FIGURE 1. GEOLOGIC MAP OF THE ARCTIC SLOPE OF ALASKA

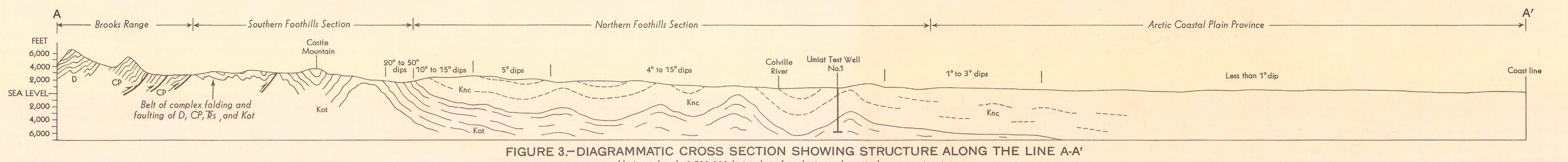

FIGURE 3.–DIAGRAMMATIC CROSS SECTION SHOWING STRUCTURE ALONG THE LINE A-A'
Horizontal scale 1:500,000 (twice that of geologic map); vertical exaggeration 4 times.

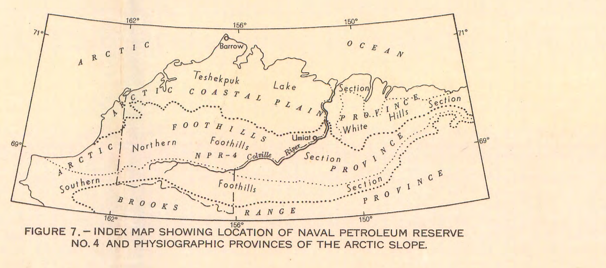

FIGURE 7.– INDEX MAP SHOWING LOCATION OF NAVAL PETROLEUM RESERVE NO. 4 AND PHYSIOGRAPHIC PROVINCES OF THE ARCTIC SLOPE.

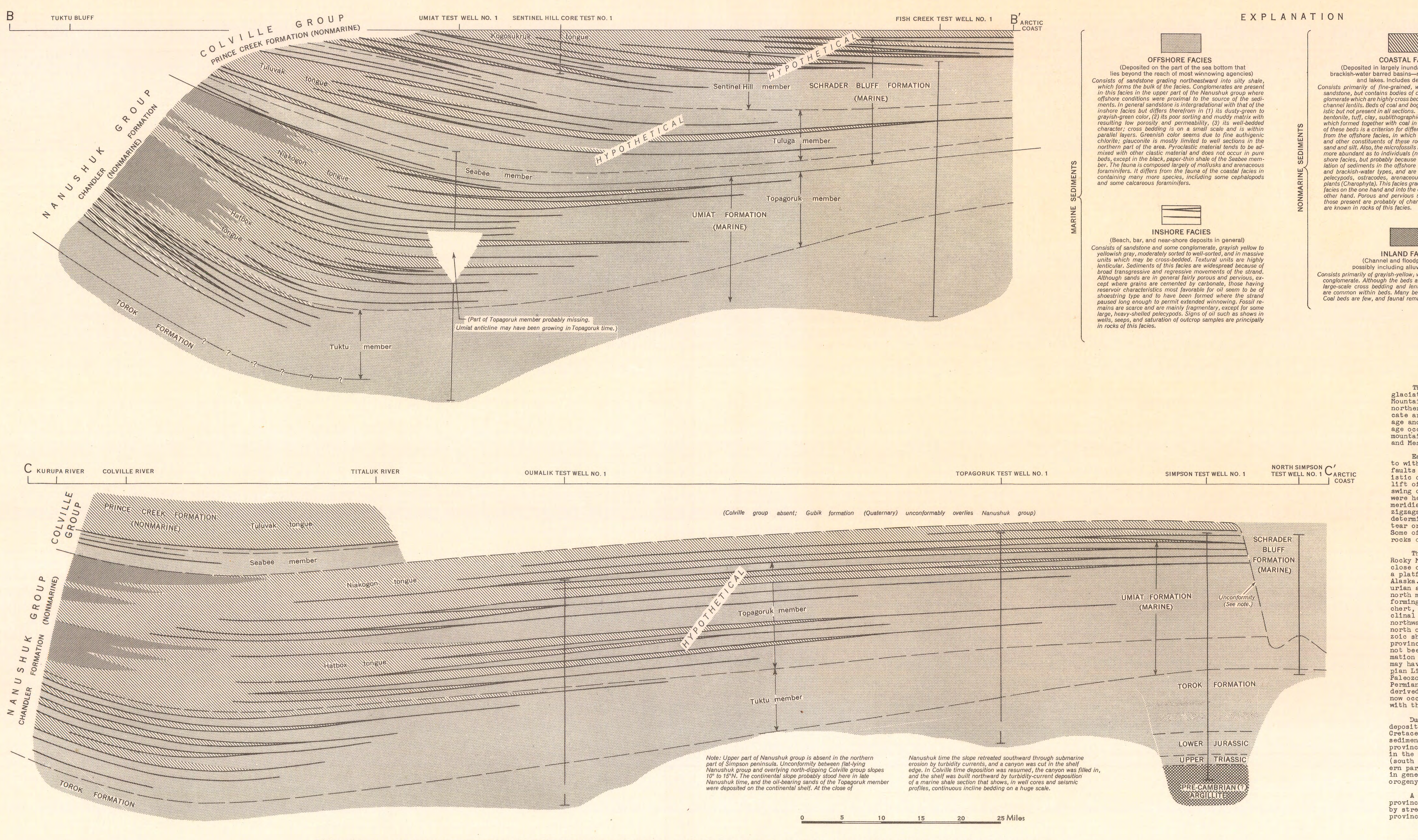

FIGURE 5.– RESTORED SECTIONS B-B' AND C-C SHOWING FACIES CHANGES IN THE NANUSHUK AND COLVILLE GROUPS

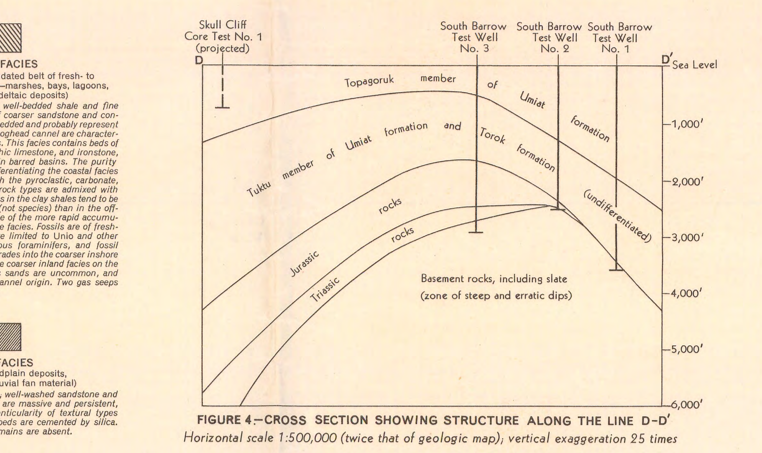

FIGURE 4.–CROSS SECTION SHOWING STRUCTURE ALONG THE LINE D-D'
Horizontal scale 1:500,000 (twice that of geologic map); vertical exaggeration 25 times

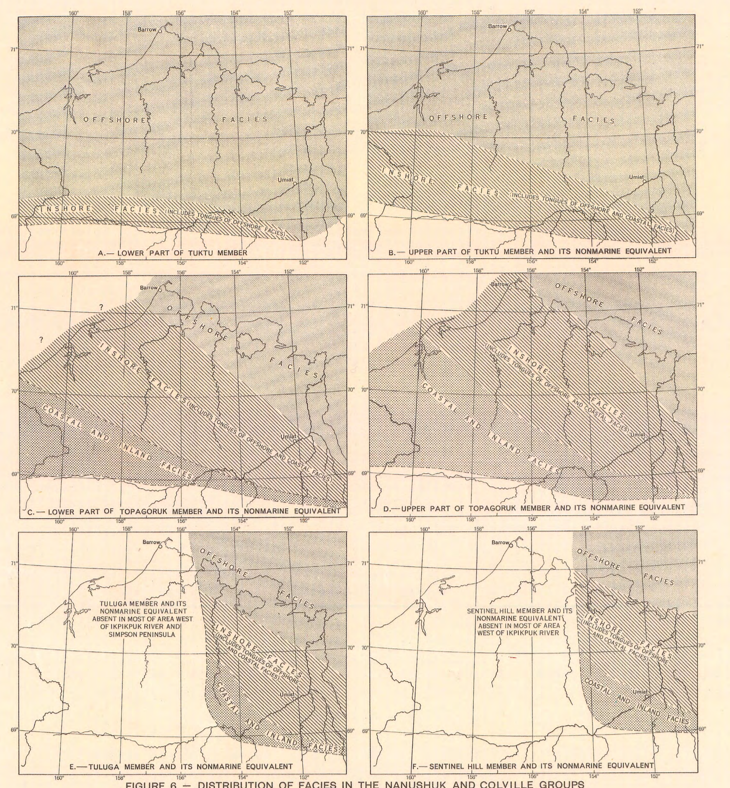

FIGURE 6.— DISTRIBUTION OF FACIES IN THE NANUSHUK AND COLVILLE GROUPS

GEOLOGY OF THE ARCTIC SLOPE OF ALASKA

BROOKS RANGE PROVINCE

The Brooks Range province (fig. 7) comprises several ranges of rugged, glaciated mountains that represent the Alaskan counterpart of the Rocky Mountains. East-striking Devonian and Mississippian rocks form most of the northern part of the province, where northward-overthrust plates in imbricate arrangement are the major structural features. Limestone of Silurian age and metamorphic rocks of earlier Paleozoic and probable pre-Cambrian age occupy the southern part of the province. The northern border of the mountain province coincides in general with the contact between Paleozoic and Mesozoic rocks.

East of the 149th meridian the Brooks Range province bulges northward to within about 25 miles of the Arctic coast. Inasmuch as folds and thrust faults in the area of the bulge maintain the general east strike characteristic of the province, the bulge seems to have been caused by greater uplift of the area east of the 149th meridian rather than by a northward swing of the structural axes. Thus resistant Paleozoic and older rocks were here exposed to erosion far north of their position west of the 149th meridian. Between the Sagavanirktok and Canning Rivers the mountain front zigzags northeastward; the configuration of the mountain front is in part determined by the trace of east-striking thrust faults and of northstriking tear or normal faults on which the west sides are stratigraphically higher. Some of the folds of the mountain area plunge westward under Cretaceous rocks of the Arctic Foothills province.

The area now occupied by the Brooks Range, like that occupied by the Rocky Mountains, probably was not orogenically deformed during or at the close of Paleozoic time. During early Paleozoic time this area was part of a platform region bounded on the south by a geosynclinal belt in interior Alaska. Early Paleozoic rocks, including limestone of Ordovician and Silurian age, were deposited in this platform region. In Devonian time the north margin of the geosynclinal belt shifted northward; and materials, forming Devonian clastic rocks and limestone and Mississippian limestone, chert, shale, sandstone, and chert conglomerate, were deposited in geosynclinal thickness in much of the Brooks Range province. The area of the northward bulge of the Range, in the Canning River region, probably was north of the east-trending geosynclinal belt and was part of a late Paleozoic shelf that occupied the northern part of the present Coastal Plain province. In the area of the bulge Devonian and lower Paleozoic rocks have not been found. The contact of Mississippian rocks with the Neruokpuk formation (pre-Cambrian ?) is not well exposed; the Mississippian sediments may have been deposited directly on the Neruokpuk formation. The Mississippian Lisburne limestone here is overlain by a few hundred feet of younger Paleozoic clastics, probably Permian. The Devonian, Mississippian, and Permian (?) clastics in the Brooks Range province are inferred to have been derived in considerable part from the north, from a platform in the region now occupied by the Arctic Ocean, a platform that was probably continuous with the Canadian shield.

During Triassic, Jurassic, and Early Cretaceous time sediments were deposited in the Brooks Range province, but during most of Albian and later Cretaceous and Tertiary time this province was a land area and a source of sediments. An Early Cretaceous (Albian) orogeny deformed the rocks of the province; the most intense deformation, including metamorphism, took place in the southern part, where the granite of the Baird Mountains was intruded (south of the area of the map). Cleavage in Paleozoic rocks in the southern part of the Range and in Mesozoic rocks immediately north of the Range in general strikes east; it was probably developed during the Albian orogeny.

A Tertiary orogeny further deformed the rocks of the Brooks Range province and was followed by peneplanation. Quaternary uplift and erosion by streams and glaciers are the latest events in the development of the province.

ARCTIC FOOTHILLS PROVINCE

The Arctic Foothills province is a hilly region between the mountainous Brooks Range province and the nearly flat Arctic Coastal Plain province. It is subdivided into a Southern Foothills section and a Northern Foothills section, which differ in topography and in geology.

Southern Foothills section.--The Southern Foothills section has the structural complexity of the Brooks Range but differs in being composed in considerable part of less resistant rocks, including great thicknesses of shale of Triassic, Jurassic, and Early Cretaceous age. The irregularity of the topography distinguishes this section from the Northern Foothills section. Irregular, isolated hills and ridges of sandstone, conglomerate, limestone, and chert rise above low-lying shale areas of little relief. Of the more resistant rocks, the sandstone and conglomerate are mostly Lower Cretaceous, and the limestone and chert are mostly Triassic and Mississippian.

The Mesozoic rocks of the Southern Foothills section were deposited in an east-trending geosyncline. Structurally conformable Triassic, Jurassic, and Lower Cretaceous (Neocomian) marine sediments accumulated in moderate thicknesses in this geosyncline, were deformed in some areas, and were buried by a great thickness of Lower Cretaceous (Albian) sediments of the Torok formation. The great thickness of marine sediments, forming the sandstone and conglomerate of graywacke type in the upper part of the Torok formation, probably was deposited rapidly during the Early Cretaceous (Albian) orogeny. The Torok formation includes intraformational unconformities.

Complex tight folds, including folds overturned to the north, and reverse faults upthrust on the south characterize the structure of the Southern Foothills section. The first phase of this deformation was during the Early Cretaceous orogeny; the second and probably the more intense phase was during the Tertiary orogeny.

Northern Foothills section.--The Northern Foothills section is a belt of Appalachian-type folds principally involving strata of the Nanushuk and Colville groups, which include Lower Cretaceous (Albian) and Upper Cretaceous rocks. The anticlines commonly are asymmetric, the north limbs being steeper. A few thrust faults are known, and other faults may be present that have not been recognized because of scarcity of outcrops. The deformation took place predominantly in the Tertiary period. In contrast to the Southern Foothills, the relative structural simplicity of the Northern Foothills section is reflected in greater regularity of the topography, with persistent ridges, mesas, and hills that are approximately accordant in altitude.

The strata in the Northern Foothills, although folded, have a strong north component of regional dip; in the Arctic Coastal Plain province the strata show little folding and have very slight north and south components of dip. In addition, the following structural conditions from west to east are indicated in both provinces:

1. A regional west component of dip from the broad north-trending arch centering about at the longitude of the Meade River toward a basin in the present Chukchi Sea; this involves westward thickening of the Nanushuk group and the presence at Cape Beaufort of marine bentonitic sedimentary rocks probably in part correlative with the Colville group.

2. The aforementioned arch centering about at the Meade River, on which strata of the Colville group are missing and the Nanushuk group is exposed.

3. A regional east component of dip from this arch into a basin, centering about at the longitude of the Kuparuk River, in which the Colville group and rocks of Tertiary age, in addition to the Nanushuk group, are present.

4. A west component of dip into this basin from the basement high in the area of the Brooks Range bulge (Canning River region).

The boundary between the southern foothills and the northern foothills is coextensive with the contact between the Torok formation and the overlying Nanushuk group. Along the trace of the contact the lithologic change from incompetent shale of the Torok formation to bluff-forming basal sandstone of the Nanushuk group is relatively sharp and is one of the most easily recognized and most persistent stratigraphic "horizons" in the Arctic Slope. Whether the apparently greater deformation of the shales of the Torok formation is due entirely to their lesser competence or is due in part to an angular unconformity has not been determined. Where exposed, the contact is conformable and appears to be gradational. Deformation during the time of deposition of the Torok was intense in the Brooks Range province, was probably less intense in the Southern Foothills section, and may have been slight in the Northern Foothills section.

In the lower Colville River area, north of Umiat, the maximum aggregate thickness of the Nanushuk and Colville groups is about 10,000 feet. The two groups are structurally conformable, but a considerable time lapse is indicated between deposition of the Nanushuk and the Colville; this lapse is represented by an erosional unconformity in the area of Cape Simpson. The lithologic facies pattern of the Nanushuk and Colville groups indicates (1) intertonguing marine and nonmarine sediments, (2) progressive northward overlap of nonmarine on marine sediments, (3) west and northwest strike of belts of similar facies, and (4) derivation of sediments from a land area to the south, where the Brooks Range now stands. The presence of oil-bearing sandstone in inshore marine facies of the Nanushuk group has been established by drilling at Umiat and by study of outcrops.

ARCTIC COASTAL PLAIN PROVINCE

The Arctic Coastal Plain is characterized by abundant lakes and swampy areas, by wet tundra, and by meandering streams. Inasmuch as the annual precipitation is only 5 to 7 inches, the general wetness seems to be the result of little evaporation, of poor surface drainage due to the flatness of the terrain, and of permafrost, which extends from a few feet below the surface to almost 1,000 feet and inhibits underground seepage.

In the part of the province west of the Colville River, Cretaceous rocks underlie the thin undeformed mantle of the Gubik formation (Quaternary) with slight angular unconformity. Extensive geophysical work and cores from drill holes in the Coastal Plain have shown that the Cretaceous, Jurassic, Triassic, and inferred Paleozoic strata are but slightly deformed; structural reversals are few, except in the southern part of the province, and are of small amplitude. The major tectonic elements are outlined in the description of the northern foothills.

The Sagavanirktok formation, consisting of terrestrial red beds probably Early Tertiary in age, occurs in the eastern part of the Arctic Coastal Plain province. At about lat. 69°20' N. on the Sagavanirktok River Tertiary rocks are exposed near Cretaceous rocks of the Nanushuk group, and the Colville group is mostly or entirely absent. The Sagavanirktok formation appears to be in angular unconformity with the overlying Gubik formation, as are the Cretaceous strata west of the Colville River. Therefore, it is interpreted that deformation and erosional beveling took place both (1) in Late Cretaceous or in Early Tertiary (pre-Sagavanirktok) time, at which time the Colville group was eroded at least locally in the White Hills section, and (2) in later Tertiary (post-Sagavanirktok) time.

In the coastal plain area exposures of formations older than the Gubik formation are scarce and are limited to low bluffs along the major streams and the coast. These exposures, together with well samples, indicate that the facies pattern of the Nanushuk and Colville groups represents a northward continuation of the intertonguing pattern of the Northern Foothills section. In the Coastal Plain province the marine Umiat and Schrader Bluff formations predominate, and a larger proportion of the rocks consists of shale of offshore marine facies. Tongues of the nonmarine Chandler and Prince Creek formations, prevalent in the foothills, constitute only a small part of the rocks in the area. Drill holes have encountered oil-bearing sandstones in the upper part of the Umiat formation, and it is believed that oil in seepages in the coastal plain comes from this formation.

In the northernmost part of the Coastal Plain province, at Barrow and Simpson, Triassic, Jurassic, and Cretaceous rocks rest on a surface of highly deformed and locally metamorphosed basement rocks, probably pre-Cambrian in age. Seismic profiles extending south from Barrow and Simpson indicate relatively steep south plunge of the basement surface in the Coastal Plain province. Seismic horizons in the Nanushuk group do not plunge south, except on the south flank of the Barrow high, and zones of the Nanushuk group do not deepen southward in wells. These conditions indicate great southward thickening of the rocks below the Nanushuk group. Those rocks thicken southward probably by (1) southward thickening of two Lower Cretaceous formations that are thin or absent at Barrow and Simpson, namely, the Okpikruak formation (probably absent) and the Torok formation (present but thin); (2) southward thickening of Jurassic and Triassic rocks, whose total thickness is only about 1,000 feet at Barrow and Simpson; and (3) entry and southward thickening of a unit, absent at Barrow and Simpson, that is presumed to be of Paleozoic age.

Numerous conformable reflections from the Paleozoic (?) unit show a regional south dip component of a fraction of a degree, and suggest that the strata are generally in slight angular unconformity with the overlying Mesozoic beds. In some places, however, steeper dips are recorded in this unit, and faulting has been interpreted. Refraction studies have indicated a very high velocity for this unit, which suggests the presence of orthoquartzite or limestone. These rocks have not yet been penetrated by wells and are not exposed in the Coastal Plain province. Their absence at Barrow and Simpson and presence to the south lends support to the theory that the northernmost part of the coastal plain was part of a Paleozoic shield, now largely submerged beneath the Arctic Ocean, and that the remainder of the coastal plain was an area of shelf sedimentation during the Paleozoic.

The stratigraphic conditions described above for the Arctic Coastal Plain province suggest the presence of northward overlaps or of pinchouts by convergence and truncation in Paleozoic (?), Triassic, Jurassic, and Lower Cretaceous rocks.

System	Series	Stratigraphic units	Sections: Brooks Range	Southern Foothills	Northern Foothills	Arctic Coastal Plain	Thickness, lithology, facies, and contacts (by Thomas G. Payne)	European equivalents / Northern Great Plains equivalents	Paleontology (by George Gryc)	Micro-paleontology (by Helen Tappan)	Petrography of sandstones (by Robert H. Morris and Ernest H. Lathram)
			Wide column used for outcrop sections across areas in which facies changes have been determined and are shown in column. Medium width column used for sections representing large areas of rock in which facies changes have not been determined. Narrow column used for well sections.								
QUAT.	PLEISTOCENE	GUBIK FORMATION	(Erosion by glaciers and streams)	(Glacial moraine and outwash deposits)	(River terrace deposits—sand and gravels)		0 to 150 feet. Unconsolidated marine and nonmarine gravel, sand, silt, and clay. Includes peat and ice, and oil residue at seeps. REGIONAL SLIGHT ANGULAR UNCONFORMITY		Marine invertebrate fossils rare. Only pelecypods and gastropods have been collected. Vertebrate remains present, including mammoth, mastodon, horse, bison, and musk ox.	Shallow-water calcareous fauna; no pelagic species. Contains numerous polymorphinids, and *Elphidium*, *Cribroelphidium*, *Elphidiella*, *Cassidulina*, and *Rotalia*.	All mineral grains very well rounded. Heavy-mineral suite much more varied than in formations below.
TERTIARY	EARLY TERTIARY	SAGAVANIRKTOK FORMATION	(Gradual emergence and erosion; source of sediments of Sagavanirktok formation)	(Erosion ?)	(Sediments possibly deposited and removed by erosion)		1,000 to 2,000 feet. Known only in White Hills section of Coastal Plain province. Mostly or entirely nonmarine; poorly consolidated conglomerate, silty sandstone and siltstone. Coal, common in lower part and rare in upper part, is predominantly lignite but some is boghead cannel. Red, brown, and yellow beds alternate with nearly white. LOCAL EROSIONAL UNCONFORMITY (?)		Marine fossils unknown. Plant fossils rare.	No microfossils observed.	Limestone, chert, and quartzite boulders well-rounded; grains subround to angular. Grains are (percent) milky quartz, 60; gray, green, and yellow chert, 15; quartzite, 10; black chert, 10; traces of rose and smoky quartz; rock fragments, 5. *Kyanite zone*—kyanite, the characteristic heavy mineral, rare but consistently present; also tourmaline, zircon, and garnet, some reworked from older rocks.
CRETACEOUS	UPPER	COLVILLE GROUP: PRINCE CREEK FORMATION (Nonmarine), Kogosukruk tongue, Tuluvak tongue; SCHRADER BLUFF FORMATION (Marine), Sentinel Hill member, Tuluga member	(Gradual emergence and erosion; source of sediments of the Colville group)	(Erosion ?)	(Sediments of Sentinel Hill member and its equivalent nonmarine section were deposited here but have been mostly removed by erosion)	1,195' FISH CREEK TEST WELL NO. 1	Maximum thickness about 5,000 feet in Colville River area downstream from Umiat. Limited to the Coastal Plain province and Northern Foothills section east of long. 156° W. Mostly or entirely absent at lat. 69°20' N. on Sagavanirktok River, where Tertiary strata crop out near Nanushuk group strata, suggesting local erosional unconformity. In Cape Sabine-Cape Beaufort area, upper 4,000 feet of Cretaceous section bentonitic and mostly marine, may be equivalent to part or all of the Colville group, but fauna is different, possibly owing to existence of separate western basin. Most distinctive feature of Colville group is large quantity of bentonite and tuff, present both as beds and admixed in sandstone and shale. Pyroclastic material increases upward in section. Bulk of marine sandstone is greenish-gray low-rank graywacke; differs from sandstone of Nanushuk group in generally lighter color due to presence of pyroclastic material. The group consists of a nonmarine formation that intertongues with a marine formation. Two major nonmarine tongues (Tuluvak and Kogosukruk) imply major northward regressions of Cretaceous sea; numerous minor tongues imply repeated north-south fluctuations of the strand. Initial deposits of the group (Seabee member) are everywhere marine (fig. 5, B-B'). Upper part of this member is low-grade oil shale (paper shale) that contains fossiliferous limestone concretions and bentonite layers and is a widespread marker bed. Base of the Tuluga member and its equivalent nonmarine section rests on the paper shale. Early in Tuluga time the Cretaceous seashore began a gradual fluctuating northward regression. This continued through first half of Tuluga time. During maximum regression the strand moved north of Fish Creek where a thin nonmarine section (with coal) is present in middle of Tuluga member (fig. 5, B-B'). Except for this brief extreme northward retreat the shoreline was maintained south of Fish Creek. Last half of Tuluga time was period of transgression; at its close the seashore was again far south of Umiat. During the major regression and transgression a large nonmarine tongue (Tuluvak tongue) was deposited. General strike of the fluctuating shoreline was northwest (fig. 6, E). Contact between Tuluga and Sentinel Hill members is drawn primarily on paleontologic criteria, but these members differ in several respects. Tuluga member and its equivalent nonmarine section in general are better indurated. Sentinel Hill member and its equivalent nonmarine section have more color, including shades of red and brown, and in gross aspect are somewhat finer-grained. The last regression of the Cretaceous sea occurred gradually during Sentinel Hill time, at close of which the seashore probably was near the present Arctic coast (fig. 6, F). Kogosukruk tongue was deposited during this regression.	SENONIAN AND POSSIBLY YOUNGER / PIERRE SHALE AND POSSIBLY YOUNGER	Marine, brackish, and fresh-water invertebrate fossils rare, predominantly pelecypods and gastropods.	Distinctive radiolarian fauna of about 40 species. The foraminiferal assemblage includes *Verneuilinoides*, *Gaudryina*, *Trochammina ribstonensis*, *Bulimina*, *Nonionella*, and *Eoeponidella strombodes*. Equivalent to lower part of Riding Mountain formation and Lea Park shale of Canada.	The range of grain composition in sandstones of the Colville and Nanushuk groups (by percent) is: quartz, 22 to 66; chert, 6 to 31; rock fragments (slate, phyllite, and graywacke), 11 to 36; feldspar, largely oligoclase and andesine but some orthoclase and microcline, 2 to 10; large flakes of muscovite, biotite, and chlorite, 1 to 3; and grains of andesite and felsite, 0 to 5. Illite is the principal interstitial material and the main bonding agent; others are chlorite, kaolinite, and montmorillonite. Sandstones of the Colville group contain more of the silicic feldspars (orthoclase and microcline), montmorillonite, as much as 8 percent of some sandstones, and a suite of abundant volcanic and metamorphic heavy minerals. The following mineralogic zones are recognized from variations in the heavy-mineral suite: *Fractured garnet zone*—upper part of the Sentinel Hill member. *Fractured garnet-glaucophane zone*—lower part of Sentinel Hill member. Fractured pink and colorless garnets are the most abundant heavy minerals. Glaucophane is also present and upper occurrence of this mineral marks the top of the zone.
								SENONIAN / NIOBRARA, TELEGRAPH CREEK, AND EAGLE FORMATIONS	Marine invertebrate fossils common in upper 1,700 feet in outcrop sections; predominantly pelecypods, cephalopods, with gastropods, and worm borings. Fish remains rare. Characterized by a greater number of individuals and species than other Cretaceous units. Original shell material commonly preserved. Diagnostic fossils, in order of abundance: *Inoceramus* cf. *I. lundbreckensis*, *Inoceramus* n. sp., *Protocardium* cf. *P. borealis*, *Glycimeris* cf. *G. borealis*, *Scaphites* n. sp. Lower part of member partly nonmarine in outcrop sections. Marine or brackish-water pelecypods occur in lower part but are rare. Characteristic fossil: *Inoceramus* sp.	Numerous calcareous Foraminifera, including *Bulimina venusae*, *Neobulimina canadensis*, *Bolivina*, and *Anomalina*, as well as the agglutinated forms, *Haplophragmoides*, *Spiroplectammina mordenensis*, *Verneuilinoides*, and *Trochammina*. A few radiolaria are present. Equivalent to the Boyne and Morden members of the Vermilion River formation of Canada.	*Augite-biotite zone*—upper part of the Tuluga member. Angular cleavage fragments of augite are very abundant. Biotite plates, both light rust and dark brown in color, comprise as much as 40 percent of the fraction. *Biotite-hornblende-andalusite zone*—lower part of the Tuluga member. Biotite plates constitute 40 to 70 percent of the heavy-mineral fraction. Fresh hornblende laths are pleochroic from green to brown. Prismatic, colorless andalusite is common.
								TURONIAN / CARLILE SHALE	Marine fossils common, predominantly cephalopods and pelecypods, commonly flattened. Fish remains common. Diagnostic fossils: *Scaphites delicatulus*, *Borissjakoceras* sp., *Watinoceras* sp., *Inoceramus* sp., *Inoceramus labiatus*		
		Seabee member					LOCAL EROSIONAL UNCONFORMITY	GREENHORN LIMESTONE		The restricted fauna includes *Haplophragmoides*, *Spiroplectammina*, *Trochammina*, and some radiolaria, which are usually pyritized. In the northern wells, a limited zone contains *Globigerina* and *Gümbelina*. Equivalent to the mid-Lloydminster and Favel formations of Canada.	*Biotite zone*—in the Seabee member. Biotite flakes constitute over 90 percent of the heavy mineral assemblage.
CRETACEOUS	LOWER (?) AND LOWER	NANUSHUK GROUP: CHANDLER FORMATION (Nonmarine), Niakogon tongue, Hatbox tongue; UMIAT FORMATION (Marine), Topagoruk member, Tuktu member	(Gradual emergence and erosion; source of sediments of the Nanushuk group)	(Sediments of Nanushuk group were deposited here but have been removed by erosion)		4,350'; 4,350'	About 5,500 feet in foothills south of Umiat. Thickens westward to 12,000 feet in Kokolik-Kukpowruk Rivers area. Thins northward to about 4,000 feet at Cape Simpson. Erosional unconformity between Colville and Nanushuk groups in Simpson peninsula and possibly elsewhere; at Simpson Colville group rests on eroded surface of Nanushuk group (fig. 5, C-C'). Top of Nanushuk group in area between Oolamnagavik and Nanushuk Rivers is marked by a quartz conglomerate. Main lithologic difference between Nanushuk and Colville groups is absence of bentonite and tuff in Nanushuk group, except in uppermost part. In foothills area moderately rapid accumulation is suggested by lack of separation, except locally, of mud from sand; considerable thickness of zones of *Inoceramus* and ammonites; absence of glauconite; sparsity of microfossils and dominance of arenaceous foraminifers; and general sparsity of megafossils. In wells in northern part of the Coastal Plain province sandstone is better-sorted; glauconite is present in a few very thin zones; and microfossils are more abundant and include more calcareous species. Here sandstone is friable. Sandstone in foothills area is well-indurated; cement is mostly interstitial detritus, calcite, and silica. Marine sandstone of Tuktu member is predominantly dark-greenish gray and argillaceous; Topagoruk member includes more "salt-and-pepper" sandstone, better-sorted and commonly buff. Thus sandstones of the inshore facies are more prominent in the Topagoruk member. At beginning of Nanushuk time marine sedimentation was dominant in Arctic Slope region (fig. 6, A). In this respect Nanushuk group resembles Colville group. During last half of Tuktu time the Cretaceous sea began a fluctuating northward regression and nonmarine strata were deposited. Throughout Tuktu time the trend of the shoreline was approximately west. Northward regression continued during early Topagoruk time; nonmarine strata were deposited as far north as Oumalik Test Well No. 1; sediments of inshore facies were deposited as far north as Umiat and Topagoruk Test Well No. 1. In middle Topagoruk time a southward transgression of sea occurred, but in late Topagoruk time a marked regression deposited nonmarine and inshore-facies sediments north as far as Simpson peninsula. This terminal regression (Niakogon tongue) is analogous to Kogosukruk tongue in Colville group (fig. 5, B-B'). Dominant trend of the seashore in Topagoruk time was northwest (fig. 6, C, D), in contrast to the west trend during Tuktu time. This marked trend change, far northerly extension of nonmarine upper Nanushuk strata in western part of N.P.R.-4, and westward thickening of Nanushuk group imply greater northward outpouring of sediment from western part of the Brooks Range area than from eastern part. Nanushuk group, particularly nonmarine equivalent of Topagoruk member, contains large reserves of coal throughout most of northern foothills and coastal plain area west of longitude of Umiat. More than half the footage drilled to date in test wells and core holes is in Nanushuk group. Oil encountered in the Arctic Slope region is mostly from Nanushuk group, the Topagoruk member being main petroliferous unit.	CENOMANIAN ?	Marine invertebrate fossils present in upper 1,500 feet. Predominantly poorly preserved pelecypods and scaphopods. Molds and casts most common type of preservation. Diagnostic fossils: *Inoceramus* n. sp. (linguiform type). Rare nondiagnostic pelecypods in marine and brackish-water deposits in lower part of member, which is predominantly nonmarine in outcrop sections.	Contains an abundant and diversified microfauna to the north (offshore facies), with *Miliammina*, *Tritaxia manitobensis*, *Verneuilinoides*, *Discorbis*, *Gyroidina*, *Globigerina*, and other simple Lagenidae, Buliminidae, and Rotaliidae. Barren or sparsely fossiliferous in the area to the south, with dominantly arenaceous and tolerant genera such as *Bathysiphon*, *Haplophragmoides*, *Ammobaculites*, *Verneuilinoides*, *Gaudryina*, *Miliammina*, *Massilina*, and *Trochammina*, and some charophytes. Equivalent to the Ashville and lower Lloydminster of Canada.	Sandstones of the Nanushuk group have approximately the same grain composition as those of the Colville group (see above). Feldspars are less silicic, and the heavy-mineral suites include fewer nonresistant minerals than do those of the Colville group. Montmorillonite is absent. In one horizon in the Topagoruk member glauconite is abundant, characteristically occurs as casts of microfossils. The following mineralogic zones are recognized: *Glaucophane-hornblende zone*—upper part of the Topagoruk member in the Barrow-Simpson-Fish Creek-Umiat area, stratigraphically equivalent to the *euhedral colorless zircon zone* (see below). Glaucophane laths are pleochroic blue and lavender. Hornblende laths exhibit deep-blue to green pleochroism. Biotite plates are common but never constitute more than 40 percent of the heavy-mineral fraction. The base of the zone is established by the lowest occurrence of glaucophane. *Euhedral colorless zircon zone*—stratigraphic equivalent of the glaucophane-hornblende zone identified in the Meade-Oumalik-Topagoruk area (see above). Colorless euhedral zircon grains have length to width ratio which may exceed 4:1, first-order prisms and pyramids are common. Glaucophane is absent.
								OR ALBIAN	Marine invertebrate fossils present. Predominantly pelecypods with a few scaphopods, cephalopods, starfish, and gastropods. Fossils most common in basal 1,000 feet associated with greenish-gray sandstones. Diagnostic fossils: *Inoceramus* n. sp. (subcircular type), *Cleoniceras* sp. (also ranges into underlying Torok formation).	Outcrops contain arenaceous Foraminifera, such as *Ammodiscus*, *Haplophragmoides*, *Ammobaculites*, *Gaudryina*, and *Massilina*. The few calcareous species of the Lagenidae, Buliminidae, and Rotaliidae are more frequent to the north in wells.	*Zoned zircon zone*—present in the Tuktu member, the lower part of the Topagoruk member, and part of the Torok formation. Most zoned zircon crystals are doubly terminated, have length to width ratio of about 3:1, and are yellow or very light pink. Deeply colored ovoid tourmaline grains with faintly colored prismatic overgrowths are present.
CRETACEOUS	LOWER	TOROK FORMATION	(Orogenic deformation; rapid emergence and erosion; source of sediments of Torok formation)		3,855 OUMALIK TEST WELL NO. 1; 10,880'	T.D. 7,020'; (Thin but widespread in northern part of Coastal Plain province)	STRUCTURAL CONFORMITY (?) Maximum thickness about 10,000 feet at Castle Mountain, the type region. Crops out throughout most of Southern Foothills section. Contains local intraformational angular unconformities; in places upper part rests on Okpikruak or older rocks. Irregular in lithologic character; no persistent lithologic units; entirely marine. At type locality two parts recognized. Lower part, 1,750 feet thick, is dark-gray shale and siltstone with graywacke interbeds and limestone concretions. Carbonized plant remains. Upper part, about 8,500 feet thick, is graywacke and graywacke conglomerate, in massive beds and lenses, and dark silt and clay shale. Carbonized plant remains abundant. Rare lenses of grahamite. Graywacke is heterogeneous and has large proportion of chloritic matrix; is nonpermeable and very tight. Pebbles and cobbles in conglomerate, graywacke, and shale beds are chert, oil shale and other shale types, mafic igneous rock, and some limestone and gneissoid granite. Conglomerate distinguished from that of Nanushuk and Colville groups by scarcity of quartz and quartzite. Upper part, 8,500 feet in syncline at Castle Mountain, is 4,000 feet and mostly shale at Tuktu Bluff; may be due to thinning or truncation and northward loss of coarse upper section. About 6,000 feet and mostly shale in Oumalik Test Well No. 1. In Simpson and Barrow wells dark shale with scattered chert and quartz as coarse sand grains, granules, and pebbles. LOCAL ANGULAR UNCONFORMITY	ALBIAN; APTIAN	Marine invertebrate fossils very rare. Predominantly cephalopods and pelecypods. Fish remains very rare; one specimen of fish of the family Aspidorhynchidae. Diagnostic fossils: *Aucellina* sp., *Beudanticeras* sp., *Cleoniceras* sp., *Lemuroceras* sp., *Lemuroceras* cf. *L. belli*, *Lemuroceras* cf. *L. aburense*	Foraminifera present include *Ammodiscus*, *Glomospira*, *Haplophragmoides*, *Dorothia*, *Verneuilinoides*, and a few Lagenidae and Rotaliidae.	Sandstones contain very little quartz and feldspar and consist primarily of rock fragments, including nonresistant rocks. Basalt grains are very abundant. Dark interstitial material is highly chloritic. Augite cleavage fragments comprise at least 60 percent of the heavy-mineral fraction. Zircon grains are euhedral and have length to width ratio of 2.5:1. Most garnet grains are etched, other grains are fresh.
		OKPIKRUAK FORMATION	(Gradual emergence and erosion; source of sediments of Okpikruak formation; coarse sediments deposited locally in northern part of province)		T.D. 11,872'	(Very thin to absent in northern part of Coastal Plain province)	Maximum thickness in central Southern Foothills section is 1,850 feet; may be thicker elsewhere in this area, possibly in western part. Present in Oumalik Test Well No. 1; believed absent in northern part of Coastal Plain province. Probably entirely marine. Regionally rather uniform; cyclically interbedded argillaceous sandstone, siltstone, and shale. Sandstone layers are generally fine grained, greenish gray, and quartzose. Calcareous siltstone occurs as lenticular concretions.	NEOCOMIAN	Marine invertebrate fossils rare. Diagnostic fossils: *Aucella crassicollis*, *Aucella okensis*, *Aucella crassa*	Contains only simple forms of *Bathysiphon*, *Glomospira*, *Ammodiscus*, and *Trochammina* in the outcrops.	Sandstone grains angular and consist (by percent) of quartz, 20 to 40; decomposed feldspar, 10 to 20; and fragments of chert, quartzite, phyllite, and slate, about 50. Interstitial material highly chloritic but is not as conspicuous as in Torok formation. Epidote and zoisite constitute over 70 percent of heavy-mineral fraction in most samples. Most mineral grains are fresh.
JURASSIC	UPPER, MIDDLE, LOWER	KINGAK SHALE	(Possibly deposited in Brooks Range area. This area, together with interior Alaska, may have been emergent and a source of sediments of Kingak shale sediments)		(Probably present at great depth)	SOUTH BARROW TEST WELL NO. 3; 1,645'; 2,610'	STRUCTURAL CONFORMITY. About 4,500 feet thick at type locality in Canning River area; dark shale with siltstone interbeds and calcareous ironstone layers and concretions. Upper Jurassic section not shown in lithologic column in central Southern Foothills section; maximum of 1,500 feet; is shale, commonly varicolored with blocky fracture, sandstone, graywacke, varicolored bedded chert (or silicified tuff), breccia, and coquinoid (*Aucella*) limestone. Lower Jurassic in Simpson and Barrow wells is about 800 feet thick and is glauconitic sandstone and shale. Everywhere marine.		Jurassic rocks known in Canning River region, Nanushuk-Siksikpuk Rivers area, in subsurface in Barrow-Simpson and Topagoruk areas. In these areas marine fossils are largely cephalopods and pelecypods. Characteristic forms, in stratigraphic order: *Aucella bronni*, *Amoeboceras* sp., *Cosmoceras castor*, *Arctocephalites* cf. *A. kochi*, *Inoceramus lucifer*, *Pseudolioceras* sp., *Pentacrinus subangularis* var. *alaskana*, *Oxytoma* sp., *Amaltheus* sp., *Dactylioceras* spp., *Peronoceras* sp.	Outcrops sparsely fossiliferous, with a few species of *Ammodiscus*, *Ammobaculites*, and *Trochammina*. An abundant and diversified fauna occurs in wells of the Simpson-Barrow area, with numerous Lagenidae, such as *Astacolus*, *Frondicularia*, *Nodosaria*, *Dentalina*, *Marginulina*, and others in addition to the arenaceous forms.	Glauconite is common in sandstones. Prismatic tourmaline makes up over 50 percent of heavy-mineral suite; also present are muscovite, zircon, garnet, and hornblende. Tourmaline is olive green or brown. Garnet grains are etched, and hornblende grains are bleached along edges and cleavages.
TRIASSIC	UPPER TRIASSIC	SHUBLIK FORMATION	(Probably deposited across Brooks Range area but now eroded)		(Probably present at great depth)	SIMPSON TEST WELL NO. 1; 6,300'; 6,545'	STRUCTURAL CONFORMITY. 300 feet in central Southern Foothills; thicker in east and west parts but probably nowhere more than 1,000 feet. 250 feet or less in Simpson and Barrow wells. In outcrop is interbedded dense bituminous limestone, dark-gray chert, clay shale, oil shale, and siltstone. In Simpson and Barrow wells, fossiliferous limonite oolite, limestone, and glauconitic calcareous siltstone; entirely marine.		Marine fossils common, predominantly brachiopods, pelecypods, and cephalopods, including: *Monotis subcircularis*, *Halobia cordilleriana*, *Gryphea* cf. *G. capeba*, *Aviculopecten* sp., *Atractites* sp.; *Arcestes* sp., *Rhynchonella* sp.; *Lima* sp., *Terebratula* sp.; *Pecten* sp., *Spiriferina* sp.; *Avicula* sp.	Contains simple Foraminifera in the Sadlerochit River region and in Simpson Test Well No. 1, including minute *Gaudryina*, polymorphinids, and lagenids, such as *Astacolus*, *Nodosaria*, *Lingulina*, and *Pseudoglandulina*.	Glauconite is common in sandstones. Heavy-mineral suite is characterized by subround to round tourmaline grains. Tourmaline, olive green, mauve, and blue, makes up over 80 percent of heavy-mineral suite; remainder is ovoid zircon.
PERMIAN		SADLEROCHIT SANDSTONE		?	?		STRUCTURAL CONFORMITY. 300 to 600 feet thick. Found only in Canning River area. Largely marine. Mainly fine quartzitic sandstone. Thickens, coarsens, and becomes conglomeratic northward. Grades southward into black argillite and slate.		Marine invertebrate fossils scarce; predominantly brachiopods with a few pelecypods, gastropods, corals, and conodonts. May include some Pennsylvanian.		
CARBONIFEROUS	MISSISSIPPIAN	LISBURNE LIMESTONE	(Locally exposed or at relatively shallow depth in anticlines, anticlinoria, and hanging walls of reverse faults)	(Probably present at great depth)		(Paleozoic rocks are absent in the Simpson and Barrow test wells. The northernmost part of the Coastal Plain province and the inferred Paleozoic shield to the north probably were a source of clastic material in Paleozoic rocks exposed in the Brooks Range province. Seismic profiles indicate presence of Paleozoic rocks in the southern part of the coastal plain)	DISCONFORMITY(?). About 1,500 to 4,000 feet thick. Largely marine shell fragments, secondary dolomite and chert; lower member, coarse limestone and dolomite, and shaly argillaceous limestone; middle member, fine-grained cherty limestone, coarse limestone and dolomite; upper member, dark-gray shale, shaly limestone, bedded chert, and phosphatic limestone, intertongues with middle member.		Marine fossils common. Blastoids, crinoids, and zaphrentoid corals in lower 500 feet; brachiopods common in top of lower member. Lithostrotionoid corals, *Gigantella*, brachiopods, and gastropods in middle member; *Leiorhynchus*, *Moorefieldella*, *Goniatites*, and *Homoceras* in upper member.		
		NOATAK FORMATION	(Possibly present; not exposed)	(Possibly present at great depth)			PROBABLE CONFORMITY. More than 5,000 feet thick. Top 900 feet is black marine shale with ferruginous limestone at the top, argillaceous limestone 150 feet below the top, and 160 feet of ferruginous quartz sandstone at the base. Along north front of Brooks Range this lies disconformably on 1,000 feet of clay and silt shale with interbeds of quartzitic chert sandstone and conglomerate. Near Brooks Range divide 2,000 feet of black shale with some quartz-chert sandstone and boney coal intervenes between these two units. Remainder of section to bottom of formation is massive quartzitic chert-pebble and cobble conglomerate with interbeds of quartzitic chert sandstone near the base.		Marine fossils lacking in black shale but common in limestone. Brachiopods, Bryozoa, and blastoids, crinoids, trilobites, and fish fragments common in ferruginous limestone; poorly preserved plant fossils in shale and quartzose sandstone. Brachiopods in lowest 800 feet of the conglomerates, but no other marine invertebrates.		

EXPLANATION: Conglomerate; Sandstone; Quartzite; Silty shale; Clay shale; Bentonite; Tuff; Coal, boghead cannel; Phosphate rock; Oil shale; Coarse-grained bioclastic limestone; Fine-grained limestone, some beds bituminous; Bedded chert; Dolomite; Chert nodules and lenses in limestone; Limestone concretions and lenses; Ironstone concretions and lenses. Vertical scale in feet: 2,000; 1,500; 1,000; 500; 0.

FIGURE 2. — GENERALIZED COLUMNAR SECTION OF POST-DEVONIAN ROCKS OF THE ARCTIC SLOPE

GEOLOGY OF THE ARCTIC SLOPE OF ALASKA

by

Thomas G. Payne and others

1951

Drafted by Frances G. Kline

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