflectors than the sequences that lie above and below, and probably contains more shale. The unit could have served as a seal for hydrocarbon fluids in the underlying faulted rocks, and also as a hydrocarbon source rock. Where the infilling unit is absent, the base of the upper Brookian sequence unconformably overlies the faulted beds and may have placed sealing beds or reservoir beds across truncated sandstones and shales of the lower sequence. The upper Brookian rocks offer possible traps against small normal faults, in a few very low amplitude folds (closure not demonstrated), against possible up-dip permeability barriers or pinch-outs, and around shale(?) diapirs.

Assessment of the petroleum potential of North Chukchi basin is particularly sensitive to its thermal history and the hydrocarbon maturation stage of its sedimentary rocks. In the absence of actual data, we have applied the position of the liquid window in the somewhat similar Norton basin to the North Chukchi basin. Fisher (1982) estimates that in the assumed moderately high heat-flow extensional, epicontinental Norton basin the liquid window might lie about 2.8 to 5.0 km subsea. If this range is even approximately applicable to the North Chukchi basin, the liquid window there intersects the structurally important boundary between the extensively faulted lower Brookian and the little-faulted upper Brookian sequences. If the Norton basin model or one that assumes a less intense thermal history is realistic, then a substantial part of the faulted lower Brookian section and perhaps the deepest part of the little-faulted upper Brookian section are in the liquid window. However, if the basin had two episodes of crustal thinning and subsidence, as proposed in an earlier section, then most of the lower Brookian sequence and the deepest parts of the upper Brookian section may be overmature, and the liquid window might encompass the lower part of the upper sequence and only the structurally highest parts of the lower sequence. The Norton basin or "cooler" models would thus place substantially more of the very prospective block-faulted lower Brookian sequence in the liquid window than the two-stage model. However, even the latter model places a large volume of lower Brookian rocks at the margins of the basin in the liquid window and the overmature rocks could contain substantial deposits of dry gas. In addition, some faults cut both the lower and upper Brookian sequences and these might have provided pathways for the migration of hydrocarbon fluids out of the lower sequence into higher reservoirs before the lower sequence became overmature. Updip migration of hydrocarbon fluids in the little-faulted upper sequence might have achieved a similar result.

Relative prospectivity of the structural provinces: Ranking the relative petroleum potential of the seven structural provinces found in the Barrow arch planning area is in part an assessment of a reconnaissance data set, and in part a prediction of what more complete data sets will reveal. Subsurface information in areas 2, 3, and 7 are especially needed. From the perspective of a preliminary evaluation of our reconnaissance data, and ignoring the difficult logistic and engineering problems posed by the Arctic climate and polar ice pack (fig. 2), the Arctic platform east of Hanna trough (area 1), Hanna trough (area 2), the Chukchi platform (area 3), and North Chukchi basin (area 7), are tentatively estimated to have a potential for significant deposits of oil or gas. However, in large parts of these areas, difficult-to-define stratigraphic traps will have to be sought. Exploration in western NPRA suggests that in at least the eastern part of area 1 the potential may be greater for gas than for oil. The Foreland fold belt (area 4) and the northern tip of Hope basin (area 6) are estimated to have modest potential for significant deposits of oil and gas, and they may be gas-prone. Structural complexity and estimated thermal conditions suggest that most of the Herald arch overthrust belt (area 5) has a low potential for significant deposits of oil or gas. The northwest part of area 5 may have some potential in

Ellesmerian rocks beneath the overthrust faults, but our data are inadequate for assessment.

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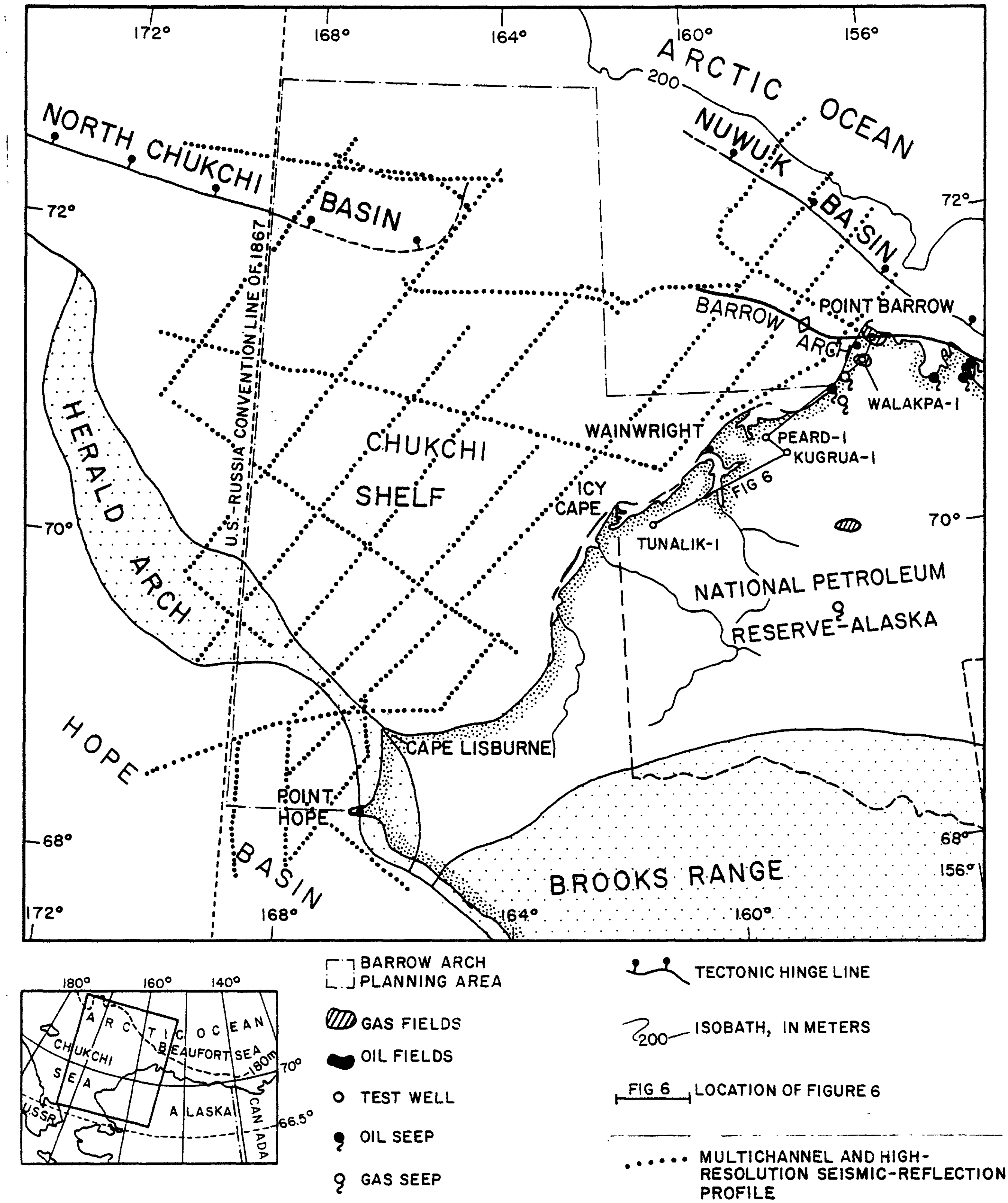


Figure 1.--Map of central and northern United States Chukchi Sea and vicinity showing major geologic features, petroleum development, oil and gas seeps, Barrow arch planning area, and seismic-reflection profile data base.

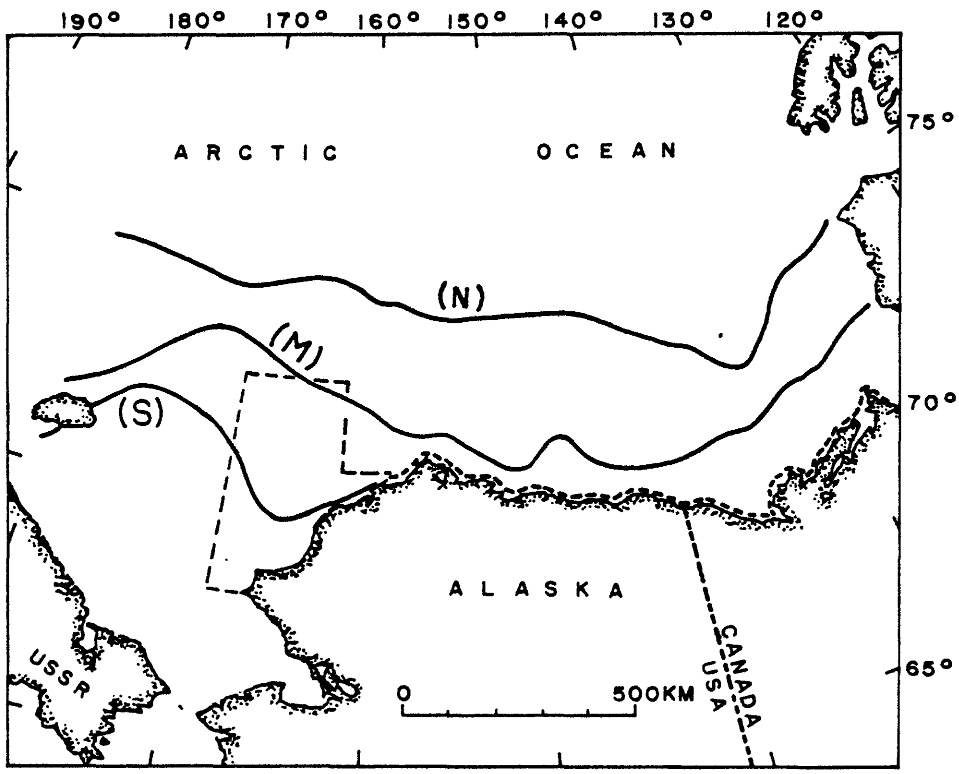


Figure 2. Most northerly (N), most southerly (S), and median (M) position of the southern edge of the Arctic ice pack north of Alaska during the usual period of maximum retreat, September 16 to 30, based on data from 1954 through 1970 (after Brower and others, 1977). Barrow Arch planning area is outlined by dashed line.

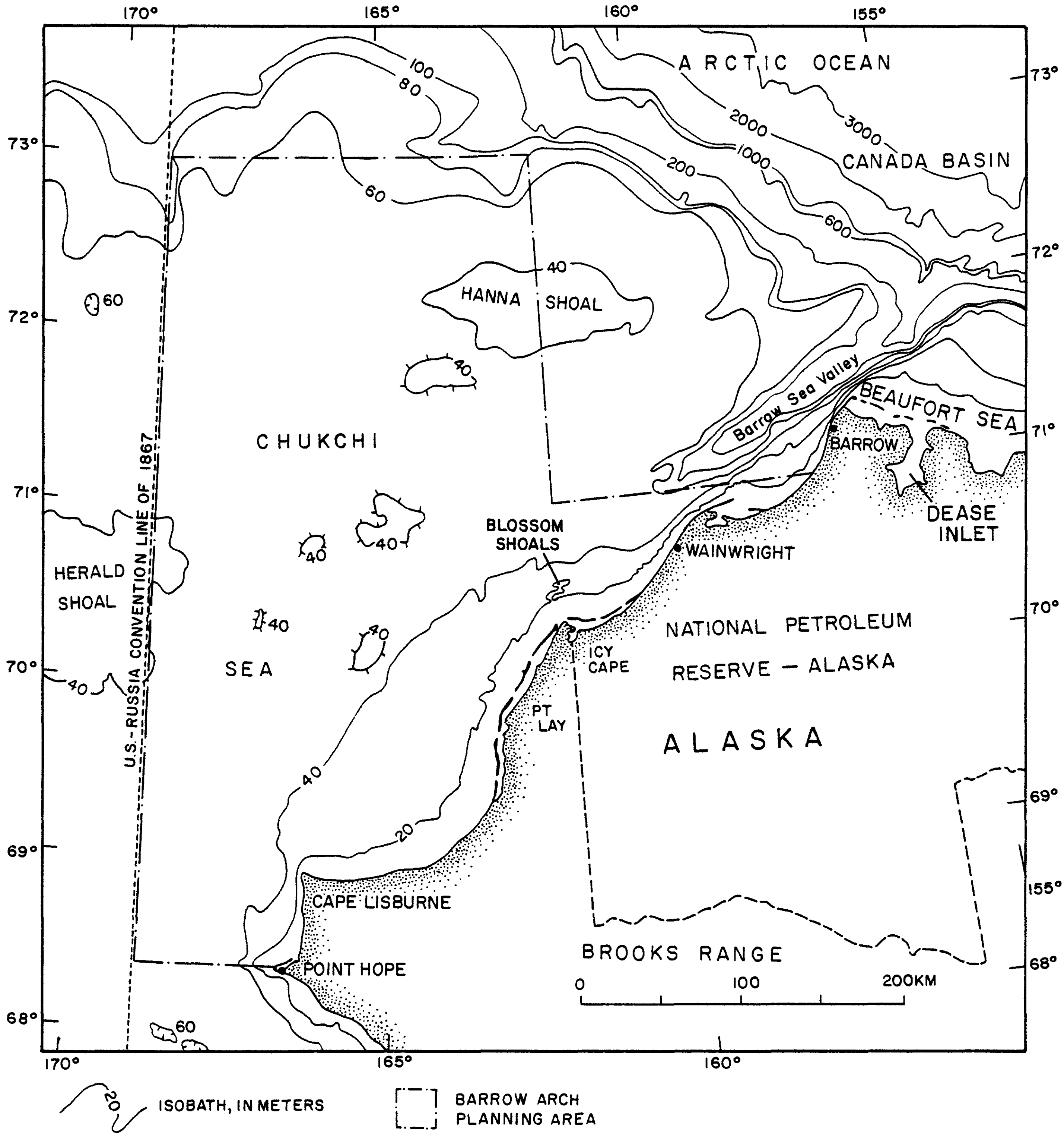


Figure 3.--Bathymetric map of northern United States Chukchi Sea showing location of Barrow arch planning area.

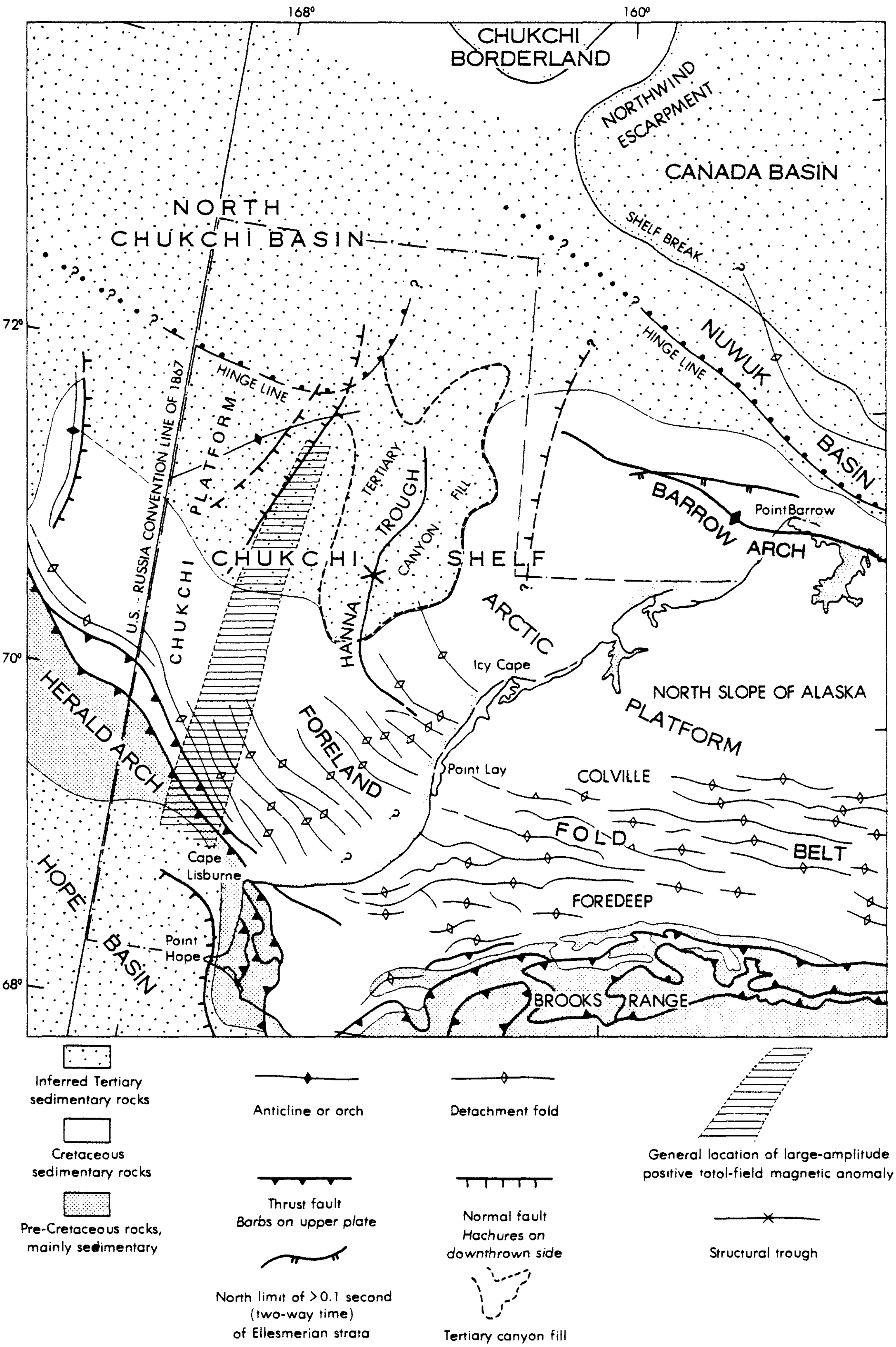


Figure 4.--Preliminary tectonic map of the United States Chukchi shelf and vicinity.

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.

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

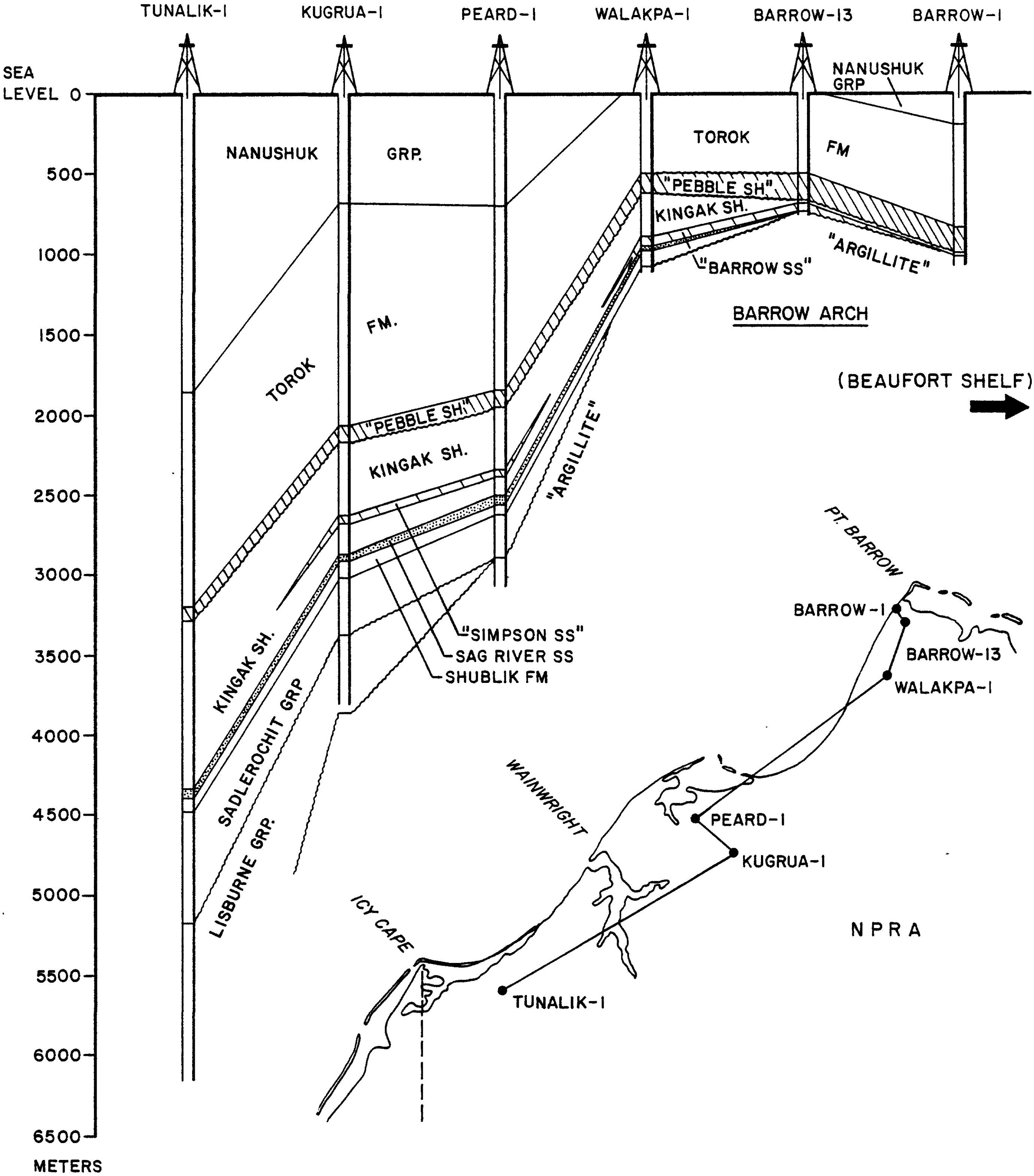


Figure 6.--Geologic cross section based on correlated test wells in National Petroleum Reserve in Alaska that lie near the northern Chukchi Sea. Data from Bird (1982). See figure 1 for location.

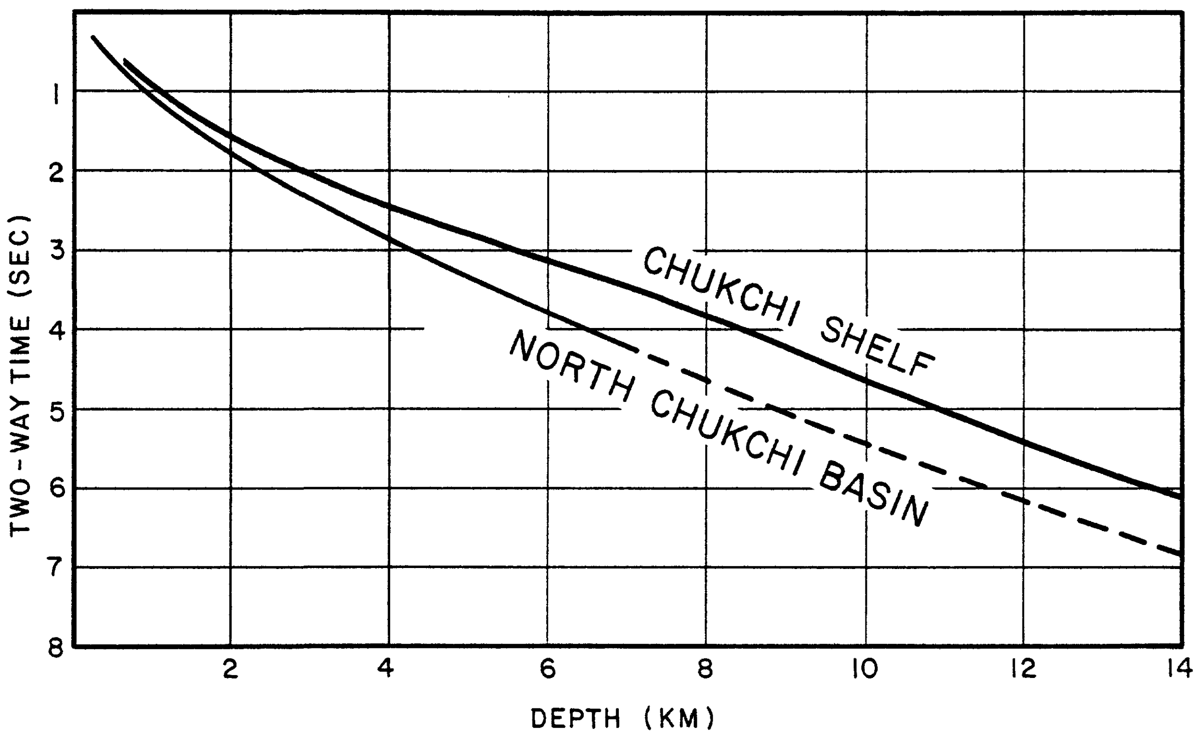
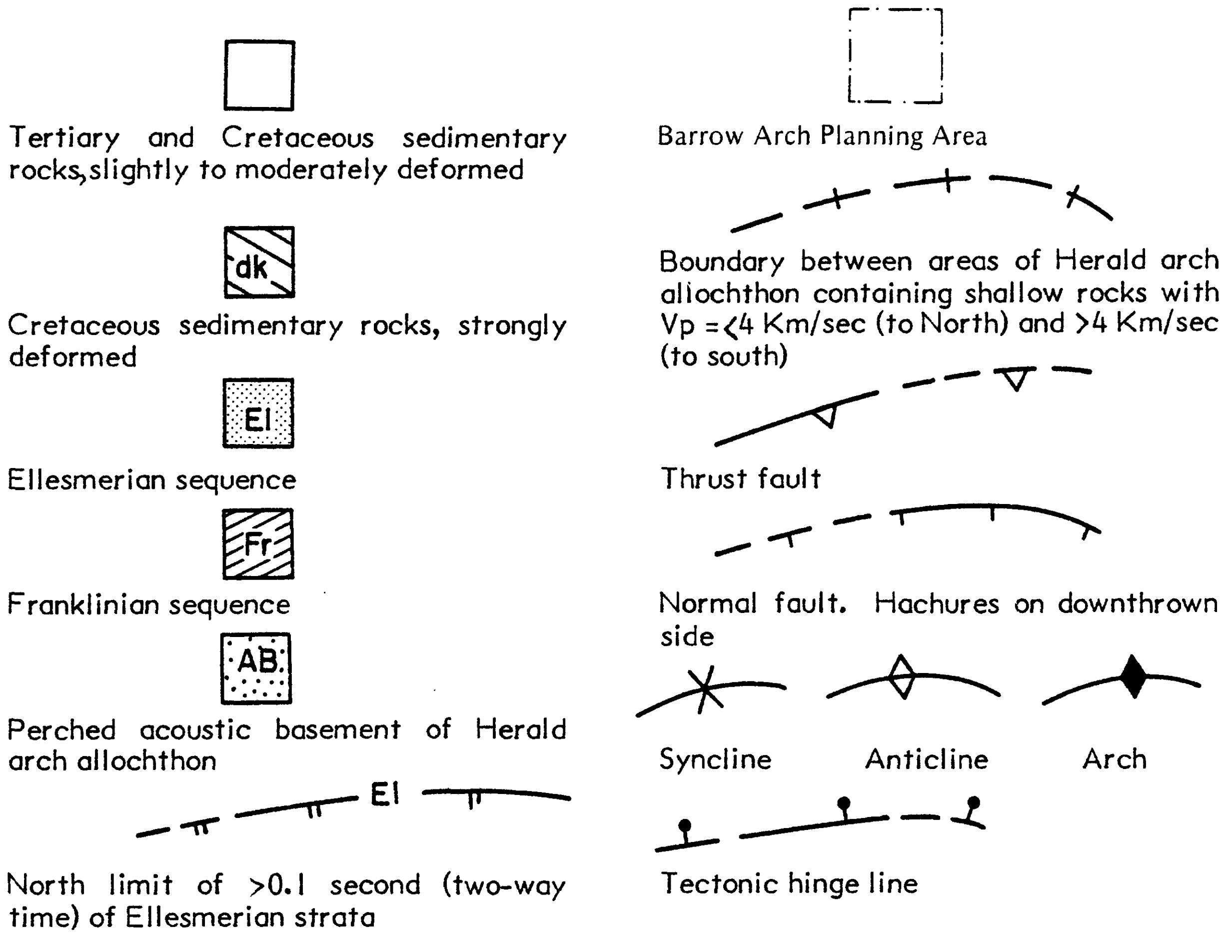


Figure 7.--Generalized average seismic-reflection time as a function of depth for the Chukchi shelf and North Chukchi basin derived from seismic-stacking-velocity measurements. The curve for the North Chukchi basin also approximates conditions in the northern part of Hope basin.



Note--All geologic lines, including isochrons and isopachs, on Figures 8 to 14 are solid where interpolated between adequately distributed control points, dashed where extrapolated beyond adequate control, dotted where speculative, queried where doubtful.

Figure 8.--Explanation of map symbols in figures 9 to 15.

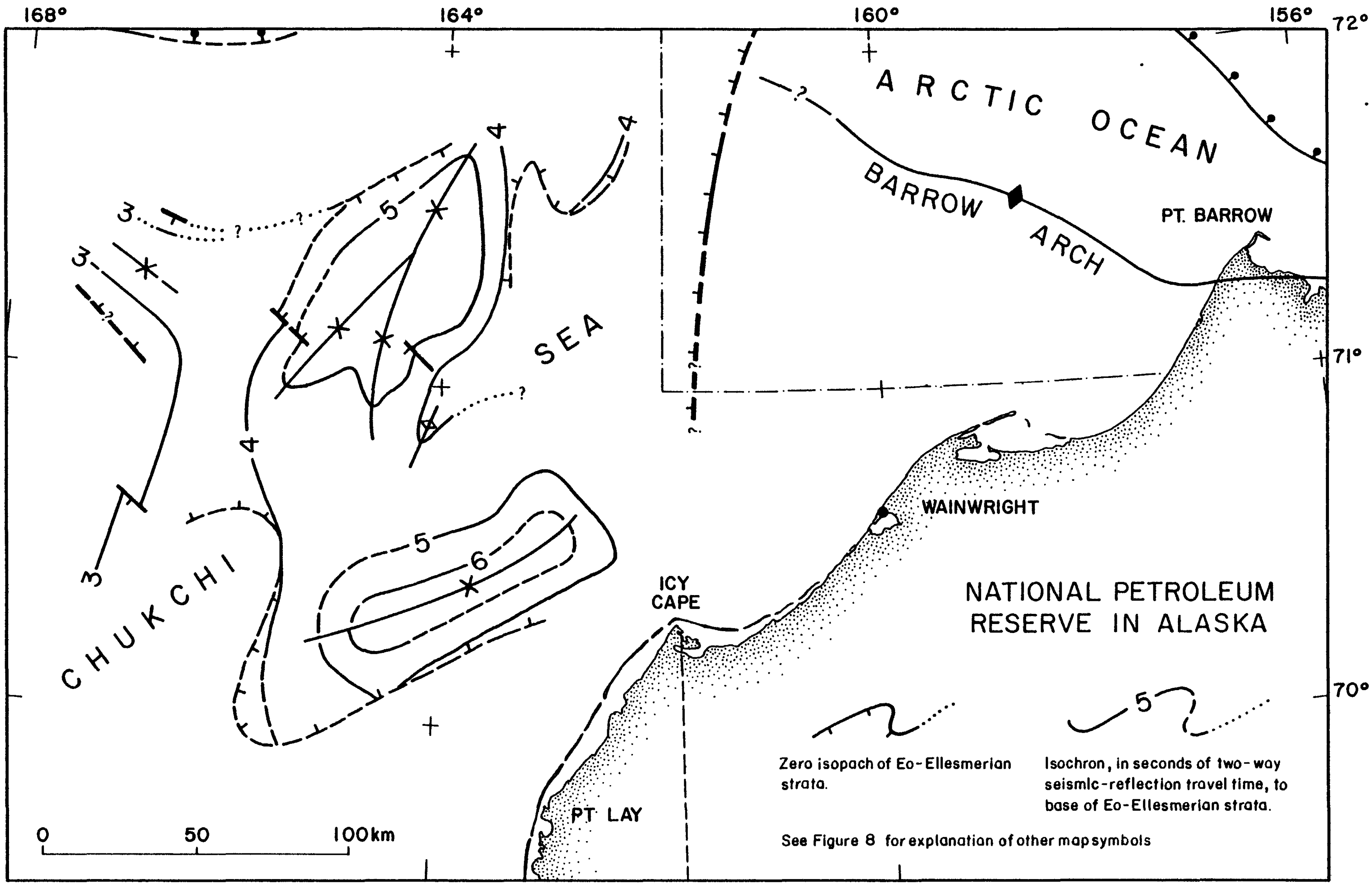


Figure 9.--Isochrons on base of Eo-Ellesmerian strata, top of Franklinian sequence, beneath the northern part of the United States Chukchi shelf. The northeast limit of the Eo-Ellesmerian sedimentary prism was not recognized on the seismic-reflection profiles. Only part of the Barrow arch planning area boundary is shown; see figure 3 for the complete boundary.

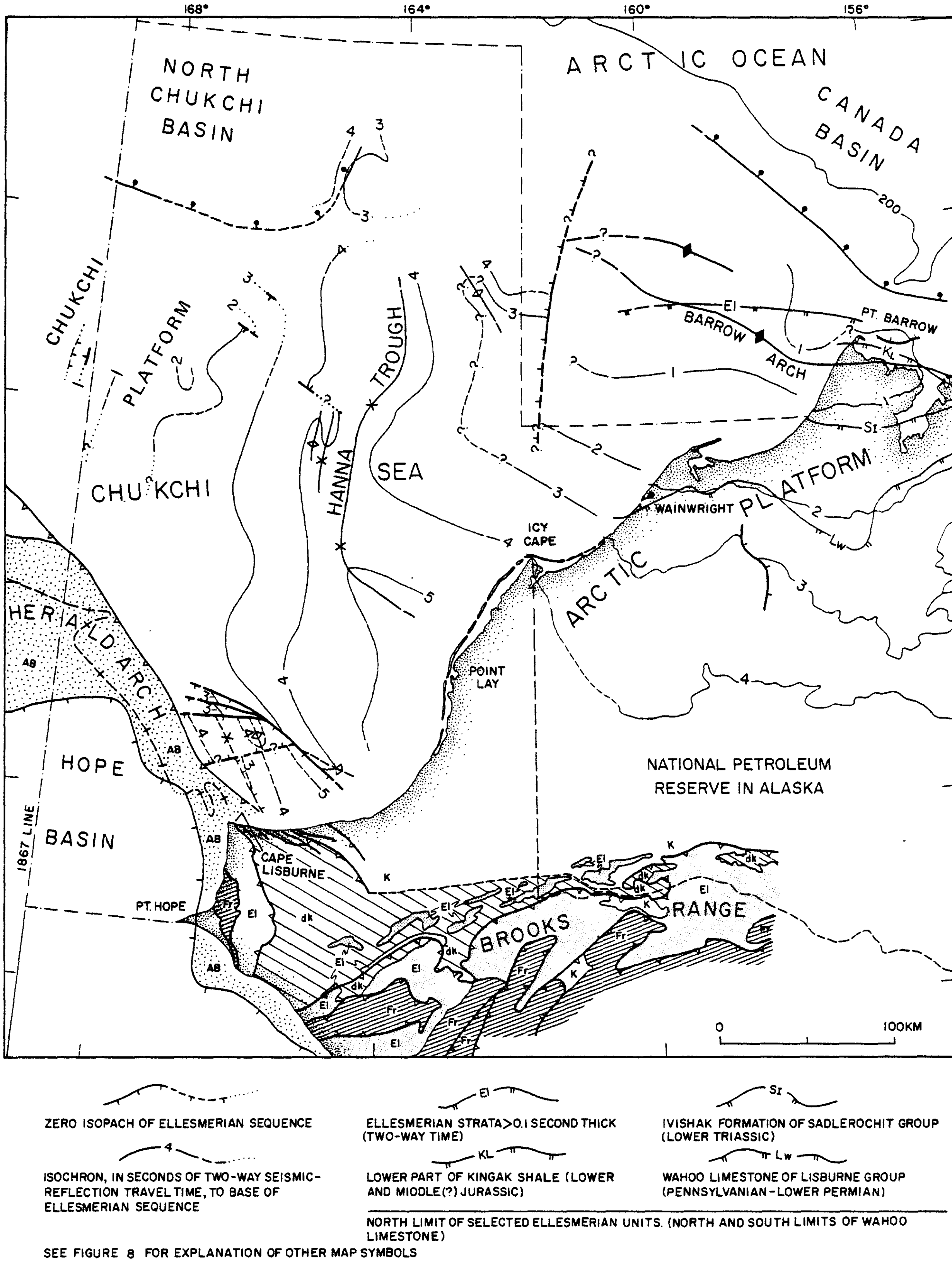


Figure 10.--Isochrons on base of Ellesmerian sequence beneath United States Chukchi shelf. Onshore isochrons from Miller and others (1979), onshore limits of selected Ellesmerian stratigraphic units from Guldenzopf and others (1980) and Tetra Tech, Inc. (1982).

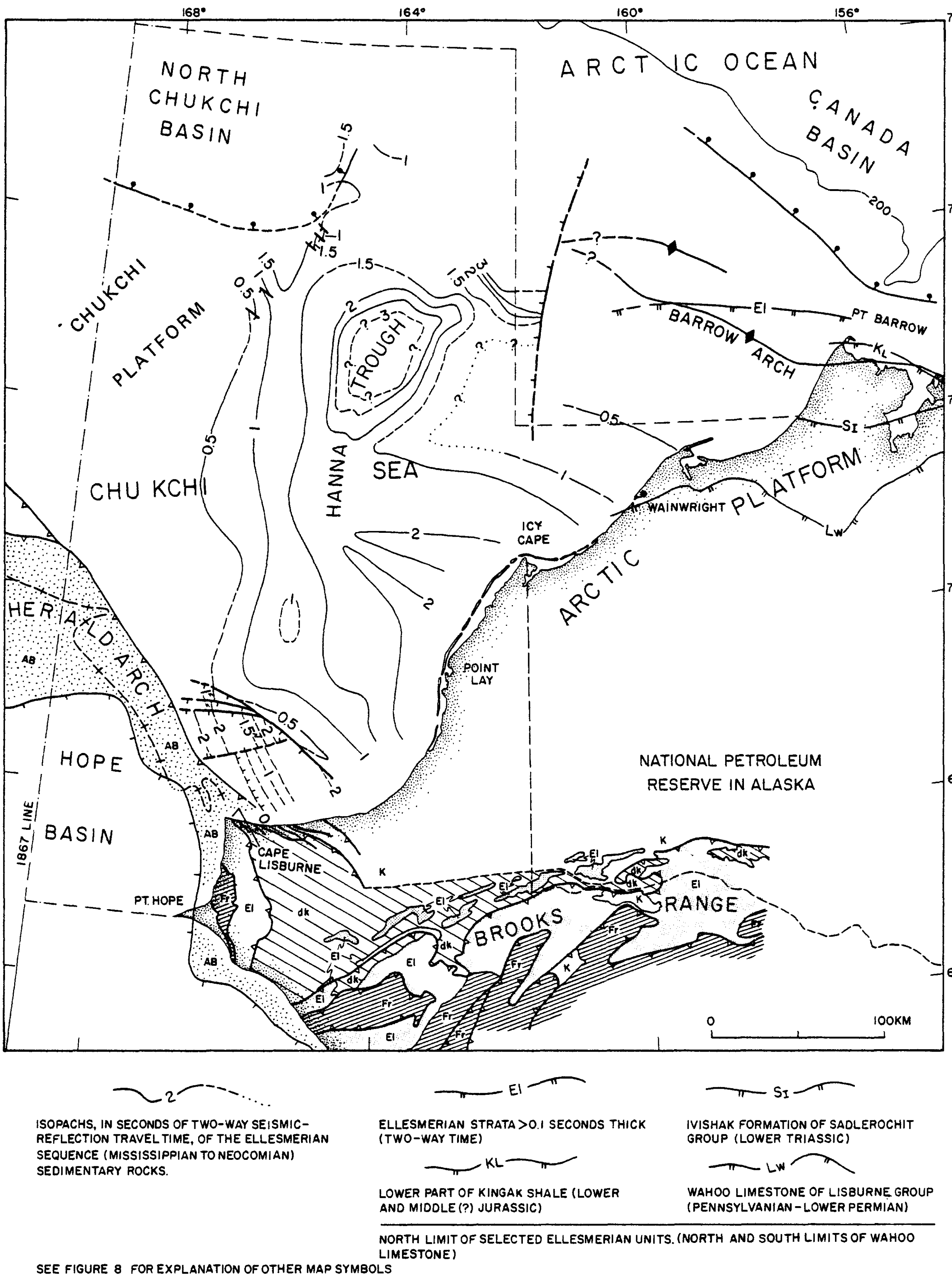


Figure 11.--Isopachs, in seconds of two-way seismic-reflection time, of the Ellesmerian sequence beneath the United States Chukchi shelf. Onshore limits of selected Ellesmerian stratigraphic units from Guldenzopf and others (1980) and Tetra Tech, Inc. (1982).

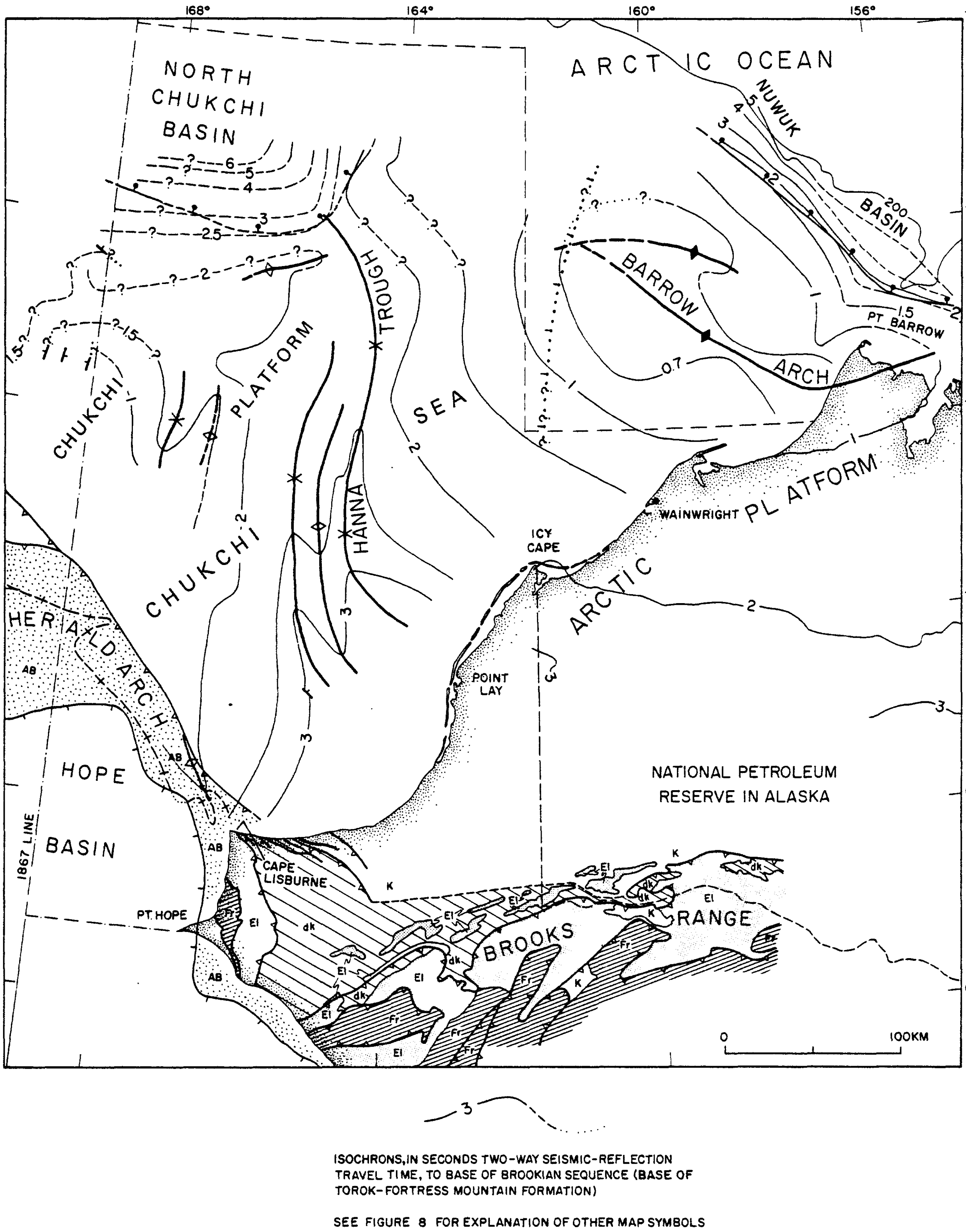


Figure 12.--Isochrons on base of lower Brookian sequence (Torok-Fortress Mountain Formation) beneath the United States Chukchi shelf. Onshore data from Miller and others (1979).

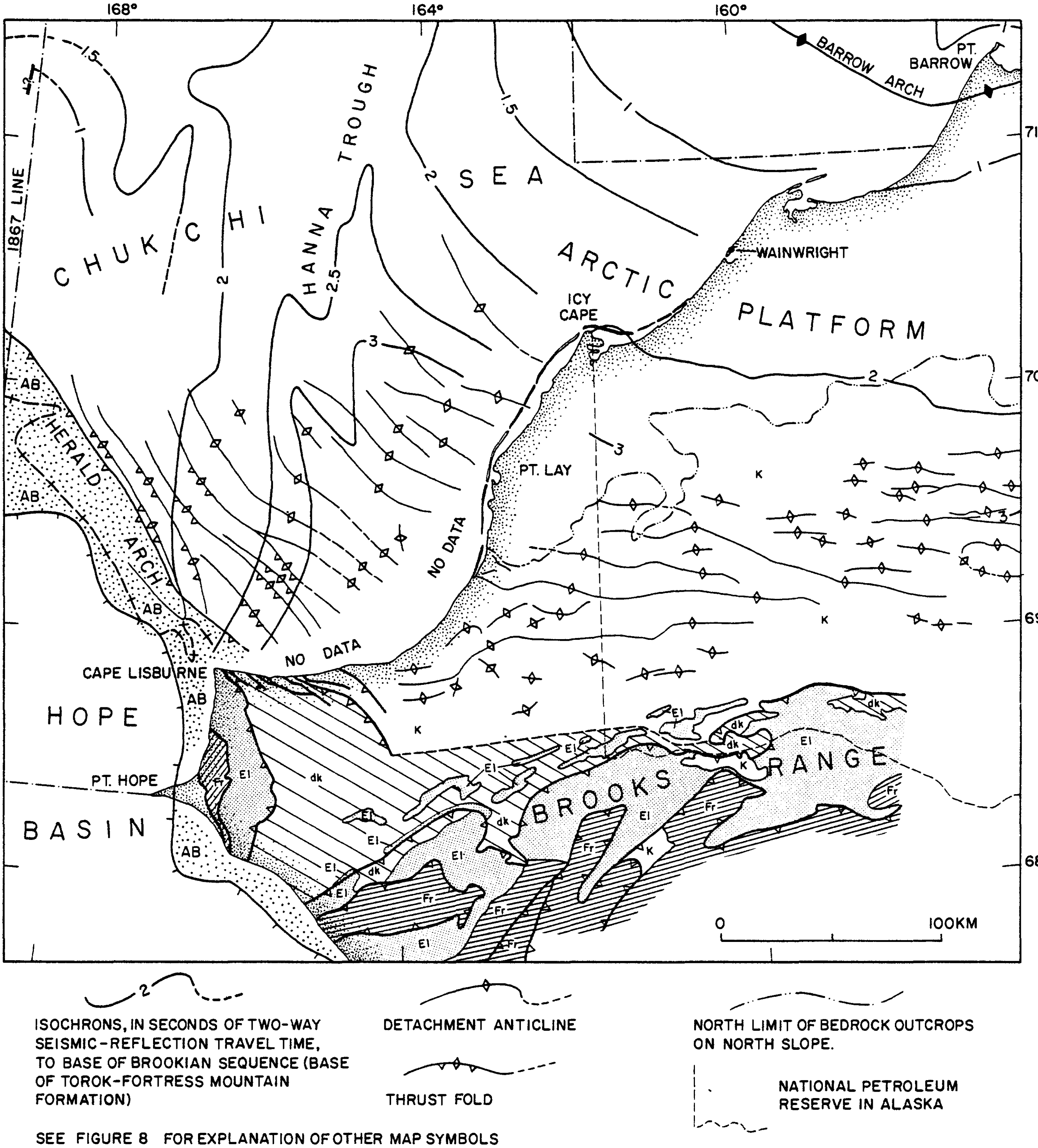


Figure 13.--Detachment folds and thrust folds in Cretaceous sedimentary rocks of the Colville foredeep on the United States Chukchi shelf and western North Slope. Some of the more southerly structures mapped as detachment folds on the North Slope are probably also thrust folds. Beneath the Chukchi shelf the folds are detached at or close to the base of the Torok-Fortress Mountain Formation, which is contoured in isochrons. Onshore isochrons from Miller and others (1979); onshore folds from Lathram (1965). Only part of the Barrow arch planning area boundary is shown; see figure 3 for the complete boundary.

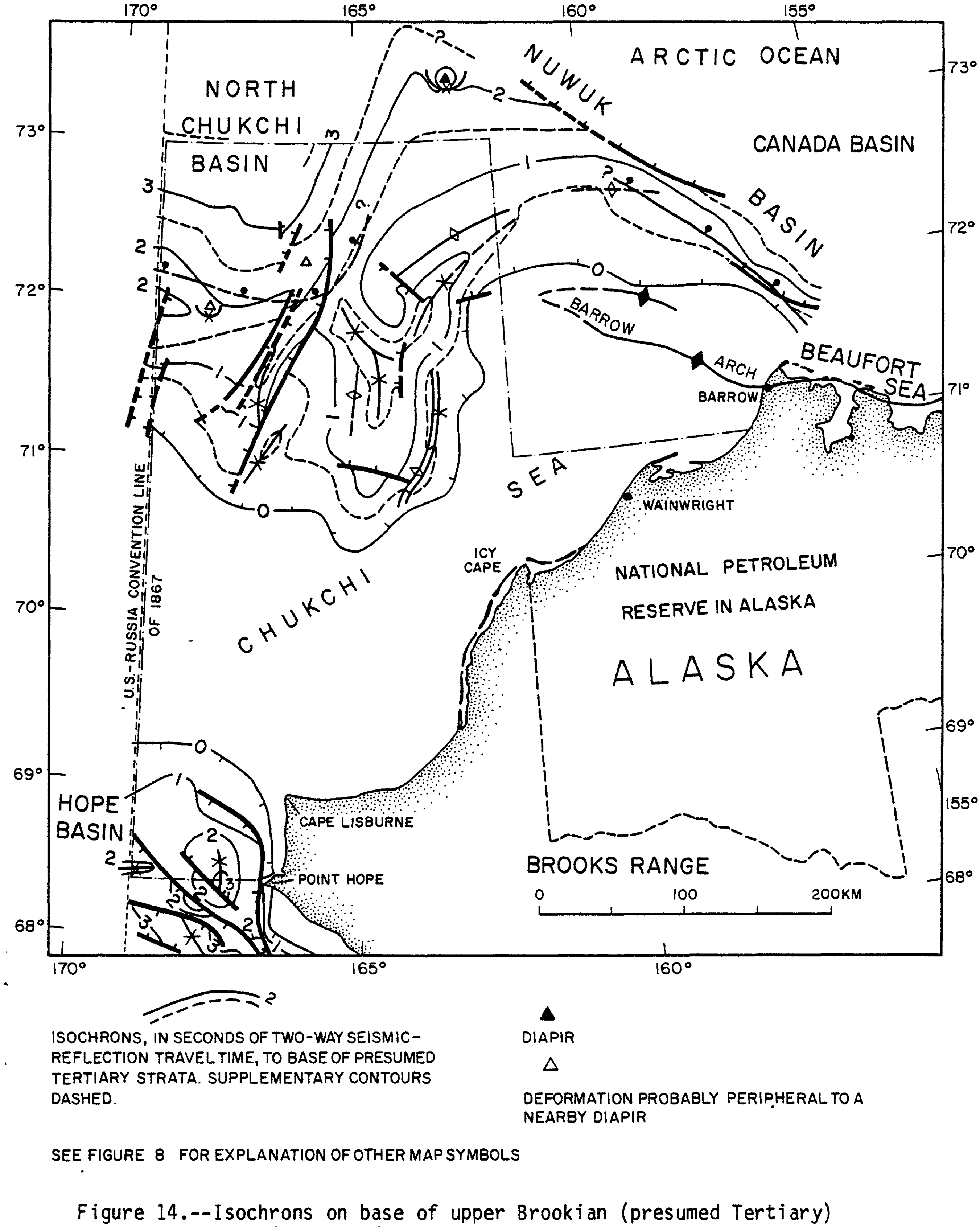
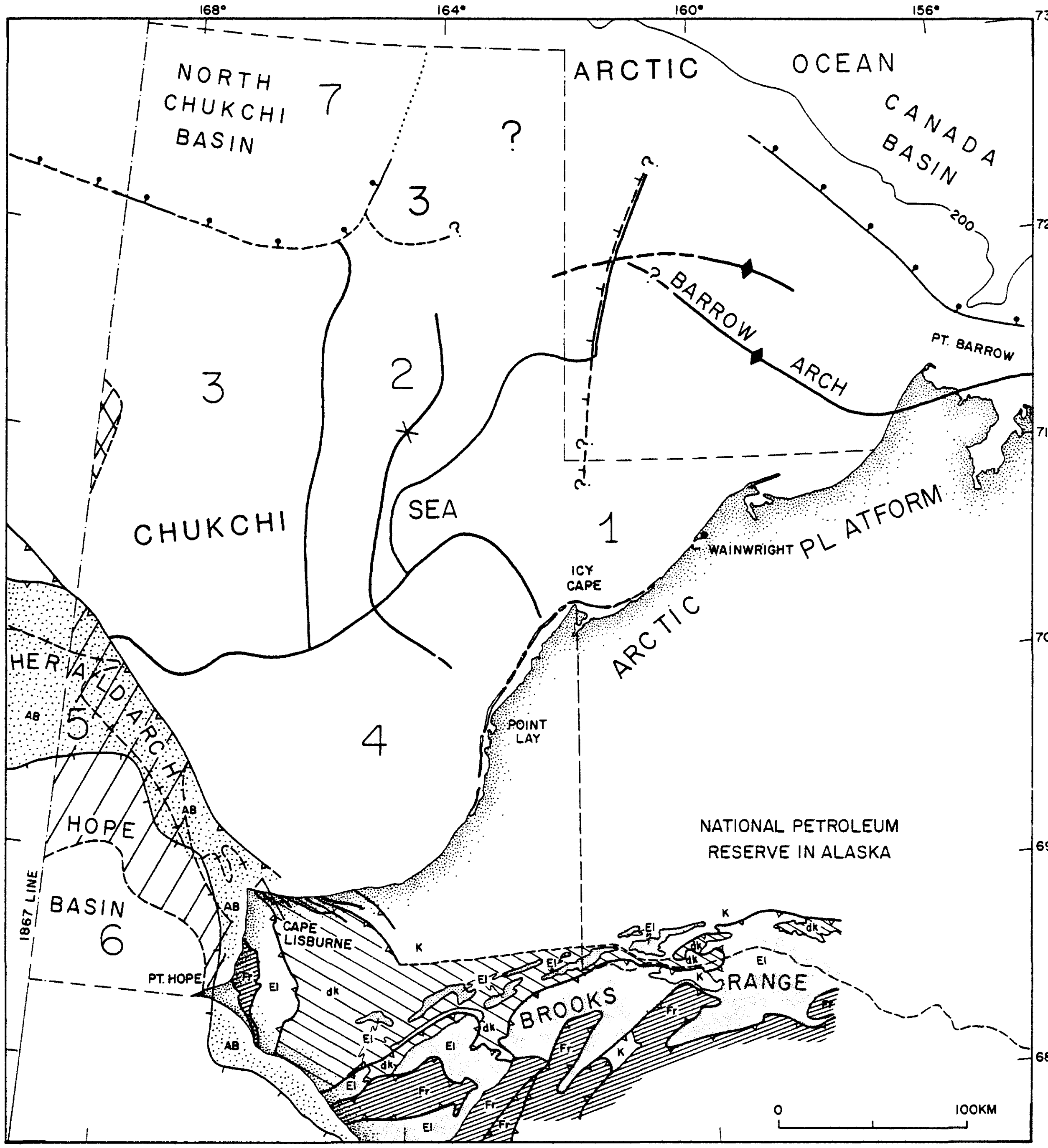


Figure 14.--Isochrons on base of upper Brookian (presumed Tertiary) strata in part of Hope basin and the northern United States Chukchi Sea, including part of North Chukchi and Nuwuk basins. Isochrons north of the multichannel lines (fig. 1) are based only on shallow-penetration single channel seismic-reflection profiles, and are speculative.



AREAS PROSPECTIVE FOR PETROLEUM

AREAS THAT MAY BE PROSPECTIVE FOR PETROLEUM BUT DATA ARE INADEQUATE FOR ASSESSMENT

AREAS NOT PROSPECTIVE FOR PETROLEUM

1. BARROW ARCH AND ARCTIC PLATFORM
2. HANNA TROUGH
3. CHUKCHI PLATFORM
4. FORELAND FOLD BELT OF COLVILLE FOREDEEP
5. HERALD ARCH OVERTHRUST BELT
6. HOPE BASIN
7. NORTH CHUKCHI BASIN

Figure 15.--Structural provinces and areas prospective for petroleum in Barrow arch planning area. Explanation of map symbols shown in figure 8.

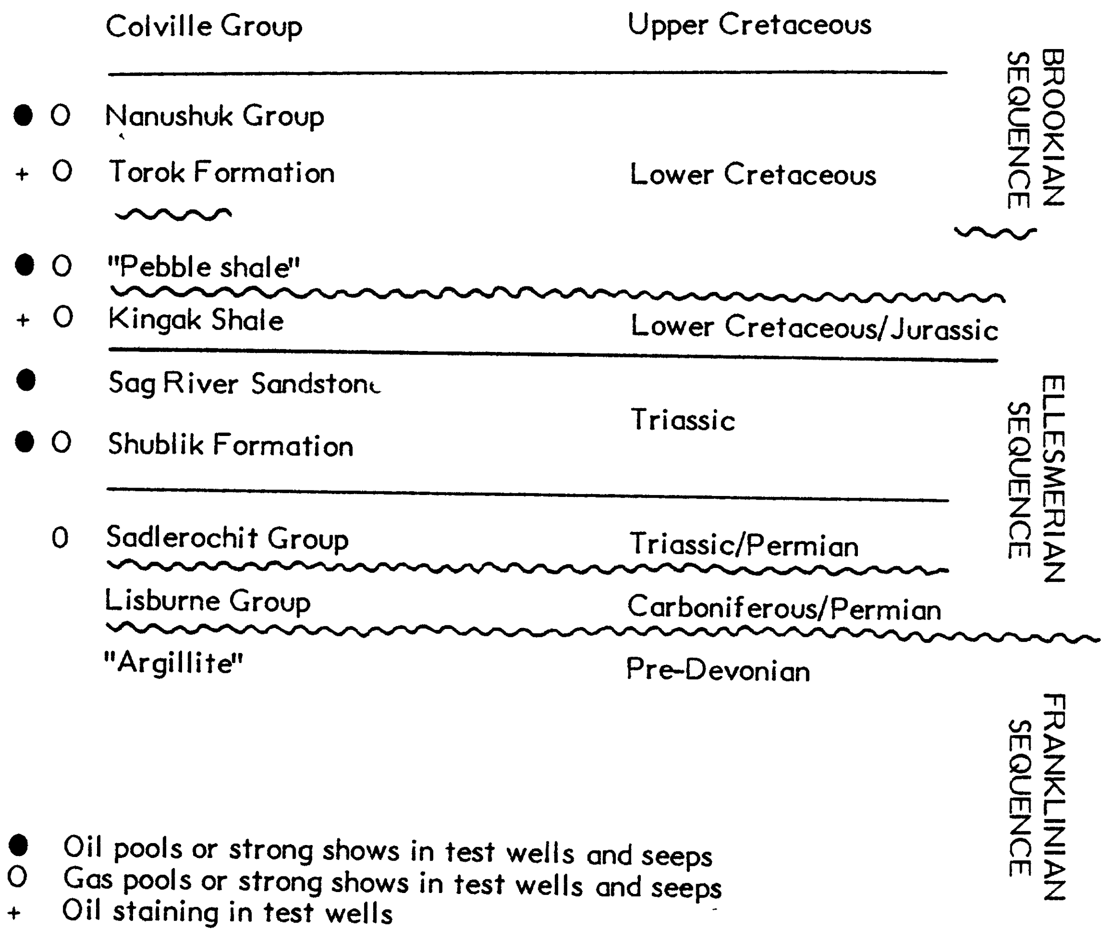


Figure 16.--Generalized stratigraphic column beneath the Arctic coastal plain of northwestern Alaska west of Dease Inlet showing position of oil and gas pools, strong shows of oil and gas, and oil staining encountered in test wells and seeps. (Data from Alaska Geological Society, 1981; Bird, 1982; and Kenneth J. Bird, personal communication, 1982).