Geology of the Shaviovik and Sagavanirktok Rivers Region, Alaska

EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4 AND ADJACENT AREAS, NORTHERN ALASKA, 1944-53

PART 3, AREAL GEOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 303-D

Prepared and published at the request of and in cooperation with the U.S. Department of the Navy, Office of Naval Petroleum and Oil Shale Reserves

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By A. SAMUEL KELLER, ROBERT H. MORRIS, *and* ROBERT L. DETTERMAN

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GEOLOGY OF THE SHAVIOVIK AND SAGAVANIRKTOK RIVERS REGION, ALASKA

By A. Samuel Keller, Robert H. Morris, and Robert L. Detterman

ABSTRACT

An uninhabited 3,200-square-mile glaciated area on the north slope of the Brooks Range in Arctic Alaska was investigated in 1951 and 1952 as part of the exploration of Naval Petroleum Reserve No. 4 and adjacent areas. The purposes of the investigations were to correlate the rocks of Mesozoic and late Paleozoic age in the Arctic Foothills province from the Itkillik River east to the Canning River, and to determine the petroleum possibilities of that area.

Rocks of Mississippian to Tertiary age are present, with all systems represented except the Pennsylvanian. The rocks that crop out include the Mississippian Lisburne group, the Permian and Triassic Sadlerochit formation, the Triassic Shublik formation, the Jurassic Kingak and Tiglukpuk formations, the Cretaceous Okpikruak, Fortress Mountain, Torok, Tuktu, Chandler, Ninuluk, and Ignek formations, and the Tertiary Sagavanirktok formation. The Triassic and older rocks probably had a northerly source; the younger rocks, a southerly source. The sedimentary record indicates that there may have been eight separate transgressions and regressions of the sea in the area since Permian time.

The Lisburne group is a gray crystalline fossiliferous limestone that forms the north front of the Brooks Range. The sequence is at least 2,900 feet thick locally.

The Sadlerochit formation has been divided into two members, the Echooka and the Ivishak. The Echooka ranges in thickness from 300 to 600 feet, contains Permian fossils, and is typically more sandy and conglomeratic in the northern part of its outcrop belt. The Ivishak, which is also more coarsely clastic to the north, ranges in thickness from about 1,000 to 2,000 feet and contains ammonoids of Early Triassic age. The Sadlerochit formation is overlain with no apparent angularity by the Shublik formation which is composed principally of 200 to 300 feet of limy shale and limestone containing *Monotis* sp. and *Halobia* sp.

Two formations, one of Late Jurassic age and one of Early, Middle, and Late Jurassic age, have been mapped. The former, the Tiglukpuk, a coarsely clastic unit of variable thickness crops out along the southwestern part of the area. To the east and north, it intertongues with the upper part of the Kingak shale, a fossiliferous sequence locally 5,000 feet thick.

The facies of the older Cretaceous rocks, the Okpikruak, Fortress Mountain, and Torok formations, reflect the same general depositional trends as the Jurassic rocks. The Okpikruak formation in its southern outcrop belt comprises a variable thickness of rhythmically alternating beds of sandstone of graywacke type, conglomerate, siltstone, and shale. This coarse clastic sequence grades northward to a shale and siltstone rock unit characterized by *Aucella* sp. In the northeastern part of the area the Okpikruak formation contains a basal winnowed sand unit, the Kemik sandstone member. The Fortress Mountain formation, a sequence of unknown thickness composed of conglomerate, shale, siltstone, and sandstone of graywacke type, crops out in the southwestern part of the area where it overlies older rocks with erosional unconformity. It probably is correlative in part with, and in part older than, the Torok formation, a sparsely fossiliferous shale sequence of unknown thickness.

The Nanushuk group comprises three formations, the Tuktu, Chandler, and Ninuluk. The contacts between them presumably are gradational, and the rocks of this group reflect oscillations of the seas between Albian and Cenomanian time. The Tuktu is at least 800 feet thick and is composed of marine fossiliferous sandstone, siltstone, and shale; the Chandler is about 2,500 feet thick and is characterized by near-shore and nonmarine sandstone, conglomerate, shale, and coal. Several hundred feet of marine sandstone of the Ninuluk formation remains in the mapped area. The Nanushuk group crops out only in the western part of the area. To the east it has been correlated with the lower part of the Ignek formation.

The Ignek formation has been divided into two informal units, a lower member believed to be correlative at least in part with the Nanushuk group, and an upper member of Late Cretaceous age. In its outcrop belt, the lower member unconformably overlies the Okpikruak and Kingak formations and ranges in thickness from 2,590 feet to 1,000 feet. It locally contains fossiliferous sandstone but for the most part comprises deltaic and lagoonal deposits of carbonaceous and ferruginous sandstone, siltstone, and coaly lenses. Separated from the lower member presumably by an erosional unconformity, the upper member is at least 4,000 feet thick and contains in its lower part, in addition to the rock types found in the younger member, bedded tuffs and bentonite.

Tertiary rocks crop out only in the northeastern part of the mapped area and presumably overlie the upper member of the Ignek formation unconformably. These rocks, the Sagavanirktok formation, consist of more than 2,000 feet of near-shore and nonmarine porous and permeable sandstone and conglomerate, shale, and coal.

Only one intrusive mass is known in the area, a small mafic sill in the Mississippian limestone beds; its exact age is unknown.

Major deformation of the rocks in the area occurred during a Late Jurassic and Early Cretaceous orogeny and during

the Tertiary. Structurally the northeastern part of the mapped area is less complex than the southwestern, but both parts are characterized to some degree by high-angle reverse faults, minor thrust faults, and eastward-trending normally asymmetric anticlines with steeper north flanks. The mountain front is a series of en echelon folds in rocks of Paleozoic age. These folds plunge east and west beneath younger Mesozoic sedimentary rocks. The largest structure in the foothills part of the area is Shaviovik anticline, which is about 15 miles long and probably has about 1,100 feet of closure.

The rock units which contain potential petroleum reservoir beds are the Lisburne group, the Sadlerochit and Shublik formations, the Kemik sandstone member of the Okpikruak formation, the Tuktu, Chandler and Ninuluk formations, the lower and upper members of the Ignek formation, and the Sagavanirktok formation. Of these formations the Tuktu, Chandler, Ninuluk, and Sagavanirktok are not present at depth where conditions are favorable for drilling. Excluding structural considerations, all the other formations could be tested in the northeastern part of the mapped area; elsewhere, only the three oldest. Although the authors do not rule out the possibility of producing oil southwest of the Echooka River, they believe that the stratigraphy and geologic structure east of that drainage are more favorable.

INTRODUCTION

The Shaviovik and Sagavanirktok Rivers region is on the north slope of the Brooks Range in Arctic Alaska. The 3,200-square-mile area is bounded on the southeast by the Brooks Range and extends northeast from the Toolik to the Canning River. Studies were confined to a relatively narrow strip which ranges in width from 10 miles in the southwestern part of the mapped area to 30 miles in the northeastern part (fig. 26). The investigations were made during the summers of 1951 and 1952 as part of the work conducted by the U.S. Geological Survey from 1945 to 1953 in cooperation with the U.S. Department of the Navy, Office of Naval Petroleum and Oil Shale Reserves, in its exploration of Naval Petroleum Reserve No. 4 and contiguous areas.

ACCESSIBILITY AND TERRANE

The mapped area (pl. 21) is an uninhabited, for the most part treeless, tundra-covered, permafrost region readily accessible only by plane. Willows grow extensively along the major water courses and small groves of poplar trees are present locally along the Shaviovik and Sagavanirktok River tributaries. All major rivers in the area are navigable by boat from early June until late October. None of the streams have impassable rapids, although the incised Sagavanirktok River is difficult to navigate where it flows through an end moraine a short distance upstream from its junction with the Ribdon River. Navigation of the smaller streams depends largely on local river

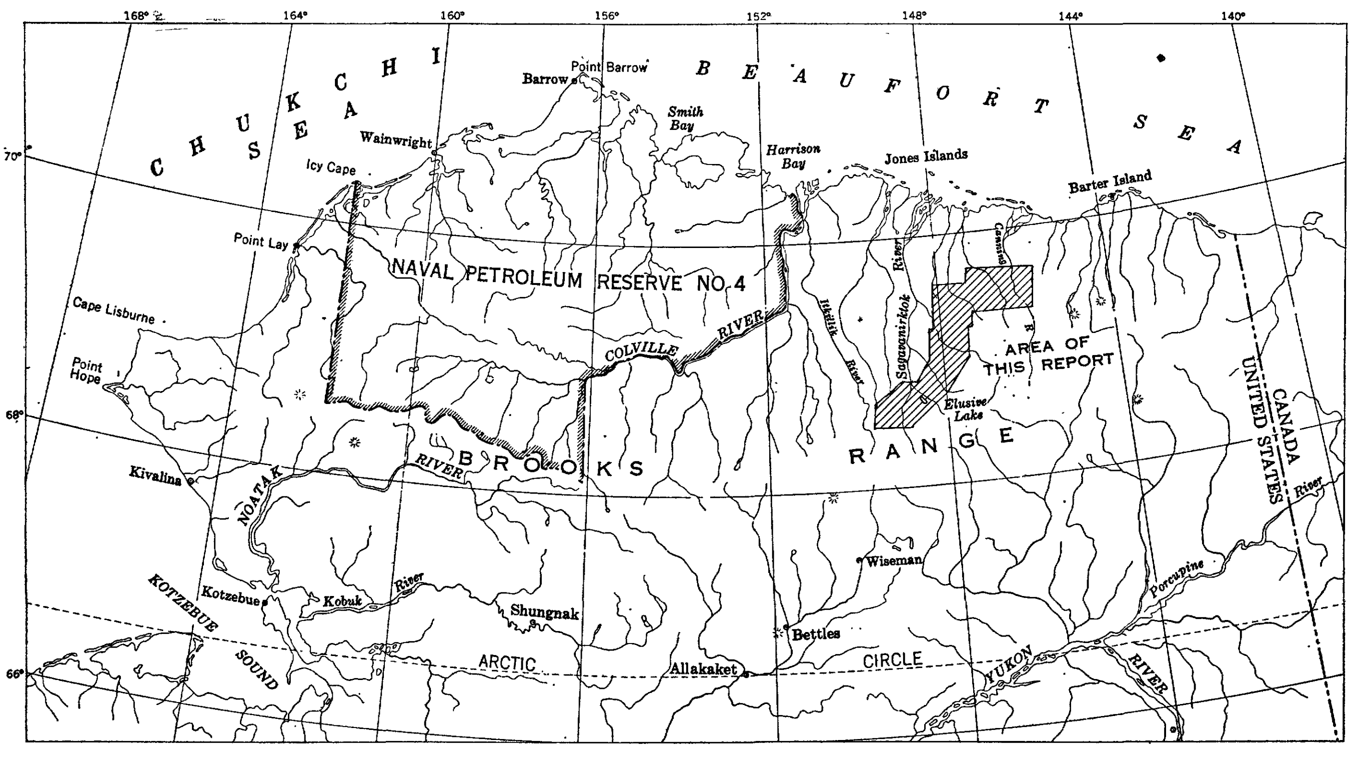

FIGURE 26.—Index map of northern Alaska showing Naval Petroleum Reserve No. 4 and area of report.

conditions at a given time. During the spring breakup, water in the Shaviovik River and in tributary streams such as Gilead Creek, Lupine, Echooka, and Kavik Rivers is sufficient to permit use of small craft, but after the flood waters subside these tributary streams are intermittent.

CLIMATE

The summer weather of the north slope of the Brooks Range is affected by local geographic conditions, and the weather records kept at Umiat, the closest source of year-round data, are not entirely applicable to the area mapped. From approximately May 20 until July 20, the sun remains above the horizon, and the long days coupled with generally fair weather afford good working conditions for about 3 months. The length of the working season is dependent partly on snow conditions in the early spring and late summer. As a rule, enough snow has melted by the last week in May to permit operations, and it is generally the last week in August or the first week in September before the snow and cold hamper activities.

Table 1 is a chart of weather data compiled by the authors for the period May 24, 1951, to August 24, 1951, for the Sagavanirktok River area. Records were kept only during a daily 12-hour period. Temperatures were recorded from thermometers not afforded the protection of a standard instrument shelter, so these readings are probably high. The amount of precipitation and the force of the wind were estimated.

As indicated by the table, the best weather may be expected in May and June, the worst in July and August. Snow may fall during any month; rain is predominant during the summer. Thunderstorms, although not usually common in Arctic regions, occur in June and July and are often accompanied by hail. The strongest and prevailing winds are from the northwest. Ground fog is common to the stream valleys during the breakup of the river ice and occurs more rarely during the summer months. During the 1951 working season 17 days were lost owing to inclement weather; during the 1952 field season, 19 days.

PREVIOUS WORK

The first published report on the area is by Leffingwell (1919), who investigated the Canning River region during the years 1906–15. Leffingwell established the nomenclature for some of the Paleozoic and Mesozoic rocks on the north slope of the eastern part of the Brooks Range, and the authors have retained these names in modified form.

Parts of the area were studied later by the U.S. Geological Survey in connection with exploration by the Office of Naval Petroleum and Oil Shale Reserves. In 1946 George Gryc and Ernest H. Lathram studied the rocks on the upper Sagavanirktok River, and during the same year Gryc investigated outcrops on the upper part of the Ivishak River. In 1947 Gryc and Marvin D. Mangus made reconnaissance and semidetailed studies of the sedimentary rocks along parts of the Shaviovik drainage and Canning River. In 1950 Gryc, Ralph W. Imlay, and Allen N. Kover restudied the outcrops on the Canning River.

PRESENT INVESTIGATION

The present studies were made during the field seasons of 1951 and 1952 as an adjunct to the work done between 1946 and 1950. The primary objective in the investigation of the Shaviovik and Sagavanirktok Rivers region was to map the rocks of the Mesozoic and late Paleozoic age in the Arctic Foothills province from the Itkillik River east to the Canning River. A secondary objective was to define the cause

TABLE 1.—*Weather data in Sagavanirktok River area, Alaska, 9:00 a. m.–9:00 p. m., May 24—Aug. 24, 1951*

Sky condition: ○, clear sky; ⦶, less than 50 percent cloud cover; ⦷, more than 50 percent but less than 100 percent cloud cover; ⊕, 100 percent cloud cover.

Ceiling: −20, ceiling less than 2,000 ft; +20, ceiling more than 2,000 ft but less than 10,000 ft; unl., ceiling more than 10,000 ft.
Precipitation (amount estimated): S, snow; R-L, rain or drizzle.

Month	Observations	Sky condition (percentage of observations)				Ceiling (percentage of observations)			Precipitation			Temperature (°F)			Wind										
									Occurrence		Amount (inches)				Velocity (mph)		Direction (percentage of observations)								
		○	⦶	⦷	⊕	−20	+20	unl.	S	R-L		Avg.	Maximum	Minimum	Avg.	Maximum	Calm	N.	NE.	E.	SE.	S.	SW.	W.	NW.
May	41	49	15	19	18	15	5	80	5	0	Tr.	46	68	22	5.8	18	24	7	24	0	2	0	2	5	34
June	139	14	28	32	28	19	31	50	4	14	1.0	53	92	32	8.5	30	5	13	25	2	4	2	15	17	17
July	143	4	19	31	46	18	46	36	0	25	1.9	62	92	38	5.0	15	25	20	6	I	3	7	8	6	23
August	114	2	15	37	45	25	46	28	4	18	.6	54	90	32	8.2	30	13	23	4	0	11	16	13	4	17
Total	437										3.5														
Average		17	19	30	34	19	32	48	3	14		54			6.9		17	16	15	1	5	6	10	8	23

of the pronounced northeasterly swing in the trend of the Brooks Range front and to determine the structural implications of this swing. The objectives also included isolating areas for more detailed geologic studies, and contour mapping of structures that could be drilled for oil.

The 1951 field party consisted of 6 men: A. S. Keller, party chief; R. L. Detterman, geologist; I. W. Marine and D. E. Reed, field assistants; L. G. Barbin, cook and field assistant; and T. F. Derrington, mechanic. Work began on the Echooka River on May 24, 1951, and the season ended on the Toolik River on August 24, 1951. The 1952 field party also consisted of 6 men: A. S. Keller, party chief; R. H. Morris, geologist; John Downs and H. G. Richards, field assistants; L. G. Barbin, cook and field assistant; and T. F. Derrington, mechanic. Because of deep snow, work began on the Echooka River relatively late, on June 9, 1952. Early snow ended the investigations on August 22, 1952, on the Shaviovik River.

Because of the remoteness of the area, exploratory methods were somewhat different from those generally employed. In April and early May of each year, eight food caches were placed at predesignated locations. In addition to the food, which was sealed in 55-gallon drums, blazo, kerosene, gasoline, and motor oil were distributed along the proposed route of travel. Three amphibious tracked vehicles (weasels), to be used by the party for its movements during the summer, were driven to the initial field station, Rodnoc Lake, prior to the breakup of the ice in the major rivers. The geologic party was flown to the initial field station by ski-equipped Norseman plane. Fifteen field camps were established during each year. At the close of the 1951 field season the weasels were driven to Umiat, and at the end of the 1952 field season they were cached for future use at a large lake on the divide between the Kadleroshilik and Sagavanirktok Rivers.

The area was mapped at a scale of 1:20,000 on vertical aerial photographs made by the Navy; the data were transferred to 1:96,000-scale planimetric maps compiled from trimetrogon photographs. Areal maps were then reduced to a scale of 1:125,000. The authors also used 1:20,000-scale vertical aerial photographs as horizontal control for structure-contour maps. Altitudes were determined by altimeter traverse and referred to approximate sea level datum. The use of the vertical photographs facilitated mapping, and permitted the mapping of larger areas than would otherwise be possible in the limited time available during the normal field season.

ACKNOWLEDGMENTS

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PHYSIOGRAPHY

TOPOGRAPHY

Northern Alaska has been subdivided into three physiographic provinces (Payne and others, 1951): the Brooks Range province, a belt of mountains that trend east across northern Alaska; the Arctic Foothills province, a belt of hills that lie north of the Brooks Range province; and the Arctic Coastal Plain province, an area of low relief with numerous lakes and bogs. The area mapped lies for the most part within the Arctic Foothills province, although the northern part of the Brooks Range is its southeast and east boundary.

From the southwest edge of the mapped area the mountain front trends northeast to Kemik Creek. From Kemik Creek it trends almost due east to the Canning River and there, on the east side, heads due north. Along the entire front, the range is characterized by a series of en echelon plunging anticlines which control its configuration. The mountain peaks are higher than 6,000 feet and relief ranges from 2,000 to 3,000 feet. The crest lines are formed by intersecting cirques, arêtes, horns, and irregular ridges. Typically the range is composed of rocks of Paleozoic age except in one area between the Ribdon and Sagavanirktok Rivers where coarse clastic rocks of Mesozoic age form the mountain front.

Within the mountain area the typically broad and U-shaped river valleys are filled with alluvium that extends from the edges of the rivers to the valley slopes and there merges with alluvial fan and cone deposits. Along the larger rivers that supported glaciers, hanging valleys are common; scour marks on the main valley slopes indicate the path and upper limit of the ice advance.

The change from mountains to foothills generally is abrupt in most of the mapped area because of the difference in resistance to weathering of the rocks of

Paleozoic age that, for the most part, form the mountains, and the rocks of Mesozoic and Cenozoic age that form the foothills. North of the mountain front, except locally for mesas, cuestas, and hogbacks underlain by resistant sandstone, siltstone, and conglomerate, the landform consists of gentle slopes, low terraces, and lowlands covered with glacial debris. Some of the mesas are higher than 3,000 feet with as much as 2,000 feet of relief, but elsewhere the hills rarely are higher than 2,500 feet and in the northeastern part of the mapped area relief is less than 1,000 feet. In the lowlands, moraines, till, and outwash gravel cap the landforms, and glacial lakes dot the area. Both in the mountains and in the lowlands, Quaternary gravels fill the main river valleys, but terraces are more extensive in the lowlands and locally as many as three levels are distinguishable. On many of the rivers the lowest terrace level is characterized by oxbow lakes, cutoff meanders, and abandoned channel scars. Much of the area is marked with polygonal ground, pingos, mud slumps, and other permafrost features.

DRAINAGE

The mapped area is drained by three major river systems, the Canning, the Shaviovik, and the Sagavanirktok. Of these, the Sagavanirktok and its tributaries drain about one half of the area. These rivers head in relict cirques, snow fields, and small glaciers of the Brooks Range; they flow northward and empty into the Arctic Ocean. Glacial scour marks which are present only part way up the valley slopes, indicate that the larger rivers predate the Pleistocene and that their courses were probably carved in a late Tertiary surface. The main river channels follow antecedent courses, although locally their tributaries are structurally controlled. During the Pleistocene the river valleys probably were enlarged and straightened; after recession of the ice, moraine and outwash deposits covered the valley floors with various thicknesses of gravel. This reworked gravel veneer forms the floor on which some of the rivers flow, although in many of the stream beds the gravel layer is thin and the water flows directly on bedrock. All the streams in the mapped area can be waded during normal runoff, but fording localities on the larger Canning and Sagavanirktok Rivers are limited mostly to the area close to the mountain front. On many of the rivers the flood-plain areas are locally wider than 4,000 feet, and these areas are crossed by many small streams which interconnect to form a braided pattern. Periodically during flood stages new channels are formed, and when the water recedes the new braided pattern is so different that the entire aspect of the river is changed. Between the channels in the larger braided areas many smooth gravel bars as much as 500 feet long are exposed during low water, and these serve as excellent landing fields for small wheeled aircraft. Ice fields are present on many of the larger braided areas; the smaller fields disappear each year, but remnants of some of the larger ones persist throughout the summer and become incorporated in the ice of the season following. The largest of these fields are on the Canning, Echooka, Ivishak, and Ribdon Rivers. At the junction of the Saviukviayak and Ivishak Rivers the ice field is about 12 miles long, and the ice 15 to 20 feet thick.

The gradients of the rivers are controlled by bedrock structure, differences in resistance of the rocks, and glacial deposits. The longitudinal profiles, which generally are steep in the valley heads, flatten and remain relatively smooth through the mountains; from the foothills northward through the coastal plain there is a gradual decrease in gradient. Now that the glacial gravels have been redistributed, rivers such as the Canning and the Ivishak flow more nearly at grade than do the unglaciated or postglacial streams.

Most of the lakes in the area are glacial in origin; many are shallow or filled or partly encroached by tundra. The largest lakes, whose beds were probably scoured by ice during a part of the Pleistocene, are Elusive Lake and Rodnoc Lake. The latter is on the east side of the Echooka River and is about 3,400 feet long and 2,000 feet wide. The former is on the west side of Ribdon River and is about 2 miles long and 4,000 feet wide. The depths of the two lakes are not known, but both are large enough for float planes to land. Other lakes that can be used for float-plane landings are on the west side of the Ivishak River north of the junction with the Saviukviayak River, and on the west side of the Sagavanirktok River in the southwest part of the mapped area. These, however, are too small to support landings by float planes other than the smaller types.

At the west end of the Shublik Mountains on the east side of the Canning River, springs of meteoric origin flow from orifices in the talus-covered hillsides about 400 feet above the river level. As nearly as can be ascertained, the water flows from an aquifer either in the lower part of the Sadlerochit formation or at the contact of this formation with the Lisburne group. Leffingwell (1919, p. 59) reported that during June of one year the temperature of the water at Shublik Springs was 43° F, and that the springs flow year round.

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GLACIAL HISTORY

Four Quaternary glacial advances on the north slope of the Brooks Range have been differentiated. These are, from oldest to youngest: the Anaktuvuk, Sagavanirktok, Itkillik, and Echooka glaciations (Detterman, 1953, p. 11–12). Only the three youngest advances have been recognized in the mapped area, and they have been tentatively assigned a pre-Wisconsin, early Wisconsin, and late Wisconsin age by Péwé and others (1953, p. 13). The distribution of the gravels of these advances is shown on plate 22.

The individual glaciers apparently originated in valley heads in the Philip Smith Mountains, increased in size, moved downstream, and eventually merged to form major trunk valley glaciers. During the maximum development of the glaciers the highest mountains remained above the ice. Tributary glaciers eroding headward locally cut passes between major stream valleys which subsequently became diversion channels through which ice from one valley system merged with that of the adjacent system. The ice spread out in broad lobes as the glaciers moved from the confining mountain valleys to the open foothills, and the lowlands between some of the major streams were covered as ice lobes coalesced. The end result of the glaciation is a fretted mountain region characterized by arêtes, cols, and cirques. Valleys were straightened, scoured, and broadened, and gravel was deposited extensively in the Arctic foothills province.

The individual glacial features of the region were interpreted mostly from a study of vertical aerial photographs and, to a lesser extent, from observations made by the authors while in the area. The most important of the various criteria used for differentiating and correlating the three ice advances are: the superposition and configuration of the moraines, the extent of tundra encroachment on glacial lakes, the relative degree to which streams have been integrated in the various morainal areas, and the topographic expression of knob and kettle topography in the end-moraine zones.

SAGAVANIRKTOK GLACIATION

Detterman (1953, p. 11) stated that the "Sagavanirktok glaciation is named for morainal remnants that cover an area of 230 square miles along the Sagavanirktok River, 60 miles east of the Anaktuvuk." Till of this advance extends about 18 miles north of the mountain front on the Echooka and Ivishak Rivers and about 30 miles north of the mountain front on the Sagavanirktok River.

On the Echooka River, the ice from the Sagavanirktok advance upon emerging from the mountains, spread out as a piedmont lobe and spilled over the low divide between the Echooka River and Gilead Creek. The terminal moraines are locally preserved as a belt of low ridges which trend across the valley flat of the river. The east and west lateral moraines are less well preserved. Many of the kettle lakes in the end-moraine zone have been filled or drained, and most of the lake outlets have been integrated with present streams. Over some of the area, moraines of this advance are partly covered by outwash of more recent glacial advances.

On the west side of the Ivishak River, the lateral moraine of the Sagavanirktok glaciation is moderately well preserved and the low hummocky ridges can be traced almost continuously for 10 miles. The end moraine is poorly preserved, and the typical knob and kettle topography of the end moraine zone has been much eroded. A tributary stream of the Ivishak River flows along the outer limit of the lateral moraine; together with its tributaries it has dissected the morainal ridges.

Till of the Sagavanirktok advance also extends almost unbroken from the east side of the Lupine River to the west side of the Sagavanirktok River. The present distribution of the gravel defines a piedmont lobe formed by the coalescing Lupine River, Ribdon River, and Sagavanirktok River valley glaciers. Lakes, gravel mounds, low hummocky hills, and swamps typify the ground-moraine area. The lakes have been reduced in size by encroaching tundra and are integrated with the drainage pattern. Within this piedmont lobe discontinuous lateral moraines are developed best on the west side of the Sagavanirktok River valley from a point opposite its junction with the Lupine River to west of the Ribdon River junction. End moraines have been partly reworked and incorporated in the outwash gravels.

ITKILLIK GLACIATION

The Itkillik ice advance was named by Detterman (1953, p. 11) for the river approximately 20 miles west of the Sagavanirktok. The general features of this glaciation in the Sagavanirktok and Shaviovik Rivers region are described by Detterman in his report on the Sagavanirktok-Anaktuvuk Rivers region. He stated that:

> * * * Till of the Itkillik glaciation covers approximately 1,000 square miles, and the drift forms fan-shaped deposits at the mouths of major valleys. The greatest extent of this glaciation was about 20 miles north of the maximum advance of the next glaciation. Over much of the area the till forms a mantle, 30 to 50 feet thick, over bedrock. A few well-developed moraines are as much as 200 feet thick. Terminal and lateral moraines are easily recognized, as well as the knob

and kettle topography. Glacial features have been less modified by weathering than have the earlier * * * Sagavanirktok deposits. Numerous kettle lakes, a few tens of feet to half a mile in length, occur on the moraines. Relatively few have been filled or drained. Lakes up to several miles in length are enclosed behind the moraines in many of the stream valleys at the front of the range.

Till of the Itkillik glaciation is thickest in isolated belts on the Echooka and Ivishak Rivers and in an almost continuous piedmont lobe which extends from the east side of the Ribdon River to the west edge of the mapped area. In all localities, the generally undissected ground- and end-moraine areas are characterized by numerous kettle and moraine-dammed lakes, some of which are partly encroached by tundra. On the Echooka River, both the east and the west lateral moraines are well-defined belts of moderately high ridges. The upper limit of the west lateral moraine does not quite reach the crest of the Echooka River-Gilead Creek divide, nor does the east lateral moraine reach the crest of the Echooka-Shaviovik divide. On the west side of the Ivishak River, till of the Itkillik glaciation constitutes a belt about 2 miles wide, which extends approximately 15 miles north of the mountain front. An almost continuous series of generally undissected gravel ridges and knobs forms the lateral and end moraines. In the southwestern part of the mapped area a piedmont lobe was formed during this glaciation by coalescing valley glaciers which emerged from the mountains along Ribdon River, Accomplishment Creek, and the Sagavanirktok River. This glacial belt is well defined by the moraines which, controlled by the preglacial topography, curve downstream from the mountain front. Erratics, probably dating from the Itkillik glaciation, are present on both the east and the west side of the Sagavanirktok River at altitudes greater than 3,000 feet.

ECHOOKA GLACIATION

The Echooka glaciation was named by Detterman (1953, p. 12) for the Echooka River, the most easterly tributary of the Sagavanirktok River, and is the last recognizable major ice advance in the region. Till of this advance does not quite extend to the north front of the Brooks Range on tributary streams of the Shaviovik and Sagavanirktok Rivers; in all localities it represents deposits of independent valley glaciers.

The glacial features of the Echooka advance are most conspicuous on the east side of Ribdon River and on Accomplishment Creek. In the former area, end moraines enclose Elusive Lake. In the latter, knob and kettle topography in the end-moraine zone is relatively fresh. The end moraine is a prominent gravel ridge which curves downstream from the valley walls and which is breached only in the central part. Upstream from the end moraine, the lateral and ground moraines are well defined, as are kame terraces along the scoured valley walls.

UNDIFFERENTIATED GLACIAL DEPOSITS

Glacial deposits in two areas, the east sides of the Ivishak and the Canning Rivers, were mapped as undifferentiated units (pl. 22). In the former area the deposits are sparse and there are few criteria for correlation. The gravel, however, may represent till of both the Sagavanirktok and Itkillik glaciations. The moraine along the Canning River valley appears to represent only one major advance. The glacial features are more similar to those of the earlier Sagavanirktok than to those of the Itkillik glaciation. Lacking enough criteria for correlation, however, the authors mapped the deposits as an undifferentiated belt.

The glacier, till from which covers the Canning River valley, was supplied by numerous tributaries in the mountain headlands. On emerging from the mountains, it spread out westward to the Canning-Kavik Rivers divide and eastward into tributary valleys. Owing to preglacial topography, most moraine deposits are on the west valley slope of the Canning River. The west lateral moraine is well preserved in a series of linear ridges and benches extending about 25 miles north of the mountain front. West of the junction of Cache Creek and the Canning River, the moraine is about 2,000 feet above the river level. The uppermost lateral ridges, which are composed of silt- to cobble-size particles with erratics as much as 4 feet in diameter, are superimposed on a pediment(?) gravel surface. A moderately well defined end moraine forms an arc from the crest of the Canning-Kavik divide down to the valley floor and crosses the Canning River about 8 miles north of the junction of Ignek Creek. Kettle lakes in the moraine areas have been partly filled by encroaching swamp; most have been integrated with the drainage pattern.

STRATIGRAPHY

Geologic studies in the Shaviovik and Sagavanirktok Rivers region included examination of the Mississippian Lisburne group, the Permian and Triassic Sadlerochit formation, the Triassic Shublik formation, the Jurassic Tiglukpuk and Kingak formations, the Cretaceous Okpikruak, Fortress Mountain, Torok, Tuktu, Chandler, Ninuluk, and Ignek formations, and the Tertiary Sagavanirktok formation (fig. 27). Owing to the limited time available for the field studies, the rock units were examined only in semidetailed fash-

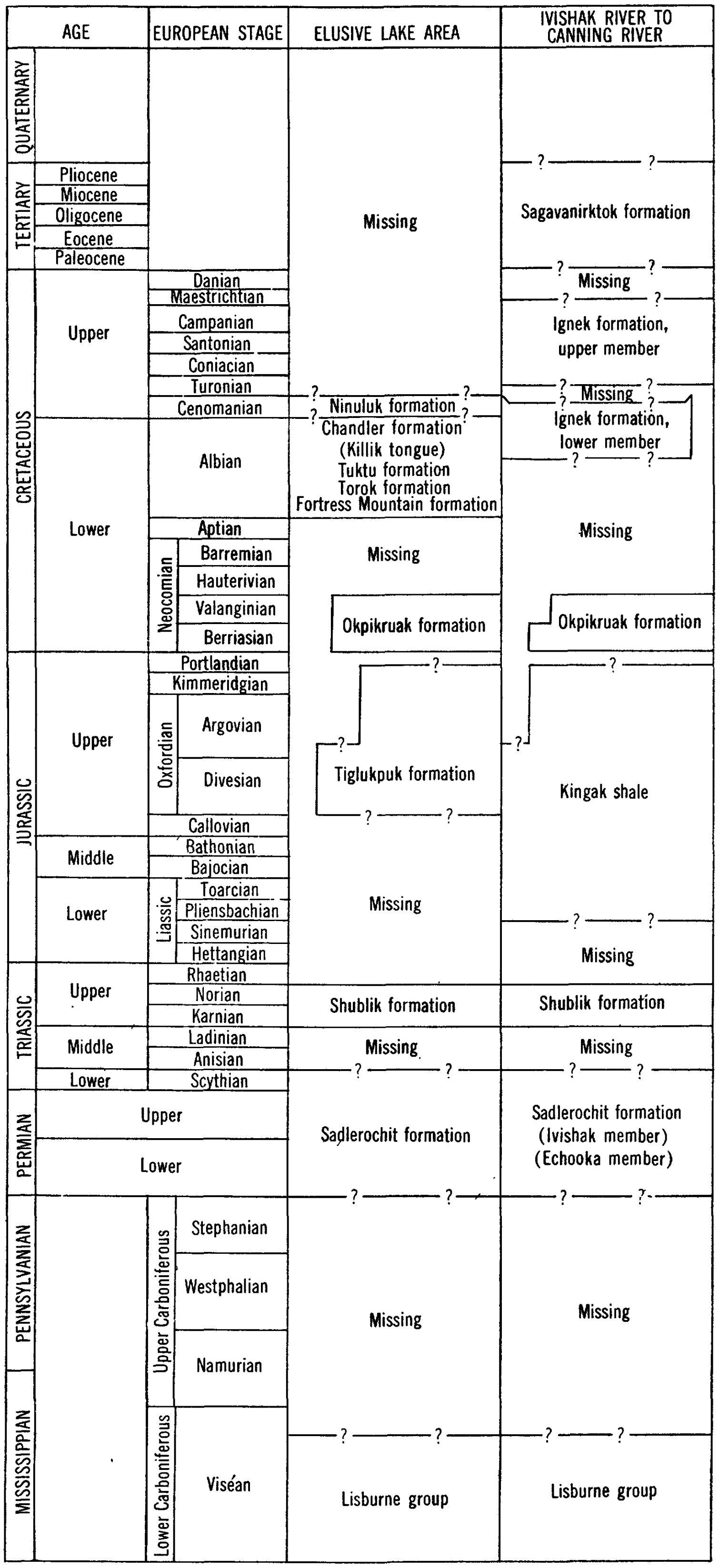

Figure 27.—Correlation of stratigraphic units in the Shaviovik and Sagavanirktok Rivers region, Alaska.

ion; the Lisburne group was studied briefly. The generalized measured sections of the rock units are correlated on plate 23.

MISSISSIPPIAN SYSTEM

LISBURNE GROUP

History and age.—The Mississippian rocks were originally named the Lisburne formation by Schrader (1904, p. 62) "to designate the limestone, with some shale, occurring next above the Stuver series at the head of Anaktuvuk River." Schader (p. 62–63) stated that the name was "taken from Cape Lisburne, where apparently the same formation, consisting of limestone and shale, occurs." Smith and Mertie (1930, p. 168–169) used the name Lisburne limestone for the formation and noted that in general it "crops out in one or more belts, from 1 to 20 miles in width, extending from the Arctic Ocean in a general easterly direction to the Anaktuvuk River and thence into the Canning River region and eastward to the international boundary." Bowsher and Dutro (1957) raised the Lisburne to group status and divided the group into two formations, the Wachsmuth limestone (the lower part) and the Alapah limestone (the upper part). In the earlier work of Schader (1904, p. 62) the rocks were considered to be Devonian in age. George H. Girty's critical study of the earlier collections and his examination of the fossils collected in the Cape Lisburne locality by Collier (1906) resulted in the assignment of a Mississippian age for the rocks of this group.

The Lisburne was studied only briefly by the authors, and therefore no breakdown of the group into formations was attempted.

Distribution and lithology.—The resistant limestone of the Lisburne group forms the north front of the Brooks Range and is the major rock unit constituting the folded and faulted mountain system. Owing to its occurrence in mountainous peaks and its distinctive light-gray color, this rock unit is the one most easily recognized in the Shaviovik and Sagavanirktok Rivers region. Over most of the area the Lisburne group underlies the younger Sadlerochit formation disconformably, although locally the older rocks abut the younger in high-angle reverse-fault relationship; the contact of the group with older rocks is not exposed in the mapped area.

In general, the Mississippian rocks consist of crystalline and hydroclastic limestone which locally is oolitic and lithographic. The limestone is normally thin bedded, although more massive in the lower part of the unit. The massively bedded limestone is generally lighter in color than the somewhat siliceous blue-gray thin-bedded variety. Chert lenses and nodules are common throughout the unit. The entire sequence of rocks in the Lisburne group has a strong organic odor and is generally abundantly fossiliferous.

No complete sections of the Mississippian rocks were measured by the authors. In the south-central part of the area on Flood Creek, the upper 2,900 feet of the group is preserved along the north limb of an anticline, but its base is not exposed. The lower part of the section is composed of fine- to medium-crystalline limestone, in beds as much as 15 feet thick, and thinner interbeds of dark-gray limestone. Higher in the section the rocks are less massively bedded, more coarsely crystalline, and darker in color. An 80-foot unit of tan crinoidal limestone is near the middle of the section. Fossils are relatively scarce and include crinoid stems, brachiopods of productid and *Spirifer* type, and corals.

PERMIAN AND TRIASSIC SYSTEMS

SADLEROCHIT FORMATION

History.—The Sadlerochit formation was first mapped by Leffingwell in the general area of the Sadlerochit Mountains. He (1919, p. 113) applied the name "Sadlerochit sandstone" to a sequence of rocks "consisting of about 300 feet of light sandstone or dark quartzite * * * [which] overlies the Lisburne limestone with conformable contact and underlies the Shublik formation with unknown contact but with parallel bedding." It is not entirely clear where the type locality of the Sadlerochit sandstone was intended, but presumably Leffingwell had in mind the south side of the Sadlerochit Mountains. The rock unit was originally assigned a Pennsylvanian age (Leffingwell, 1919, p. 114–115), but with additional work G. H. Girty became convinced that it was "more properly to be regarded as belonging to the Permian." (Smith, 1939, p. 32).

The rocks which lie stratigraphically between the Lisburne group and the Shublik formation in the Canning River area and elsewhere in the area mapped by the authors include siltstone, shale, limestone, and chert, in addition to sandstone. It is more consistent with present terminology, therefore, to designate the unit the Sadlerochit formation rather than the Sadlerochit sandstone. The succession defined above is thicker than Leffingwell's measurement of 300 feet; it includes rocks of two ages: Permian, in the lower part, and Early Triassic, in the upper. Moreover, the two age units differ in lithologic characteristics. It appears that Leffingwell mapped the same rock sequence as did the authors, but his description of the formation, thickness, and fossil suites applies in general only to the lower part.

The authors divided the formation into two members which are here named the Echooka member of Permian age and the Ivishak member of Early Triassic age. The type locality for the former is on the upper part of Kemik Creek (see p. 181); the type locality for the latter is on Flood Creek (see p. 182). The Ivishak member rests on the Echooka member with no apparent angularity and underlies the Shublik formation disconformably. Because of the reconnaissance nature of the field studies, the members are shown only locally on the geologic map; on other illustrations the formation is mapped as an undifferentiated unit.

Distribution.—The Sadlerochit formation is well exposed and is one of the most persistent units within the mapped area. It crops out in a belt 1 to 3 miles wide extending in a northeasterly direction along the north front of the Brooks Range. Typically the rocks are the flanking beds of the east- and west-plunging en echelon anticlines which form the mountain front, and generally are exposed best in cutbanks on the smaller streams. In the areas between major streams, where anticlines in the Mississippian limestone have been dissected, the resistant brown-weathering rocks of the Echooka member form north-dipping triangular-shaped wedges on the limbs of the structures and locally are present as erosional remnants on the crests. In similar fashion, the resistant brown-weathering rocks of the upper part of the Ivishak member typically form discontinuous cuestas which trace a sinuous course parallel to the belt of north-dipping sedimentary rocks of the Range front; and locally they are preserved also as mesas in the axial parts of the synclines.

Echooka member.—In the mapped area the Echooka member ranges in thickness from about 300 to about 600 feet. Whether this range is due to thinning during deposition or to erosion is not readily determinable on the basis of the available data. The member varies in facies from one part of the area to another; these changes are shown in part on figure 28. In the northern Canning River area (section *D*, fig. 28), it is typically sandy to conglomeratic and locally contains fossiliferous limestone. From the Canning to the Echooka River it characteristically consists of massively bedded dense cherty siltstone that is dark blue gray and locally limonite spotted. Subvitreous gray-green to black chert and light-gray quartzite are interbedded with the siltstone, and fossiliferous limestone lenses are present locally. Examined in thin section the chert is composed of randomly oriented sponge spicules and detrital grains widely spaced in a groundmass of silica. The only nonopaque accessory mineral is olive-green tourmaline; small irregular grains of magnetite and leucoxene are scattered throughout the rock. The siltstone is composed predominantly of subangular quartz grains, which constitute as much as 80 percent of the rock in some samples, and chert fragments. The quartz grains have serrate edges showing some replacement by silica cement, have a subquadrille fracture pattern, are well sorted, and average 0.15 mm in size. The tourmaline grains are rounded. Minute specks of limonite are scattered throughout the rock or are present as stringers filling fracture veins.

In the area of Flood Creek (section *A*, fig. 28) the Echooka member consists of blue-gray limy brown-weathering siltstone, gray limy shale, and blue-gray limestone. Fossils are more abundant at this locality but constitute the same suite that is found in the sections to the northeast. No sections of the member were measured in any detail southwest of Flood Creek. However, the rocks of the Sadlerochit formation that immediately overlie the Lisburne group southwest of Flood Creek are more like the rocks of the Flood Creek section than they are like those of the sections farther northeast. The general facies trends shown on figure 28 indicate that the Echooka member was deposited from a northerly or northeasterly source.

Ivishak member.—The Ivishak member ranges in thickness from about 1,000 to 2,000 feet. Near Eagle Creek (section *D*, fig. 28) the rock unit contains more sandstone than elsewhere in the area. Excepting this and minor variations, the rocks of the member are nearly the same at one locality as they are at another. The member typically consists of two parts: a lower nonresistant shale and minor siltstone unit and an upper resistant siltstone, shale, and sandstone unit.

Limy disk-shaped concretions ranging in diameter from several inches to several feet are present locally in the lower part of the Ivishak member and contain Early Triassic ammonites and pelecypods. The fossils are somewhat more abundant in the sections near the Ivishak River but were found in most sections throughout the mapped area. The upper part of the Ivishak member consists of an alternation of dense siliceous laminated siltstone, shaly siltstone, and minor sandstone. The siltstone weathers brown and is locally massive with blocky fracture, although more commonly it is thin bedded; when seen in isolated exposures it cannot always be distinguished from some of the massive siltstone of the Echooka member. The similarity between the siltstone of the two members is also apparent in thin sections. For example, a sample collected from the upper part of the Ivishak

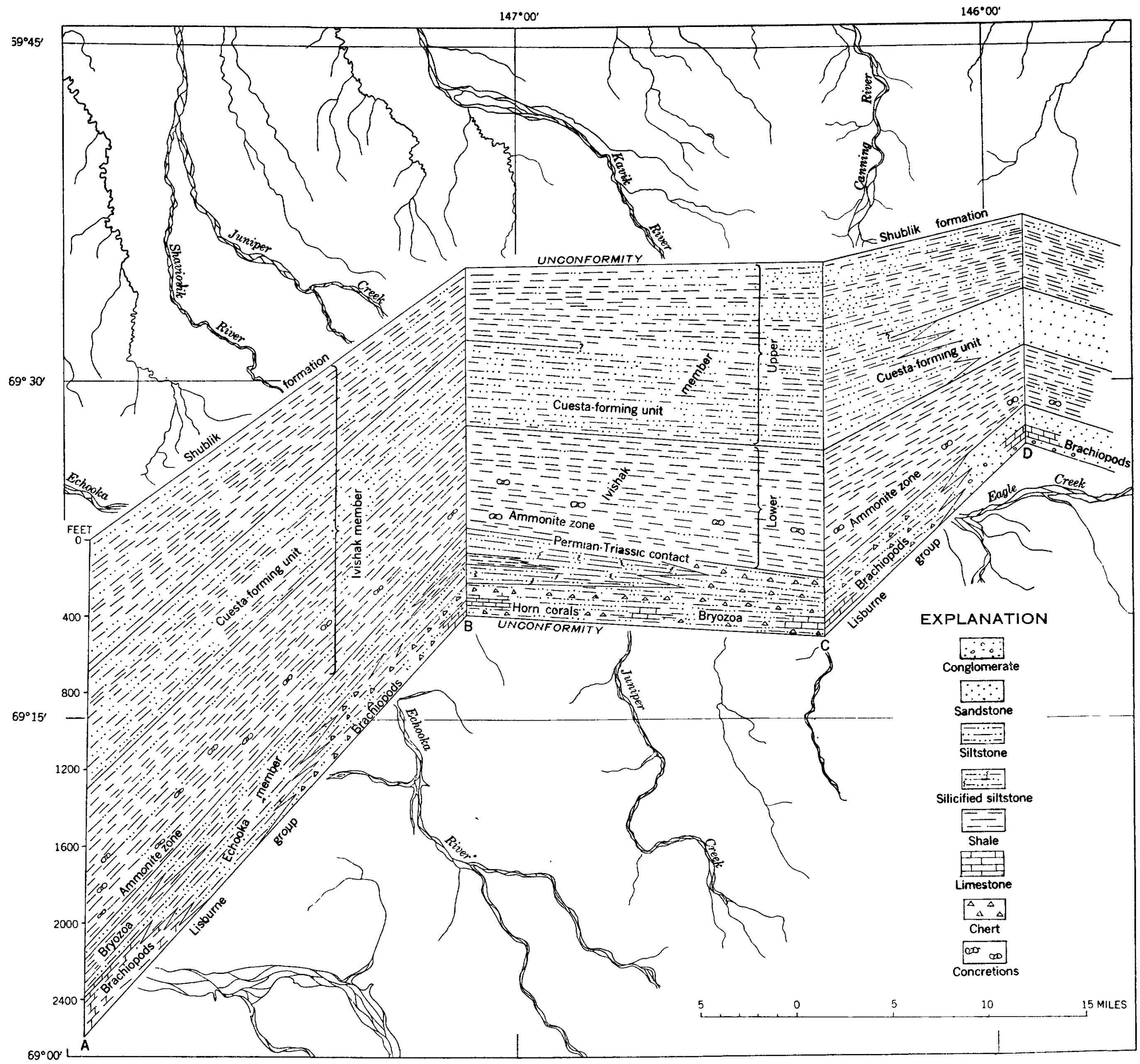

FIGURE 28.—Generalized fence diagram of the Sadlerochit formation.

member is composed of about 82 percent subangular quartz grains, 13 percent chert fragments, and small amounts of plagioclase, calcite, and leucoxene. The similarity between the siltstone of the two members and the general facies trends shown on figure 28 indicate that the source area for both members was the same.

Measured sections.—Seven stratigraphic sections of the Sadlerochit formation were measured in semidetailed fashion in the mapped area, and these are illustrated on plate 23. Locations of the sections are shown on plate 21.

The incomplete Canning River section (section 20) was measured along an incised stream approximately 1½ miles east of the Canning River at lat 69°26′ N., and long 146°02′ W. The section is confined on either side by high-angle reverse faults, and the strata are overturned in many places. One fault juxtaposes limestone of Mississippian age with the rocks of the Echooka member and the other fault juxtaposes the upper beds of the measured section with contorted rocks of the Ivishak member. Details of this section and those that follow are listed in descending stratigraphic succession.

Sadlerochit formation, section 20

Contorted strata of the Ivishak member.
Thrust fault.

	Feet
Ivishak member:	
Alternating finely laminated, locally crossbedded dark-gray siltstone and hackly-fracturing shaly siltstone; siltstone weathers rust brown	236
Partly exposed section similar to above	206
Alternating beds of siltstone and rust-weathering shaly siltstone; siltstone bedded from a few inches to 2 ft thick, locally cherty; some layers finely laminated and crossbedded	191
Rust-weathering shaly siltstone and very fine platy micaceous siltstone	138
Covered interval	76
Rust-weathering black shaly siltstone with hackly fracture and large concretions containing poorly preserved ammonite impressions	232
Echooka member:	
Massively bedded blue-gray rust-weathering siltstone and blue-gray chert	83
Fault.	
Total measured thickness of Sadlerochit formation	1,162

Lisburne group.

The Kavik River section (section 18) is exposed in cutbanks at lat 69°21′ N., and long 146°25′ W. The rocks of the measured section form the north flank of an east-plunging anticline and dip 45° N. At the top of the measured section a high-angle reverse fault juxtaposes the 45° north-dipping strata with contorted strata of the Ivishak member. At the base of the section the Echooka member rests disconformably on the Lisburne group. The measured section at this locality does not represent a total thickness for the formation, owing to a high-angle reverse fault at the top. However, this section has been correlated with its unfaulted counterpart on the south flank of the anticline, where the formation in its entirety is approximately 1,500 feet thick.

Sadlerochit formation, section 18

Contorted strata of the Ivishak member.
High-angle reverse fault.

	Feet
Ivishak member:	
Alternating siliceous thin to massively bedded dark-gray limonite-stained siltstone and hackly-fracturing dark-gray shaly siltstone	182
Covered interval	87
Alternating beds of dark-gray finely laminated siltstone, locally cherty, from ½ to 2 in. thick and brown-weathering shaly siltstone	215
Covered interval	61
Similar to third unit above; siltstone more massive with blocky fracture	27
Hackly-fracturing brown-weathering shaly siltstone and thin beds of dense siltstone; spheroidal limonite-stained siltstone concretions present in the shale and contain ammonites and pelecypods (field sample 52 AKe 23; see p. 187)	100
Unit consists of limonite-stained hackly-fracturing shaly siltstone and of dark-gray finely laminated pyritic siltstone lenses and beds that weather to metallic hues. Ammonite 38 ft above base of unit (field sample 52 AKe 22)	150
Echooka member:	
Covered interval; chert float	50
Massively bedded dense blue-gray brown-weathering cherty siltstone and chert. Poorly preserved bryozoans and brachiopods present in cherty limestone about 80 ft above base	250
Disconformity.	
Total measured thickness of Sadlerochit formation	1,122

Lisburne group.

The Pogopuk Creek section (section 16) is exposed along an incised valley at lat 69°23′ N., and long 146°38′ W., where the strata, dipping from 35° to 60° N., form the north flank of an east-plunging anticline. The contact between the Ivishak member of the Sadlerochit formation and the Shublik formation is well exposed along the creek, and no angular discordance is apparent between the two units. The contact between the Echooka member and the Lisburne group is covered. The measured section is thicker than the sections farther east, and the formation contains a greater amount of chert in the lower member.

Sadlerochit formation, section 16

Shublik formation.

	Feet
Ivishak member:	
Dense siltstone interbedded with light- to medium-gray sandstone; siltstone locally micaceous; minor dark-gray hackly-fracturing shaly siltstone	520
Alternating well-indurated siltstone and shaly siltstone and 1- to 3-ft beds of light- to medium-gray, brown-weathering sandstone; some of the sandstone crossbedded and ripple marked; locally siltstone and shale beds micaceous and carbonaceous	128
Less resistant unit of thin-bedded dense siltstone and of hackly-fracturing shaly siltstone; siltstone weathers brown. Ammonite on bedding plane at base of unit	335
Covered interval	700±
Echooka member:	
Silicified dark-gray limonite-stained siltstone in beds as much as 3 ft thick	12
Covered interval	120
Dense blue-gray limestone grading laterally into olive-gray chert in beds 1 to 2 ft thick; chert contains abundant small pyrite crystals. Fossils present in the limestone	47

Echooka member—Continued	Feet
Dark-gray to blue-gray chert and silicified brown-weathering limestone	17
Dark-blue-gray chert in beds as much as 4 ft thick and silicified dark-blue limestone	46
Covered interval	20
Contact(?) arbitrarily placed at base of covered interval.	
Total measured thickness of Sadlerochit formation	1,945
Lisburne group.	

The Juniper Creek section (section 15) is exposed along a deeply incised tributary of Juniper Creek at lat 69°22′ N., and long 146°48′ W. Only the basal 564 feet of the formation is well exposed and these strata are overturned to the north.

Sadlerochit formation, section 15

Echooka member:	Feet
Brown-weathering cherty and silicified siltstone and blue-gray chert in beds as much as 4 ft thick; quartz veins as much as 1 ft thick	339
Limonite-stained cherty and silicified siltstone containing abundant horn corals, spirifer-type brachiopods, and bryozoans (USGS Paleozoic loc. 15820)	17
Massively bedded siliceous siltstone and dark-gray chert	72
Cherty limestone containing abundant brachiopods (USGS Paleozoic loc. 15819)	4
Massively bedded siliceous siltstone and dark-gray iron-stained chert	132
Total measured thickness of Echooka member	564
Lisburne group.	

Section 12 was measured along Kemik Creek between lat 69°22′ N. and lat 69°23′ N. The lowest 460 feet of the rock unit is the type section of the Echooka member. These strata are exposed on the east side of the creek and dip 24° N. on the flank of an east-plunging anticline. In the type section fossils are poorly preserved. The collections listed are from correlative horizons on the Shaviovik River approximately 3½ miles west of the type section.

Sadlerochit formation, section 12

	Feet
Shublik formation.	
Contact not exposed.	
Ivishak member:	
Poorly exposed platy hackly-fracturing shaly siltstone and light-gray thinly bedded siltstone with metallic-blue-weathered surfaces	400±
Cuesta-forming unit of alternating light-gray siltstone in beds as much as 6 inches thick, platy limonite-stained medium-gray finely laminated siltstone, quartzite, and hackly-fracturing shaly siltstone	430
Poorly exposed tan-weathering platy siltstone and shaly siltstone	520±
Echooka member:	
Massive limonite-stained cherty and quartzitic siltstone and limonite-stained hackly-fracturing shaly siltstone	130
Thin-bedded brown-weathering shaly siltstone, and dense medium-gray siltstone	100
Quartzite, varicolored chert, cherty dark-gray massively bedded siltstone, and light-gray thinly bedded siltstone. Fossils are present in brown-weathering limestone beds approximately 50 ft above the base of the section. (USGS Paleozoic locs. 15806 and 15826)	230
Total measured thickness of Sadlerochit formation	1,810±
Lisburne group.	

The Gilead Creek section (section 9) was measured in cutbanks on both sides of a small tributary of Gilead Creek at lat 69°16′ N. and long 147°29′ W. Strata of the measured section dip 32° N. and are overlain by contorted beds of the Ivishak member. Only the basal 896 feet of the formation was measured.

Sadlerochit formation, section 9

Ivishak member:	Feet
Interbedded shaly siltstone and siltstone; lower part of unit comprises proportionately equal amounts of shaly siltstone and siltstone; upper part almost 100 percent siltstone; siltstone dense, cherty, and dark-gray with blue- and brown-weathered surfaces; locally limonite-stained; limy siltstone concretions present in the shale	251
Interval largely covered; few thin beds of dense cherty brown-weathering siltstone	90
Dense dark-gray thinly bedded brown-weathering siltstone and hackly-fracturing dark-gray shaly siltstone	82
Fissile dark-gray brown-weathering shaly siltstone; some disseminated pyrite	80
Echooka member:	
Hard massively bedded gray siltstone with metallic-blue- and brown-weathered surfaces	181
Less massive blue-gray siltstone	30
Dense massive cherty brown-weathering siltstone in beds as much as 5 ft. thick; cleavage at right angles to bedding; limonite nodules, pyrite, and quartz stringers locally present in the unit. Bryozoans, horn corals, and pelecypod fragments present in lenses in the lowest beds of the section	182
Total measured thickness of Sadlerochit formation	896
Lisburne group.	

The thickest section of the formation was measured along the east side of Flood Creek between lat 69°02′ 40″ N. and lat 69°03′20″ N. where the strata dip from 40° to 54° N. Neither the upper nor lower contacts of the formation are well exposed at this locality, but both can be mapped with relative accuracy. The

Echooka member of this section (section 7) is composed predominantly of limestone and shale in contrast with the resistant siltstone and chert which make up the member in the sections farther northeast. The upper 2,110 feet of the measured rock unit is the type section of the Ivishak member.

Sadlerochit formation, section 7

	Feet
Ivishak member:	
Dense cherty siltstone and hackly-fracturing dark-gray shaly siltstone; siltstone has light- to dark-gray interiors and is locally limonite stained on weathered surfaces; in beds from ½ to 6 in. thick; finely laminated and locally crossbedded	620
Cuesta-forming unit comprising alternating beds of hackly-fracturing cherty siltstone and shaly siltstone and of sandy siltstone; siltstone, medium-gray with yellow- and brown-weathered surfaces	520
More shaly than overlying cuesta-forming unit but retains the general characteristics; siltstone dense, cherty, finely laminated, and iron stained; shale dark gray	400
Predominantly medium-gray brown-weathering hackly-fracturing shaly siltstone and dense thin-bedded siliceous siltstone; limy red-brown concretions as much as several feet in diameter in random distribution throughout the shale. Nodules contain abundant ammonites and pelecypods (field sample 51 AKe 104A); many of the fossils in varying stages of pyritization	570
Echooka member:	
Upper part of unit consists of 50 ft of massive dense cherty brown-weathering siltstone; remainder of unit consists of interbedded massive limy blue-gray siltstone, light brown-weathering limestone, and dark-gray to silvery limy and nonlimy shale; limestone hydroclastic and locally coquinoid, is present both as lenses and beds (USGS Paleozoic loc. 15814)	465
Total measured thickness of Sadlerochit formation	2,575
Lisburne group.	

IDENTIFICATION OF FOSSILS

Echooka member.—The fossils of the Echooka member which were collected by the authors were examined by James Steele Williams, Helen Duncan, and Mackenzie Gordon, Jr. Mr. Gordon examined the cephalopods; Miss Duncan, the bryozoans and corals; all other fossil material was examined by Mr. Williams. Their assignment of a Permian age for the fossil collections whose localities are listed below is based in part on a comparison of these forms with Sadlerochit fauna identified as Permian by Girty, and in part upon the presence of forms in these collections characteristic of the Permian in other parts of the world.

Localities where fossils were collected from the Echooka member

USGS Paleozoic locality	Field sample	North latitude	West longitude	Description
15808	51 AKe 94	69°04′30″	147°47′	Coquinoid limestone near base of formation on Ivishak River.
15814	51 AKe 104			Limestone in Flood Creek section (section 7, pls. 21, 23).
15815	51 AKe 106	69°	148°02′	Limy siltstone and limestone, from lower contact to 400 ft above base of member on Saviukviayak River.
15816	51 AKe 123	68°51	148°04′	Limestone near base of member on Lupine River.
15817	51 AKe 162	68°40′30″	148°20′	Limy shale and siltstone near base of member near small tributary of Ribdon River.
15806	51 ADt 8	69°22′	147°11′	Limestone lenses near base of member on Shaviovik River; correlated with a horizon in section 7, plate 23.
15807	51 ADt 69	69°17′30″	147°22′	Limestone near base of member on west side of Echooka River.
15810	51 ADt 117	69°04′30″	147°47′30″	Limestone near base of member on small tributary on west side of Ivishak River.
15811	51 ADt 126	68°57′	148°07′30″	Limestone on small western tributary of Saviukviayak River.
15812	51 ADt 146	68°48′30″	148°17′	Lupine River.
15813	51 ADt 147	68°50′	148°17′	Small tributary of Lupine River.
15818	52 AKe 1A; 52 AKe 1A	69°22′30″	147°14′	Limestone immediately above contact of member with Lisburne group on Shaviovik River.
15819	52 AKe 8			Cherty limestone in Juniper Creek section (section 15, pls. 21, 23).
15820	52 AKe 9			Limy siltstone in Juniper Creek section (section 15, pls. 21, 23).
15821	52 AKe 19	69°20′30″	146°26′	Limy siltstone on Kavik River about 100 feet above base of member.
15823	52 AKe 21	69°20′30″	146°26′	Same as above, about 200 feet above base of member.
15824	52 AKe 31	69°30′30″	146°	Limy siltstone on small northern tributary of Cache Creek.
15825	52 AKe 38	69°31′	146°13′	Limy siltstone near Shublik Springs.
15826	52 AMo 5	69°22′30″	147°15′	Silicified siltstone on Shaviovik River; correlated with a horizon in section 7, plate 23.
15827	52 AMo 6	69°22′	146°58′	About 50 feet above base of member on Fin Creek.
15828	52 AMo 30			Pogopuk Creek section (section 16, pls. 21, 23).
15829	52 AMo 37	69°30′30″	145°57′	Limestone just above base of member on small northern tributary of Cache Creek.
15830	52 AMo 39	69°30′30″	145°57′	Same as 15829, but 30 ft above the base.
15831	52 AMo 40	69°30′30″	145°57′	Same as 15829; limestone about 50 ft above the base.
15832; 15833	52 AMo 41; 52 AMo 42	69°30′30″	145°57′	Same as 15829; limestone about 166 ft above the base.
15834	52 AMo 43	69°30′30″	145°57′	Same as 15829; about 261 ft above the base.

Seven reports on the identifications of fossils were submitted to the authors between 1952 and 1954: one in November 1952 covering Mr. Gordon's examinations and 6 in February 1954 covering Miss Duncan's and Mr. Williams' identifications. The following material is quoted from Mr. Williams' memoranda, except where otherwise noted:

"Previously fossils from beds in the Sadlerochit had been examined and reported on by Girty. The Sadlerochit material that Girty had was poor. The fossils were obviously more closely related to species from the Arctic Island regions of North America and from northern Europe and Asia than they were to species from farther south in North America. Girty had no adequate suites of typical specimens of these Arctic species for comparative purposes. Much of the important literature was in the Russian language. Because of these conditions, Girty identified almost none of the species. Instead, he considered most of them probably to be new species, but he did attempt to give as much of an idea as he could of their general appearance by citing the name of a species to which they were in some degree related. He indicated possible relationships by 'aff.' references. Girty had also designated fossils from Permian beds in other parts of Alaska by the same method.

"In examining the specimens collected during the present investigation of the Shaviovik-Sagavanirktok area, I had to contend with many of the same difficulties that attended Girty's earlier work. In terms of what is required nowadays for identifications of genera and species, the material is poor, commonly being molds or incomplete specimens, which ordinarily lack ornamentation. This one would expect because of the unfavorable lithology and the distortion to which the rocks were subjected. The material for comparison is meager to nonexistent; the literature is scattered and in many languages, some of which are imperfectly known to the writer. As a consequence it was decided to identify the species as nearly as possible with the material studied in Girty. This, it was felt, would provide a substantial basis for correlation within Alaska. Girty's material was available for direct comparison. Identification with species from other parts of the world could come later, when good material for comparison became available. Then more reliable correlation with foreign deposits can be made. Both the Geological Survey and the U.S. National Museum are making efforts to increase the number of topotype and authentic specimens of Arctic Permian species in their collections. Studies now in progress on better material from more accessible and less rugged and isolated parts of Alaska may in the future provide the keys for more secure and informative identifications of the Permian species of the Alaskan Naval Petroleum Reserve and for correlations with Permian deposits of other countries."

USGS Paleozoic locality	*Field sample*	
15808	51 AKe 94	"This collection contains remains of several productoid shells and also remains of other brachiopods that are undeterminate as to family but that suggest spiriferoids. Two of the productoids are closely related to the form referred to by Girty as *Productus* n. sp. aff. *P. septentrionalis* Tschernyshew [*Marginifera septentrionalis* of authors] from Permian rocks in Alaska. The affinities of the other productoid are not clear. * * *
15814	51 AKe 104	"This collection contains several specimens of a species identical with or closely related to the form from Alaska, designated by Girty as *Productus* n. sp. aff. *P. septentrionalis* Tschernyshew [*Marginifera typica septentrionalis* and *M. septentrionalis* of authors] and other productoid forms, one of which resembles in size and shape a form from the Sadlerochit formation thought by Girty to be related to *Productus timanicus* of Stuckenburg. The ornamentation on our specimen is unfortunately not well shown. Also present are several other indeterminate productoid forms and a brachial valve of a brachiopod whose external characters resemble those of some Camerophorias (Stenocismas) illustrated by Tschernyshew from the late Paleozoic (Upper Carboniferous or Permian) of Russia." A poorly preserved bryozoan was designated as a "stenoporoid bryozoan genus indeterminate" by Helen Duncan who examined it. Duncan later reported that "a diagnostic Permian coral, *Calophyllum* [=*Polycoelia* of authors] occurs in this assemblage."
15815	51 AKe 106	"This is a small collection, but it does contain a fragment of a productoid shell and that is sufficient to restrict it to Permian or older age. The fragment does not appear to have been reworked. Also in the collection are indeterminate remains of several other shells. Fragmentary horn corals in this collection have been referred to Helen Duncan. She says that the material is too poorly preserved for certain identification but reports that one specimen has an axial structure and other features suggestive of *Verbeekiella*, a Permian genus."
15816	51 AKe 123	"This collection consists of a single specimen of a spiriferoid brachiopod that resembles in general shape a form identified from the Sadlerochit by Girty as one related to *Spirifer rectangulus* Kutorga. It cannot, however, be definitely identified."
15817	51 AKe 162	Gordon reported brachiopods, pelecypods, and gastropods of too fragmental a nature for identification.
15806	51 ADt 8	"The principal fossils in this collection comprise a number of productoid forms. One is the form identified by Girty in the early 1900's as *Productus* n. sp. aff. *P. septentrionalis* (Tschernyshew) (*Marginifera typica septentrionalis* and *M. septentrionalis* of authors). Another productid

USGS Paleozoic locality	Field sample	
		resembles to a degree in form a species identified by Girty as being closely related to *P. multistriatus* Meek. The ornamentation is not preserved and the likeness of the form to *P. multistriatus* is only moderately close. Still another of the productid type of shells seems to be closely related in shape to a form identified by Tschernyshew as *P. mammatus* Keyserling. All the forms mentioned by name above have been identified from beds classified as Permian in Alaska, and I believe that the presence of these forms with the absence of contradictory forms gives substantial evidence on which to base a Permian age assignment.
15807	51 ADt 69	"The collection * * * contains indeterminate remains of a coral and of bryozoans, and brachiopods largely represented by molds. Among the brachiopods are molds of productoids and pieces of of molds of other brachiopods, which pieces are indeterminate. One of the productoid fragments is a piece of the lateral slope of a form whose surface ornamentation suggests that it is a *Waagenoconcha*. A mold of the pedicle valve of a productoid suggests a new species known from the Permian. Another brachiopod is probably a chonetid, whereas remains of other brachiopods are indeterminate." Miss Duncan examined the remains of a coral which she described as a crushed mold of a horn coral, indeterminate. The bryozoans she speaks of as "many molds of ramose Bryozoa, indeterminate, and a *Fenestella*? sp. indet., an impression. The aspect of this faunule is strongly Permian."
15810	51 ADt 117	"This collection consists mainly of many incomplete molds and fragments of molds of productoid brachiopods. Some slabs are almost coquinas of remains of such shells. None can be identified. One mold resembles the form that has previously been identified in Alaskan collections as *Productus multistriatus* Meek in general shape but there is not enough of it to make a positive identification. * * *"
15811	51 ADt 126	Gordon reported a *Pseudogastrioceras* sp. in this collection, bearing "the typical raised spiral lirations of this characteristic Permian genus." Williams added that the "other forms represented in it are mainly remains of brachiopods and include a specimen that is probably a *Meekella* or a closely related form. Another resembles a *Derbyia* in form and ornamentation, two others are productoids, one especially resembling a form in the Alaskan Permian and several fragmentary indeterminate remains of spiriferoid forms. Bryozoa in the collection were referred to by Miss Duncan as stenoporoid bryozoans, indeterminate. This collection could not be younger than Permian and its general aspect strongly suggests that it is Permian in age."
15812	51 ADt 146	Gordon identified indeterminate gastropods and gastrioceratid cephalopod, genus undetermined.
15813	51 ADt 147	"This collection contains many fragmentary productoid shells and also parts of molds of productoid shells. A single gastropod in the collection has been examined by Ellis Yochelson who describes it as an indeterminate straparollid gastropod.
15818	52 AKe 1A	"This collection contains markings that are probably from crinoid columnals and brachiopods of several types including two or three genera of productoid forms. One of the productoids is either closely related to or actually the species identified by Girty as *Productus* n. sp. aff. *P. septentrionalis* (Tschernyshew); another productoid is indeterminate as to genus. Among other brachiopods is a large chonetid, similar in form to a manuscript species of Girty from the Permian of Alaska. Also present are fragments of other brachiopods. * * *
15819	52 AKe 8	"Collection contains remains of brachiopods, pieces of fibrous hinge structure of a pelecypod, and possibly remains of other organisms, all indeterminate. * * *
15820	52 AKe 9	"This collection * * * has cross sections and other remains of brachiopods, pieces of the fibrous hinge structure of pelecypods and indeterminate remains of pectinoid pelecypods. Among the brachiopods are incomplete re-

USGS Paleozoic locality	*Field sample*	
		mains of a specimen that is definitely a *Chonetes* and parts of specimens representing probably two species of *Productus* * * *" Miss Duncan added that "this collection contains a good many specimens or parts of specimens of stenoporoid bryozoans. I am fairly certain some of them are *Stenopora* in the strict sense. No comparable material has been described from North America. * * * *Stenopora* is especially characteristic of the Permian, and is one of the most diagnostic forms found in the Permian of eastern Australia."
15821	52 AKe 19	This collection contains "many incomplete remains of fossils, including a portion of a trilobite pygidium and a brachiopod that is not preserved well enough to determine definitely its generic affiliation. It is either a chonetid or a productoid. * * *
15823	52 AKe 21	"This collection contains several specimens of a brachiopod that resembles very much in shape and proportions a form referred to by Girty as *Productus* (or *Marginifera*) n. sp. aff. *P. aagardi* Toula (*Anidanthus* and *Pseudomarginifera aagardi* of authors) from the Permian of Alaska. * * *
15824	52 AKe 31	"This collection contains remains of spiriferoid and productoid brachiopods. Included among the spiriferoids are forms representing the species identified by Girty as *Spiriferella* aff. *S. arctica* Houghton. One of the productoids is the form from the Permian of Alaska referred to by Girty as *Productus* (or *Marginifera*) n. sp. aff. *P. aagardi* Toula. * * *
15825	52 AKe 38	"This is a large collection containing a piece of a horn coral, several genera of Bryozoa, brachiopods and remains of a pelecypod. * * * Among the brachiopods are several specimens belonging to *Phricodothyris* (*Squamularia* of authors) or to a closely related genus, a few remains of the form identified by Girty as *Spiriferella* aff. *S. arctica* Houghton, and indeterminate pieces of productoid shells. The age is Permian." Miss Duncan added that in "addition to an indeterminable fragment from the calyx of a horn coral, this collection consists largely of molds of fenestrate bryozoans * * * the only genus I can certainly identify is *Fenestella*. Some of the forms with stout branches and coarse meshwork undoubtedly belong to other genera, but structures needed to place them are not preserved. There are also molds and a few fragments of some goniocladiid bryozoan and indications of branching forms. * * *"
15862	52 AMo 5	"This collection contains several productoids, at least two specimens of which are of the same size and shape as the species referred to by Girty as related to *Productus* (or *Marginifera*) n. sp. aff. *P. septentrionalis* (Tschernyshew). Other brachiopods of Permian aspect are also represented, as are indeterminate pectinoid pelecypods. A steinkern of an indeterminate gastropod was examined by Mr. Yochelson. * * *
15827	52 AMo 6	"This collection contains fibrous remains of the hinge-structure of pelecypods, two or three productoids, one of which resembles a species from the Permian of Alaska thought by Girty to be closely related to *Productus aagardi* of Toula. In addition there are several shells of a species that I tentatively have placed in *Rhynchopora*.
15828	52 AMo 30	"This collection consists of remains of brachiopods but there are also several pieces of fibrous structures that are probably the remains of the hinge-structures of pelecypods, possibly of *Myalinas*. Among the brachiopods are remains of several spiriferoids, at least one of which represents the form thought by Girty to be related to *Spiriferella arctica* of Houghton. One mold seems to be of a productoid that is not complete enough for generic determination. There are also several specimens that I am tentatively referring to *Rhynchopora*. The aspect of this faunule is Permian.
15829	52 AMo 37	"This collection contains a fauna whose affinities I am not able to definitely determine. Several incomplete specimens of '*Spiriferina*' s. l., remains or probably

USGS Paleozoic locality	Field sample	
		two species of *Chonetes*. A piece of fenestrate bryozoan and possibly fragments of other genera of brachiopods comprise it. The 'Spiriferinas' and the species of *Chonetes* are not distinctive species as regards Permian vs. Carboniferous age. Some fragments of brachiopods suggest the form known in Alaska as *Spiriferella artica* Houghton but the fragments are very small and the suggestion cannot be counted upon to indicate the correct identity of the brachiopods.
15830	52 AMo 39	"This collection contains several specimens that actually are or are closely related to the form identified in Alaskan collections by Girty as *Productus* (*Marginifera*) n. sp. aff. *P. septentrionalis* (Tschernyshew). Also several incomplete specimens of the form Girty thought was related to *Spiriferella arctica* Houghton. Other incomplete molds of brachiopods and poorly preserved bryozoans are present * * * The age is Permian.
15831	52 AMo 40	"This collection contains remains or molds of indeterminate brachiopods that probably represent spiriferoid and productoid genera and one specimen that is probably a *Rhynchopora*. * * *" Miss Duncan stated that "bryozoans in this lot are mostly broken into very small fragments. Both fenestrate and ramose forms are present. * * * I think that *Fenestella*, *Polypora*, and some sort of goniocladiid are present. The ramose forms are not identifiable. A small slab was apparently collected for the impression of a fairly large piece of frond, which I think represents *Fenestella*; however, I cannot be sure about the identification. The general aspect of the bryozoans is Permian rather than older."
15832	52 AMo 41	"Collection 41 has crinoid columnals, remains of productoid and other brachiopods, and two horn corals. * * *" Miss Duncan added that the "coral in this lot suggests *Euryphyllum*, a genus known from the Permian of Australia. Pieces of rock that were sawed were found to contain abundant bryozoan debris derived mainly from fenestrate types—fenestellids and probable goniocladiids—none of which are generically identifiable, but in general rather characteristic of the Permian."
15833	52 AMo 42	"Collection 42 * * * contains several productoid forms, and some spiriferoid forms of brachiopods. None is completely preserved. Productoid forms include portions of forms that may be Buxtonias, Waagenoconchas and dictyoclostids, and a form that is most certainly a *Linoproductus*. One of the spiriferoids resembles in general shape and in all external features preserved, the form from the Alaskan Permian said by Girty to be related to *Spiriferella arctica* Houghton. Some of the other spiriferoids are large and have the general proportions of some of the Mississippian spirifers. * * *
15834	52 AMo 43	"* * * Jack Smedley * * * examined this specimen and he believes it to be an *Aviculopecten* of a sort related to *A. girtyi* Newell, which species is known from the Permian of the mainland of the United States."

Ivishak member.—The fossil collections from the Ivishak member were examined by Bernhard Kummel, and those fossils that can be readily identified he assigned to the early part of the Scythian stage (Early Triassic).

Localities where fossils were collected from the Ivishak member

USGS Mesozoic locality	Field sample	North latitude	West longitude	Description
----------	51 AKe 87	69°08′30″	147°48′	Limy concretions in lower part of member in small cutbank on an eastern tributary of Ivishak River.
----------	51 AKe 104A	----------	----------	Flood Creek section (section 7, pls. 21, 23).
----------	52 AKe 22	----------	----------	Kavik River section (section 18, pls. 21, 23).
----------	52 AKe 23	----------	----------	Do.
----------	52 AMo 31	----------	----------	See section 16, plate 21.
----------	51 ADt 106	69°09′	147°41′	Limy concretions in complexly faulted zone on Kashivi Creek.
23595	51 ADt 108	69°09′30″	147°43′30″	Limy concretions in faulted zone on Kashivi Creek.
----------	52 AKe 7	69°22′20″	146°44′30″	The upper cuesta-forming beds of member between Cobble Creek and Juniper Creek.
----------	51 ADt 91	69°16′30″	147°34′	Probably the upper cuesta-forming beds of member on Gilead Creek.

Kummel reported (written communication, April 1954) as follows on the identification of fossils from the Ivishak member:

USGS Mesozoic locality	Field sample	
-------	51 AKe 87-----	*Ophiceras* (*Lytophiceras*) cf. *O. commune* Spath ?*Discophiceras* sp. indet. Ammonoids indet. These specimens are comparable to ophiceratids from East Greenland. Their preservation leaves much to be desired, and the two identifiable specimens are juveniles. They are probably of older age than the material of 52 AKe 23, but younger than 51 ADt 108. [See listings below.]
-------	51 AKe 104A--	Ammonites and pelecypods.
-------	52 AKe 22-----	Ammonoids indet.
-------	52 AKe 23-----	*Ophiceras* cf. *O. greenlandicum* Spath *Proptychites* cf. *P. rosenkrantzei* Spath *Claraia stachei* Bittner All the identifiable specimens * * * show strong affinities to the East Greenland Scythian faunas described by Spath 1930, 1935. The Proptychitids occur in a younger horizon than the Ophiceratids in the East Greenland fauna. * * * The specimens of these lots are of a slightly younger horizon than that of 51 ADt 108 [see USGS mesozoic loc. 23595 below], * * * that is, they are late Octoceratan or early Gyronitan.
-------	52 AMo 31----	* * * indeterminate ammonoids (*Proptychites*) and *Gervillea* sp. The ammonoids * * * are too poorly preserved for identification, but there is enough available to say they are Triassic and probably Proptychitids.
-------	51 ADt 106----	*Ophiceras* cf. *O. tibeticum* Griesbach *O. tibeticum* Griesbach is a conspicuous member of the earliest Scythian beds in the Himalayas. The identification of the Alaskan specimens with the Himalayan species has been done to emphasize its gross morphological features. Identity with any of the Greenland species described by Spath is difficult to establish because of faulty preservation and lack of extensive topotype collections.
23595---	51 ADt 108----	*Otoceras boreale* Spath The *O. boreale* Spath * * * is the most interesting and diagnostic specimen in all of this material. This specimen is, as far as can be told from the crushed specimen, identical to the East Greenland *O. boreale* described by Spath. All species of *Otoceras* are very similar. *Otoceras* is diagnostic of the lowest Scythian and is known only from the Himalayas, East Greenland, and possibly Djulfa in Armenia.
-------	52 AKe 7------	Ammonoids indet. (*Proptychites*?).
-------	51 ADt 91-----	?*Glyptophiceras* sp. indet.

CORRELATION

The Sadlerochit formation has not been definitely correlated with other Triassic and Permian rocks of northern Alaska. Southwest of the area mapped by the authors, Patton (1957) mapped a Permian(?) rock unit (the Siksikpuk formation) of 250 to 300 feet of red, green, gray, and black shale, siltstone, and chert, the basal part of which is characterized by a brachiopod, gastropod, and horn coral fauna. Although the features of the Siksikpuk formation are not similar to those of the Echooka member of the Sadlerochit formation, it is quite possible that the two units are in part equivalent.

Early Triassic fossils have not been reported previously in Alaska, and to the knowledge of the authors no rock units equivalent to the Ivishak member of the Sadlerochit formation are present west of the Sagavanirktok River.

TRIASSIC SYSTEM

SHUBLIK FORMATION

History.—The Shublik formation was first described by Leffingwell in his report on the Canning River region, in which he stated (1919, p. 115–116):

> The Shublik formation, which consists of about 500 feet of dark limestone, shale, and sandstone, overlies the * * * Sadlerochit sandstone and underlies the * * * Kingak shale. Neither the upper nor the lower contact has been found, but the dip of the three formations seems to be the same. As a rule the Shublik is easily separated from the next older rocks * * * but the younger Kingak shales are so similar to those of the Shublik formation that the determination of the dividing line between these formations must rest on paleontologic evidence.

Leffingwell (p. 116) named Shublik Island "at the southwest corner of the Shublik Mountains, where the formation was first discovered" as the type locality, but he pointed out that the "locality * * * is not favorable for study, for the exposures are complicated and scattered." For a typical section he listed one at "Camp 263 Creek", which is probably a tributary of the Sadlerochit River on the south side of the Sadlerochit Mountains. Leffingwell's section (1919, p. 116) is given below:

Triassic section at Camp 263 Creek

	Feet
1. Unexposed, probably soft shales	800
2. Scattered exposures of dark limestone, some shaly beds	80
3. Unexposed, probably soft rocks	140
4. Dark calcareous sandstone, conglomeratic(?)	30
5. Unexposed, probably soft rocks	300
	1,350

The authors believe that Leffingwell's unit 4 is the base of the Shublik formation in the Canning River area and that his unit 5 is part of the Sadlerochit formation. In general his units 2, 3, and 4 constitute the total Shublik formation from the Canning to the Itkillik River.

Distribution.—Rocks of Late Triassic age have been reported from many localities along the north slope of the Brooks Range from the Okpilak River to Cape Lisburne. In the mapped area, the rocks of the Shublik formation crop out in a belt, generally less than 2,000 feet wide, which can be traced along the Range front from the Canning River to Elusive Lake. The Triassic rocks are present also about 2 miles west of the Sagavanirktok River in a breached and faulted anticlinorium. The present surface underlain by Triassic rocks is typically one of low relief, and the formation is generally exposed in small cutbanks along the streams. Only locally are the rocks sufficiently resistant to form rubble traces in the interstream areas, and these persist only short distances along the strike. The formation is easily identified by its characteristic black shale, its abundant Late Triassic fossil suite, and its buff-weathering limestone. It is especially important as a marker unit, inasmuch as it represents the only predominantly calcareous unit between the Lisburne group and the marine formations of the Nanushuk group. The unit overlies the Sadlerochit formation without angular discordance; it is overlain disconformably by the Kingak shale and, depending on the amount of post-Tiglukpuk and post-Okpikruak erosion, may be overlain locally by the Tiglukpuk, Okpikruak, or Fortress Mountain formations.

Lithology.—The thickness of the Shublik formation is relatively uniform within the entire mapped area; it ranges from about 200 to 300 feet. The rocks are typical of those deposited in the lagoonal environments or in waters of restricted circulation; except for local variations facies change very little from one part of the mapped area to another. All the rocks of the formation have a strong fetid odor on fresh fracture surfaces.

The lower part of the formation consists of phosphatic siltstone, shale, and very fine grained sandstone. The shale is characteristically black, owing to the high carbon content, limy, and clayey to silty; it contains abundant dark-gray nodules which are coated with a white salt. The phosphate-bearing siltstone is most extensive in the eastern half of the mapped area and the fine grained sandstone on the east of Kemik Creek. The phosphatic siltstone, in thin sections, is composed of 56 percent quartz, 14 percent phosphate, 29 percent calcite, and 1 percent plagioclase. The quartz grains are angular, are in a lime matrix, and are partly replaced by calcite. Phosphate is present as small oolites and amorphous dark-brown pellets and has accumulated about and enclosed the quartz grains. The limy matrix has recrystallized to calcite in the form of isolated rhombs or large irregular masses.

The upper part of the Shublik formation consists of clayey to silty shale with interbeds of dark-gray limestone. The uppermost beds form a unit composed predominantly of limestone which weathers buff. The limestone ranges from sandy to cherty and is characterized by an abundant fauna of Late Triassic age. Phosphatic siltstone is present locally at the contact of the Shublik with the Kingak shale, megascopically it appears similar to the phosphatic siltstone in the lower part of the formation.

Measured sections.—Four sections of the Shublik formation were measured in the mapped area, and these are correlated on plate 23. The locations of the sections are shown on plate 21. Most of the sections are poorly exposed and only the one on Kavik River (section 18) is suitable for detailed study. Section 18 was measured in the cutbanks along the east side of the river at lat 69°21′30″ N., long 146°25′ W. In this locality the Triassic rocks outline the configuration of a major east-plunging anticline and syncline; the strata of the measured section dip northward 60° and form the south flank of the east-plunging syncline.

The structure of the section is relatively uncomplicated except in the upper part where the strata are isoclinally folded. The lower contact of the rock unit with the Sadlerochit formation is well exposed and no angular discordance is present between the formations. The limy shale and limestone of the Shublik formation is readily distinguishable from the overlying shaly siltstone of the Kingak shale at this locality, but the contact between the two is not exposed.

Shublik formation, section 18

Kingak shale.
Contact(?), placed arbitrarily at the top of the phosphatic siltstone.

Shublik formation:	Feet
Interbedded black buff-weathering hydroclastic limestone, limy black shale, and medium-gray fossiliferous phosphatic siltstone (USGS Mesozoic locs. 24048, 24047, and 24046; see p. 190)	58
Interbedded black limy shale and black limestone (USGS Mesozoic loc. 24045)	27
Interbedded massive medium-gray nodular limestone, locally hydroclastic, and black nodular clay shale (USGS Mesozoic loc. 24044)	25
Interbedded medium-gray dense limestone, earthy limestone, and black limy clay shale	30
Medium-gray dense limestone and black limy shale	11
Predominantly black earthy limy clay shale, minor dense hydroclastic limestone. Fossils 30 ft above base of unit (USGS Mesozoic loc. 24043); fossils 20 ft above base of unit (USGS Mesozoic loc. 24042)	62
Massive medium-gray phosphatic siltstone	17
Total measured thickness of Shublik formation	230

Sadlerochit formation.

Section 14 was measured along the west side of Cobble Creek, a small western tributary of the Kavik River. Only the lower part of the section is well exposed and the east-striking strata dip approximately 45° N. The lower contact is marked by a 1-foot zone that weathers red; the upper contact is not exposed but has been arbitrarily placed at the top of the phosphatic siltstone.

Shublik formation, section 14

Kingak shale.

Shublik formation:	Feet
Unit largely obscured; upper part phosphatic fossil-bearing silty limestone and siltstone (fossils are the same as those of USGS Mesozoic locs. 24048, 24047, and 24046); exposures of black limy shale	200±
Thin-bedded black fissile shale and white-weathering limestone	30
Black shaly siltstone and dense phosphatic slightly calcareous siltstone	22
Phosphatic siltstone grading into clay and shaly siltstone	27
Total measured thickness of Shublik formation	279±

Sadlerochit formation.

Section 9a was measured in a cutbank along a small tributary of Gilead Creek at lat 69°16′ N., and long 147°32′30″ W. Only the basal 180 feet of the formation is exposed at this locality, and the contact with the Sadlerochit formation is covered. This section contains more siltstone than the sections farther east; it does not contain the phosphatic siltstone beds that characterize the eastern sections.

Shublik formation, section 9a

	Feet
Interbedded calcareous siltstone and silty to clayey shale. Entire section is very dark blue gray to almost black. Most of the siltstone beds are 1 to 4 ft thick with the shale interbeds 6 to 8 in. thick. Shale constitutes about 30 percent of the section. The siltstone has hackly fracture with quartz veins in the fracture zones. Buff-weathering limestone in beds 3 ft thick is present at the top of the unit. Mud lumps are abundant throughout the section, and fossils are present about 10 ft from the top (USGS Mesozoic loc. 23591)	180

Sadlerochit formation.

Section 6 was measured in cutbanks along a small eastern tributary of the Saviukviayak where the northeast-striking strata dip about 30° N. Neither the upper nor the lower contact of the formation is well exposed although it is possible to map both with relative accuracy. The upper limestone beds of the section are more cherty than their counterparts in the other 3 sections.

Shublik formation, section 6

Kingak shale.

Shublik formation:	Feet
Section predominantly black calcareous fissile and platy clay shale, silty shale, and mudstone; upper part of section consists of buff-weathering silty and cherty fossil-bearing limestone (USGS Mesozoic loc. 23589)	300±

Sadlerochit formation.

Age.—The fossils collected by the authors in the Shaviovik and Sagavanirktok Rivers region were examined by Bernhard Kummel and John B. Reeside, Jr., and their analyses of the fossil lots were submitted to the authors in the form of written communications at various times during 1952. In the section that follows, the fossil lots, or the individual fossils marked with an asterisk were identified by Reeside; other fossils were identified by Kummel.

Fossils and localities at which they were collected from the Shublik formation

USGS Mesozoic locality	Field sample	North latitude	West longitude	Fossil	Description of locality
23586	51 AKe 12	69°23′15″	147°07′30″	*Germanonautilus brooksi* Smith Ammonite indet. (fragment) Monotis sp.	Limy sandstone rubble trace east of Kemik Creek.
*23587	51 AKe 55	69°11′50″	147°43′	*Spiriferina* cf. *S. yukonensis* Smith "*Rhynchonella*" sp. *Monotis subcircularis* (Gabb) Gastropod indet.	Sandy limestone and black sooty shale north of Kashivi Creek.
*23588	51 AKe 79	69°09′50″	147°46′30″	*Spiriferina yukonensis* Smith *Lima*? sp.	Gray massive limestone on south side of Kashivi Creek.
23589	51 AKe 111			**Halobia* cf. *H. cordillerana* Smith **Cardiomorpha*? sp. **Margarites*? of J. P. Smith *Hoplotropites* cf. *H. moffiti* Smith	See section 6, plates 21, 23.
23590	51 AKe 126	68°53′	148°08′30″	**Spiriferina* cf. *S. yukonensis* Smith **Halobia* cf. *H. cordillerana* Smith **Trachyceras*? sp. *Tropites stantoni* Smith *Halobia* sp. indet. **Juvavites*? sp. *Sirenites* sp. indet.	Light-brown limestone and fetid black shale along east side of Lupine River.
*23591	51 ADt 80			*Halobia* cf. *H. dilatata* Kittl	See section 9a, plates 21, 23.
*23592	51 ADt 83	69°16′20″	147°33′	*Pecten* n. sp *Lima*? n. sp.	Small cutbank on Gilead Creek.
23593	51 ADt 84	69°16′10″	147°34′30″	**Halobia cordillerana* Smith **Posidonia* cf. *P. jacksoni* Smith **Trachyceras* (*Protrachyceras*?) sp. **Clionites*? sp. *Tropites stantoni* Smith *Sirenites* cf. *S. hayesi* Smith *Halobia* cf. *H. superba* Mojsisovics Ammonite indet. (juvenile)	Black shale and limestone in cutbank on Gilead Creek.
*23594	51 ADt 88	69°16′	147°35′	*Pecten* cf. *P. deformis* Gabb *Monotis subcircularis* (Gabb) *Myophoria*? sp.	Limy siltstone lens in small cutbank on Gilead Creek.
*23596	51 ADt 124	69°	148°04′30″	*Spiriferina* cf. *S. yukonensis* Smith "*Rhynchonella*" sp. *Halobia* cf. *H. cordillerana* Smith	Black calcareous shale and limestone in cutbank on east side of Saviukviayak River.
*23597	51 ADt 148			*Halobia* sp	Black calcareous limestone and shale in cutbanks where Triassic beds cross Lupine River.
24042	52 AKe 24			*Halobia* sp. indet	See section 18, plates 21, 23.
24043	52 AKe 25			*Pecten* sp. indet *Avicula* sp. indet. Echinoid spines.	Do.
24044	52 AKe 26			*Spiriferina* cf. *S. yukonensis* Smith *Ostrea* (*Liostrea*) cf. *O. L. keilhaui* (Bohm). *Rhynchonella* sp. indet. Gastropods indet.	Do.
24045	52 AKe 27			*Halobia cordillerana* Smith	Do.
24046	52 AKe 28			*Spiriferina* cf. *S. yukonensis* Smith *Hoplotropites* cf. *H. moffiti* (Smith).	Do.
24047	52 AKe 29			*Ostrea* (*Liostrea*) cf. *O. keilhaui* (Bohm) *Monotis subcircularis* (Gagg).	Do.
24048	52 AKe 30			*Rhynchonella* sp. indet. *Lima* cf. *L. martini* Smith.	Do.
24071	52 AMo 32	69°22′50″	146°37′	*Pecten* (*Entolium*) cf. *P. yukonensis* Smith *Rhynchonella* sp. indet. *Spiriferina* cf. *S. yukonensis* Smith. *Lima* cf. *L. martini* Smith.	Silty limestone in upper beds of formation in cutbank on east side of Pogopuk Creek.
24072	52 AMo 33	69°23′	146°25′	*Halobia* sp. indet *Lima* cf. *L. martini* Smith. *Perten* (*Fntolium*) cf. *P. yukonensis* Smith. *Rhynchonella* sp. indet. Gastropods indet.	Phosphatic siltstone and limestone in upper beds of formation in cutbanks on Kavik River.
24073	52 AMo 34			?*Arca* cf. *A. inflata* Oberg	Black oolitic limestone about midway in formation at same site as USGS Mesozoic loc. 24072.
24074	52 AMo 35	69°22′30″	146°25′	*Pecten* (*Entolium*) cf. *P. yukonensis* Smith *Spiriferina* cf. *S. yukonensis* Smith. *Rhynchonella* sp. indet.	Three-foot bed of phosphatic siltstone on Kavik River.

The fossil lots of the Shublik formation have been assigned a Late Triassic age by Reeside and Kummel. In a written communication to the authors on December 5, 1952, Kummel stated that:

The faunal assemblage of these lots [lots 24042 to 24048, inclusive] * * * suggests a Karnian age. Most of the species are identical with or very similar to species from Karnian beds of central and southern Alaska. The brachiopods and pelecypods are likewise similar to forms from the Karnian of Bear Island.

The identification of *Monotis subcircularis* in lot 24047 is made with much question. The specimens are incomplete but what can be observed strongly suggests this nomenclature. *Monotis subcircularis* is generally considered a good Norian guide fossil but the whole assemblage reported on here is Karnian in aspect. Any meaning read into this association at this time would be inadvisable on the data available * * * *Halobia* ranges from the Karnian into the Norian. *Monotis subcircularis* is Norian in age. *Halobia* has its biggest development in the Karnian, but it is important to remember that it also occurs in Norian strata.

In the same memorandum, Kummel further stated that:

Lots 24071, 24072, and 24074 contain essentially the same fauna. The pelecypods, gastropods, and brachiopods are the same as those from the Karnian fauna of the Nation River, Alaska. * * * These faunas are likewise similar to the fauna of Bear Island described by Rohm (1903). The pelecypods of lot 24073 were only tentatively placed in *Arca inflata* Oberg which was originally described from Anisian beds of Spitzbergen. They by no means suggest an Anisian age, however.

In a written communication, April 7, 1952, Kummel noted that lots "23586, 23589, 23590, and 23593 are Karnian in age. The fossils present are related to species found in the Chitistone limestone of the Nizina Valley and to forms reported from the numerous Karnian localities in Alaska including those of the Firth and Canning Rivers, northern Alaska."

JURASSIC SYSTEM

Two Jurassic formations were mapped in the Shaviovik and Sagavanirktok Rivers region: (a) the Tiglukpuk formation, a shale and coarse clastic rock unit which is believed to be entirely Late Jurassic in age, and (b) the Kingak shale, a Lower, Middle, and Upper Jurassic rock unit composed predominantly of shale. The suggested correlation and depositional relations of the Jurassic rocks are shown in figure 29. The two formations intertongue in the general area of the Lupine River but the change in facies is not as abrupt as the areal map might indicate. The Jurassic rocks in the Lupine River area reflect a transition between the two formations and were separated at this locality for convenience.

KINGAK SHALE

History.—The name Kingak was assigned by Leffingwell (1919, p. 119) to the rocks at the type locality "Kingak Cliff, near Camp 263, at the southeast end of Sadlerochit Mountains." He described the formation as consisting "of about 4,000 feet of black shales, * * * [which overlie] the Shublik formation of Triassic age and probably * * * [underlie] the Ignek formation of Jurassic(?) [now Cretaceous] age." Leffingwell further describes the formation as including nearly black thin-bedded friable shale and fossiliferous and nonfossiliferous "concretions both in spheroidal form and in beds half a foot thick." Leffingwell called this rock unit the Kingak shale, and the authors apply this name to all strata between the Triassic and Cretaceous systems in the area east of Lupine River. As Leffingwell indicated, the Kingak locally underlies the Ignek formation, and although he assigned the Ignek a Jurassic(?) age, it is now known to belong to the Cretaceous system (p. 205–207).

Distribution.—The Kingak shale crops out along the front of the mountain range between the Canning River and the Lupine River in a belt ranging from 3 to 10 miles in width; it is infolded with Permian and Triassic rocks within the mountains near the Kavik River. The formation overlies the Shublik formation with no apparent angularity; it underlies the Cretaceous Okpikruak formation disconformably, and, depending on the amount of post-Okpikruak erosion, locally unconformably underlies the Cretaceous Ignek formation. The area underlain by the Kingak is typically one of low relief; exposures of the formation are relatively few and are confined generally to cutbanks along north-flowing streams. Locally, rubble traces of ironstone and shale are present on the hillsides in the interstream areas, but these exposures of the Kingak shale are so spotty that they are of little help in defining the rock unit. Over much of the area it is difficult to differentiate the rocks of the Kingak from those of the Okpikruak formation,

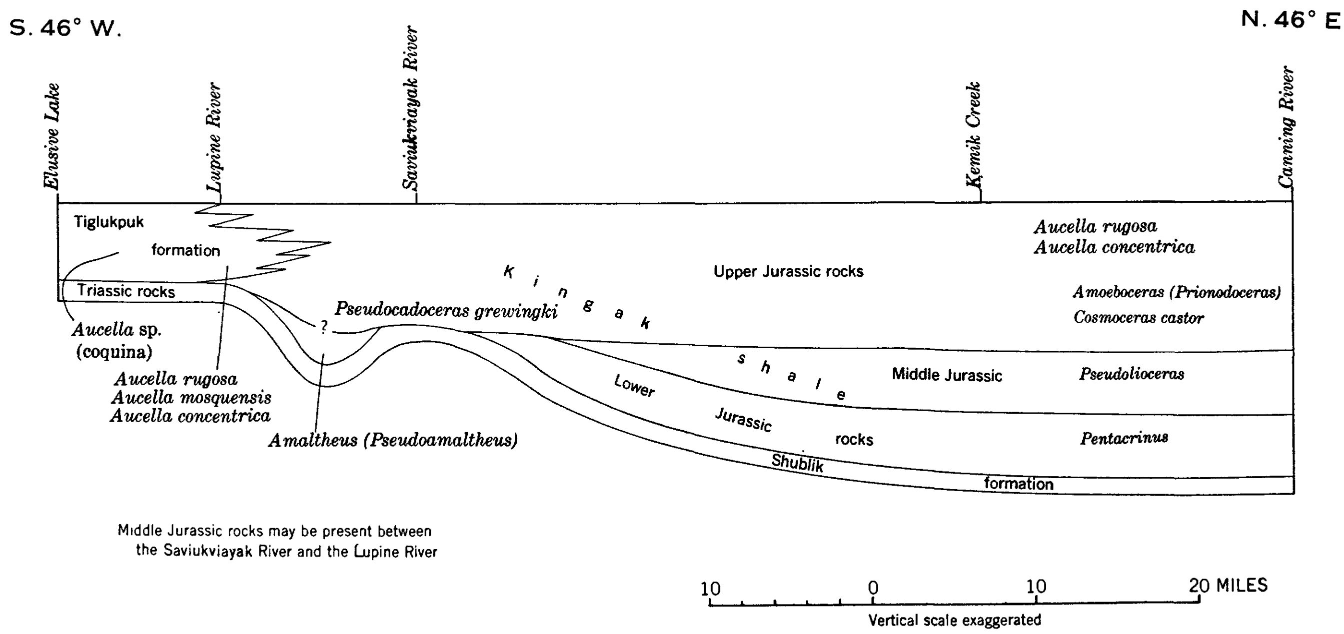

FIGURE 29.—Diagram showing suggested correlation and depositional relations of Jurassic rocks from the Canning River to Elusive Lake.

and in such localities these units have not been differentiated.

Lithology.—No detailed sections of the Kingak formation were measured by the authors, and for simplification the rocks are discussed in three general localities: (a) from the Canning River to Kemik Creek, (b) from Kemik Creek to Kashivi Creek, and (c) from Kashivi Creek to the Lupine River.

The thickness of the Kingak shale from the Canning River to Kemik Creek is indefinitely known. Gryc (oral communication) believed that as much as 5,000 feet of Jurassic rocks may be present in the cutbanks on the west side of the Canning River opposite the mouth of Cache Creek; in these cutbanks neither the upper nor the lower contact of the formation is present. The authors believe that on Kemik Creek, the only locality where the contacts of the formation can be mapped relatively accurately, the Jurassic rocks are no more than 3,000 feet thick. From the Canning River to Kemik Creek the Kingak predominantly consists of black pyritic clay shale and shaly siltstone. The shaly siltstone is locally iron stained and the clay shale is coated with a white salt. Black dense siliceous locally fossiliferous siltstone and rust-weathering ironstone are present as beds and lenses in the shale. Beds that weather reddish brown and contain crinoid stems (USGS Mesozoic locs. 24011 and 24012; see p. 193) are present near the base of the formation; these beds form rubble which can be traced for short distances in the interstream areas. On the Canning River, limy concretions containing carbonized wood, pelecypods, and ammonites (USGS Mesozoic loc. 24035) are present in the shale in the middle part of the formation; in this same locality, the upper shale beds of the formation contain abundant fossils (USGS Mesozoic locs. 24013 and 24014). A glauconitic green friable sandstone with black chert pebbles is present locally near the contact between the Kingak shale and the younger rocks near the Canning River.

The rocks of the Kingak shale from Kemik Creek to Kashivi Creek are similar to those described above, but the reddish-brown-weathering beds of crinoid stems and the upper glauconitic sandstone are missing or not exposed. The thickness of the Jurassic rocks was not measured by the authors in this locality, but locally in the interstream area between Kashivi Creek and Gilead Creek it appears that less than 1,500 feet of the Kingak is present. It further appears that in this interstream area the upper rocks of the Kingak shale were eroded during an interval between the deposition of either the Kingak and Okpikruak formations or the Okpikruak and Ignek formations.

Only a few exposures of the Kingak shale are present from Kashivi Creek to the Lupine River, and these are in cutbanks close to exposures of Triassic rocks. Four hundred feet of Jurassic strata overlie the Shublik formation on the west fork of the Ivishak River; these rocks consist predominantly of shaly siltstone with interbeds and massive lenses of very hard and dense siliceous siltstone. Pyrite cubes are common, and the section weathers rust brown. Fossils of Late Jurassic age (USGS Mesozoic loc. 22745) were collected from this section. On the Lupine River where the same type of rocks is exposed, fossils of Early Jurassic age (USGS Mesozoic loc. 22747) were collected from beds immediately above the Shublik formation contact.

Age.—Leffingwell (1919, p. 119–20) assigned an Early Jurassic age to the rocks of the Kingak shale in the Canning River region, basing the age on the identifications assigned to his fossil lots by T. W. Stanton and Frank Springer. On the basis of the fossils collected by the authors and identified by Ralph W. Imlay, it now appears that in addition to rocks of Early Jurassic age, the formation also includes rocks of Middle and Late Jurassic age. The fossils collected by the authors, their localities, and Mr. Imlay's identifications are given in the following table.[1]

[1] The name *Aucella* has been ruled invalid in favor of *Buchia* by the International Commission on Zoological Nomenclature (Opinion 492). This decision was received too late to make modifications herein.

Fossils and localities at which they were collected from the Kingak shale

USGS Mesozoic locality	Field sample	North latitude	West longitude	Fossil	Description of locality
22739	51 ADt 22	69°23′40″	147°14′	*Tancredia* sp.	Siltstone bed close to upper contact of formation in cutbank on east side of Shaviovik River.
22745	51 ADt 134	69°	148°04′30″	*Pseudocadoceras grewingki* (Pompeckj)	Siltstone concretion about 160 ft above Shublik formation in cutbank on east side of Saviukviayak River.
22747	51 ADt 144	68°	148°12′	*Amaltheus* (*Pseudoamaltheus*) sp. *Lytoceras* cf. *L. fimbriatum* (Sowerby)	Shale beds immediately above Shublik formation in cutbank on west side of Lupine River.
22748	51 ADt 145	68°	148°12′	Brachiopod	Do.
22759	51 AKe 48	69°14′30″	147°42′30″	*Aucella concentrica* (Sowerby)	Limy concretion in cutbank on east side of Gilead Creek.
22760	51 AKe 54	69°15′30″	147°40′	*Inoceramus* sp.	Limy concretion in cutbank on south side of Gilead Creek.
22763	51 AKe 98	69°03′	147°57′	Ammonite fragments	Limy concretion in cutbank of small eastern tributary of Saviukviayak River.
22764	51 AKe 113	69°	148°04′30″	Rhynchonellid brachiopods *Inoceramus* sp.	Limy concretion about 80 ft above Shublik formation.
24011	52 AMo 4	69°23′30″	147°03′	*Pentacrinus subangularis* var. *alaska* Springer	Rubble trace of ironstone between Kemik Creek and Fin Creek.
24012	52 AMo 36	69°22′15″	146°25′	*Pentacrinus subangularis* var. *alaska* Springer *Plicatula* sp. *Oxytoma*? sp.	Ironstone bed on east side of Kavik River.
24013	52 AMo 48	69°32′30″	146°23′	*Aucella spitiensis* Holdhaus *Lima* sp. *Phylloceras* sp.	Limy concretions in beds underlying Ignek formation in cutbank on west side of Canning River.
24014	52 AMo 50	69°33′	146°23′	*Aucella spitiensis* Holdaus Belemnite indet. *Amoeboceras* (*Prionodoceras*?) sp.	Do.
24028	52 AKe 14	69°24′45″	146°38′	*Aucella rugosa*, *A. concentrica*	Limy concretions in cutbank on east side of Cobble Creek.
24029	52 AKe 15	69°25′10″	146°37′30″	*Aucella* sp.	Do.
24033	52 AKe 37	69°27′	146°13′30″	*Reineckeia* (*Reineckeites*) cf. *R. stuebeli* Steinmann *Inoceramus* sp.	Shale and limy concretions in a cutbank on west side of Canning River.
24035	52 AKe 46	69°34′	146°23′	*Posidonia* cf. *P. ornata* Quenstedt *Pseudolioceras whiteavesi* (White). Belemnite indet. *Inoceramus* sp. *Camptonectes* sp. *Oxytoma* sp.	Concretions and shale in cutbank on west side of Canning River.

In a written communication to the authors on January 28, 1952, Imlay stated that:

The Lower Jurassic is definitely represented by lot 22747 as shown by the presence of *Amaltheus* which has only been found in the upper part of the Pliensbachian. The *Lytoceras* has the peculiar, delicate ribbing that is present in *L. fimbriatum* (Sowerby), a species that ranges through the middle part of the Lower Jurassic in Europe.

The Callovian is represented by lot 22745 which contains *Pseudocadoceras grewingki* (Pompeckj). The species in the Cook Inlet area, Alaska, ranges through the middle third and lower part of the upper third of the Chinitna formation. It is most common in the middle third which I consider equivalent to the upper part of the *Sigaloceras calloviense* zone and the entire *Cosmoceras jason* zone of Europe. The genus ranges to the top of the Chinitna formation whose upper third is correlated with the *Erymnoceras coronatum* zone. In Europe the genus ranges from the *Sigaloceras calloviense* zone to the *Erymnoceras coronatum* zone * * *.

The upper Oxfordian is probably represented by lot 22759 which contains *Aucella concentrica* (Sowerby). * * *

In later correspondence, October 1952, Imlay assigned an Early Jurassic age to USGS Mesozoic locs. 24011 and 24012 which "contain the same species of *Pentacrinus* as occurs at Black Island on the Canning River and which are there placed in the Lower Jurassic on the basis of stratigraphic position"; an early Bajocian age (early Middle Jurassic) to USGS Mesozoic loc. 24035; a Callovian age (early Late Jurassic) to USGS Mesozoic loc. 24033; and a late Oxfordian-early Kimmeridgian age (Late Jurassic) to USGS Mesozoic loc. 24014.

Imlay's identifications indicate that from Kemik Creek to the Canning River, rocks of Early Jurassic age (USGS Mesozoic locs. 24011 and 24012) overlie the Shublik formation; that on the Saviukviayak River, rocks of Callovian age (early Late Jurassic) are present 160 feet above the Shublik formation (USGS Mesozoic loc. 22745); and that on the Lupine River, rocks of Pliensbachian age (Early Jurassic) immediately overlie the Shublik formation (USGS Mesozoic loc. 22747). The authors consider it unlikely that rocks of Early Jurassic age and Middle Jurassic age can be represented in the 160-foot interval beneath the rocks bearing the fossils of Callovian age on the Saviukviayak River; this and Imlay's age assignments, indicate that the Kingak shale in the mapped area may be characterized by overlap relationships or unconformities (fig. 29).

TIGLUKPUK FORMATION

History.—The Tiglukpuk formation was named by Patton (1956a) for the section "along a series of cutbanks on the east side of Tiglukpuk Creek between lat 68°22′ N. and lat 68°22′30″ N." Patton stated that:

Shale, siltstone, and graywacke are the principal components of the Tiglukpuk formation. The graywacke is typically a greenish-gray, slightly calcareous, highly argillaceous, poorly sorted sandstone or conglomerate with low porosity and permeability. It occurs as poorly stratified lenticular masses in gray silt and clay shale along with a wide variety of silty calcareous, cherty, and ferruginous nodules and concretions. Diverse rock types are found in the lower half of the formation in subordinate amounts. These include bedded chert, siliceous black shale, variegated shale and siltstone, and a coquinoid limestone composed largely of compacted specimens of *Aucella*.

The type section of the formation on Tiglukpuk Creek, about 75 miles west of the Sagavanirktok River, was listed by Patton as follows:

	Approximate thickness, in feet	*Stratigraphic interval measured from base of section, in feet*
Fault.		
Sandstone, siltstone, and shale. Greenish-gray fine-grained graywacke sandstone in lenticular masses 5 to 40 ft thick, locally calcareous. Interbeds of dark-gray shaly siltstone and medium dark-gray siltstone. Minor calcareous siltstone lenses that weather moderate red	350	1, 100–1, 450
Predominantly sandstone, siltstone, and shale as above. Shale locally hackly. Minor lenticular masses of greenish bedded chert and cherty siltstone as much as 20 ft thick in minor amounts	650	450–1, 100
Chert and siltstone, greenish to grayish; glassy bedded chert, greenish to brownish cherty siltstone, and grayish-orange-weathering dark-gray highly calcareous siltstone	200	250–450
Shale and sandstone. Chiefly dark-gray shaly siltstone, locally hackly. Greenish-gray lenticular masses as much as 30 ft thick of very fine grained graywacke sandstone in subordinate amounts. Minor dark greenish-gray siltstone. Several coquinoid limestone lenses as much as 5 ft thick composed chiefly of *Aucella* sp. Several lenses of greenish chert as much as 10 ft thick. A few 2- to 6-in. layers of graywacke-granule conglomerate. Cherty siltstone concretions that weather gun-metal blue. Cannonball concretions of siltstone as much as 8 in. in diameter	250	0–250
Shublik formation.		

Distribution.—The rocks of the Tiglukpuk formation are present in the foothills from the Lupine River to the western boundary of the mapped area and as Patton points out, have "been recognized and mapped * * * [as far west as] the Nuka River." From the Ribdon River to the western boundary of the mapped area, the folded and faulted strata of the formation crop out in an anticlinorium whose south flank is composed of resistant rocks of the Fortress Mountain formation and whose north flank consists of rocks of the Fortress Mountain and Torok formations. In the mapped area the Tiglukpuk formation is overlain with probable angularity by the Okpikruak and Fortress Mountain formations; it overlies the Shublik formation with little or no angular discordance.

Lithology.—The Tiglukpuk formation is composed of a marine unit of shaly siltstone, shale, siltstone, conglomerate, and graywacke which interfinger northward with the shale of the Kingak. The predominant rock type is a medium-gray hackly-fracturing shale with blue metallic luster, although black silicified shale is not uncommon. About 30 percent of the formation is composed of siltstone and graywacke that are generally highly argillaceous, noncalcareous, light gray to green, and low in porosity and permeability. The siltstone and sandstone are present as beds and massive lenses which pinch out laterally in short distances in the shale. The sandstone beds are more abundant in the upper part of the formation and locally are cross-bedded and coated with prismatic calcite and siderite. Cherty, ferruginous, silty, and limy concretions and nodules are common throughout the rock unit. Conglomerate is rare and is present only in the lower part of the formation near Elusive Lake. Pebbles are subround to angular and black chert constitutes 80 percent of the detritus. Locally interbedded with the conglomerate is coquinoid limestone, black silty limestone, and botryoidal siltstone concretions that emit a fetid odor on fresh fracture surfaces. The coquinoid limestone is present as beds from a few inches to several feet thick, is composed almost entirely of compressed *Aucella* sp., and weathers reddish brown. The rock is blue gray on a fresh surface and has incipient cleavage. This lithofacies does not occur east or north of the Lupine River, and it is best developed in the lower part of the formation west of Elusive Lake. Locally, however, it is present higher in the formation between the Lupine and the Ribdon Rivers.

Measured sections.—No complete section of the Tiglukpuk formation was measured by the authors. The Tiglukpuk formation on the Lupine River is known to be at least 1,800 feet thick, but the upper part of the formation is not exposed in this locality. West of Elusive Lake it is unlikely that more than 500 feet of the rock unit could be present between the confining beds of the Okpiruak and Shublik formations; several miles northwest of Elusive Lake the formation is missing entirely. The variation in the thickness of the formation is probably due mostly to post-Tiglukpuk erosion but may be due in part to overlap of the Late Jurassic rocks in a southwest direction.

Section 5 (pls. 21, 23) was measured in outcrops along the Lupine River and one of its small eastern tributaries. The upper beds and the contact of the formation with the Shublik formation are covered.

The rocks of this section are actually transitional between those of the Kingak and the Tiglukpuk formations, but they are more like the Tiglukpuk than like the Kingak at the respective type localities.

Tiglukpuk formation, section 5

	Feet
Unexposed.	
Black clay shale with blue metallic luster and hackly-fracturing sandy to shaly siltstone; large dense siltstone nodules and concretions; sandstone and sandy siltstone lenses coated with siderite, pyrite, and prismatic calcite; fossils are present in the shale beds (USGS Mesozoic loc. 22768)	1,200±
Black brown-weathering fissile locally sandy shale; pyrite stringers; spheroidal siderite-coated siltstone nodules and concretions (USGS Mesozoic locs. 22766 and 22769)	400±
Black reddish brown-weathering hackly-fracturing sandy shale; massive siltstone lenses and beds; 2-in. beds of black limestone	200±
Total measured thickness of Tiglukpuk formation	1,800±
Shublik formation.	

Age.—The fossils collected from the Tiglukpuk formation by the authors were identified and assigned a Late Jurassic age by Ralph W. Imlay. In the only controlled section of the formation measured in the mapped area the lowest 200 feet are unfossiliferous. Nevertheless, the authors consider it unlikely that rocks older than Late Jurassic are represented in the Tiglukpuk formation from the Lupine River to the western boundary of the mapped area. The fossiliferous localities and Imlay's identifications are:

Fossils and localities at which they were collected from the Tiglukpuk formation

USGS Mesozoic locality	Field sample	North latitude	West longitude	Fossil	Description of locality
22766	51 AKe 135	68°51′	148°17′30″	*Aucella concentrica* (Sowerby) *rugosa* (Fischer) *mosquensis* (von Buch)	Shale beds on east side of small tributary of Lupine River 200–600 ft above base of formation.
22768	51 AKe 153	68°51′50″	148°18′30″	*Aucella rugosa* (Fischer)	Black platy shale beds on east side of Lupine River 1,500–1,800 ft above base of formation.
22769	51 AKe 154	68°51′	148°18′	*Aucella concentrica* (Sowerby) *mosquensis* (von Buch) *rugosa* (Fischer) Ammonite fragment	Blue-weathering shale beds on east side of Lupine River 200–600 ft above base of formation.
22746	51 ADt 136	68°52′	148°06′	*Aucella rugosa* (Fischer)	Dark fissile shaly siltstone beds east of Lupine River.
22749	51 ADt 149	68°49′30″	148°21′	*Aucella rugosa* (Fischer)	Coquinoid limestone from a siltstone-shale section about 1½ miles west of Lupine River.
22750	51 ADt 151	68°49′45″	148°22′	*Aucella* cf. *A. mosquensis* (von Buch)	Siltstone nodules in cutbank along small western tributary of Lupine River.
22751	51 ADt 152	68°50′	148°20′30″	*Aucella rugosa* (Fischer) *mosquensis* (von Buch)	Coquinoid limestone in cutbanks east of 22750 above.

In a written communication in January 1952 Imlay stated:

Many of the Jurassic fossil collections that were made * * * are of middle to upper Kimmeridgian or lowermost Portlandian age on the basis of several species of *Aucella* including rare *A. concentrica* (Sowerby) and abundant *A. rugosa* (Fischer) and *A. mosquensis* (von Buch). The Russian geologists have shown that *Aucella concentrica* ranges through the upper Oxfordian and Kimmeridgian, and *A. rugosa* and *A. mosquensis* range through the middle and upper Kimmeridgian into the lowermost Portlandian (Pavlow, 1907: Soc. Imp. Nat. Moscow, mem. v. 17, table opposite p. 84) not higher than the zone of *Zaraiskites albani* (See Arkell, 1946: G.S.A. Bull. v. 57, p. 24-26; Spath, 1936: Medd. om. Gronland, Bd. 99, no. 3, p. 167). *A. mosquensis* in Europe is not known below the zone of *Subplanites wheatleyensis*. I doubt whether the Portlandian is represented in the collections from northern Alaska. At least lots 22766 and 22769 which contain *A. concentrica* in association with *A. mosquensis* and *A. rugosa* represent some part of the middle or upper Kimmeridgian. The other lots (22768, 22746, 22749, 22750 and 22751) containing only *A. mosquensis* and *A. rugosa* could not be younger than basal Portlandian if the ranges of these species are the same as in Europe.

CRETACEOUS SYSTEM

LOWER CRETACEOUS SERIES

OKPIKRUAK FORMATION

History.—The Okpikruak formation was named by Gryc, Patton, and Payne (1951, p. 159) for the rocks typified by the section along the Okpikruak River. They stated:

* * * The type section lies in the middle of a major syncline and is exposed on a small tributary of the Okpikruak River at about lat 68°34′30″ N. and long 153°38′ W. The formation crops out in the southern part of the Arctic foothills province from the Itkillik River west to the Kukpowruk River. In the Arctic foothills province, as far as known, it rests on Jurassic or Triassic rocks with little or no angular discordance. At its type locality it is about 2,400 feet thick * * *. It is predominantly fine-grained greenish-gray sandstone of the graywacke type, dark clay, and silt shale with minor amounts of conglomerate near the base. On the Siksikpuk River, where part of the formation is well exposed, it is 1,850 feet thick. Here it is characterized by a rhythmic alternation of fine-grained sandstone, silt shale, and clay shale. This alternation is not well developed in the forma-

tion along the Okpikruak River, although there is a suggestion of it.

Distribution.—In the area mapped the Okpikruak formation crops out discontinuously in the foothills from the Canning River to the Sagavanirktok River. In part of this area, a considerable thickness of the formation has been eroded, and locally younger formations rest uncomformably on Jurassic rocks.

From the general vicinity of the Lupine River east to the Canning River, the nonresistant rocks of the Okpikruak formation are exposed in scattered outcrops in much the same fashion as those of the Kingak shale. The two formations are not always distinguishable one from the other and locally they have been mapped as undifferentiated. From the Lupine to the Canning Rivers the Okpikruak formation is differentiated from the underlying Kingak shale by the presence of fossils and the rhythmic alternation of shale and siltstone. From the Echooka River to the Kavik River, the contact between the two formations is locally discernible, for in this part of the mapped area 220 feet of sandstone, which the authors tentatively assign to the Okpikruak formation, overlies the Jurassic shale. This sandstone unit of Early Cretaceous age (p. 198), here named the Kemik sandstone member, forms faulted rubble ridges in the interstream areas and apparently pinches out both to the west and east.

West of Elusive Lake, the rocks of the Okpikruak formation form resistant mesas, and here the sandstone and conglomerate that constitute part of the rock unit are not always distinguishable from those of the overlying Fortress Mountain formation. However, the rhythmic alternation that characterizes the formation from the Lupine to the Canning Rivers also typifies the Okpikruak sections west of Elusive Lake, and is lacking in the Fortress Mountain sections.

Lithology.—From the Lupine to the Canning Rivers the Okpikruak formation principally consists of dark nodular and earthy clay shale and shaly siltstone coated with a white or yellow powdery salt. Light-brown to gray dense siltstone and ironstone are present as lenses in the alternating beds in the shale. The dense siltstone and ironstone lenses are pyritized; the siltstone lenses are commonly fossiliferous and their surfaces weather rust brown. The only sandstone unit in the Okpikruak formation between the Lupine and the Canning Rivers is at the base, between the Echooka and the Kavik Rivers; the type section of this, the Kemik sandstone member, is on Kemik Creek (section 11, pl. 23).

The total thickness of the Okpikruak formation east of the Lupine River is not known, but presumably it varies from one place to another depending upon the amount of post-Okpikruak erosion. On the east side of Kemik Creek between lat 69°24′ N. and lat 69°25′ N., a composite incomplete section (section 11) 720 feet thick was measured in two cutbanks. In the southernmost cutbank, the measured strata form the gently south-dipping flank of a west-plunging syncline, and the upper beds of the formation have been eroded. In the other cutbank, the measured strata dip 20° to 64° S. on the upthrown block of a reverse fault; the upper beds of the formation have been faulted out. In the southern cutbank, the Kemik sandstone member overlies the Kingak shale with no apparent angular discordance.

Okpikruak formation, section 11

	Feet
Unexposed.	
Principally nodular clay and platy shaly siltstone coated with a white or yellow salt; siltstone beds in rhythmic alternation with the shale; light-brown to gray nodules and concretions of dense silicified fossiliferous limy siltstone and noncalcareous ironstone (USGS Mesozoic loc. 22757; see p. 197); fossils are partly pryitized	500
Kemik sandstone member:	
Quartzose fine- to medium-grained sugary-textured light-gray sandstone; the rocks are slightly argillaceous, noncalcareous, and well indurated; the sandstone (examined in thin section) is composed of 75 percent subangular grains of quartz, 23 percent chert and rock fragments, 2 percent phosphate, and a trace of limonite, leucoxene, and chlorite; the base of the member consists of several thin layers of rusty-weathering quartz-grit conglomerate; USGS Mesozoic locs. 24008 and 24009	220
Total measured thickness of Okpukruak formation	720
Kingak shale.	

West of Elusive Lake the rocks of the Okpikruak formation are more coarsely clastic than those which crop out east and north of the Lupine River; the formation comprises alternating beds of dense siltstone and sandstone of graywacke type, and to a lesser degree, shaly siltstone and conglomerate. The sandstone, in sharp contrast with the Kemik sandstone member, is a typical graywacke which (in thin section) is composed of angular grains of quartz (10 percent), chert, schist, and igneous fragments (33 percent), microcline and andesine (12 percent), a trace of titanite and leucoxene, and a matrix of sericite, chlorite, silt, and clay (45 percent).

Two sections of the Okpikruak formation were measured west of Elusive Lake: section 3, which includes about 1,500 feet of the lower part of the formation, and section 2 which constitutes the upper 884 feet of the formation. The two sections cannot be correlated and the total thickness of the formation west of Elusive Lake is not known.

At Elusive Lake (section 3) the Okpikruak formation overlies the lower part of the Tiglukpuk formation; the upper beds of the formation have been eroded. The 1,500-foot section is exposed as a scarp facing the west side of Elusive Lake near lat 68°41′ N., between long 148°27′ W. and 148°29′ W. The section comprises alternating beds of dense medium-gray siliceous siltstone and fine- to medium-grained gray to green graywacke. The siltstone beds are several inches to a foot thick and the sandstone beds are 2 to 4 feet thick. Shaly siltstone constitutes about 20 percent of the section. The base of the section contains siderite- and calcite-coated rusty-weathering nonlimy siltstone concretions and nodules; the rocks in the lower part of the formation are slaty. The section is unfossiliferous.

Section 2 is exposed in cutbanks along Section Creek, a small incised tributary of the Sagavanirktok River drainage system, between lat 68°40′20″ N. and 68°40′50″ N. The measured strata form the steeply south dipping north flank of a west-plunging syncline. The contact of the formation with the overlying Fortress Mountain formation was not seen and the lower part of the formation is unexposed owing to a high-angle reverse fault. The unfossiliferous section comprises alternating beds of dirty graywacke-type sandstone, siltstone, and shaly siltstone. The sandstone is, for the most part, fine grained, argillaceous, noncalcareous, and dark gray; it is present in beds 1 inch to 15 feet thick. Nonpersistent conglomerate lenses with black and green angular chert granules and pebbles are present in the upper beds. The siltstone and shaly siltstone constitute approximately 50 percent of the total measured section. The siltstone is dark gray, hackly fracturing, and locally fissile; it contains minor pyrite nodules and limy concretions.

Age.—The fossils collected from the Okpikruak formation were examined and identified by Ralph W. Imlay (written communication). He assigned the fossils, except those too fragmental for precise determination and those of long-ranging habit, to the lower part of the Neocomian stage of the Early Cretaceous. The fossiliferous localities and Imlay's identifications are listed below.

Fossils and localities at which they were collected from the Okpikruak formation

USGS Mesozoic locality	Field sample	North latitude	West longitude	Fossil	Description of locality
22738	51 ADt 18	69°24′30″	147°15′	*Aucella subokensis* Pavlow *okensis* Pavlow Belemnite fragment	Limy lenses and concretions in cutbank on east side of Shaviovik River.
22740	51 ADt 33	69°26′	147°12′	*Aucella* sp.	Limy lenses and concretions in cutbank on east side of Kemik Creek in beds believed to be correlative with 500-ft thick shale section overlying Kemik sandstone member of type section.
22741	51 ADt 49			*Aucella* cf. *A. okensis* Pavlow sp.	Do.
22742	51 ADt 50			*Aucella sublaevis* Keyserling	Do.
22744	51 ADt 94	69°15′15″	147°49′	do	Limy lenses and concretions in cutbank on Gilead Creek.
22757	51 AKe 23	69°25′30″	147°12′	*Aucella okensis* Pavlow *subokensis* Pavlow	Limy lenses and concretions in 500-ft section of shale which overlies Kemik sandstone member in cutbank along Kemik Creek.
22761	51 AKe 76	69°11′20″	147°45′30″	*Aucella sublaevis* Keyserling	Limy siltstone lenses and concretions in cutbank on small northern tributary of Kashivi Creek.
22762	51 AKe 77			*Aucella subokensis* Pavlow	Limy siltstone lenses and concretions in cutbank about one-fourth mile north of cutbank of USGS Mesozoic loc. 22761.
22765	51 AKe 128	68°56′	148°15′30″	*Aucella okensis* Pavlow *subokensis* Pavlow	Lenses and concretions in cutbank on southwest side of Lupine River.
22767	51 AKe 139	68°54′15″	148°19′	*Aucella crassicollis* Keyserling	Limy lenses and concretions in cutbank on east side of Lupine River.
24008	52 AMo 8	69°25′		*Lytoceras* sp. *Plicatula* sp. Rhynchonellid brachiopod	Kemik sandstone member in cutbank along east side of Kemik Creek.
24009	52 AMo 2			*Parallelodon*? sp.	Do.
24010	52 AMo 3	69°24′30″	147°15′	*Aucella subokensis* Pavlow	Same as 22738.
24026	52 AKe 2	69°27′10″	146°56′	*Aucella* sp.	Limy lenses and concretions in small cutbank along east side of small tributary of Fin Creek.
24030	52 AKe 16			do	Limy lenses and concretions in cutbank on small eastern tributary of Juniper Creek in beds underlying Ignek formation.
24031	52 AKe 33	69°31′15″	146°24′	*Aucella okensis* Pavlow *subokensis* Pavlow *Camptonectes* sp. Belemnite indet.	Limy lenses and concretions in small cutbank of tributary of Canning River in beds underlying upper member of Ignek formation.

Imlay, on the basis of comparison of its *Aucella* faunules with those in Russia and Siberia, considered (written communication, 1956) that the Okpikruak formation, in the Shaviovik and Sagavanirktok Rivers region, represents only the Berriasian and Valanginian stages.

The Berriasian is represented in USGS Mesozoic locs. 22757, 22762, 22765, 22738, 24031 by *Aucella okensis* Pavlow, *A. subokensis* Pavlow, the lower Valangian in USGS Mesozoic locs. 22742, 22744, 22761 by *A. sublaevis* Keyserling, and the middle to upper Valanginian in USGS Mesozoic loc. 22767 by *A. crassicollis* Keyserling.

Imlay (written communication, 1955) believed that the fossils in USGS Mesozoic locs. 24008 and 24009, which were collected from the Kemik sandstone member, are nondiagnostic as to age. Inasmuch as these lots contain the only fossils collected from the Kemik sandstone member, its age is not precisely known. The sandstone unit overlies strata of Jurassic age and underlies strata bearing fossils which Imlay assigned to the Cretaceous (Berriasian, USGS Mesozoic loc. 22757). Although it lacks definitive criteria, the authors believe that the sandstone member more logically belongs to the Cretaceous system than to the Jurassic.

FORTRESS MOUNTAIN AND TOROK FORMATIONS

The Fortress Mountain and Torok formations are considered jointly in this report. The relationships between the two formations are not known definitely. In early work (Gryc, Patton, and Payne, 1951, p. 160), the two formations were considered one mappable unit, the Torok formation; however, Patton (1956b) later recognized the need for two formation names for these rocks and revised the earlier nomenclature.

History and type sections.—The Fortress mountain formation was named by Patton (1956b), "from the exposures on Fortress Mountain (lat 68°34′30″ N., long 152°58′ W. * * *) where it is typically exposed and where it was first studied in detail." For a type section, Patton (p. 219) reported "a composite of several partial sections exposed nearby along the Kiruktagiak River and on Castle Mountain. * * *" Patton's type section is given below.

	Approximate thickness, in feet	*Stratigraphic interval measured from base of section, in feet*
Top of Castle Mountain.		
Conglomerate and sandstone. Dark greenish-gray very thick bedded pebble and cobble graywacke conglomerate that weathers moderate yellowish brown. Pebbles and cobbles are 60 percent chert and the rest limestone, sand- [Conglomerate and sandstone—Con.] stone, mafic igneous rock, and pink gneissoid granite. Dark greenish-gray fine- to coarse-grained lenticular thick-bedded graywacke sandstone	500	9, 680–10, 180
Sandstone and conglomerate. Dark-green fine- to medium-grained medium-bedded to massive sandstone. Medium-green massive pebble conglomerate. Pebbles similar to above but no gneissoid granite. Minor interbeds of dark-gray silt shale and siltstone. Section partly covered	490	9, 190–9, 680
Shale, sandstone, and siltstone. Dark-gray clay and silt shale. Interbedded medium-green very fine grained thin- to medium-bedded sandstone. Dark-gray to green siltstone. Section partly covered	600	8, 590–9, 190
Shale, dark-gray clay and silt shale. Calcareous siltstone concretions. Section poorly exposed	1, 260	7, 330–8, 590
Conglomerate and sandstone. Green, yellow-red weathering, massive, lenticular chert-pebble conglomerate. Medium-green fine- to coarse-grained sandstone with scattered chert pebbles. Minor interbeds of dark-gray shale and siltstone. Section partly covered	310	7, 020–7, 330
Shale, siltstone, and sandstone. Dark-gray clay and silt shale with calcareous, ferruginous, and siliceous siltstone concretions. Dark-gray to green very fine to fine-grained medium-bedded sandstone. Section poorly exposed	1, 720	5, 300–7, 020
Sandstone and conglomerate. Medium- to dark-green very fine to fine-grained medium-bedded to massive sandstone with scattered chert pebbles. Lenses 6 in. to 5 ft thick of green chert-pebble conglomerate. Minor interbeds of dark-gray shale and dark-gray to green siltstone	880	4, 420–5, 300
Shale, siltstone, and sandstone. Dark-gray clay and silt shale. Dark-gray siltstone. Medium-green to gray very fine grained medium-bedded to massive calcareous sandstone. Section partly covered	950	3, 470–4, 420
Shale, dark-gray clay and silt shale with numerous calcareous, siliceous, and ferruginous siltstone concretions. Minor interbeds of dark siltstone and light-green to gray, very fine grained, thin- to medium-bedded calcareous sandstone. Section partly covered	1, 050	2, 420–3, 470
Shale, siltstone, sandstone, and conglomerate. Dark-gray clay and silt shale and dark-gray siltstone. Medium dark-green, very fine to coarse-		

	Approximate thickness, in feet	Stratigraphic interval measured from base of section, in feet
Shale, siltstone, sandstone, and conglomerate—Continued		
grained, thin- to medium-bedded sandstone with occasional chert granule or pebble. Dark-green thin- to medium-bedded lenticular chert-granule and pebble conglomerate. Section partly covered	410	2, 010–2, 420
Sandstone and conglomerate. Medium-green fine- to coarse-grained medium-bedded to massive sandstone. *Inoceramus* sp. Green lenticular chert-granule and pebble conglomerate. Minor interbeds of dark clay shale and silt shale	270	1, 740–2, 010
Shale, sandstone, and siltstone. Dark-gray clayey shale with numerous septarian calcareous siltstone concretions. Seventy-five ft of medium-green to gray thin- to medium-bedded very fine grained sandstone and dark-gray siltstone near middle of section. Section partly covered	570	1, 170–1, 740
Shale, sandstone, and siltstone. Dark-gray clay and silt shale with a few septate calcareous siltstone concretions. Light-green thin-bedded very fine grained sandstone and gray siltstone. Section partly covered	650	520–1, 170
Shale, dark-gray clay shale with lenses of gray silty limestone and septate calcareous siltstone concretions. Section partly covered	520	0–520
Tiglukpuk formation.		

The Torok formation, as originally defined by Gryc, Patton, and Payne (1951, p. 160), included the rocks later defined by Patton (1956b) as the Fortress Mountain formation (this report, p. 198); in addition it also included a 6,000-foot section, composed mostly of shale, along a tributary of the Chandler River near Castle Mountain. Patton (1956b) limited the name Torok to the rocks characterized by the 6,000-foot shale section along the tributary of the Chandler River. The exact location of the type section is "along the Chandler River and Torok Creek between lat 68°40′ N. and 68°43′45″ N."

The Torok formation was described by Patton as consisting of 1,500 feet of "dark-gray silt shale and clay shale with subordinate amounts of fine-grained graywacke sandstone * * * [overlain] by 700 feet of dark greenish-gray graywacke sandstone locally containing thin lenses of chert-granule conglomerate * * * [which is in turn overlain by 3,800 feet] of dark-gray clay shale with intercalated beds of dark-gray silt shale and greenish-gray siltstone."

Distribution.—The Fortress Mountain formation crops out in the southern part of the Foothills province from the Ribdon River to the western edge of the mapped area, thence (Patton, 1956b) "west beyond the Kukpowruk River." It does not crop out and probably is not present north of lat 68°55′ N. West of Elusive Lake, the formation forms mesas and bluffs which rise in bold relief above the surrounding country. Its strata, depending upon the amount of post-Tiglukpuk and post-Okpikruak erosion, locally overlie the Okpikruark formation, the Tiglukpuk formation, and, at one locality about a mile northwest of Elusive Lake, the Shublik formation. The contact of the Fortress Mountain formation with younger rocks is not exposed in the mapped area; which formation directly overlies the rock unit is not known.

The Torok formation crops out only in a few isolated cutbanks in a low gravel-covered outcrop belt that extends from the Ivishak River to the west side of the Sagavanirktok River. The formation does not crop out east of the Ivishak River and probably was not deposited there. The formation's outcrop belt lies to the north of the outcrop belt of the Fortress Mountain formation; west of Ribdon River the strata of the two are separated by a reverse fault. The contact of the Torok formation with the overlying Tuktu formation of the Nanushuk group was not seen by the authors, but the strata of the two formations are probably conformable. As the contact of the Torok formation and older rocks is not exposed in the mapped area, which formation directly underlies it is not definitely known. The authors believe, however, that east of the Ribdon River it is underlain by the Okpikruak formation.

The exact relation between the Fortress Mountain and Torok formations cannot be established, inasmuch as the nature of the contacts between the Fortress Mountain and younger formations and between the Torok and older formations are not known. Patton (1956b) stated that the megafossils of the two formations, in the area west of that mapped by the authors, "are approximately of the same age, but the microfaunas are [of] somewhat different [ages] * * *. [Presumably the Torok formation] is underlain by the Okpikruak formation and perhaps by a part of the Fortress Mountain formation." Although there is no definite evidence, for the purposes of this report the authors postulate that the Torok formation is, in part, a northerly time-equivalent of the Fortress Mountain formation, and in part, younger. The postulated depositional relations between the two formations are shown diagrammatically on figure 30.

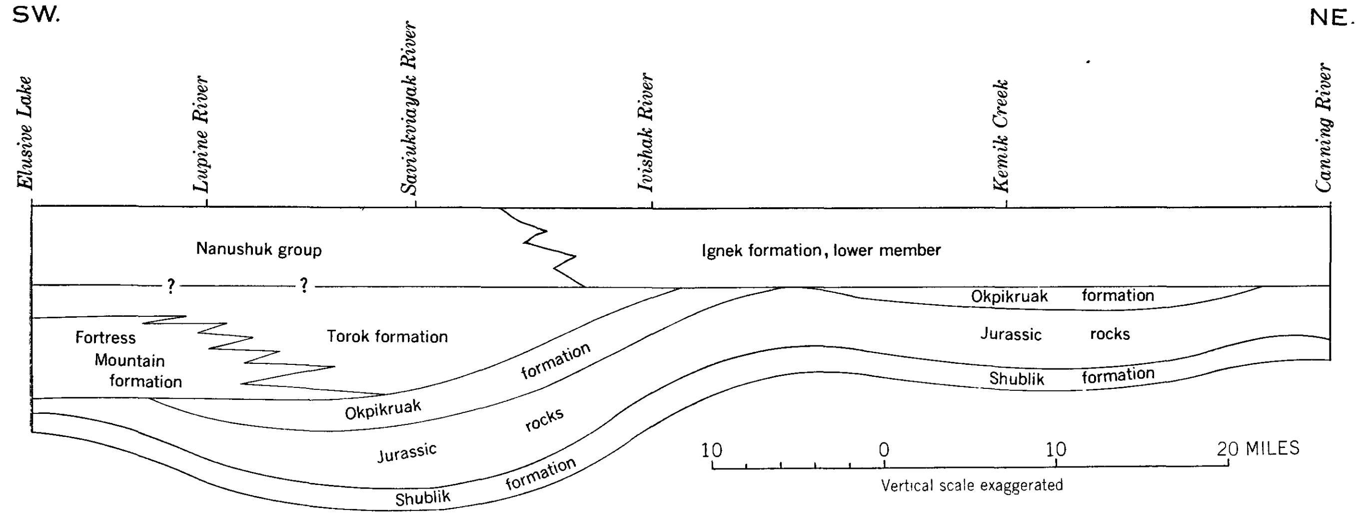

FIGURE 30.—Diagram showing suggested correlations and depositional relations of various stratigraphic units of Mesozoic age from the Canning River to Elusive Lake.

Lithology and measured sections.—The Fortress Mountain formation is a coarse clastic unit consisting of an interbedded succession of marine sandstone, siltstone, shaly siltstone and clayey shale, and conglomerate. The conglomerate and sandstone are both of the graywacke type and the detritus consists of black and green chert, feldspar, and angular mafic igneous rock fragments in a green mudstone matrix. The sandstone and conglomerate are typically low in porosity and are impermeable. The conglomerate occurs as large masses and discontinuous lenses. Locally the sandstone contains shale lenses and carbonized wood fragments. The siltstone is typically gray or green and locally siliceous. The clay shale and shaly siltstone are medium gray and locally contain pebbles of green and black chert. The formation is characterized by a wide variety of calcareous, ferruginous, argillaceous, and siliceous nodules, concretions, and lenses. The Fortress Mountain formation is generally unfossiliferous and contains no reliable horizon markers. The thickness of the entire formation in the mapped area is not known, but west of Elusive Lake it exceeds 2,955 feet.

The Torok formation comprises interbedded medium-gray platy and locally fissile shaly siltstone, and, in lesser amounts, finely laminated siltstone. The siltstone beds are 2 inches to a foot thick and the rocks weather light brown. Brown-weathering siltstone concretions are common. The formation is essentially unfossiliferous, although locally *Inoceramus* sp. is present.

Only one section of the Fortress Mountain formation was measured by the authors. This section (section 4, pls. 21, 23) is exposed in a steep east-facing cliff about 3 miles northwest of Elusive Lake. The measured strata form the south limb of a west-plunging anticline and overlie shale of the Tiglukpuk formation. The upper strata of the formation have been eroded.

Fortress Mountain formation, section 4

	Feet
Dark-gray to green brown-weathering medium- to thick-bedded sandstone; black chert-granule graywacke conglomerate with shale inclusions	100
Interbedded dark-gray to green sandstone; conglomeratic sandstone with black chert granules; shaly siltstone	1,600
Graywacke sandstone, siltstone, and shaly siltstone	485
Interbedded graywacke conglomerate, sandstone, and siltstone	100
Interbedded siltstone, conglomeratic sandstone, and shaly siltstone; granules are mostly black chert set in a green sandstone matrix; sandstone mostly dark gray, very fine to medium grained, argillaceous and slightly calcareous, in beds as much as 4 ft thick; siltstone dark gray, dense, in beds as much as 6 ft thick; lenses of conglomerate	500
Black shaly siltstone and soft clay shale with a few siltstone interbeds	170
Total measured thickness of Fortress Mountain formation	2,955
Tiglukpuk formation.	

No sections of the Torok formation were measured, and it is unlikely that more than several hundred feet of the unit crops out at any one locality in the area mapped. Isolated exposures of the formation are present along a small western tributary of the Ivishak River at lat 69°00′15″ N., between long 148°11′ W. and 148°14′ W.; there the Torok strata strike and dip about the same as the overlying beds of the Nanushuk group. The several hundred feet of Torok formation that is exposed comprise fissile shaly siltstone and brown-weathering siltstone in beds from 2 inches to 1 foot thick. Large brown-weathering siltstone concretions are present in the shale; one poorly preserved *Inoceramus* sp. was found.

LOWER CRETACEOUS AND UPPER CRETACEOUS SERIES

NANUSHUK GROUP

History.—The name "Nanushuk," taken from the Nanushuk River, was originally applied by Frank C. Schrader to a rock "series" along a part of the Anaktuvik and Colville Rivers in northern Alaska. Gryc, Patton, and Payne redefined these rocks (1951, p. 162) and assigned the name "Nanushuk" "to a group of rocks * * * exposed along the Nanushuk River where the river cuts across the Arctic Foothills province of northern Alaska." They further divided the group into two formations: "[(a)] the Chandler (nonmarine), which tongues into the [(b)] Umiat (marine) to the north." Detterman (1956) redefined the group and further modified the nomenclature by dividing the rocks into four formations: "the Tuktu formation (marine, no nonmarine equivalents) at the base; the Grandstand and Ninuluk formations, marine; and the Chandler formation (nonmarine) which intertongues with and grades into the two upper marine formations." Detterman subdivided the Chandler formation into two tongues, the Killik and the Niakogon; the relationships of the rock units that he defined are shown diagrammatically on figure 31. Of these formations, only the Tuktu, the Killik tongue of the Chandler, and the Ninuluk crop out in the area mapped by the authors.

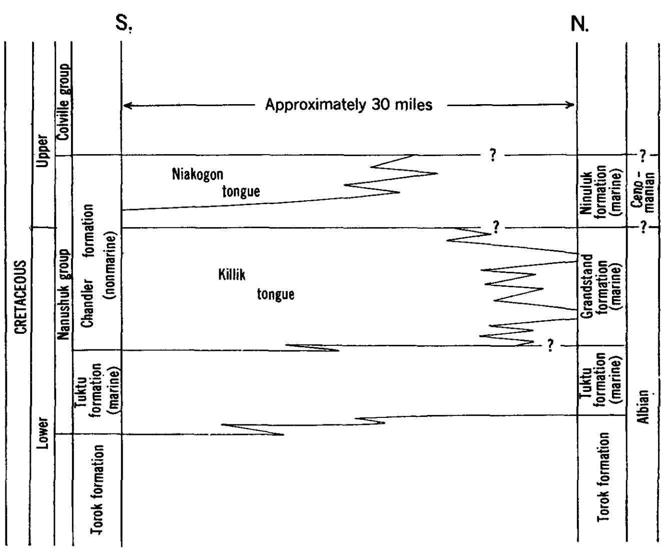

FIGURE 31.—Diagrammatic sketch of intertonguing marine and nonmarine units of the Nanushuk group in the type localities, Colville River region, Alaska. Modified from Detterman (1956).

Type sections.—Detterman (1956, p. 234) reported the type section of the Tuktu formation to be "at Tuktu Bluff on the north side of the Chandler River at the point where the river cuts the escarpment * * * lat 68°44′ N., long 152°18′ W." The formation is described (p. 235) as consisting of 1,030 feet of: "dirty green to greenish-gray very fine to fine-grained sandstone; much of the sandstone borders on siltstone. Siltstone and silt shale form a subordinate but important part of the formation. The sandstone is commonly thin bedded, but in places is more massive and cliff forming. It is commonly calcareous, highly argillaceous, and in places micaceous. Small ironstone nodules are commonly found throughout the formation, particularly in the siltstone-silt shale units."

The type section of the Killik tongue of the Chandler formation was reported by Detterman (p. 237) to be "along the east bank of the Killik River between lat 68°52′ N. and 68°55′ N. and long 153°26′ W." The formation is described (p. 238–239) as comprising two parts: the lower, 1,095 feet thick, consists of "characteristic thick-bedded, bluff-forming sandstones * * * [and] grayish, micaceous, carbonaceous siltstone and silt shale with numerous thick coal seams * * *; [the upper, 1,720 feet thick,] is characterized by * * * massive white quartz conglomerate," sandstone, siltstone, silt shale, and thin seams of coal."

Detterman (p. 241) described the type section of the Ninuluk formation as 657 feet thick and "on the right bank of the Colville River at Ninuluk bluffs 20 miles downstream from the junction of the Killik and Colville Rivers, lat 69°08′ N., long 153°18′ W." The formation was further described by Detterman:

> Greenish-gray siltstone, silt shale, and dark blue-gray clay shale constitute about 60 percent of the sequence. Coarse clastics account for most of the remainder. Several thick sandstone units are present near the top of the formation. Stringers and lenses of grit-pebble conglomerate are present at intervals throughout the coarser clastic units. The sandstone grades from "salt and pepper" through various shades of gray and yellow red. Most of them have a distinct greenish cast. Siliceous, argillaceous, and ferruginous concretions are commonly associated with siltstone and silt shale units.

Distribution.—In the mapped area, the Tuktu formation, the Killik tongue of the Chandler formation, and the Ninuluk formation have been mapped only at Marmot syncline where these rocks form a mesa which stands in bold relief above the surrounding country. However, the Nanushuk group has been mapped also as an undifferentiated unit at several localities between the Ivishak and the Lupine Rivers. At one of these localities, in cutbanks along the Saviukviayak River, the rocks are part of the Tuktu formation. At the other localities where the Nanushuk group has not been differentiated, probably both the Tuktu and the Chandler formations are represented. The Nanushuk group has not been mapped east of about long 148° W. The authors mapped as Ignek formation, lower member, rocks east of long 148° W. believed, for reasons stated on page 205, to be equivalent in age to those of the Nanushuk group (fig. 30).

TUKTU FORMATION

Lithology.—The several hundred feet of the Tuktu formation exposed in the cutbanks along the Saviukviayak comprise interbedded mudstone, clayey to shaly siltstone, and sandstone. The shaly siltstone constitutes approximately 40 percent of the rock and is dark gray, micaceous, and carbonaceous. The sandstone is dark gray with brown-weathered surfaces, thin to medium bedded, very fine grained, and highly argillaceous. The section is abundantly fossiliferous (USGS Mesozoic locs. 22753 and 22754).

At Marmot syncline 800 feet of the Tuktu formation crops out on the east side of the mesa and consists of interbedded siltstone, shaly siltstone, and silty sandstone. This section (section 1, pl. 23) is overlain gradationally by the Chandler formation; the contact of the section with the underlying Torok formation is covered. About 60 percent of the unit is composed of gray- to rust-brown-weathering siltstone and hackly-fracturing shaly siltstone. Small ferruginous nodules are common near the base. The sandstone is thin bedded, very fine grained, argillaceous, slightly calcareous, dark gray to green, and, in the lower part of the section, commonly lenticular. Locally the sandstone is laminated and crossbedded, and worm trails and tubes are present on the bedding planes. Fossils are abundant near the base of the section (USGS Mesozoic loc. 22755).

Age.—Only three fossil lots were collected from the Tuktu formation in the mapped area: two from the cutbanks along the Saviukviayak River, and one from the lower part of the section at Marmot syncline. The fossils were identified by Ralph W. Imlay.

Fossils and localities at which they were collected from the Tuktu formation

USGS Mesozoic locality	Field sample	North latitude	West longitude	Fossil	Description of locality
22753	51 ADt 112	68°04′45″	148°03′	*Inoceramus* cf. *I. altifluminis* McLearn cf. *I. cadottensis* McLearn	Sandstone and shale beds in cutbank on west fork of Ivishak River.
22754	51 ADt 113	68°04′45″	148°03′	*Gastroplites* n. sp.: cf. *G. kingi* McLearn *Inoceramus anglicus* Woods	Same as 22753 above but from rocks slightly lower in section.
22755	51 ADt 178			*Inoceramus* sp. juvenile *Arctica?* sp. *Pleuromya*	Sandstone and shale beds in lower part of section 1, plates 21, 23.

Only USGS Mesozoic loc. 22754 contains fossils on which definite age determination may be based. These have been assigned to the Albian stage of the Early Cretaceous by Imlay (written communication) who stated:

> The range of *Inoceramus anglicus* in northwest Europe is middle and upper Albian. It is not known below the middle Albian. Concerning *Gastroplites,* recent studies show that the genus ranges throughout the middle Albian and may extend into the upper Albian. * * *

Detterman (1956, p. 234) stated that Imlay's work indicates that in the type section the characteristic fossils are of middle Albian age.

CHANDLER FORMATION (KILLIK TONGUE)

Lithology.—The Killik tongue of the Chandler formation was recognized only at Marmot syncline where the formation gradationally overlies the Tuktu formation and gradationally underlies the Ninuluk formation. The sequence (section 1, pl. 23) is approximately 2,500 feet thick and consists of nonmarine to nearshore sandstone, conglomerate, siltstone, shale, and coal. Most of the sequence is covered and only the resistant conglomerate and sandstone beds are well exposed. The base of the section is a massively bedded, medium-grained salt-and-pepper sandstone with estimated fair porosity and permeability. Overlying this sandstone is approximately 1,000 feet of more thinly bedded fine-grained argillaceous rusty-weathering sandstone, shaly siltstone, and gray-green crossbedded siltstone and minor coal.

The upper 1,500 feet of the measured section consists of interbedded sandstone, conglomerate, siltstone, coal, and shale, of which sandstone and siltstone make up the bulk of the unit. The resistant ledge-forming conglomerate is composed of as much as 30 percent rounded white quartz grains, and black, gray, and green chert with a few pebbles of limestone of Mississippian age. The sandstone is medium grained and fairly clean; it has a salt-and-pepper appearance and rust-brown-weathered surfaces. The siltstone is thin bedded, medium grained, and stained with limonite. Ironstone nodules and concretions are present throughout the 1,500 feet.

Age.—The Killik tongue of the Chandler formation is unfossiliferous at Marmot syncline. However, it gradationally overlies the Tuktu formation of middle Albian age and is probably overlain gradationally by the Ninuluk formation, which in the type locality (Detterman, 1956, p. 242) contains "abundant specimens of *Inoceramus dunveganensis* McLearn, which are of late Cenomanian age." It seems logical therefore that the age of the Killik tongue of the Chandler formation is middle or late Albian.

NINULUK FORMATION

Lithology.—The Ninuluk formation was recognized only at Marmot syncline where about 100 feet of the formation forms the top beds. At this locality the sequence comprises thin-bedded fine-grained highly argillaceous green slightly calcareous sandstone, siltstone, and shaly siltstone shale; it is unfossiliferous.

IGNEK FORMATION

History.—The Ignek formation was originally defined by Leffingwell (1919) in his report on the Canning River region in which he stated (p. 120):

> The Ignek formation consists of about 2,500 feet of black shales with coal or "red beds" and subordinate sandstone members. It probably overlies the Kingak shale. * * * The formation occurs at both ends of the Sadlerochit Mountains and probably along the northern front. * * * The type locality is on the south side of Red Hill, in the Ignek Valley at the west end of these mountains.

Leffingwell (p. 120) listed the type section at Red Hill as follows:

	Feet
Blue-gray fine-grained sandstone	200
Black shales, with red bed near the top; fauna of locality 3	1,500
Unexposed	400
Gray sandstone, weathering yellow	100
Unexposed	400
	2,600

It is not clear what stratigraphic interval Leffingwell intended that the Ignek formation represent. For the purposes of this report, the authors have retained the name Ignek but have redefined the formation as those strata which, from the Ivishak to the Canning River and east, unconformably overlie the Okpikruak and Kingak formations and underlie the Sagavanirktok formation. The formation consists of two parts: a lower member of siltstone, shale, and dirty to relatively clean subgraywacke-type locally fossiliferous sandstone; and an upper member, predominantly of shale with lesser sandstone and siltstone beds, characterized by pyroclastics. Although the evidence is not conclusive, the authors believe (see p. 38) that the age of the lower member is Early Cretaceous, that the age of the upper member is Late Cretaceous, and that the two members are separated by an erosional break. Over much of the mapped area the contact between the two members is covered, and, for this reason and because of the complexity of the folding involving the two units along part of their contact zone, they have been mapped locally as undifferentiated.

The rocks mapped as Ignek formation were formerly mapped as the Nanushuk and Colville groups (Payne and others, 1951). The lower member of the Ignek formation is probably equivalent at least in part to the Nanushuk group, and the upper member is probably equivalent at least in part to the Colville group (an Upper Cretaceous unit which crops out west of the mapped area). However, although there are lithologic similarities in these rock units, the descriptions of the type sections of the Nanushuk and Colville groups are not applicable to the Ignek formation.

LOWER MEMBER

Distribution.—The lower member of the Ignek formation crops out in cutbanks along the west side of the Canning River north of Shublik Springs, along Gilead Creek, and along the west side of the Ivishak River. The strata of the lower member form the limbs of the syncline between the Kavik River and Juniper Creek, of the one on the east side of Gilead Creek, and of the faulted synclinorium between Gilead Creek and the Ivishak River. The lower member also is exposed in cutbanks along Fin Creek, Juniper Creek, and the Kavik River, but in these localities, it could not be mapped separately from the upper member. The lower member rests unconformably on the Okpikruak formation and, depending upon the amount of post-Okpikruak–pre-Ignek erosion, locally overlies the Kingak shale.

Lithology.—The lower member of the Ignek formation generally ranges in thickness from 2,590 feet on the Ivishak River to 1,000 feet on the Canning River. The variance in thickness probably is due partly to erosion during the time between deposition of the lower member and of the upper member, but it may be due also to progressive overlap of the younger beds of the lower member on the older beds in a general northeasterly direction.

The lower member of the Ignek formation comprises sandstone of subgraywacke type, siltstone, shale, and, less commonly, conglomerate. The sandstones are locally crossbedded, ripple marked, and characterized by curly bedding or hassock structure. They range from thin-bedded carbonaceous fine-grained rocks to reddish-orange-weathering medium-grained salt-and-pepper rocks. Most of the sandstones have low porosity and permeability, but some are estimated to be moderately porous and permeable. The sandstones (examined in thin sections) are composed of as much as 65 percent subangular quartz grains and lesser amounts of chert and rock fragments, plagioclase. orthoclase, leucoxene, hematite, pyrite, chlorite, and sericite. In some of the samples the grains are moderately well sorted. The siltstone in the lower member is thin bedded and ferruginous; the shale is medium to dark gray and locally contains blue-gray limestone lenses. Macerated plant remains, carbonaceous material, coal, and limonite nodules and concretions are locally present throughout the rocks of the lower member. The sequence is not abundantly fossiliferous except in the more northerly sections on the Canning River.

Measured sections.—Three sections of the lower member of the Ignek formation were measured: one between the Kavik River and Juniper Creek, one on the Canning River, and one between Gilead Creek and the Ivishak River. The latter 2, sections 8 and 19, are designated the standard sections of the lower member and are illustrated on plate 23. The locations of the sections are shown on plate 21.

Section 8 was measured on the south flank of a syncline between Gilead Creek and the Ivishak River, where the rocks of the lower member unconformably overlie the Okpikruak formation and the upper beds of the member have been eroded. About a mile northeast of the locality where this section was measured, the same sequence of rocks overlies the Kingak shale. No fossils were found in the measured section. Only the sandstone is well exposed; it crops out as resistant ledges in much the same manner as that of the Chandler formation at Marmot syncline.

Lower member of the Ignek formation, section 8

	Feet
Interbedded carbonaceous micaceous moderately argillaceous dark-gray very fine grained sandstone, siltstone, and iron-stained shaly siltstone	100
Covered interval	120
Thin-bedded ferruginous siltstone; dark-gray iron-stained shale; very fine to fine-grained micaceous carbonaceous argillaceous ripple-marked sandstone	140
Covered interval; some coal and sandstone float	90
Interbedded massive crossbedded fine-grained sandstone, siltstone, and shaly siltstone	80
Covered interval; some rubble of rocks as above	260
Dark-gray highly micaceous carbonaceous argillaceous, fine- to locally coarse-grained sandstone; iron-stained siltstone and shaly siltstone	190
Covered interval; rubble of rocks as above	760
Dark-gray dirty carbonaceous micaceous sandstone; weathers in large rectangular blocks; macerated plant remains and limonite-coated concretions	280
Covered interval	70
Massively bedded greenish-gray carbonaceous micaceous ripple-marked sandstone; limonite-coated concretions; minor shaly siltstone interbeds	400
Covered interval; float of rocks as above	100
Contact (arbitrarily placed).	
Total measured thickness of lower member of Ignek formation	2,590
Okpikruak formation.	

Approximately 1,500 feet of the lower member of the Ignek formation was measured in a faulted syncline about 5 miles north of the mountains between the Kavik River and Juniper Creek, where, on the north side of the syncline, the member rests on strata bearing fossils of Valanginian age (USGS Mesozoic loc. 24030; see p. 197). The section is overlain by a sandstone bed which is probably equivalent to one which forms the base of the upper member of the Ignek formation on the west side of the Canning River. The 1,500-foot section comprises iron-stained fine-to-medium-grained argillaceous micaceous, locally ripple-marked sandstone, iron-stained siltstone, and brown-weathering shaly siltstone. Only the sandstone is well exposed and it forms resistant ledges similar to those of section 8. Macerated plant remains and limonite nodules are present locally in the sandstone and shale of the measured section, and coal is interbedded in thin seams.

An incomplete section (section 19) of the lower member of the Ignek formation was measured along the west side of the Canning River north of Shublik Springs, where the lower sandstone units of the member form three bluffs that project into the river flats. The strata overlie the Kingak shale; the upper beds of the lower member are not exposed.

Lower member of the Ignek formation, section 19

	Feet
Unexposed.	
"Paper" shale, dark-gray to blue-gray; iron-stained and locally coated with white or yellow powdery salt. Ironstone and limestone concretions and nodules; marcasite and pyrite nodules; carbonaceous material near base	280

	Feet
Sandstone, dark-gray, fine-grained, iron-stained; locally contains white quartz and olive-green chert granules and pebbles in thin layers; sandstone cleaner in upper part of unit with some large cross beds; 3–4 in. sandy ironstone concretions; fossils abundant in red-weathering sandstone 2 ft from top of unit (USGS Mesozoic locs. 24018 and 24019; fossil lots of the lower member are discussed below)	75
Sandstone, medium- to dark-gray; in beds 1–3 ft thick; medium-grained; locally weathers reddish brown; white quartz and olive-green chert common on bedding planes; fossils common in red-weathering beds in upper 4 ft (USGS Mesozoic locs. 24016, 24017, and 24020) and in base of unit (24015)	100
Siltstone, dark-gray, hackly-fracturing, thin-bedded; weathers reddish brown	15
Clay shale, medium-gray; coated with powdery yellow salt; ironstone lenses and concretions	30
Total measured thickness of lower member of Ignek formation	500

Kingak shale.

Age and correlation.—The fossils collected from the lower member of the Ignek formation were identified by Ralph W. Imlay. Of the USGS Mesozoic localities listed below, 22752 is in beds whose stratigraphic position in the Ignek formation is not known. Fossil lots from other localities were collected from beds not higher than 500 feet above the base of the formation.

Fossils and localities at which they were collected from the lower member of the Ignek formation

USGS Mesozoic locality	Field sample	North latitude	West longitude	Fossil	Description of locality
22752	51 ADt 101	69°17′	147°58′30″	*Inoceramus* sp.	Red-weathering sandstone beds in cutbank along Gilead Creek.
24016	52 AMo 44A			*Yoldia*? cf. *Y. kissoumi* McLearn *Arctica*? sp. *Panope*? *kissoumi* (McLearn) *elongatissima* (McLearn)	Red-weathering sandstone beds 141–145 ft above base of section 19.
24017	52 AMo 45			*Arctica*? sp. *Astarte* sp. *Ditrupa* sp.	Do.
24018	52 AMo 46			*Arctica*? sp. *Tancredia* sp.	Red-weathering sandstone beds 218 ft above base of section 19.
24019	52 AMo 47			*Astarte* sp. *Panope elongatissima* (McLearn)	Do.
24020	52 AMo 53			*Panope*? *elongatissima* McLearn	Same as 24016.
24025	52 AKe 4	69°29′	146°58′	*Yoldia*? cf. *Y. kissoumi* McLearn *Eopectin*? sp. Brachiopod (aff. *Mentzeliopsis*) *Entolium* sp.	Rust-weathering sandy siltstone beds in cutbank on east side o Fin Creek.
24027	52 AKe 6	69°28′30″	147°03′	*Astarte* sp. Brachiopod (aff. *Mentzeliopsis*) *Entolium* sp.	Rust-weathering sandstone beds on hillside east of Fin Creek.
24034	52 AKe 44	69°34′30″	146°22′30″	*Astarte* sp. *Entolium* sp. *Acteon* sp. *Arctica*? sp. Worm burrows	Red-weathering sandstone beds in cutbank along west side o Canning River.

Leffingwell originally assigned a Jurassic(?) age to the Ignek formation, but believed (p. 124) it "to be younger than the Kingak shale." The authors did not visit Leffingwell's type locality of the Ignek formation; however, on the west side of the Canning River several miles north of the outlet of Shublik Springs, rocks that he mapped as Ignek formation (section 19 of this report) overlie rocks of Late Jurassic age (USGS Mesozoic locs. 24013, and 24014; see p. 193). Between the Kavik River and Juniper Creek, rocks which are probably approximately equivalent in age with those of the Ignek formation on the Canning River locally overlie rocks of Valanginian age (USGS Mesozoic loc. 24030; see p. 197); in other localities as far west as the Ivishak River, the Ignek formation locally overlies the Kingak and the Okpikruak formations. The age of the lower member of the Ignek formation as defined by the authors, therefore, is Early Cretaceous or younger.

Imlay stated (written communication, June 7, 1956) that the fossils listed above include species common in the Tuktu and Grandstand formations. H. R. Bergquist (written communication) identified *Bathysiphon* sp., *Ammobaculites* sp., *Haplophragmoides* sp., and *Pelosina* sp., in samples from the lower member on the Kavik River; he stated that "the fauna is of a general sort that ranges from the Torok formation into the Chandler formation."

The rocks of the lower member of the Ignek formation crop out along the Ivishak River in close proximity to rocks bearing the typical fauna of the Tuktu formation (USGS Mesozoic locs. 22753 and 22754, p. 202); parts of the two formations appear to be approximately on strike. The Colville group, which crops out west of the mapped area, is typified both in the lower and upper parts by pyroclastic material which is missing in the lower member but is present in the upper member of the Ignek formation. For these reasons and because of the lithologic similarities, the authors believe that the lower member of the Ignek formation is equivalent to the Nanushuk group.

UPPER MEMBER

Distribution.—The outcrop belt of the upper member typically is one of low relief; the rocks of the member crop out in isolated cutbanks. The best exposures are along the lower part of the Canning River and in the icefield areas on the Kavik River and Juniper Creek near lat 69°30′ N. The member also crops out on Fin Creek between lat 69°28′ N. and 69°30′ N., on Fin Creek and on Juniper Creek where the streams have breached Shaviovik anticline, and probably on the lower part of Gilead Creek. The basal sandstone and beds of tuff in the lower part of the member locally form rubble ridges in the interstream areas, but these persist only for short distances and are of little value in defining the unit.

The beds of the upper member overlie the lower member with unknown attitude. Locally, the lower member appears to have been eroded, and on the Canning River the upper member rests directly on rocks of Berriasian age (USGS Mesozoic loc. 24031; see p. 197). The upper member is overlain by the Sagavanirktok formation and in most of the area the beds of the two strike and dip about the same. However, on Fin Creek and on Juniper Creek where the streams have breached Shaviovik anticline, the rocks of the upper member dip more steeply than do those of the flanking Sagavanirktok formation.

Lithology.—In all the localities where the upper member crops out, it is either so poorly exposed or so complexly folded that its thickness cannot be accurately determined. Between Fin Creek and the Shaviovik River the outcrop belt of the combined lower and upper members of the formation is approximately 4 miles wide. Comparable structural belts in which thicknesses are known seem to indicate that more than 4,000 feet of the upper member could not be represented in this area. However, assuming an angular discordance between the strata of the upper member and the Sagavanirktok formation, additional beds may be obscured by the depositional lap of the younger formation.

The upper member of the Ignek formation may be divided into two parts: a lower unit characterized by bentonite and beds of silicified tuff and an upper unit composed of conglomerate, sandstone, siltstone, and shale. The base of the lower unit, which has been identified only in the syncline between the Kavik River and Juniper Creek and along the west side of the Canning River between lat 69°30′ N. and 69° 34′ N., consists of about 100 feet of ferruginous light-gray massively bedded, slightly to moderately argillaceous, locally carbonaceous sandstone. Locally, pebbles of black chert are alined along the bedding planes. Multicolored silicified tuff beds crop out on the west side of the Canning River several hundred feet higher than the sandstone; this same facies also is present on the east side of Juniper Creek where about 600 feet of the member crops out along a large icefield. At this locality the base of the section consists of about 40 feet of medium-gray fissile shale with 1-foot thick interbeds of multicolored tuff. Massive calcareous concretions as much as 5 feet in diameter are alined along the bedding planes of the shale and give off a kerosene odor when freshly broken. Overlying the lower 40 feet is approximately 200 feet of silicified tuff in beds 2 to 8 inches thick with thin interbeds of bentonitic shale and lenticular concretions. One of these concretions contained the pen of a large squid (USGS Mesozoic loc. 24112; see below). The tuffs are light gray to blue gray and weather various hues of yellow, red, green, and orange. About 360 feet of medium-gray fissile and nodular clay shale with minor interbedded siltstone overlies the silicified tuffs.

The upper part of the upper member is exposed best in isolated cutbanks along the west side of the Canning River between lat 69°35′ N. and 69°40′ N. This part of the member overlies, by an unknown thickness, beds of red ocher which are probably correlative with the "red beds" of Leffingwell's type section and which probably occupy the same approximate position in the stratigraphic column as the beds of tuff and bentonite on Juniper Creek. The upper part of the upper member comprises conglomerate, fine- to coarse-grained relatively clean salt-and-pepper sandstone, medium-gray carbonaceous coaly siltstone, and shaly siltstone. Abundant coaly wood, partly silicified logs, plant remains, and ironstone nodules are present, and fucoidal and mudflow markings locally characterize the sandstone and siltstone in this part of the member.

Age.—A questionable *Panope* sp. from USGS Mesozoic loc. 24032, sandstone beds west of the Canning River at lat 69°31′ N. and long 146°25′ W. was identified by Imlay (written communication). The pen of a squid that was collected from the concretion in the cutbank along Juniper Creek (USGS Mesozoic loc. 24112) at lat 69°30′05″ N. was identified by John B. Reeside, Jr. In a written communication (1952) to the authors he stated: "This specimen is the pen of a large squid. I cannot distinguish it from *Teusoteuthis longus* Logan of the upper part of the Niobrara formation of Kansas and would assign it that name and that age. The beds are * * * middle Upper Cretaceous."

In addition to this macrofauna, a microfauna of Late Cretaceous age was identified by H. R. Bergquist (written communication) from samples collected in the shale beds which contained the squid-bearing concretion on Juniper Creek. This microfauna includes *Spongodiscus* sp., *Archicorys* sp., and *Dictyomitra* sp.

The evidence cited indicates that part of the upper member of the Ignek formation is Late Cretaceous in age and that the beds characterized by the squid-bearing concretion belong in the Coniacian-Santonian stages. Whether all the Late Cretaceous stages are represented in the upper member is not known, and the authors arbitrarily postulate that the member ranges in age from Turonian to Maestrichtian (fig. 27).

TERTIARY SYSTEM

SAGAVANIRKTOK FORMATION

History.—The Sagavanirktok formation was named by Gryc, Patton, and Payne, who stated (1951, p. 167):

> The Sagavanirktok formation crops out in the Franklin Bluffs, its type locality, along the lower part of the Sagavanirktok River and is also well exposed in the White Hills area. It consists mainly of red-bed-type, poorly consolidated siltstone, sandstone, conglomerate, and lignite. No fauna has been found, but the formation does contain an early Tertiary flora.

Distribution.—In the northeastern part of the mapped area the Sagavanirktok formation crops out in broad plunging anticlines and synclines. The more resistant sandstone and conglomerate form ledges and whaleback ridges on the limbs of the structures between the Kavik and Shaviovik Rivers. The best exposures of the formation are in the interstream area between Fin Creek and the Shaviovik River, where the rocks form the south flank of the Shaviovik anticline, and in cutbanks along Fin Creek. The formation is overlain by flat-lying Tertiary and Quaternary deposits along present stream flood plains, terraces, and hillsides; although the evidence is not conclusive, the authors believe that it is separated from the underlying Ignek formation by an erosional unconformity.

Lithology.—The Sagavanirktok formation consists of nonmarine to beach-type sediments consisting of poorly consolidated conglomerate, sandstone, and siltstone with interbeds of shale and coal. The conglomerate crops out as lenticular masses, grades laterally into crossbedded massive coarse-grained sandstone, and contains rounded pebbles and cobbles of white quartz, green and black chert, quartzite, igneous rock, and silicified tuff lithologically similar to that present in the lower part of the upper member of the Ignek formation. The sandstone ranges from light gray to buff, yellow brown, pink, and red, and locally is moderately porous and permeable. The siltstone is medium to light gray, slightly calcareous, and friable to semiconsolidated. The coal is thin bedded and of low rank; it has a dull to waxy luster. Except for one questionable pelecypod impression, no fauna was found in the formation. The siltstone and shale interbedded with the coal do contain a flora, but no collections were made. The rock unit has been mapped as the Sagavanirktok formation, partly because of its lithologic similarity to the rock unit described by Gryc, Patton, and Payne (1951, p. 167) and partly because it can be traced, although somewhat discontinuously, to the Sagavanirktok River where the Sagavanirktok formation has been noted.

Measured sections.—Two sections of the Sagavanirktok formation were measured in the mapped area and these are shown on plate 23. The locations of the sections are shown on plate 21.

Section 17 was measured in the area just west of the Kavik River where an incomplete sequence about 1,600 feet thick is preserved in a broad syncline. The basal conglomerate of the Sagavanirktok formation overlies the Ignek formation at this locality with no apparent angularity, and the upper beds of the formation have been eroded. The massive sandstone and conglomerate beds form resistant ledges which are separated by tundra-covered lowlands. The nature of the rocks underlying the tundra has, where possible, been inferred from the character of the material brought to the surface by frost heaving.

Sagavanirktok formation, section 17

	Feet
Coarse-grained poorly consolidated light-gray sandstone with a few quartz and chert pebble to granule lenses; sandstone weathers light yellowish brown; massive crossbeds as much as 4 ft thick; few plant remains and bituminous(?) material	50
Mostly tundra covered; small amount of light-brown sandy shale	120
Clean poorly consolidated light-gray coarse sandstone and lenses of conglomeratic sandstone; conglomerate constituents are well-rounded white quartz, olive, gray, and black chert, silicified tuff, and a few pebbles of quartzite; massive crossbedding in upper part of unit; plant remains and thin beds of low-grade coal in lower part	40
Mostly tundra covered; some fine-grained sandstone and gray shale	290
Poorly consolidated buff to light-gray sandstone and conglomerate similar to that described above	50

	Feet
Tundra covered	70
Poorly consolidated conglomerate and coarse light-gray to buff sandstone; sand grains are subround quartz and chert; the pebbles in the conglomerate are well rounded and comprise white quartz and minor chert and tuff	60
Mostly tundra covered; some sandy shale	230
Friable coarse-grained light-gray massive sandstone, and conglomerate containing rounded pebbles and cobbles of white quartz, chert, and tuff; conglomerate cemented with limonite; one poorly preserved pelecypod impression on a sandstone bedding plane; sandstone in upper part of unit has a porosity of 14.6 percent and a permeability of 14 millidarcys	70
Mostly tundra covered; some fine-grained light-gray sandstone with a porosity of 17.75 percent and a permeability of 10 millidarcys	580
Conglomerate and sandstone as described above; sandstone massive, crossbedded, almost impermeable with a porosity of 5.53 percent	40
Total measured thickness of Sagavanirktok formation	1,600
Ignek formation, upper member.	

Section 10 is a composite and includes the exposures in the cutbanks along the east side of Fin Creek and the outcrops of the formation on the south flank of the Shaviovik anticline between Fin Creek and the Shaviovik River. The rocks dip as much as 37° N. in the exposures along the creek and dip from 8° to 24° S. on the south flank of the anticline. The contact of the formation with the underlying Ignek formation is not exposed at this locality, but just north of the measured section in the breach of the anticline along Juniper Creek the rocks of the Ignek formation dip more steeply than do the rocks of the overlying Sagavanirktok formation, and a structural unconformity is indicated between the two rock units. The upper beds of the younger formation have been eroded at this locality.

Sagavanirktok formation, section 10

	Feet
Fine- to medium-grained yellowish-brown-weathering friable sandstone	40
Mostly tundra covered; some ferruginous shale	200
Medium-grained yellowish-brown-weathering friable sandstone	25
Tundra covered	45
Friable light yellowish-gray clean sandstone with interbeds and lenses of sandy conglomerate; conglomerate constituents are rounded cobbles and boulders from 6 in. to 1 ft in diameter of quartzite, white quartz, tuff, and fine-grained igneous rock and limestone of Mississippian age	80
Tundra covered; some sandy shale	200
Fine- to medium-grained light-gray friable clean sandstone	60
Mostly tundra covered; some fine-grained yellowish-gray sandstone and sandy shale	100
Low-rank coal with blocky fracture and dull to waxy luster; coal seams as much as 2 ft thick; interbeds of light-gray clay shale and siltstone; plant remains	20
Sandy light-gray shale and dark shale containing carbonaceous fragments and plant remains	100
Yellowish-brown medium-grained friable crossbedded sandstone; minor lenses of conglomerate containing rounded pebbles of chert, tuff, and white quartz	70
Massive beds of sandstone and lenses and beds of conglomerate as much as 15 ft thick; conglomerate contains pebbles and cobbles of rounded white quartz, chert, tuff, limestone (Lisburne) and quartzite (Sadlerochit?) in a limonite matrix; sandstone friable, light-gray to yellowish-brown, crossbedded; plant remains and coaly material along bedding planes; salt-and-pepper sandstone with a porosity of 17.1 percent and a permeability of 420 millidarcys; 5-ft bed of light-pink medium-grained sandstone near top of unit	410
Tundra covered	120
Yellowish-brown-weathering coarse-grained sandstone	75
Medium-gray thin-bedded shale	40
Interbedded friable sandstone and conglomerate	190
Tundra covered; salt-and-pepper sandstone at base and sandy medium-gray shale	270
Contact (arbitrarily placed at base of sandstone).	
Total measured thickness of Sagavanirktok formation	2,045
Ignek formation (upper member).	

Age.—No fossils were collected from the rocks mapped as Sagavanirktok formation; the Tertiary age assignment is based on a correlation of this rock unit with that described by Gryc, Patton, and Payne (1951, p. 167). Roland W. Brown identified *Metasequoia occidentalis* (Newberry) Chaney, *Morus* sp., *Cinnamomum ficoides* Hollick, *Pterospermites conjunctivus* Hollick, *Trapa microphylla* Lesquereux, and *Cercis*? sp. from the beds in the lower part of the Sagavanirktok formation on the Sagavanirktok River; he assigned these beds an early Tertiary age.

Not all evidence supports a Tertiary age assignment for the rocks mapped as Sagavanirktok formation, however. H. R. Bergquist (written communication) identified a microfauna from the United Geophysical Company's seismic shotholes on the flanks of Shaviovik anticline in the beds mapped by the authors as Sagavanirktok formation:

> Paleontologically speaking, I cannot see any strong evidence to support a Tertiary age for the [rocks designated as Sagavanirktok formation in the area of the Shaviovik anticline] * * *. Only specimens of *Pelosina* sp. and of *Trochammina ribstonensis*? Wickenden are of any consequence in this part of the section. Pelosinas are long ranging and those found in the northern Alaska Cretaceous sediments are either the same or closely similar to [those present in these shothole samples] * * *. The *Trochammina* sp. has been questionably referred to *T. ribstonensis* because of its similarity to that Upper Cretaceous form. A specimen of *Nonionella austinana* Cushman in shotpoint 3, line 3, [see pl. 24, this paper] is the

same as the species of *Nonionella* found in the Schrader Bluff formation * * * of the Upper Cretaceous. The Radiolaria found in S.P. 2 and 3 and in 19 and 20 of line 6 appear to be the same as Upper Cretaceous Radiolaria. In short, there is nothing diagnostic of Tertiary found in these sediments and the microfossils appear more likely to be of Late Cretaceous age.

Despite the conflicting evidence, the authors believe that those rocks between the Shaviovik and Canning Rivers mapped as Sagavanirktok formation are the lithologic and age equivalents of those in the Sagavanirktok River area designated as Tertiary by R. W. Brown (see above).

TERTIARY AND QUATERNARY SYSTEMS

SURFICIAL DEPOSITS

As the study of bedrock geology in the area mapped was the primary objective of the field investigations, only a minor amount of data on surficial deposits was assembled. On the areal map, the surficial deposits were divided into two general groups: alluvium and gravels; the latter group includes glacial, high-level terrace, and pediment gravels. These gravel deposits have been mapped mostly from study of aerial photographs; they are shown on the areal map as an overlay pattern under which the bedrock geology has been projected. The glacial gravel was discussed on p. 175, and its distribution is shown on plate 22. The bulk of the surficial deposits west of the Echooka River are interpreted to be glacial in origin. East of the Echooka River, however, the glacial deposits overlie a more or less continuous blanket of gravel which caps an erosion surface of moderate relief, and the authors believe that these deposits resulted from fluviatile deposition on a late Tertiary and early Quaternary piedmont slope.

The pediment(?) gravel is almost flat lying; it rests unconformably on Permian to lower Tertiary rocks and extends almost continuously from the crest of the Canning-Kavik Rivers divide, where it is overlain by glacial gravel, to the divide between the Echooka River and the Shaviovik River where it is similarly overlain. These deposits are present just north of the mountain front along the Canning-Kavik Rivers divide at an altitude of 2,200 feet and near Kemik Creek at an altitude of 2,000 feet. Their most northerly occurrence is along the east valley slope of the Kavik River at an altitude of about 1,300 feet, their lower limit of outcrop along the slopes of the valley ranges from 75 to 100 feet above the present floor.

The pediment(?) gravel deposits consist of a mixture of unconsolidated sand, cobbles, and boulders; they are at least 50 feet thick. The sand is light gray and ranges from fine to coarse grained; it weathers light brown. The cobbles and boulders comprise white quartz, quartzite, and quartzitic siltstone (Sadlerochit formation), limestone (Lisburne group), and variously colored chert. The deposits are coarser near the mountains where the boulders are as large as 4 feet in diameter, and progressively finer northward. As no fossils were found, the assignment of age of the deposits is based entirely on their relationship with other stratigraphic units. The gravel is younger than the Sagavanirktok formation and presumably older than the overlying Pleistocene moraine and therefore is probably of late Tertiary to early Quaternary age.

IGNEOUS ROCKS

The only igneous rock observed in the mapped area is a mafic sill which intrudes the limestone beds of an anticline between the Ivishak River and Flood Creek. Near Flood Creek, the sill, the age of which is unknown, is about 150 feet thick. Its border zone contains numerous limestone zenoliths as much as 1 foot in diameter, and pyrite has been introduced into the host rock.

The border phase of the sill adjacent to its lower contact is (sample examined in thin section) a holocrystalline fine-grained porphyritic diabase composed predominantly of andesine and chlorite. Interstices between prismatic plagioclase laths are filled with chlorite and an irregular highly mottled substance that is tentatively identified as titanite or perovskite. The phenocrysts are composed of chlorite; some have peripheral zones of microcrystalline chlorite which pass into central zones of serpentine. The edges of the phenocrysts are corroded and so indistinct that former crystal outlines are obliterated, but the texture of the serpentine appears more like that derived from pyroxine or amphibole. The plagioclase is andesine ($Ab_{63}An_{37}$); some of the laths show albite twining, others zonal growth. The plagioclase seems to have formed early and is locally enclosed by titanite(?) or perovskite(?). Where chlorite is in contact with the plagioclase, the contact along the long dimension of the lath is abrupt; on the ends it is dentate with chlorite replacing plagioclase.

The limestone xenoliths have rounded corroded borders; they have been recrystallized to coarsely crystalline calcite. In a few inclusions quartz is present also. Chlorite is the most common mineral in contact with calcite and generally occurs in a microcrystalline narrow zone surrounding the inclusion. The replacement of, and penetration into, calcite along cleavage planes by chlorite has produced a comblike texture.

The central zone of the sill (sample examined in thin section) is an aphanitic andesite porphyry. The rock consists of a feltlike groundmass of plagioclase crystals containing corroded phenocrysts of chlorite and calcite. The interstices are filled with veinlets, irregular masses, and minute crystals of magnetite. Plagioclase (andesine, $Ab_{60}An_{40}$) is present as subhedral laths. Chlorite has partly replaced calcite along the cleavage planes in the phenocrysts; the primary minerals which have been replaced cannot be identified. Quartz and sericite fill some of the fracture veins.

STRUCTURE

FOLDS AND FAULTS

The north flank of the Brooks Range from the Canning to the Sagavanirktok River comprises a succession of en echelon east- and west-plunging anticlines and synclines. The anticlines are normally asymmetric with steeper north flanks, and those in the limestone of Mississippian age plunge about 20° from their structural highs in the mountains to their point of disappearance beneath the younger strata of Mesozoic age. The synclines, at least those in the Cretaceous and Tertiary rocks of the mapped area, are normally broad, open folds with gently dipping limbs, although locally they are cut by high-angle reverse faults.

From Elusive Lake to the Canning River the structural features are relatively simple. The anticlines are asymmetric, locally overturned, and commonly faulted. The faults are of the reverse type with the south side upthrown, with hades seldom exceeding 30°, and generally with minor displacement. Transverse faults are present locally; those of greatest displacement are along the east side of the Ivishak River south of Kashivi Creek, along the Lupine River, and, possibly, along the Shaviovik River. On the Lupine River the transverse faults cut the strata in the structurally low area between the predominantly west-plunging structures on the east side of the creek and a doubly-plunging anticline on the west side of the creek. The most westerly of these faults has juxtaposed limestone of the Lisburne group with shale and siltstone of the Tiglukpuk formation; the stratigraphic displacement probably exceeds 2,000 feet. Thrust faults are not common in the area northeast of Elusive Lake; however, on the east side of the Ivishak River the strata of the Lisburne group have been thrust over Permian and Triassic rocks and two klippen of the Lisburne group overlie the Sadlerochit formation. Between the Echooka and the Kavik Rivers, strata of the Kingak shale and the Kemik sandstone member of the Okpikruak formation locally have been thrust over younger rocks. North of these thrust faults between the Echooka River and Fin Creek, the rocks of the Kingak and Okpikruak formations have been cut by a series of east-trending high-angle reverse faults that may be the surface expression of a deeper thrust. This same structural condition is present in the northernmost strata mapped on Gilead Creek and may also reflect a deeper thrust.

The rocks west of Elusive Lake are more contorted than those in the more northerly part of the mapped area; they are overturned and are characterized by tight folds and high-angle reverse faults. Southeast of Elusive Lake rocks of the Lisburne group and the Sadlerochit formation locally are recumbent and have been thrust over younger strata. Westward this thrust becomes a high-angle reverse fault juxtaposing Permian and Triassic rocks with Jurassic and Cretaceous rocks.

AGE OF FOLDING AND FAULTING

The rocks in the Shaviovik and Sagavanirktok River region were folded and faulted at various times since the deposition of the Lisburne group, and the nature of this deformation is reflected in the structural relationships between the various formations. For the purposes of the following discussion the mapped area was divided into two parts which will be treated separately: one north and east of the Lupine River, the other south and west of the Lupine River. This division has been made because the Mesozoic rocks in the latter area were deformed to a greater degree and probably during more time intervals than were the former. During the period when the rocks in the southwestern part of the mapped area were being folded and faulted and those in the northeastern part were not, the tectonic forces obviously did not die out abruptly at the Lupine River, but it is in this general locality that the change in intensity probably occurred.

Lupine River to the Canning River.—North and east of the Lupine River, the Sadlerochit, Shublik, Kingak, and Okpikruak formations are structurally conformable, and it is unlikely that any major deformation occurred from Mississippian time to the Valanginian stage of the Early Cretaceous (fig. 27). The first major deformation apparently took place prior to the deposition of the Ignek formation, for these rocks overlie the older rocks with structural unconformity. The next youngest stage of deformation is not so apparent, but the structural relationships between the members of the Ignek formation suggest a time of uplift and erosion prior to the deposition of the upper member. The difference in thickness of the lower member of the Ignek formation from one part of the mapped area to another indicates that the period between its deposition and that of the upper member was one of erosion. Along the west side of the Juniper Creek in the breached Shaviovik anticline the dip of the Cretaceous rocks, steeper than that of the flanking Tertiary rocks, indicates that the next younger folding probably occurred between the deposition of the upper member of the Ignek formation and that of the Sagavanirktok formation. The latest folding in the area between the Lupine and Canning Rivers occurred after the deposition of the Sagavanirktok formation and prior to that of the pediment(?) gravel of late Tertiary or early Quaternary age. Of the four possible periods of deformation, the folding and faulting in post-Okpikruak and pre-Ignek time and in post-Sagavanirktok times appears to have been strongest.

Lupine River to the Sagavanirktok River.—Southwest of the Lupine River the Lisburne group and the Sadlerochit and Shublik formations appear to be structurally conformable, and it is unlikely that any folding or faulting occurred until Jurassic time. The Tiglukpuk, the Okpikruak, and the Fortress Mountain formations between the Lupine and the Sagavanirktok Rivers all contain coarse clastic rocks and are typified by sandstone of graywacke type. The exact nature of the contacts between the three formations is not known. West of Elusive Lake, however, the Okpikruak locally overlies the lower part of the Tiglukpuk formation, and in a north-south distance of about 2 miles the Fortress Mountain formation in 3 fault blocks locally overlies the Okpikruak, the Tiglukpuk, and the Shublik formations. Even assuming a foreshortening by faulting, it is unlikely that such relationships could be brought about except by deformation and erosion during the period between the deposition of the Tiglukpuk and the Okpikruak formations and the one between the deposition of the Okpikruak and the Fortress Mountain formations. Furthermore, as all three formations are characterized by orogenic-type rocks, it seems possible that folding and faulting of these rocks may have taken place during their deposition.

The only other stages of folding after Albian time noted in this part of the mapped area were those that deformed the rocks of the Nanushuk group. By analogy, these younger rocks could have been deformed during the period between the deposition of the lower and upper members of the Ignek formation, between the deposition of the upper member and the Sagavanirktok formation, during post-Sagavanirktok time, or during all three periods.

ANTICLINES

The alinement and direction of plunge of the en echelon anticlines which form the north front of the Brooks Range (fig. 32) form an orderly pattern. The anticlines plunge east from Kemik Creek to the Kavik River and west from Kemik Creek to Elusive Lake. From the Canning to the Kavik Rivers, the plunge is west; from the west side of the Sagavanirktok River toward Elusive Lake, the plunge is east. The structural highs of the northeast-trending anticlines, including 2 in the mountains and 3 in the foothills, aline in a northerly direction from the headwaters of Kemik Creek to the axis of the Shaviovik anticline. Billings (1942, p. 49) defined "alinement" as a "line of culmination." Similarly there appears to be a north-trending, structurally low area (referred to as "line of depression" by Billings, p. 49) near the headwaters of Kavik River, and, although it is not as well delineated, another is present between the Sagavanirktok River and Elusive Lake. Assuming that the lines of culmination and depression are not fortuitous, the most reasonable postulation to explain their presence is that the northerly alinement is a reflection of the grain of the basement. The nature of the forces which produced it is not known; presumably such an alinement could have resulted from early deformation, but if so, the character of this earlier folding has been obscured by the deposition of younger rocks and by the forces which produced the present east-trending structural features.

The southernmost of the three anticlines in the foothills along the northerly alinement of the structural highs has steep to vertical flanks composed of the Kemik sandstone member of the Okpikruak formation. The anticline is breached and exposes the Kingak shale. The anticline as delineated by the flanking beds of the Kemik sandstone member is a closed structure. However, its tight folds and the number of high-angle reverse faults in the general area indicate that the anticline may be the folded doubly-plunging hanging wall of a reverse fault and may not continue at depth.

The next northerly anticline along the line of culmination is a closed structure with average dip of 35° to 40° on the south flank and 45° to 50° on the north flank. The anticline (Kemik anticline) has a minimum of 500 feet of east plunge and is cut by a transverse fault along its west end. The proved closed part of the anticline, delineated by the transverse fault and the flanking beds of the Kemik sandstone member, is about 3 miles long and half a mile wide with a minimum structural relief of 500 feet. The

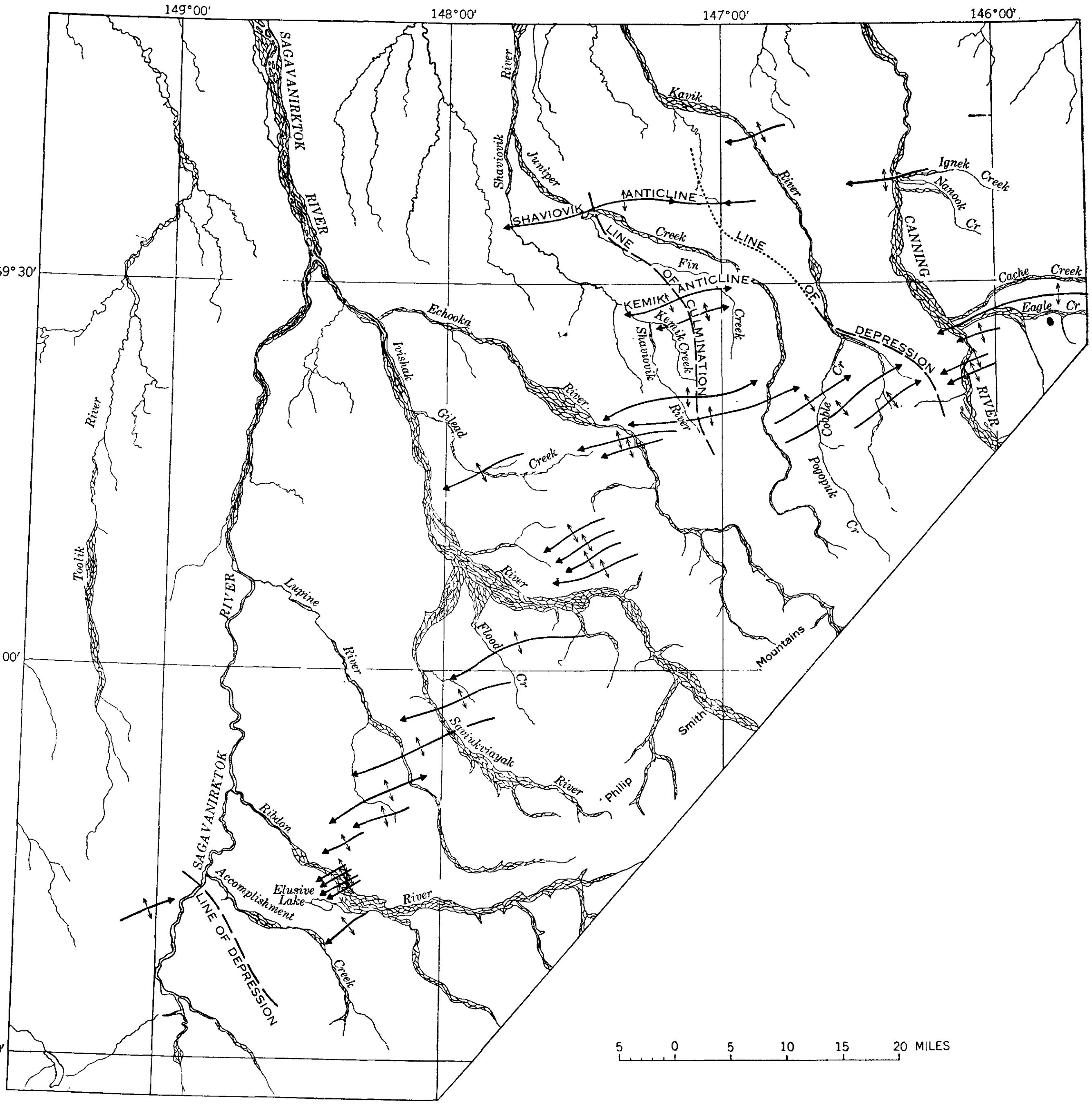

FIGURE 32.—Map showing distribution of major anticlinal axes in the Shaviovik and Sagavanirktok Rivers region, Alaska.

anticlinal trend can be traced eastward beyond the flanking beds of the Kemik sandstone member for an additional 2 miles. It cannot be traced west of the Shaviovik River but may continue beneath the gravel cover.

Shaviovik anticline.—The Shaviovik anticline, the most northerly of those along the line of culmination, is about 15 miles long and 3½ miles wide with a north-south minimum structural relief of 2,900 feet. The anticline has been interpreted to have about 1,100 feet of closure. The Sagavanirktok formation flanks the anticline, and the upper member of the Ignek formation crops out in the breach. The rocks of neither formation are particularly well exposed, but the best outcrops on the south flank of the anticline are in cutbanks along Fin Creek, Juniper Creek, and the Shaviovik River, and in the area between these streams. The rocks of the upper part of the Ignek formation and the lower part of the Sagavanirktok formation also crop out on the west sides of Juniper

Creek and the Shaviovik River on the north flank of the anticline. In addition a rubble trace of the basal sandstone of the Sagavanirktok formation crops out about 1½ miles west of the point where the axis of this structural feature crosses the Shaviovik River. Between Juniper Creek and the Shaviovik River the north flank of the anticline is devoid of outcrops, but locally the position of beds of the Sagavanirktok formation can be inferred from an alinement of darker vegetation readily visible on vertical aerial photographs. Similarly, in the breach of the anticline, the position of beds of the Ignek formation can be inferred locally, and the placing of the axis is based partly on these inferred positions.

On the north and south flanks of the anticline, structure contours were drawn on the base of the Sagavanirktok formation (pl. 24). Where the Sagavanirktok formation has been eroded from the crest of the anticline the position of the contours was established by projecting the dips of the contoured horizon from the flanks of the anticline to its crest. As interpreted by the authors, the west end of Shaviovik anticline is an asymmetric fold with gentle south flank and steeper north flank. The steeper dips along the north flank may be representative of a reverse fault, but evidence for verifying this hypothesis is lacking. From Juniper Creek to a point about 1½ miles west of the Shaviovik River, the structural feature plunges about 1,700 feet, and between these points there is an interpreted minimum closure of 90 feet. Southeast of this area of closure a transverse fault cuts the flanking beds.

East of Juniper Creek, the bedrock is obscured by tundra for about 9½ miles, and the configuration of the eastern end of Shaviovik anticline is therefore unknown. Furthermore, the east plunge of the Shaviovik anticline and its postulated closure is dependent on whether the authors' interpretation of the structure near Kik Creek is valid. At the Kavik River, an anticline, interpreted as the eastern extension of the Shaviovik trend, plunges west to Kik Creek; beyond, it is obscured beneath a tundra-covered north-trending ridge. In this part of the mapped area the topographically high areas are typically underlain by the Sagavanirktok formation; the low areas, by the less resistant rocks of the Ignek formation. Partly for this reason, partly because of the west plunge of the anticline between the Kavik River and Kik Creek, and partly because of the apparent convergence of the contacts between the Ignek and Sagavanirktok formations east of Kik Creek, the authors believe that rocks of the Sagavanirktok formation are present along the anticlinal axis beneath the tundra of the north-trending ridge. The altitude of this ridge at the point at which it is bisected by the anticlinal axis is about 1,500 feet. Along Juniper Creek the base of the Sagavanirktok formation reaches an altitude of 2,600 feet (pl. 24). Assuming that the ridge is underlain by the Sagavanirktok formation, there can therefore be no less than 1,100 feet of east plunge and no less than 1,100 feet of closure on the Shaviovik anticline.

SUBSURFACE STRUCTURE

Seismograph surveys were made on the west end of the Shaviovik anticline by United Geophysical Co., Inc. A series of 12 lines were run, and the structural interpretation of these data, including 12 cross sections and 2 structural maps, were prepared by its seismologists. The 2 structure maps are shown on plate 24, the cross sections on plates 25 and 26.

Two phantom horizons were contoured by the seismologists; one represents a zone of reflectors between −8,000 and −11,000 feet, the other a zone of reflectors between −12,000 and −14,000 feet. The contours of the lower horizon (pl. 24) show no closure but depict what may be a nose of a north-plunging anticline. The contours of the upper horizon as interpreted by the seismologists (pl. 24) show a series of low-dipping reverse faults and folds. Between the northern part of line 6–53–144 and line 10–53–144 a faulted structural feature with a possible closure of as much as 700 feet is delineated. The cross-section lines (pls. 25, 26) show no continuous reflectors between the faulted structural complex at depth and the surface structure, and therefore the relationships between the two cannot properly be evaluated.

HISTORICAL GEOLOGY

The geologic history of the mapped area has been interpreted from the nature of its sedimentary rocks and their relationships, the character of its structures, and to a large extent from the ages assigned to the formations by the paleontologist. As the oldest rocks in the area are Mississippian, only those events in geologic time since deposition of the Lisburne group are considered in this discussion.

The rocks that overlie the Lisburne group (Echooka member of the Sadlerochit formation) have been assigned a Permian age. There is not enough evidence in the mapped area to determine whether Pennsylvanian rocks were deposited and eroded prior to the deposition of the Echooka member, but the structural conformity between this member and the Lisburne group indicates a time of general structural stability between their depositions. Following this period it seems evident that in Permian and Early Triassic time sediments were shed from a northern landmass. The Echooka member of the Sadlerochit formation is more coarsely clastic in the northern part of its outcrop belt (fig. 28) and changes southward to a more marine rock type. The Ivishak member (Early Triassic age) follows the same general trend, and the similarity between the siltstone of this member and that of the Echooka (see p. 178), suggests that the two probably had the same source. There is insufficient evidence to determine whether the break between the Echooka and the Ivishak members represents an erosional interval. The Echooka changes in thickness locally, but this change may be the result of deposition rather than erosion. The structure and sedimentary relationships between the two members do not indicate a very great hiatus between them.

There is no evidence that Middle Triassic rocks were deposited in the mapped area; rocks of Late Triassic age overlie the Sadlerochit formation with structural conformity. The Late Triassic Shublik formation is typical of rocks deposited in lagoonal environments or in waters of restricted circulation; it was probably derived from a stable landmass of low relief. Its source is not known; although there are no confirming data, a northerly source is indicated.

In contrast with the older rocks that at least in part had a northern source, it seems evident that the Jurassic and all younger rocks which crop out in the Shaviovik and Sagavanirktok Rivers region had a southern source. The Kingak shale, which crops out north of its partial time-equivalent, the Tiglukpuk formation, is a thick sequence characterized by ammonoids; it coarsens slightly in a southerly direction. The Tiglukpuk formation on the other hand is composed mostly of coarse clastics, is characterized by graywacke, and contains scattered pelecypod shells in the northern part of its outcrop belt and lenses of coquina in the southern part. In addition, more conglomerate is present in the Tiglukpuk formation in the southern part of its outcrop belt than in any other part of the mapped area in which the formation is present.

Although there is no confirming field evidence, the ages assigned to the fossils in the Jurassic rocks of the mapped area indicate that the younger Jurassic rocks overlap the older in a southerly and westerly direction from the Canning River to Elusive Lake (fig. 29). The overlap may have been complicated by a pre-Late Jurassic high near the Saviukviayak River; Lower and Middle Jurassic rocks either were not deposited over this high or were eroded prior to Lake Jurassic sedimentation. As the ages assigned to the Jurassic rocks also indicate, the hiatus between the Kingak and the Shublik formations locally represents only a possible short Late Triassic and Early Jurassic interval; the one between the Tiglukpuk and the Shublik formations may represent all of the Early and Middle Jurassic epochs (fig. 27).

It is postulated, then, that the seas retreated northward during the Rhaetian, Hettangian, and Sinemurian stages but transgressed southward in the time between the Pliensbachian and Kimmeridgian stages. Although there is little evidence on which to base a conclusion, the authors believe that the part of the mapped area in which the Tiglukpuk formation crops out was relatively stable from Pliensbachian to Callovian time, and that marine deposition did not occur until the Oxfordian stage. An alternative is that Lower and Middle Jurassic rocks were deposited and eroded prior to the deposition of the Tiglukpuk formation. The first alternative necessitates only one period of subsidence; the second, subsidence followed by uplift, erosion, and a second period of subsidence. Regardless of which alternative is correct, the presence of graywacke and conglomerate in the Tiglukpuk formation indicates that it was deposited from a southern land mass which rose rapidly during the initial stages of an orogeny in late Middle or early Late Jurassic time.

The next younger formation in the mapped area also had a southerly source. The Okpikruak formation, which has been assigned to the Berriasian and Valanginian stages of the Early Cretaceous, is an unfossiliferous coarse clastic graywacke sequence near Elusive Lake. In the northeastern part of the area it is composed of shale, although from the Echooka River to Juniper Creek it contains a basal clean sandstone member. Near Elusive Lake, the coarse clastic sequence overlies the lower part of the Tiglukpuk formation with probable angularity (see p. 197); northeast of the Lupine River the formation overlies the Kingak with apparent structural conformity.

These facts indicate that the seas regressed northward during Portlandian time and that the Jurassic and older rocks in the southwestern part of the map area were uplifted, deformed, and differentially eroded. The deformational forces were apparently not transmitted so severely to the northern part of the mapped area, but the presence of the basal clean sandstone in the Okpikruak formation suggests that the area between the Echooka River and Juniper Creek may have been a relatively positive element during this stage. During the Berriasian and Valanginian stages the seas transgressed southward and the coarse clastic rocks of the Okpikruak formation were deposited near Elusive Lake; shale was deposited farther north, probably concurrently.

There is no fossil evidence that any sedimentation occurred in the mapped area from the close of the Valanginian until Albian time. Concerning this hiatus, Imlay (written communication) stated:

> The unconformity between the Okpikruak and the Torok formations [Torok formation and Fortress Mountain formations of this report] probably represents at least one-third of Early Cretaceous time as there is no fossil evidence on the Arctic Slope of Alaska for the presence of the Hauterivian, Barremian, and Aptian stages of the Early Cretaceous. Part of the Aptian may be present in the lower part of the Torok formation [and (or) the Fortress Mountain formation] beneath the beds containing the early Albian ammonites *Cleoniceras* and *Lemuroceras*. However, I doubt whether the Hautervian and Barremian are present. Recently * * * I found a statement that "there is no reliable evidence at hand of post-Valanginian/pre-Aptian beds being developed anywhere in the Arctic regions" (Maync, 1949, Medd. om Gronland, v. 133, no. 3, p. 242). I have * * * found it to be true. The most northerly occurrences of Hauterivian and Barremian deposits are in the Himalaya region, central Russia near Moscow and Simbirsk, southwest Poland, northwest Germany, and Lincolnshire, England. It seems evident, therefore, that there was general retreat of the Arctic Ocean from the bordering land masses during the Hauterivian and Barremian stages and that this retreat corresponds to the unconformity between the Okpikruak and the Torok * * * [and (or) the Fortress Mountain] formations in northern Alaska.

Imlay's data and the fact that the Fortress Mountain formation probably overlies older rocks with angular discordance (see p. 199) indicate that during the retreat of the seas in the Hauterivian, Barremian, and Aptian(?) stages the rocks in the southwestern part of the mapped area were uplifted, deformed, and differentially eroded. During Albian time the Fortress Mountain formation was deposited near Elusive Lake, and if the interpretation of the relationship between the Fortress Mountain and the Torok formations (fig. 30) is valid, the latter was deposited at almost the same time. The rocks of the Fortress Mountain formation are orogenic types characterized by conglomerate and graywacke; the Torok is composed mostly of shale. Consequently it appears that the Fortress Mountain formation was deposited from a nearby rapidly rising orogenic landmass and that the Torok formation was deposited concurrently, but at a greater distance north from the source area. Neither formation is believed to be represented east of the Ivishak River where the lower member of the Ignek formation, which has been correlated with the Nanushuk group, unconformably overlies the Okpikruak and Kingak formations. The absence of these formations east of the Ivishak River has two possible explanations. The first hypothesis is that east of the Ivishak River the area was emergent not only during the Hauterivian, Barremian, and Aptian stages but also during a large part of the Albian. The second hypothesis is that rocks equivalent in age to the Fortress Mountain and Torok formations were deposited east of the Ivishak River but were eroded prior to the deposition of the lower member of the Ignek formation. If the lower member is equivalent in age to the Nanushuk group, as postulated by the authors, this second hypothesis necessitates a period of uplift and erosion which would correspond roughly to the time interval between the deposition of the Torok and the Tuktu formations. As there is no evidence in the outcrop area of such a period of erosion, the first hypothesis is the more logical.

By middle Albian time the orogenies, reflected in the structural relationships and the type of sediments which comprise the Tiglukpuk, Okpikruak, and Fortress Mountain formations apparently drew to a close. The rocks of the Nanushuk group are characterized by subgraywackes; the structural relationships between the formations of the group indicate that deposition may have been continuous from Albian to Cenomanian time. The group is characterized by two marine formations, the Tuktu and the Ninuluk, separated by a nonmarine to near-shore formation, the Chandler. It therefore is evident that the seas oscillated during the deposition of the group. East of the Ivishak River, the area which was emergent during the Hauterivian, Barremian, and Aptian stages and probably during part of the Albian stage, was once more submerged by seas which transgressed from the north, and, concurrently with the deposition of the Nanushuk group in the western part of the mapped area, the lower member of the Ignek formation was deposited. The oscillation of the Cretaceous seas is not as well marked in these sediments, and the carbonaceous sandstones which characterize most of the rock unit appear to be typical of those deposited in deltas and lagoons or in other waters marginal to a shoreline.

The erosional break that separates the lower member from the upper member of the Ignek formation suggests that the seas regressed northward during a part of Turonian time and that this regression was followed by a transgression with minor oscillations. During this transgression the upper member was deposited in much the same environmental conditions as the lower member. The pyroclastics of the lower part of the rock unit show that the depositional period was in part one of volcanic activity.

In post-upper member time, the seas regressed northward and in Tertiary time the nonmarine to near-shore and beach sediments of the Sagavanirktok formation were deposited. The shoreline of the Tertiary basin appears to have alined relatively close to the present outcrop belt of the basal sandstone and conglomerate beds of the Sagavanirktok formation. The pyroclastic material, probably derived from the lower part of the upper member of the Ignek formation, that is present as detritus in the conglomerate beds is evidence of their nearby source.

In post-Sagavanirktok time the mapped area was uplifted and the rocks were deformed and differentially eroded. Since the Tertiary orogeny, the land-form has been modified further by glaciation, erosion, and fluviatile deposition.

PETROLEUM

The Shaviovik and Sagavanirktok Rivers region has all the requisites of a petroleum province; source rocks, potential reservoir rocks, and structures on which tests could be drilled. Structurally and stratigraphically the area east of the Ivishak River appears to be slightly more promising than that west of the river.

There are three general classes of formations in the mapped area: (a) those composed predominantly of shale with little reservoir possibility, such as the Kingak, the Okpikruak in part of the mapped area, and the Torok formations; (b) those composed mostly of orogenically derived sediments with nonporous and impermeable characteristics, such as the Tiglukpuk, the Okpikruak in the vicinity of Elusive Lake, and the Fortress Mountain formations; and (c) those rock units which, potentially at least, could contain reservoir beds, such as the Lisburne group, the Sadlerochit and Shublik formations, the Kemik sandstone member of the Okpikruak formation, the Tuktu, Chandler and Ninuluk formations, the Ignek formation, and the Sagavanirktok formation.

The Kingak shale is a thick fossiliferous sequence which could be a source for oil, and it crops out from the general vicinity of the Lupine River north and east to the Canning River. The upper part of the formation contains some sandstone in the northeastern part of its outcrop belt, but it is unlikely that the formation has reservoir potential at depth anywhere in the mapped area. In approximately the same outcrop belt (from the Lupine to the Canning River) the Okpikruak formation, excluding the basal Kemik sandstone member, is predominantly a fossiliferous shale sequence of no more reservoir potential than the Kingak, although these shales also could be an oil source. The youngest formation in this class, the Torok, crops out from the western edge of the mapped area to about the Ivishak River and probably has neither source nor reservoir potential.

The formations of the second class have approximately the same belt of outcrop as those of the first, an almost east-west distribution from the western edge of the mapped area to about the Lupine River; similar orogenic-type rocks are not present north of about lat 68°55′ N. Their lithology and structural relationships indicate that the Tiglukpuk, the coarse clastic facies of the Okpikruak, and the Fortress Mountain formations were deposited in what appears to have been a part of the mobile belt of the Jurassic and Cretaceous geosyncline. As is common with rocks of such depositional environments, the sandstones which characterize these formations in this part of the mapped area are almost nonporous and impermeable. The chances of producing oil from any of the three formations are probably not very good.

The third class of formations in the mapped area are potentially at least, those which might produce petroleum. The Lisburne group crops out across the mapped area and is a thick limestone sequence not unlike other Mississippian rocks which, in Canada and the United States, are producers. The group probably can be reached with a drill anywhere in the mapped area north of its outcrop belt. The Sadlerochit formation similarly can be drilled anywhere north of its outcrop belt. Its members, however, are more sandy and less cherty in sections near the Canning River, and the facies changes depicted on fig. 28 indicate a greater possibility of producing oil from the formation north of lat 69°30′ N. where shoreline facies might be encountered.

Unlike the Sadlerochit, the Shublik formation has about the same petroleum potential in one part of the mapped area as another. It is composed for the most part of limestone and limy shale, but between Kemik and Fin Creeks it also contains sandstone. Although it conceivably could produce oil from some of its limestone beds, the Shublik contains potentially better source than reservoir rocks. Like the two older rock units, the Shublik probably can be reached with a drill anywhere north of its outcrop belt.

The Kemik sandstone member of the Okpikruak formation, which consists of 220 feet of relatively clean and moderately well sorted sandstone, crops out only between the Shaviovik and Kavik Rivers. Although this member may underlie younger rocks north of its outcrop belt, it is probably not present in the subsurface west of the Echooka or east of the Kavik River.

The Nanushuk group, including the Tuktu, Chandler, and Ninuluk formations, contains marine and near-shore sandstones that should have fair potential if they could be drilled where structural conditions are favorable. However, these rocks crop out also only in a limited area, from the Ivishak River to the vicinity of the Sagavanirktok River, and occur so high in the stratigraphic column that they are not present at depth in the mapped area.

The lower member of the Ignek formation, which is the probable time equivalent of the Nanushuk group, and the upper member of the Ignek formation crop out from the Ivishak River east to the Canning, and both members in part contain marine or near-shore sandstone. The lower member may be present in the subsurface almost anywhere west of the Canning River north of lat 69°30′ N. beneath the rocks of the upper member. Excluding structural considerations, the complete sequence of the upper member could be tested at any locality in the mapped area where it is overlain by the Sagavanirktok formation, which, in effect, is only the outcrop belt between the Shaviovik and the Kavik Rivers.

The Sagavanirktok, although it contains more permeable and porous members than any of the older formations, crops out so far north and occurs so high in the stratigraphic column that it is not present in the subsurface of the mapped area under conditions favorable for drilling.

Of the formations that might yield petroleum, therefore, excluding structural considerations, the Lisburne groups and the Sadlerochit and Shublik formations could be drilled anywhere in the mapped area north of the outcrop belt of the Shublik formation; the Kemik sandstone member of the Okpikruak formation, only between the Shaviovik and Kavik Rivers north of lat 69°30′ N.; the lower member of the Ignek formation, anywhere west of the Canning River north of lat 69°30′ N.; and the upper member of the Ignek formation, only between the Shaviovik and Kavik Rivers in the outcrop belt of the Sagavanirktok formation. Excluding any other considerations, drilling in the northeastern part of the mapped area could test the potential of five formations; elsewhere, only three.

Structural conditions seem to be slightly more favorable for petroleum production east of the Echooka River than west. All but one of the anticlines from the Echooka River to Elusive Lake plunge west without apparent closure (fig. 32). The one exception is a closed structure between the Lupine River and the Ribdon River, but this anticline is breached and the Lisburne group is exposed in its crestal area. Petroleum production from the Lisburne group and from the Sadlerochit and Shublik formations is possible along the west-plunging anticlines, particularly if there is a terracing along the anticlinal axes beneath the Mesozoic rocks. Whether there is such structural terracing cannot be determined without drilling or geophysical investigation. West of Elusive Lake the rocks are contorted and the structure is characterized by high-angle reverse faults. The possibility of producing oil from fault traps in the three oldest formations cannot be dismissed, but, again, whether such fault traps are present can be demonstrated only by geophysical work or by drilling.

In the foothills east of the Echooka River there are at least 3 closed anticlines whose structural highs occupy positions along a line of culmination which extends northwestward for about 25 miles from the locality where Kemik Creek emerges from the mountains (fig. 32). The southernmost of the three anticlines (the anticline south of Kemik anticline; see pl. 21) is probably the folded hanging wall of a reverse fault. The next northerly anticline, the Kemik, is small with closure of about 500 feet in an area 3 miles long and ½ mile wide. The largest of the 3 anticlines, the Shaviovik, has been interpreted to have 1,100 feet of closure with possible dimensions of 15 miles by 3½ miles. However, the seismic work on the western end of the structure (pls. 24–26) did not determine the relationship of the subsurface structure to the surface structure.

In addition to structural traps in the mapped area, stratigraphic traps may also be present; their presence cannot be predicted, however, at the present stage of exploration.

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