Geology of the Chandler River Region, Alaska

By ROBERT L. DETTERMAN, ROBERT S. BICKEL, *and* GEORGE GRYC

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

PART 3, AREAL GEOLOGY

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This report is based on fieldwork by Robert L. Detterman, Robert S. Bickel, George Gryc, Edward J. Webber, Donald E. Mathewson, William W. Patton, Jr., Karl Stefansson, Robert E. Fellows, Robert M. Chapman, Calder T. Bressler, Lawrence A. Warner, and Charles E. Kirschner

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By Robert L. Detterman, Robert S. Bickel, and George Gryc

ABSTRACT

The Chandler River region is in the central part of the northern foothills section of the Arctic Foothills province, northern Alaska. The mapped area is entirely outside of Naval Petroleum Reserve No. 4, but the two areas have a common boundary along the Colville River.

The southern part of the mapped area has been glaciated at least twice; during one glaciation the valley glaciers coalesced to from a piedmont lobe between the Anaktuvuk and Itkillik Rivers. Morainal remnants from the two glacial advances cover approximately 290 square miles along the Killik, Anaktuvuk, Kanayut, Nanushuk, and Itkillik Rivers. Terrace and loess deposits of Quaternary age cover approximately 760 square miles, primarily along the Colville River and the lower parts of the Chandler and Anaktuvuk Rivers.

The exposed rocks in the Chandler River region range in age from Early Cretaceous (lower Albian) to Quaternary; these beds have a maximum total thickness of 16,300 feet and represent 10 mapped formations; four of the formations have been subdivided into four tongues and five members, all of which are mapped. Four of the formations are included in the Nanushuk group and three in the Colville group. The exposed rocks include sandstone, conglomerate, siltstone, shale, and coal; bentonite and tuff are present in rocks of Late Cretaceous age. Subordinate constituents include limestone, claystone, and ironstone.

The Cretaceous sedimentary rocks were deposited in a shallow, east-trending geosynclinal trough north of the present Brooks Range. Many transgressions and regressions of the sea are represented by the intertonguing of marine and nonmarine rocks. Angular discordance without apparent erosional hiatus is present at the base of the Nanushuk group in rocks of early middle Albian age. A Late Cretaceous major unconformity is present between the Nanushuk and Colville groups. Another major unconformity is present at the top of the Colville group, between beds of Late Cretaceous and Quaternary age.

A Late Jurassic and Early Cretaceous orogeny formed the geosynclinal trough in which the exposed rocks of the area were deposited. Local uplift and subsidence occurred throughout the remainder of Early Cretaceous time and during the Cenomanian stage of the Late Cretaceous. Most of the structures in the area were formed during orogeny at the end of the Cenomanian stage. These structures were modified somewhat during the remainder of Late Cretaceous time by local uplift and subsidence. The last orogeny to affect the area occurred during Tertiary time.

The main structural feature of the Chandler River region is an east-plunging synclinorium. The synclinorium is more than 100 miles long and 30 to 35 miles wide along the Chandler River. The anticlinal folds are all asymmetrical with steeper north flanks; axial thrust faults are common. The synclines are not folded as tightly as the anticlines and are not faulted. The Chandler River graben and the Ninuluk Creek graben are both formed along the north flank of Big Bend anticline. In addition to the axial faults there are numerous transverse, longitudinal, and oblique faults.

Hawk anticline in the southern part of the region is 11 miles long. The closed part of the structure is 7 miles long and 3 miles wide; it has a minimum closure of 600 feet. A low-angle thrust fault occurs 1 mile south of the axis with stratigraphic displacement of not more than 200 feet. Grandstand anticline in the center of the synclinorium is 52 miles long and 5 miles wide at the contour horizon; it is complexly folded and faulted. The anticline has about 2,000 feet of closure, but the structure is breached through most of the potential oil-producing horizons. Big Bend anticline is faulted also, with proven closure of 400 feet on the fault near the Chandler River. The closed part of the structure encompasses an area 10 miles long and 1 mile wide. Reflection-seismograph data proves closure on Gubik and Umiat anticlines north of Big Bend anticline.

Two gas-producing test wells have been drilled on the south flank of Gubik anticline on the west bank of the Chandler River. The main producing horizons are in the nonmarine Tuluvak tongue of the Prince Creek formation of Late Cretaceous age; lesser production was obtained from the nonmarine Chandler formation of Early and Late Cretaceous age. The only other test well drilled in the region was completed as a dry hole on Grandstand anticline.

Coal beds are found throughout the region in the nonmarine Killik and Niakogon tongues of the Chandler formation and the nonmarine Tuluvak and Kogosukruk tongues of the Prince Creek formation. The beds are more numerous and of better quality in the Chandler formation, particularly along the Colville River near the mouth of the Killik River.

INTRODUCTION

LOCATION AND SIZE OF AREA

The Chandler River region, of approximately 4,600 square miles, is immediately southeast of Naval Petroleum Reserve No. 4; the two have a common boundary along the Colville River (see fig. 33). The region is bounded on the north by the Colville River and lat 69°30′, on the east by the 150th meridian and the Itkillik River, along the south roughly by lat 68°40′, and on the west by the Killik River; it was mapped geologically as part of the U.S. Geological Survey's exploration of Naval Petroleum Reserve No. 4 and adjoining

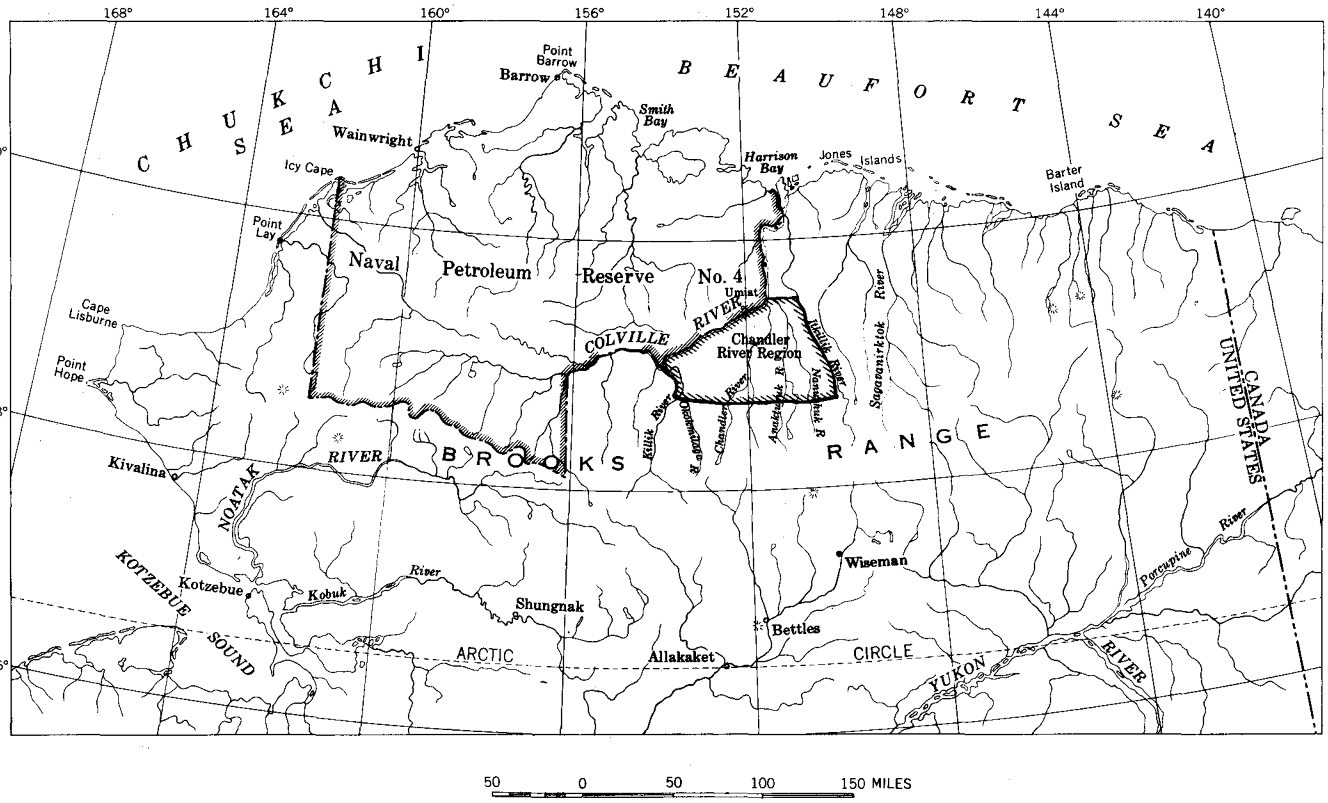

FIGURE 33.—Index map showing location of Chandler River region in relation to Naval Petroleum Reserve No. 4, Alaska.

areas in cooperation with the U.S. Navy. The mapped area includes parts of the Umiat, Chandler Lake, Ikpikpuk River, and Killik River quadrangles, at 1:250,000 scale in the Alaskan Reconnaissance Topographic Series by the U.S. Geological Survey.

In this region three test wells were drilled for the Navy by Arctic Contractors; geophysical explorations were made by United Geophysical Co. in cooperation with the Navy.

PREVIOUS WORK

The first publication to deal specifically with the geology of the Chandler River region was by Schrader (1904); he described the geology of the areas along the Anaktuvuk and the lower Colville Rivers. This report also contains information on the geology of the foothills province through which Schrader traveled in 1901. The names Nanushuk and Colville introduced by Schrader are retained, but they have been redefined and they do not apply to exactly the same rock units as in Schrader's usage.

P. S. Smith and J. B. Mertie, Jr., (1930) described the exploration in northwestern Alaska by the Geological Survey from 1923 to 1926. In 1924 they traversed the Killik River and part of the Colville River.

PRESENT INVESTIGATIONS

1944 field season.—R. R. Coats and George Gryc spent several weeks along the Colville River in the summer of 1944. That season started the present investigations in northern Alaska, though most of their work was outside of the present report area. The first full-scale geologic investigation was started in the spring of 1945.

1945 field season.—In 1945 three Geological Survey parties and one Navy party traversed the area described in this report. (See fig. 34.) One party, consisting of L. A. Warner, C. E. Kirschner, O. Daiber, and Elder Lebert, started operations of May 11 on the Killik River. Their first camp was 5 miles north of the Killik Lakes, south of the area of this report; from that point they continued down the Killik to the Colville River and down the Colville to Umiat, where they arrived August 18. For transportation they used two boats and a canoe.

A second party consisting of R. E. Fellows, R. M. Chapman, C. T. Bressler, H. B. Post, O. L. Smith, S. P. Schoonover, and A. N. Tetrault arrived May 13 at their first camp, near the junction of the Anaktuvuk and Kanayut Rivers. From this point they continued down the Anaktuvuk River by boat to the Colville River, arriving August 29. The third party arrived May 20 at Chandler Lake, where they established their first field camp. They reached the Colville River September 9. This party included the following: George Gryc, Karl Stefansson, E. J. Webber, W. G. Banks, J. Hipple, G. Hippel, and C. R. Metzger. A small Navy party spent about 1 month on the Chandler River during the same summer. E. F. Taylor, W. E. Heinrichs, G. R. Winter, K. L. Suydam, A. G. Austin, and L. E. Gentilomo were with the latter party.

These parties intended primarily to study outcropping rocks of the foothills for information about the rocks likely to be found in drilling at Umiat. Secondary objectives were to attempt a correlation of data obtained from the three traverses and to define mappable rock units. The present stratigraphic nomenclature is based largely on the work of the 1945 field parties.

1946 field season.—During 1946 no regular field parties worked in the area; however, George Gryc, E. H. Lathram, J. H. Zumberge, and L. A. Spetzman spent 5 days in late August traversing Fossil Creek and another small creek 5 miles west of Fossil Creek.

1947 field season.—In 1947 a small party was sent into the Nanushuk River area to obtain as much information as possible from the foothills region adjacent to the Reserve. E. J. Webber and R. L. Detterman started on May 20, at a point several miles upstream from the junction with May Creek. Traveling downstream by boat they arrived July 9 at the Colville River. In the meantime a third member, J. L. Townley, III, had joined the expedition. With the completion of the Nanushuk traverse the party was split; Detterman and Townley were joined by D. E. Mathewson and Charles Seigle on a traverse along the Colville River; they started at Ninuluk Bluffs and worked downstream to Umiat, where they arrived September 1. The main objectives of the Colville River traverse were to check all anticlines for possible closure and to structure contour, if possible, any closed structures found.

1948 field season.—In 1948 a party was sent into the Chandler River region to resample the outcrops. This party, consisting of R. L. Detterman, W. W. Patton, Jr., R. C. McGregor, and Elder Lebert, started on May 30

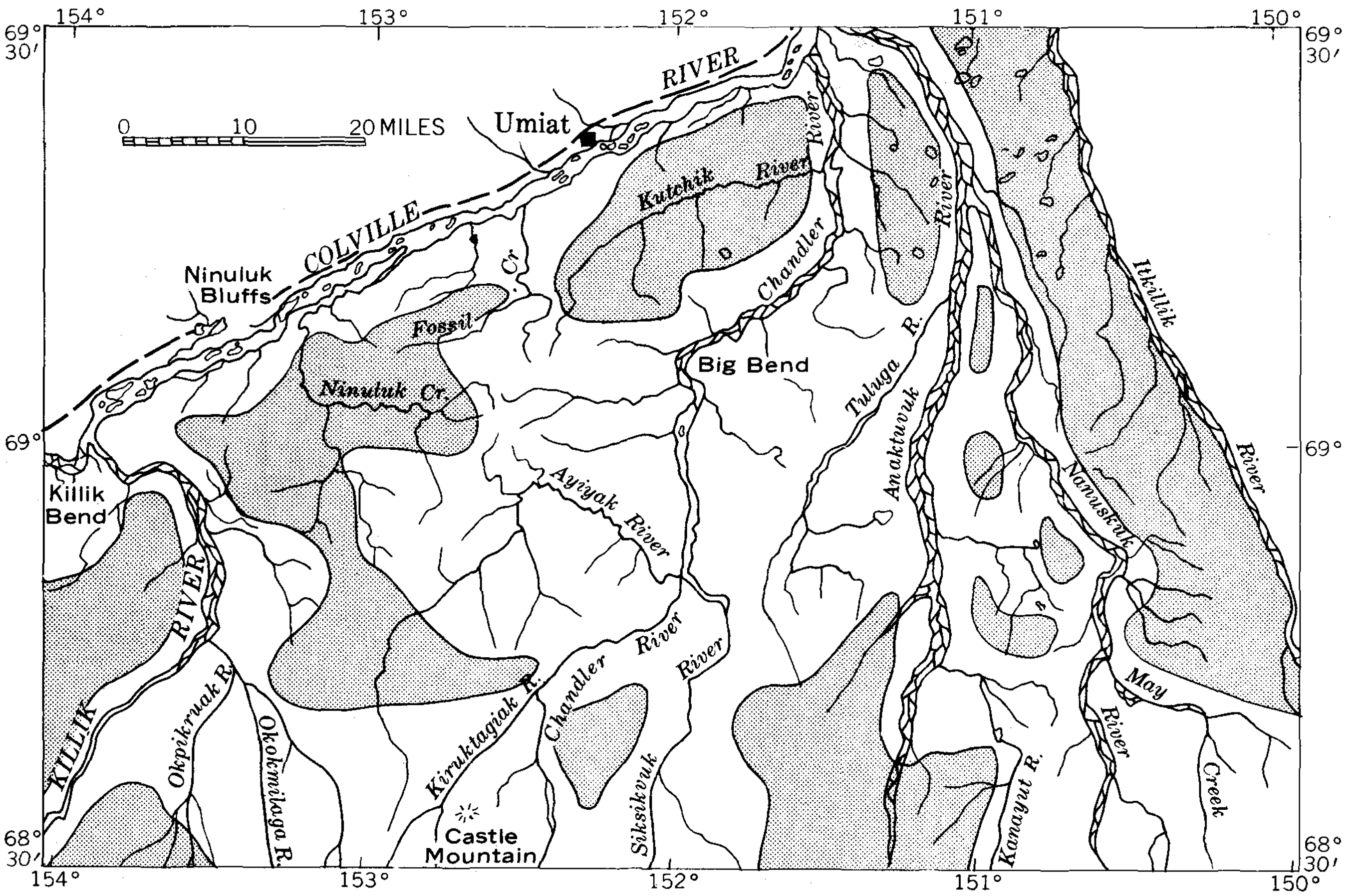

FIGURE 34.—Index map showing relation of field mapping to photogeologic mapping. Shaded areas mapped from aerial photographs. Siksikpuk River is erroneously spelled here, in figures 36 and 53, and on plates 28, 29, 31–36.

at Tuktu Bluff on the Chandler River. Progress downstream by boats was fairly rapid and on August 3 the party arrived at the Colville River. Data on the structure and stratigraphy of the area was obtained in addition to samples of microfossil-bearing rocks.

1949–50 field seasons.—The region south of the area described in this paper was traversed by W. W. Patton, Jr., and I. L. Tailleur in 1949 and by Patton, Jr. and A. S. Keller in 1950. They visited only briefly the southern edge of the Chandler River region.

1952 field season.—In 1952 a Geological Survey party consisting of R. L. Detterman, R. S. Bickel, Howard Lucas, C. S. Wemberly, P. E. Peterson, and Jack Kunz was sent into the area to structure contour several anticlines for possible drilling sites. Owing to a late spring, it was June 9 before the party arrived at the Ayiyak River to begin operations. Travel across country was by weasel (fully-tracked, military personnel carrier), and the expedition concluded the field season on August 27, at Fossil Creek. Hawk, Grandstand, and the east end of Big Bend anticline were structure contoured.

1953 field season.—As additional data on a few areas were needed, Detterman and Bickel made traverses along the Killik and Colville Rivers in June and July, 1953, and later in the summer visited parts of the Anaktuvuk and Nanushuk Rivers.

EXPLORATION

ACCESSIBILITY AND TRANSPORTATION

Northern Alaska is a remote area without roads, railroads or trails; the only effective method of reaching it is by plane or boat. Landing strips suitable for large planes have been constructed at Umiat and Barrow. Because of its central location, Umiat was used as the center of operations by the Geological Survey parties. Ski-equipped planes operated by "bush" pilots were used to transport men and equipment to field camps before the spring breakup; landings could be effected wherever there was sufficient snow. Small planes equipped with either pontoons or wheels were used after the breakup. An experienced "bush" pilot can land a single-engine pontoon plane at localities on the Killik, Chandler, and Anaktuvuk Rivers as far south as lat 68°45′ N. In general a landing cannot be made on the Nanushuk River south of the 69th parallel; the Ayiyak and Tuluga Rivers are too shallow to permit landings except during periods of high water. Many of the numerous lakes throughout the area can be used for landings from about June 15 to about September 1. About 1,500 feet is generally required for lake landings. Gravel-bar landings are essentially restricted to the same areas. "Bush" planes can be landed almost anywhere along the Colville River.

Boats were used almost exclusively by the field parties as a means of transportation during the first years of the project. A specially designed, collapsible canvas boat was used which was large and strong enough to carry 1,500 pounds, yet pliable enough to slide around the large boulders in the streams. Later, boats were largely replaced by weasels. The weasel made longer interstream traverses possible and permitted closer inspection of the geology of the area than was possible by any other method.

All the major streams are navigable by small boats; however, caution must be used when the stream passes through a glacial moraine. In these places it may be necessary to "line" the boat downstream past the large glacial erratics. On several occasions boats were swamped and equipment lost by trying to "shoot" the rapids. The Colville is the only river in which an outboard motor can be used effectively.

The weasel can be used almost anywhere within the region; however, care must be exercised in picking routes of travel through the higher ridges along the southern edge of the northern foothills. The area between the Chandler and Siksikpuk Rivers is generally inaccessible to weasel travel. The long east-west ridges formed by some of the anticlines are good interstream routes. Small streams are commonly entrenched in areas where shale is present in the lowlands between high ridges; these entrenched streams may have steep sides as high as 15 feet, which a weasel cannot cross. All the rivers except the Colville can be forded under normal conditions.

At the time of this study there were good weasel trails from Umiat to the Gubik and Grandstand test-well sites in the Chandler River Valley. Another trail had been made along the ridges west of the Ayiyak River from Umiat to the vicinity of Castle Mountain. Trails made by geophysical exploration crews could be followed between the Chandler and Tuluga Rivers.

GEOLOGIC METHODS

Before 1949, geologic investigations were hampered by inadequate maps and aerial photographic coverage. A few trimetrogon photographs were available, but most maps were obsolete and many were inaccurate; on some even the larger rivers were misplaced. Complete coverage by vertical aerial photographs on a scale of 1:20,000 was available after 1949. The geology was mapped directly on photographs and then transferred to planimetric maps at a scale of 1:48,000 and 1:96,000. The 1:20,000 vertical aerial photographs were also utilized for horizontal ground control in structure contouring. Altitudes were obtained from a triangulation net and from altimeter traverses that were closely tied to the triangulation net. Stratigraphic sections were measured by tape, Brunton compass, and alidade, using the 1:20,000 vertical photographs; the photographs were used also in computing the stratigraphic intervals for areas in which the rocks were covered.

CLIMATE

Meteorologic records were kept by Detterman for the years 1948 through 1953. The observations were made at numerous localities in the Arctic Foothills province (table 1). The records for 1948, 1952, and 1953 are from the Chandler River region, the 1949 records are from the Etivluk and Kuna River, and the 1951 records are from the Shaviovik and Sagavanirktok River areas. Table 1 was compiled from observations taken at 3-hour intervals from 9 a.m. to 9 p.m.; a total of 2,685 observations covering 535 days was made. Temperatures were read from an unprotected thermometer, and both the wind velocity and amount of precipitation were estimated.

An analysis of table 1 shows the climatic conditions under which the geologic investigations were made. The mean temperature was 47°, with a maximum of 92° and a minimum of 10°. The sky was overcast 52 percent of the time; on an average of 48 days out of every field season there was at least a trace of precipitation in some form. Snow may fall in any month; thunderstorms occur sporadically in June and July and are often accompanied by rain squalls and hail. Storms usually move in from the southwest, not uncommonly with a rising barometric trend. Precipitation usually is not heavy, although, as is common in semiarid regions, the amount may vary considerably within short periods of time. The prevailing wind directions are north or northeast, but a shift to south and southwest occurs during June and July.

TABLE 1.—*Weather data for Arctic Foothills province for periods May 1 to September 1, 1948 to 1953*

[All data are from field observations. Weather records for May 1948 were lost]

Month and year	Sky condition (percent of time)					Weather and obstruction to visibility (percent of time)							Wind (percent of time)									Wind (mph)		Temperature (°F)		
	Clear	Scattered	Broken	Overcast	Unlimited ceiling	Snow	Rain, drizzle	Fog, haze, smoke	Precipitation (inches)	Precipitation (days)	Thunderstorms	Unlimited visibility	Calm	North	Northeast	East	Southeast	South	Southwest	West	Northwest	Mean	Maximum[1]	Mean	Maximum[2]	Minimum[3]
May																										
1949	8	6	22	64	16	27	6	0	0.5	8	0	60	4	40	25	4	2	15	0	0	10	10	35	37	74	15
1951	22	31	9	38	60	11	5	9	.2	8	0	90	10	6	56	3	2	2	4	1	16	9	30	28	68	10
1952	3	12	13	72	23	27	2	14	.6	8	0	53	12	15	52	6	0	1	11	1	2	7	25	28	43	13
1953	0	0	10	90	40	30	1	12	.3	6	0	30	11	2	66	0	0	0	13	3	6	7	25	34	51	25
Mean	8	12	14	66	35	24	4	9	.4	7	0	58	9	16	50	3	1	5	7	1	9	8	27	32	59	15
June																										
1948	7	26	28	39	35	7	20	6	2.8	13	1	73	2	38	13	1	4	12	8	15	7	10	35	45	68	30
1949	4	11	40	45	18	17	14	6	1.0	15	0	80	2	31	11	2	5	13	16	3	17	13	60	48	83	23
1951	14	27	9	28	45	4	14	5	1.0	12	1	93	5	13	25	2	4	2	15	17	17	9	30	53	92	32
1952	3	18	19	60	28	7	17	12	.7	16	1	70	3	20	58	3	5	0	1	2	8	9	25	43	74	30
1953	3	26	23	48	35	1	18	8	1.3	15	1	83	7	15	31	1	2	4	8	17	15	8	40	48	70	35
Mean	6	22	24	44	32	7	17	7	1.3	14	1	80	4	23	17	2	4	6	10	11	13	10	38	47	79	30
July																										
1948	1	15	28	56	25	0	25	9	1.2	16	2	88	9	32	6	2	4	14	10	14	9	7	40	58	78	33
1949	19	29	33	19	58	0	4	1	T	5	0	81	4	23	16	13	2	23	14	1	4	11	40	58	88	31
1951	4	19	31	46	36	0	25	17	1.9	16	1	79	24	21	6	1	3	8	8	6	23	5	15	62	92	38
1952	1	19	34	46	28	0	20	7	1.5	17	2	87	6	17	13	2	9	10	23	7	13	6	40	63	84	40
1953	2	24	25	49	36	3	23	13	.9	16	0	76	8	15	22	6	2	7	14	13	13	8	45	44	79	37
Mean	5	21	30	43	36	1	15	9	1.1	14	1	82	10	22	12	5	4	12	14	8	13	7	36	57	84	36
August																										
1948	3	11	25	60	27	23	21	14	2.0	14	0	60	6	24	3	0	3	24	11	18	12	13	60	40	72	18
1949	2	14	33	51	21	1	13	2	.4	13	0	96	11	18	1	0	2	43	25	0	0	8	40	61	80	33
1951	2	18	32	48	27	3	21	22	1.7	15	0	70	17	22	3	2	9	13	13	7	14	7	40	53	92	32
1952	1	18	22	51	25	5	30	22	1.1	17	1	65	10	24	21	1	1	12	25	4	2	6	30	50	85	29
1953	0	5	33	62	12	0	25	15	.4	7	0	78	15	9	36	0	2	7	26	5	0	5	25	55	72	27
Mean	2	13	29	56	22	9	22	15	1.1	13	0	74	12	19	13	1	3	20	20	7	6	8	39	52	80	28
5-year mean	5	18	25	52	31	10	15	10	3.9	48	2	74	9	20	24	3	3	11	13	7	10	8	35	47	75	27

[1] Velocity of the single highest wind for the month, except for the monthly and 5-year means.

[2] The highest temperature for the month, except for the monthly and 5-year means.

[3] The lowest temperature for the month, except for the monthly and 5-year mean.

POPULATION

The only settlement near the area is at Umiat, on the north side of the Colville River about 2 miles upstream from Umiat Mountain. This is not a village in the true sense of the word; it was established as a construction camp by a Navy construction battalion (Seabees) in 1945 as an aid in the exploration of Naval Petroleum Reserve No. 4. Arctic Contractors, a civilian construction firm, maintained the camp from 1946 until the close of the exploration program in June 1953, at which time the U.S. Air Force took over the maintenance of the camp and airstrip. The population of the camp fluctuated; at the peak of the drilling program more than 100 men worked there and at the outlying drilling camps. At different times small temporary camps were set up at the Gubik and at the Grandstand test-well sites. They were occupied by about 30 men during drilling operations and were then abandoned.

The Chandler River region was uninhabited at the time of this study. Former camp sites of both ancient and modern Eskimos were found throughout the area. Artifacts were collected from the lower Nanushuk and Chandler River areas. Most of the sites, however, were of more recent origin, as shown by the rusted tin cans and cooking utensils. One particularly large site was noted near the junction of the Kanayut and Anaktuvuk Rivers and another at the confluence of the Kutchik and Chandler Rivers. An underground sod barabara was seen on the south bank of the Colville River, 2 miles below the mouth of Prince Creek. Rusting steel animal traps nearby indicated the barabara had been used within the past few years. Most of the other sites located had been used briefly only as hunting camps.

ACKNOWLEDGMENTS

The U.S. Geological Survey expeditions in this area were made possible by the close cooperation of the Navy Department and Arctic Contractors. The Navy Department supported the expeditions financially; Arctic Contractors furnished the logistic support necessary to maintain the parties in the field. Recognition must be given to the bush pilots of Wein Alaska Airlines, Alaska Airlines, and Transocean Airlines, who brought needed supplies and equipment to the field camps, often under adverse weather conditions. George O. Gates was in charge of the Geological Survey field program from 1945 to 1949; Ralph Miller succeeded him in 1949 and served through 1951.

Much of the fieldwork and many of the ideas represented by this report are the result of other geologists' work in the area. The authors wish to thank the following geologists for their assistance: E. J. Webber, Karl Stefansson, L. A. Warner, C. E. Kirschner, the late R. E. Fellows, R. M. Chapman, C. T. Bressler, W. W. Patton, Jr., I. L. Tailleur, and A. S. Keller. Recognition must also be given to M. D. Mangus and Frank Cernich, who handled the caching operations for the field parties; to the personnel of the Fairbanks laboratory of the Geological Survey who processed many of the samples; to H. R. Bergquist and Helen T. Loeblich, who identified the microfossils; to R. W. Imlay, who identified the megafossils; to R. W. Brown, who identified the plant fossils; and to R. H. Morris, who studied the heavy minerals.

This paper embodies the work of many people, both in the field and in the laboratory; however, in the final preparation of the report the text and most of the illustrations were prepared by Detterman, with the following exceptions: Bickel assisted in the compilation of the geologic map, and Gryc wrote part of the sections on age and correlation of formations and members of formations of the Colville group in which megafossils are discussed.

PHYSIOGRAPHY

ARCTIC FOOTHILLS PROVINCE

The Arctic Foothills province is 80 miles wide in the Killik River area and about 60 miles wide in the Itkillik River area; it can be divided into a southern section 20 to 30 miles wide and a northern section 40 to 50 miles wide. The area of this report lies almost entirely within the northern foothills section. Its southern limit is about parallel to the prominent south-facing Tuktu Escarpment that is formed by the clastic Tuktu formation. The northern limit is irregular and is marked by east-plunging folds of clastic Upper Cretaceous rocks; it swings abruptly toward the south just east of the Anaktuvuk River. With the exception of a small district along the northern limit, underlain by the Gubik formation of Quaternary age, the northern foothills section is underlain by Cretaceous rocks.

The southern edge of the northern foothills section is also the area of maximum relief. Altitude locally exceeds 3,000 feet near the Siksikpuk River, and maximum relief is 1,000 to 1,800 feet. Northward the topography becomes more subdued, with broad featureless valleys, the monotony of which is broken only by mesas of resistant conglomerate of Late Cretaceous age and ridges of sandstone of Early Cretaceous age. Relief along the northern edge of the area is rarely in excess of 400 feet and is commonly 200 feet or less.

ARCTIC COASTAL PLAIN PROVINCE

The Arctic Coastal Plain province is represented by a small area between the Anaktuvuk and Itkillik Rivers; it is an area of lakes and swamps with a maximum relief of less than 150 feet. The underlying bedrock strata are covered by Pleistocene and Recent deposits.

River systems.—The major river of northern Alaska is the Colville; with its tributaries, the Killik, Chandler, Anaktuvuk, Nanushuk, and Itkillik Rivers, it forms part of the Colville river system. The rivers, although locally controlled by structure, in general follow courses which probably predate the Pleistocene. The principal rivers head in the mountains and flow northward. Glaciation probably did not greatly change the courses of the rivers, because the northern foothills section is not extensively glaciated. Moraines and outwash deposits on the Killik, Anaktuvuk, Nanushuk, and Itkillik Rivers cover the valley floors to varying depths and modify somewhat the original valley form. Debris in the gravel ranges in size from pebbles to boulders 8 feet in diameter. Terraces are well developed in the stream valleys; locally along the Killik River, five distinct levels are recognizable. On other rivers it is not uncommon to see three terrace levels. Oxbow lakes, abandoned channel scars, and cut-off meanders are features of the lowest terrace level. In the Chandler River valley, gravel 110 feet thick was drilled in Grandstand test well 1, and 67 feet of gravel was drilled at Gubik test well 1.

The Colville River valley is 2 to 4 miles wide. The valleys of the other major rivers are 1 to 2 miles wide except where restricted to narrow canyons along the southern edge of the area. Braided channels are common where the rivers have wide flood plains. As many as eight or ten of these small interconnecting channels may be found along parts of the Killik and Anaktuvuk Rivers. These small distributary channels may carry as much water as the main channel during periods of high water.

Gradients of the rivers are primarily controlled by the strata they cut and by the topography of the area. Secondary factors are structure and topographic modifications caused by glaciation. The general trend of stream courses is transverse to the structure. Locally, however, a resistant bed on a plunging structure may have caused the stream to change direction and flow around the outcrop of the resistant stratum. Several instances of this can be seen on most of the rivers. The gradients of the major rivers are given in feet per mile in table 2. The maximum gradients are at the southern edge of the northern foothills section. Here the rivers cross the area of maximum relief where the more resistant strata crop out.

Minor streams.—There are numerous small creeks and a few minor rivers in the area traversed, many of which are structurally controlled. One notable example is Outpost Creek, which flows around the west end of Outpost Mountain. The majority of these small streams are subsequent, having developed in areas underlain by soft shale; they usually are part of a typical dendritic drainage pattern. Locally trellis drainage patterns have developed, but these are not as common as the dendritic type. A fanlike drainage pattern is characteristic of areas underlain by gravel.

TABLE 2.—*Gradients of rivers in the Chandler River region*

River	Location of gradient measure	Gradient (feet per mile)
Colville	Killik Bend to Umiat	6.5
Do	Umiat to mouth of Anaktuvuk River	5.4
Killik	Camp D–June 15–53 to junction with Okpikruak River	20.7
Do	Junction with Okpikruak River to junction with Colville River	17
Chandler	Camp D–May 30–48 to junction with Siksikpuk River	22.1
Do	Siksikpuk River to Trouble Creek	10.6
Do	Trouble Creek to Colville River	5.3
Anaktuvuk	Junction with Kanayut River to Rooftop Ridge	26
Do	Rooftop Ridge to junction with Nanushuk River	17.3
Do	Junction with Nanushuk River to Colville River	7.1
Nanushuk	Camp W–May 18–47 to camp W–June 8–47	33.6
Do	Camp W–June 8–47 to junction with Anaktuvuk River	20
Ayiyak	Camp D–June 26–52 to junction with Chandler River	5.9
Tuluga	Junction of East and West Forks to junction with Anaktuvuk	9.5

Two of the smaller rivers, the Ayiyak and the Tuluga, show evidence of having been much larger than they are at present. Both have three terrace levels and a broad flood plain occupied by a small meandering stream. It is believed that glacial moraines and outwash deposits diverted the water of the Ayiyak River into the Kiruktagiak and Okokmilaga Rivers. The Tuluga River probably lost its headwaters area by stream piracy. A small tributary of the Chandler River, cutting through shale along a fault zone, tapped the drainage of the Tuluga River, so that the Siksikpuk River now flows into the Chandler instead of continuing northeast.

STRATIGRAPHY

Stratified sedimentary rocks underlie the Chandler River region. The major rock types have been divided into stratigraphic units whose surface distribution is shown on plate 27; the relation between these stratigraphic units is given in figure 35. The localities of the measured sections that are described in detail are shown on figure 36.

Sedimentary rocks that are assigned to the Nanushuk group of Early and Late Cretaceous age and the Colville group of Late Cretaceous age underlie about 80 percent of the mapped area; in addition two pre-Nanushuk group formations and one formation of Pleistocene age are mapped. The combined thickness of the stratigraphic units is about 16,300 feet, of which about 9,700 feet is included in the Nanushuk and Colville groups.

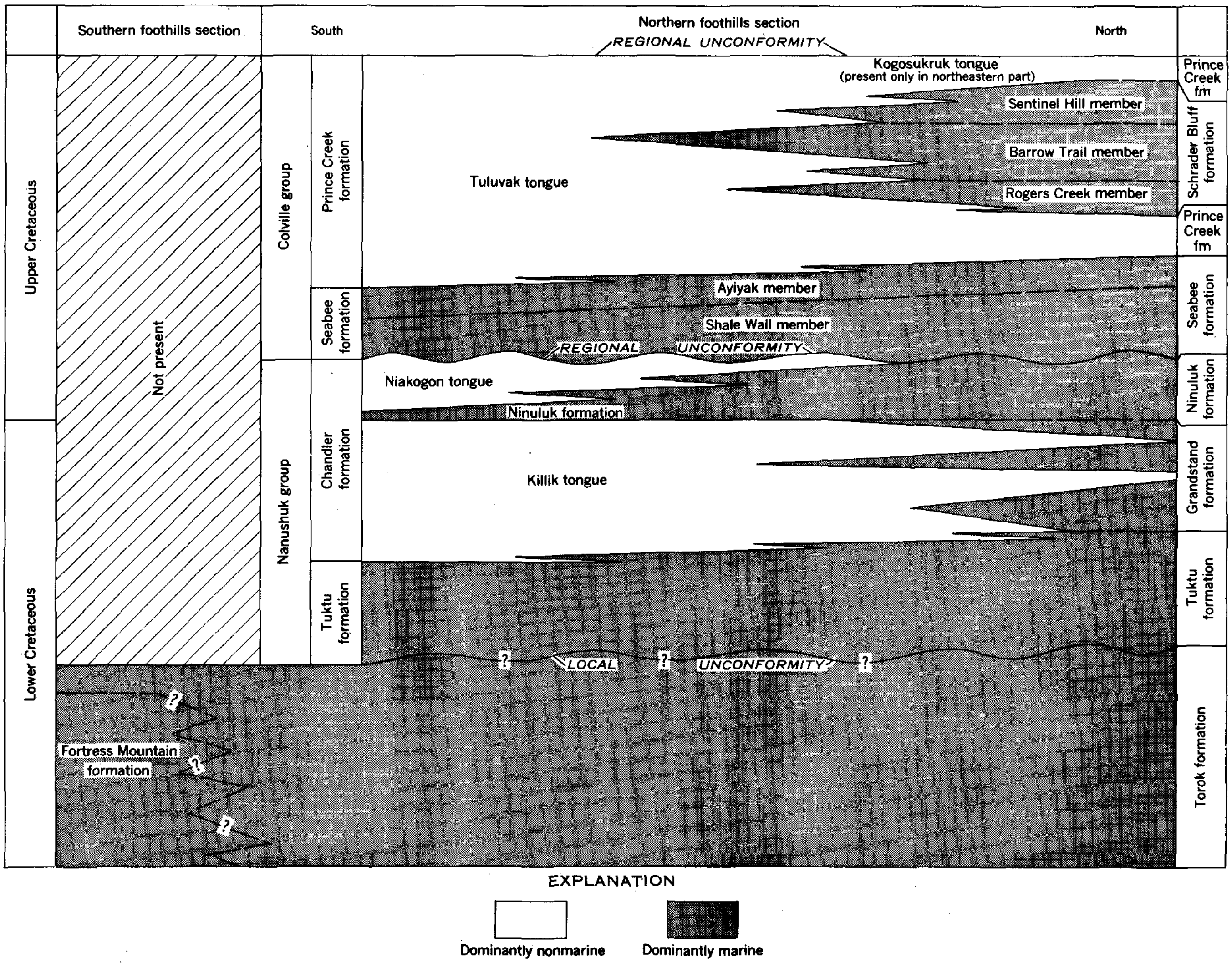

FIGURE 35.—Diagrammatic section showing facies relation of geologic units in the Chandler River region.

The exact relation between the pre-Nanushuk Fortress Mountain and Torok formations is not known. Field evidence indicates that they may be in part equivalent. Megafaunas from areas adjoining the Chandler River region indicate that at least the lower parts of the two formations are of early Albian age. The Fortress Mountain formation is dominantly a coarse clastic marine sequence about 10,000 feet thick (Patton, 1956, p. 219–222); however, only about 500 feet of the formation is exposed in the Chandler River region. The Torok formation is a marine-shale sequence about 6,100 feet thick. The Fortress Mountain formation in northern Alaska unconformably overlies rocks that are Early Cretaceous to Triassic in age. The contact between the Torok formation and the Nanushuk group is somewhat gradational although an angular break that may represent a local unconformity is present in part of the Chandler River region.

Rocks of the Nanushuk group underlie about 50 percent of the mapped area; their combined thickness is about 4,800 feet and they are divided into the Tuktu, Chandler, Grandstand, and Ninuluk formations; the Chandler formation is further subdivided into the Killik and Niakogon tongues. The dominant rock types are sandstone, conglomerate, siltstone, shale, and coal. The conglomerate and coal are generally restricted to the nonmarine Chandler formation. Fossils from the marine Tuktu and Grandstand formations are of middle Albian age, whereas those from the Ninuluk are of Cenomanian age. Structural evidence of an unconformity between the Upper and Lower Cretaceous rocks is lacking, but the basal conglomerate bed of the Ninuluk formation might suggest that one was present.

The Colville group overlies the Nanushuk group with angular discordance that ranges from about 5° to 40°. These rocks are divided into (a) the nonmarine Prince

Creek formation, with the Tuluvak and Kogosukruk tongues, (b) the marine Seabee formation, with the Shale Wall and Ayiyak members, and (c) the marine Schrader Bluff formation, with the Rogers Creek, Barrow Trail, and Sentinel Hill members. The major rock types of the Colville group include sandstone, conglomerate, siltstone, shale, coal, bentonite, and tuff. The conglomerate, coal, and bentonite are generally present only in the nonmarine Prince Creek formation.

Rocks of Tertiary age have not been identified in the Chandler River region. Deposits of Pleistocene age, including the Gubik formation, unconformably overlie strata of the Colville group.

The terrigenous deposits forming the stratigraphic sequence in the Chandler River region were laid down in a northwest-trending geosynclinal belt north of a relatively stable land mass that occupied about the same geographic position as the present Brooks Range. Local subsidence and uplift occurred in this mobile belt during the time the sediments were being deposited. The dirty graywacke sandstone, conglomerate, and shale of the Fortress Mountain formation were deposited during a period of rapid subsidence; the shale of the Torok formation was deposited when the sea in the geosynclinal trough was at its greatest depth. Sediments that formed the rocks of the Nanushuk and Colville groups were laid down during a time when the sea was relatively shallow and when minor uplift and subsidence caused rapid facies changes from marine to nonmarine sediments throughout a large part of the mapped area.

LOWER CRETACEOUS ROCKS

FORTRESS MOUNTAIN FORMATION

Rocks mapped as the Fortress Mountain formation were first recognized as being of Early Cretaceous age by Schrader (1904, p. 74); he named them the Anaktuvuk series for the Anatuvuk River. Smith and Mertie (1930, p. 196) later retained the name Anaktuvuk series for a similar group of rocks exposed in a 15-mile-wide belt north of the mountains on the Killik River. Gryc and others (1951, p. 159–160) defined

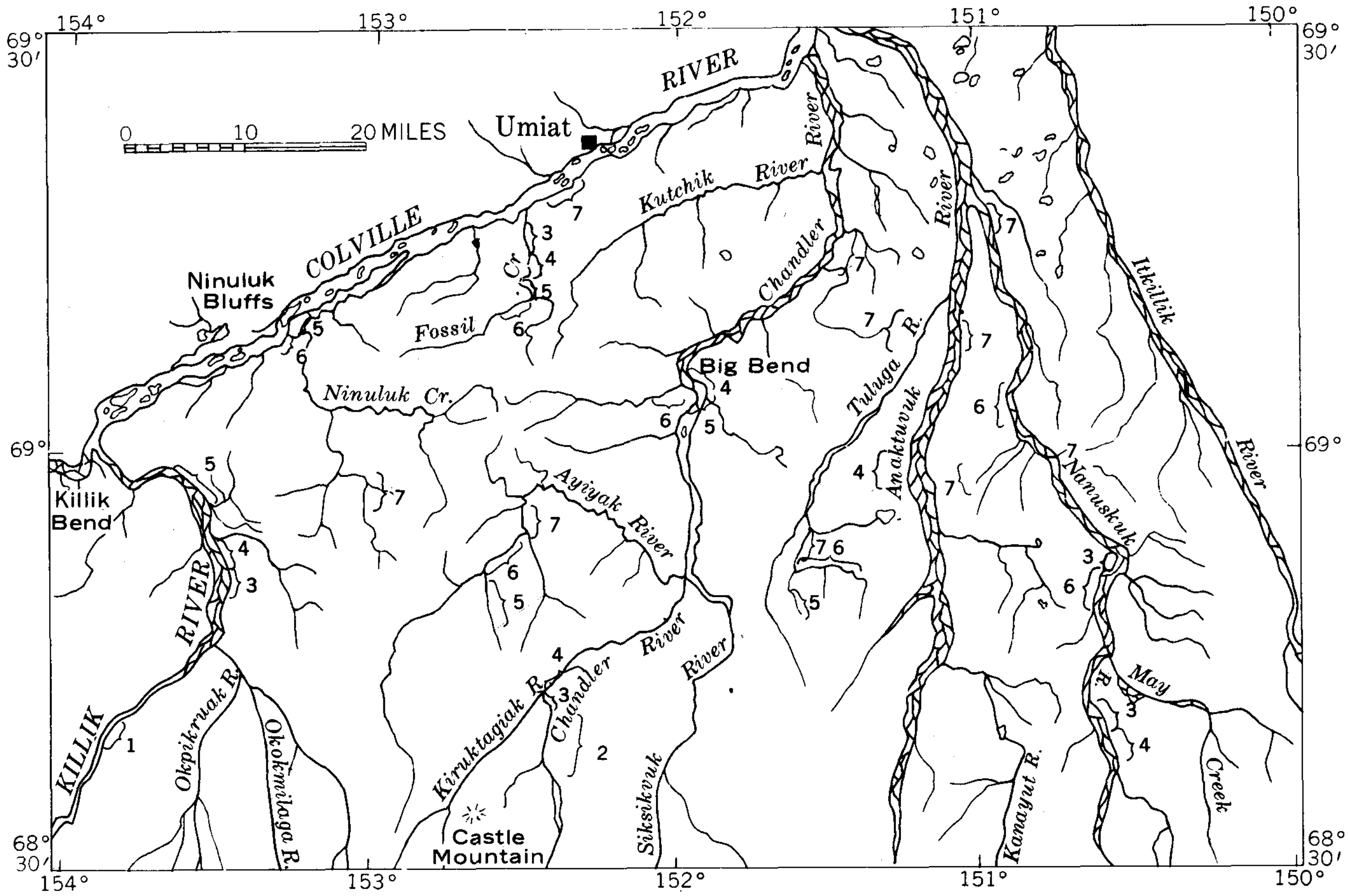

FIGURE 36.—Index map of localities of measured sections in the Chandler River region. 1, Fortress Mountain formation; 2, Torok formation; 3, Tuktu formation; 4, Chandler and Grandstand formations; 5, Ninuluk formation and Niokogon tongue of Chandler formation; 6, Seabee formation; 7, Prince Creek, Schrader Bluff, and Gubik formations.

two formations to replace the Anaktuvuk series. The lower formation was called the Okpikruak, and the upper was called the Torok formation. The Okpikruak formation is not exposed in the Chandler River region.

The Torok formation was further divided into the Fortress Mountain formation and Torok formation by Patton (1956, p. 223). The name Fortress Mountain formation was given to the conglomerate and graywacke sandstone section exposed at Fortress Mountain, south of the Chandler River region. The Torok formation was redefined and restricted to the predominantly shale section exposed along Torok Creek and the Chandler River near the mouth of the creek.

OCCURRENCE

The Fortress Mountain formation is present in a belt north of the Brooks Range from the Sagavanirktok River west at least as far as the Kukpowruk River. The formation is not exposed north of lat 68°45′, except where it has been brought to the surface by local faults.

In the Chandler River region the Fortress Mountain formation is exposed as a narrow belt in the extreme southwestern part of the region (pl. 27). Isolated and discontinuous exposures of the formation were mapped along the Killik River between lat 68°40′ N. and lat 68°42′ N. East of the Killik River, in the area of the Okpikruak and Okokmilaga Rivers, the formation crops out as rubble ridges that have been interpreted as being Fortress Mountain formation mainly by following bedding traces from the type section into the area.

The formation occurs along the Killik River in a series of small tightly folded plunging anticlines and synclines that are cut by high-angle reverse faults. Associated with the faults are small drag folds. The strata commonly dip about 40°, with dip in some beds of as much as 60°. Neither the upper nor lower contacts were observed along the Killik, as most of the area is mantled by surficial glacial deposits.

CHARACTER AND THICKNESS

The four sections of the Fortress Mountain formation measured along the Killik River cannot be correlated owing to structural complexity and discontinuity of the outcrops. The thickest section measured was 475 feet. The other sections were measured south of that locality.

Dark clay shale and shaly siltstone compose the bulk of the measured sections. The shale occurs in a rhythmically bedded sequence with light-green micaceous carbonaceous siltstone that occasionally has ropy mud-flow marks. Graywacke sandstone (Krumbein and Sloss, 1951, p. 132–134) and conglomerate are found with the shales. The graywacke sandstone is thin- to medium-bedded fine- to medium-grained pale greenish-yellow to gray, with abundant black and gray chert granules. The conglomeratic constituents are black, gray, and green chert pebbles as much as 2 inches in length. The conglomerate is massive and well sorted.

GEOLOGIC SECTIONS

The four sections of Fortress Mountain formation (fig. 37) were measured on the east bank of the Killik River. The sections are apparently not correlative and for lack of evidence to the contrary it is assumed that they are a continuous sequence.

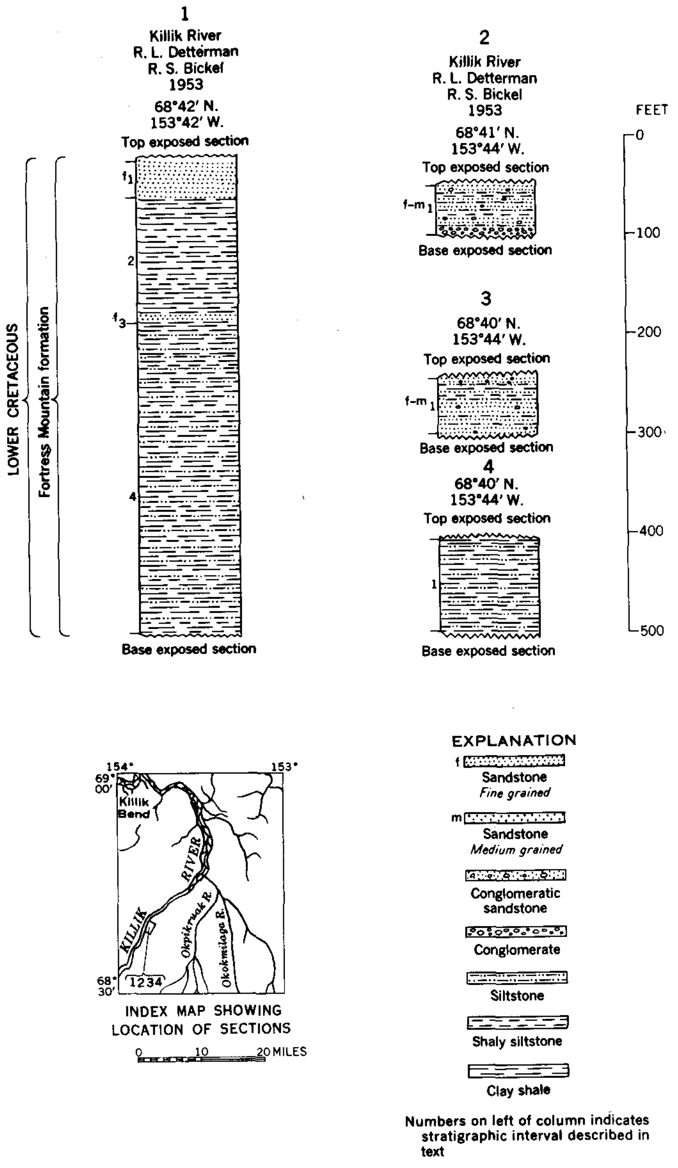

FIGURE 37.—Uncorrelated columnar sections of the Fortress Mountain formation.

Incomplete sections of Fortress Mountain formation, along the Killik River

Ten miles upstream from junction of the Killik with the Okpikruak River (fig. 37, column 1):

	Feet
1. Graywacke sandstone, thin- to medium-bedded, very fine grained, medium-gray, hard, well-indurated	35
2. Clay shale, dark blue-gray to black, fissile, crumbly, with subordinate shaly siltstone interbeds	118
3. Graywacke sandstone; similar to unit 1	8
4. Clay shale, shaly siltstone, and siltstone; rhythmically interbedded with 1 to 2 ft of shale followed by 2 to 12 in. of siltstone; light-green, swirl-bedded; abundant mud-flow marks	314
	475

One and one-half miles upstream from location of column 1 (fig. 37, column 2):

1. Conglomeratic graywacke sandstone, conglomerate, siltstone, and shaly siltstone, interbedded. Sandstone thin to medium bedded, fine to medium grained, pale greenish yellow; abundant chert granules. At base, 10 ft of chert-pebble conglomerate, pebbles ⅛ to 2 in. long	50

One mile upstream from location of column 2 (fig. 37, column 3):

1. Conglomeratic graywacke sandstone, siltstone and subordinate shaly siltstone and clay shale, interbedded. Conglomeratic sandstone thin to heavy bedded, fine to medium grained, dark neutral to greenish brown; abundant black-chert granules. Siltstone thin bedded, micaceous, carbonaceous; has ropy mud-flow marks	54

One-quarter mile upstream from location of column 3 (fig. 37, column 4):

1. Clay shale, dark blue-gray, fissile, soft, crumbly, and dark-neutral micaceous carbonaceous siltstone; in rhythmically bedded sequence. Clay shale units 1 foot thick; siltstone beds 3 to 6 inches thick	92

AGE AND CORRELATION

No megafossils were found in the measured sections of the Fortress Mountain formation. W. W. Patton, Jr. (oral communication) reported the following fossils from exposures of the formation south of the Chandler River region: *Aucellina dowlingi* McLearn, *Beudanticeras* sp., *Lemuroceras*? sp., and *Inoceramus* sp. These fossils are characteristic late Early Cretaceous forms.

Five rock samples from shale beds in the measured sections were examined for microfossils. Several fragments of Foraminifera and the radiolarian *Cenosphaerea* sp. were obtained from the samples. No conclusions concerning the age correlation of the formation can be made from this fragmentary microfauna (H. R. Bergquist, oral communication).

The contact of the Fortress Mountain with the Torok formation is not exposed; consequently, the relations of the two formations cannot be determined exactly. The relation of the Fortress Mountain formation to the older sediments in the Chandler River region is not known. Patton (oral communication) reported that the formation unconformably overlies strata of Triassic to Early Cretaceous age south of the mapped area.

TOROK FORMATION

OCCURRENCE

The Torok formation is exposed in a broad northwest-trending belt in the southern foothills section. Gross features of the Torok are identifiable from the Sagavanirktok River on the east to the Kukpowruk River on the west. This belt is characterized by low subdued topography with isolated ridges of sandstone and conglomerate rising above the lowlands developed on the shale. The lowland area is from 5 to 10 miles wide in the Chandler River region and is terminated on the north by the Tuktu Escarpment. Mountains and ridges of the Fortress Mountain formation bound the lowlands on the south. In the eastern part of the mapped area the northern limit of the Torok formation is at about lat 68°35′ N. Near the Killik River the northern limit is lat 68°48′ N. With the exception of a narrow belt at the core of Arc Mountain anticline along the Nanushuk River, the formation is not exposed north of the escarpment.

More or less discontinuous sections of the formation are exposed in small cutbanks along the major north-flowing streams within the mapped area. The strata in these exposures dip steeply and commonly are folded into small anticlines and synclines broken by small high-angle faults. In general, however, the Torok formation is not as highly deformed as is the Fortress Mountain formation. The formation has an almost constant regional dip of 30° to 50° to the north with local variations on the small structures.

The formation described here is the same stratigraphic unit that Patton redefined in 1956 (p. 222–223).

CHARACTER AND THICKNESS

The only section of the Torok formation to be discussed in detail in this report is the type section along Torok Creek and the Chandler River; it is exposed in discontinuous cutbanks along the east side of the Chandler River between lat 68°38′ N. and lat 68°48′ N. (fig. 38) and also on the west bank of the Chandler at the mouth of Torok Creek. The formation is probably about 6,120 feet thick; 2,620 feet of the formation is exposed; the remainder is computed, so the total thickness may be in error. Both the top and bottom of the type section are moderately well exposed. In both parts the strike is N. 80° E. to east-west and the dip

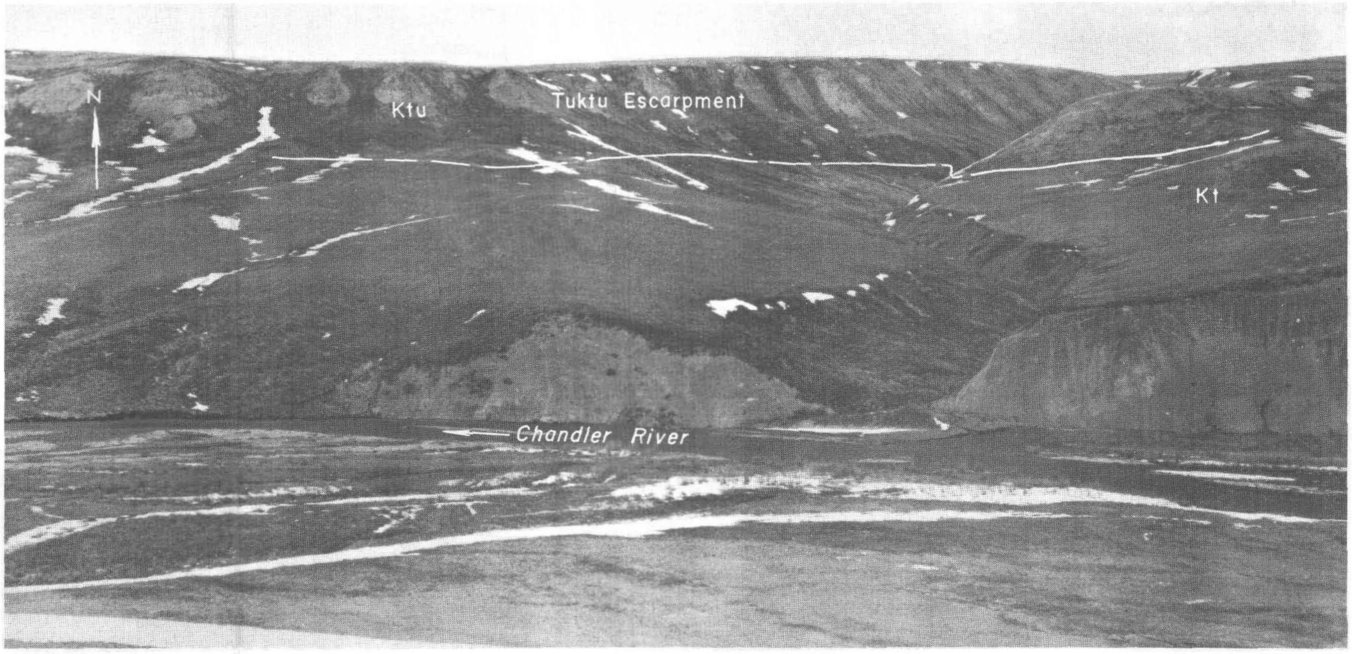

FIGURE 38.—Oblique view, looking north, of part of the type locality of the Torok formation. The upper part of the section is exposed in the bluff at the right and along the tributary stream. Tuktu escarpment is in background. Ktu, Tuktu formation; Kt, Torok formation. Photograph by U.S. Navy.

is 30° to 33° N.; consequently, even though part of the section is not well exposed, it is assumed that the structure remains constant throughout.

A reflection-seismograph profile for the area between Tuktu Bluff and Castle Mountain was made by United Geophysical Co. in 1952. The profile (pl. 42) does not substantiate the hypothesis of a continuous sequence of strata through the covered intervals. A possible fault is indicated on the profile near lat 68°41′40″ N., long 152°21′ W. There are no surface indications of a fault at that locality, but if the fault were assumed to parallel the regional strike of the rocks, it could be projected to the surface in the covered interval between 2,000 and 3,000 feet below the top of the formation. The difference in lithology between the top and bottom of the type section might tend to corroborate the presence of a fault, but the seismic reflections are of poor quality and it is impossible to estimate the direction and amount of stratigraphic displacement, if any.

The upper part of the type section is predominantly well indurated hackly fractured dark clay shale, with many ferruginous zones and some white salt efflorescence on the surface. Interbedded with the clay shale are numerous beds of dark shaly siltstone and thin green siltstone, some of which are calcareous, micaceous, and carbonaceous. Minor constituents of the upper unit are lenses, concretions, and beds of dark limestone that weather to a dark rusty brown. Small nodules and concretions of marcasite and ironstone are locally abundant. Graywacke sandstone and black chert-granule conglomerate, which compose the bulk of the lower part of the formation, are thin bedded to massive and form the ridges in the lowlands. Dark clay and shaly siltstone, siltstone, and sandstone concretions are minor constituents. The sandstone concretions, as much as 1 foot in diameter, are locally fossiliferous.

A petrographic analysis was made of two specimens of graywacke sandstone from the lower part of the type section. Field sample 48 ADt 125 (pl. 28) is from about 4,300 feet below the top of the formation. The hand specimen is greenish gray, moderately indurated, medium bedded; a fine grit of black chert is prominent on the darker gray weathered surface; this chert grit is more resistant to weathering than the main body of the rock. As seen in thin section, a siliceous clay-silt groundmass composes about 40 to 45 percent of the specimen; chert and quartz grains are as much as 1.2 mm in diameter, and rock fragments as much as 1 mm in diameter. The average grain size is 0.1 to 0.2 mm and the grains are subangular to round; fine aggregates of calcite, microcline, and andesine are present. Field sample 48 ADt 141 (pl. 28) from 4,600 feet below the top has much the same appearance in hand specimen as does 48 ADt 125. The elongated grains are 0.1 to 0.3 mm in diameter, with the average about 0.1 mm. The silt-clay groundmass is predominantly siliceous but has some secondary calcite that is in part weathered to siderite, and the biotite and hornblende are altered to chlorite. The feldspars bytownite and andesine constitute about 2 to 4 percent of the rock.

GEOLOGIC SECTIONS

The upper 4,500 feet of the type section was measured by Detterman in 1948; subsequently, Patton and Tailleur in 1949 measured an additional 1,620 feet. The section (pl. 28) is from the east bank of the Chandler River, between lat 68°41′ N. and 68°43′ N., and on the west bank at the mouth of Torok Creek.

Type section of Torok formation, on the Chandler River (pl. 28)

	Feet
Tuktu formation.	
Torok formation:	
1. Covered; computed thickness	50
2. Clay shale, dark blue-gray, hackly-fractured, well-indurated, with numerous interbeds of calcareous greenish siltstone and shaly siltstone. Small drag folds and faults common; in part rubble and cover; computed thickness	350
3. Clay shale, silty, blue-gray, hard, hackly-fractured, becoming more of a shaly siltstone near base. Many interbeds of calcareous siltstone, shaly siltstone, and silty rusty-brown limestone. Marcasite concretions locally abundant; mud lumps and rill markings common. Part of section inaccessible; computed thickness	360
4. Clay shale, paper-thin, medium blue-gray, with irregular fractures; breaks into small flakes; few limestone lenses and nodules. Greenish-yellow carbonaceous siltstone interbeds (thinner and less numerous than those in unit 3 above)	120
5. Clay shale, claystone, siltstone, and shaly siltstone. Clay shale very hard, irregularly fractured, with numerous shaly siltstone and siltstone interbeds; some thin silty limestone that weathers rusty brown. Some white salt efflorescence on the clay shale. Ferruginous zones common, with ironstone concretions as much as 2 inches in diameter common in lower part. Scattered fossils 260 ft. above base (USGS Mesozoic loc. 25120) include *Inoceramus* sp. juv. cf. *anglicus* Woods. Some of the unit along river inaccessible; computed thickness	780
6. Mostly covered, with a few rubble patches of clay shale, shaly siltstone, and siltstone; 10 feet of well-indurated rusty brown fine-grained calcareous sandstone 180 feet above base; a few wood fragments and ironstone concretions; computed thickness	2, 340
7. Clay shale, medium blue-gray, crumbly, with a few interbeds of siltstone	20
8. Graywacke sandstone, heavy-bedded, very fine grained, dark-neutral, hard, argillaceous; weathers dark brown to maroon	2
9. Clay shale	5
10. Graywacke sandstone, coarse-grained with dark-gray chert granules	1
Torok formation—Continued	
11. Clay shale	12
12. Graywacke sandstone, shaly-bedded to massive, very fine to coarse-grained, dark-neutral; weathers brown to maroon; lenses of black chert-granule conglomerate; cross-bedded. Shaly siltstone interbeds and limestone lenses	45
13. Graywacke sandstone, thin- to medium-bedded, medium-gray to green with scattered black chert granules; siltstone and shaly siltstone interbeds; in part rubble; computed thickness	110
14. Graywacke sandstone, medium-bedded, forms a series of resistant beds; black chert granules common, forming thin seams of conglomerate; small sandstone concretions as much as 2 in. in diameter. Number of chert granules increases downward in section. Siltstone, shaly siltstone, and sandstone occur between the resistant beds; in part rubble; computed thickness	285
15. Graywacke sandstone, siltstone, shaly siltstone and clay shale; chert granules common in the graywacke. Sandstone concretions 1 ft. in diameter contain fossils (USGS Mesozoic loc. 21554) *Colvillia crassicostata* Imlay, *Colvillia* cf. *C. crassicostata* Imlay, *Puzosia?* sp. juv., *Beudanticeras* (*Grantziceras*) aff. (Whiteaves), and *Inoceramus* sp. juv., plant fossils common. Asphalt, probably gilsonite, found in float, mainly concentrated near top of unit. Mostly rubble; computed thickness	320
16. Covered; computed thickness	1, 140
17. Shale, siltstone, sandstone, and limestone. Shale mostly light to dark, clayey and silty; subordinate light-gray siltstone and thin-bedded very fine grained sandstone; lenticular light-gray dense limestone; in part rubble; computed thickness	180
	6, 120

AGE AND CORRELATION

Megafossils from the Torok formation indicate a late Early Cretaceous age. Two fossil collections were obtained from the type section of the formation. One collection (USGS Mesozoic loc. 25120) from 1,400 below the top of the formation contains a single specimen of *Inoceramus anglicus* Woods that is characteristic of the *Gastroplites kingi* zone (Imlay, 1961, p. 10) and is considered to be middle Albian. The other collection (USGS Mesozoic loc. 21554) is from 4,000 to 4,600 feet below the top of the formation; it contains *Colvillia crassicostata* Imlay, *Colvillia* cf. *C. crassicostata* Imlay, *Puzosia? sp.*, *Beudanticeras* (*Grantziceras*) aff. (Whiteaves), and *Inoceramus* sp.; this fauna is characteristic of the *Colvillia crassicostata* zone (Imlay, 1961) and is of early Albian age.

The megafossils were identified by Imlay, who reported that the lower part of the Torok formation can

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be correlated with the lower part of the Fortress Mountain formation by the presence of the ammonites *Colvillia* and *Beudanticeras*, and that it can be further correlated with the Clearwater and Loon River formations of Alberta, Canada, and the Moosebar, Gates, and lower part of the Buckinghorse formations of northeastern British Columbia (Imlay, 1961).

One hundred and twenty two rock samples were collected from the type section of the Torok formation and examined for microfossils; 79 samples were barren. The microfossils were identified by H. R. Bergquist. The distribution and abundance of fossils are shown on plate 28. Some of the specimens are casts or fragments that cannot be identified; consequently, these are not shown. The microfauna in the shale sequence from the upper part of the formation is somewhat different from that of the lower part. Bergquist states (written communication, 1956):

> Less than one dozen species constitute the fauna in the samples * * *. The fauna is part of the *Verneuilinoides borealis* faunal zone which is widespread in the subsurface in the Grandstand formation and in part of the Topagoruk formation. In the Torok formation at the type locality, however, the species *Verneuilinoides borealis* Tappan which gives the name to the fauna, occurs relatively rarely (one to four specimens) in 13 samples and was abundant in one sample. Specimens of *Haplophragmoides topagorukensis* Tappan and fragments of *Bathysiphon vitta* Nauss each were common in two samples. The other species found in rare numbers and scattered occurrences include: *Miliammina awunensis*? Tappan; *M. manitobensis* Wickenden; *Ammobaculites* n. sp.; *Valvulineria loetterlei* Tappan; *Eponides morani* Tappan; *Gavelinella stictata* (Tappan); and *Eurycheilostoma robinsonae* Tappan. Nearly all are characteristic of the *Verneuilinoides borealis* fauna.
>
> The most significant species and the only one that apparently is diagnostic of the lower part of the Torok formation is *Dorothia chandlerensis* Tappan * * * In the same samples were corroded specimens of *Nanushukella umiatensis*? Tappan and distorted specimens of *Haplophragmoides linki*? Nauss and *Trochammina eilete* Tappan * * *

The contact with the overlying Tuktu formation is not well exposed; however, two distinct rock types are represented and there is a pronounced change in dip between the two formations. The change in dip is not a local feature; it occurs throughout the mapped area and is commonly about 10° to 12° but may range from 3° to 20° (pl. 27.) There is little or no change in the strike of the strata between the two formations. The change in dip may indicate an angular unconformity between the formations or may have resulted from the incompetency of the shale of the Torok formation. The widespread occurrence of these discordant dips would tend to indicate an angular unconformity. The authors support the postulation of an angular unconformity; they do not believe that any major time break was involved or that the Torok formation was subjected to any orogenic processes with subsequent erosion prior to the deposition of the Tuktu formation. The discordant dips probably are primary sedimentation features.

NANUSHUK GROUP

The term "Nanushuk series", from the Nanushuk River, was first applied by Schrader (1901, p. 79) to a belt of rocks that extends for 30 miles along the lower part of the Anaktuvuk River and continues downstream for 5 miles along the Colville River. Schrader described his type section as being a bluff on "* * * the north [northeast] bank of the Anaktuvuk about 5 miles above the mouth of Tuluga River."

Smith and Mertie (1930, p. 210) retained the Nanushuk series, but also "included in this series the lower of the rocks referred by Schrader to the Colville series on the Anaktuvuk River." During the recent exploration in northern Alaska more outcrops were examined in greater detail than had been previously possible. As new data was assembled it became apparent that the unit could be redefined and split into formations. Gryc and others (1951, p. 162) redefined the Nanushuk series to apply "to a group of rocks of Lower Cretaceous and Lower(?) Cretaceous age. These rocks are exposed along the Nanushuk River where the river cuts across the Arctic Foothills province." They further divided the Nanushuk group into the marine Umiat formation, with two members, and the nonmarine Chandler formation, with two tongues.

Data obtained since 1951 has necessitated additional changes in nomenclature within the Nanushuk group. The group was redefined by Detterman (1956a, p. 233) to include a basal marine Tuktu formation (no known nonmarine equivalents), the marine Grandstand and Ninuluk formations, and the nonmarine Chandler formation that intertongues with and grades into the two upper marine formations. Two major units of the Chandler formation, the Killik and Niakogon tongues, are recognized and mapped in the southern part of the area of this study. The type section for the Nanushuk group, defined by Gryc and others (1951) as the belt of rocks along the Nanushuk River, was retained, but some parts of the group are better exposed on adjacent rivers and these outcrops have been made the type localities for formations, members, and tongues within the group. Megafossil identifications made since 1951 have indicated that the rocks included in the Nanushuk group are of Early Cretaceous to early Late Cretaceous age.

Outcrops of the Nanushuk group are confined to the northern foothills section of the Arctic Foothills

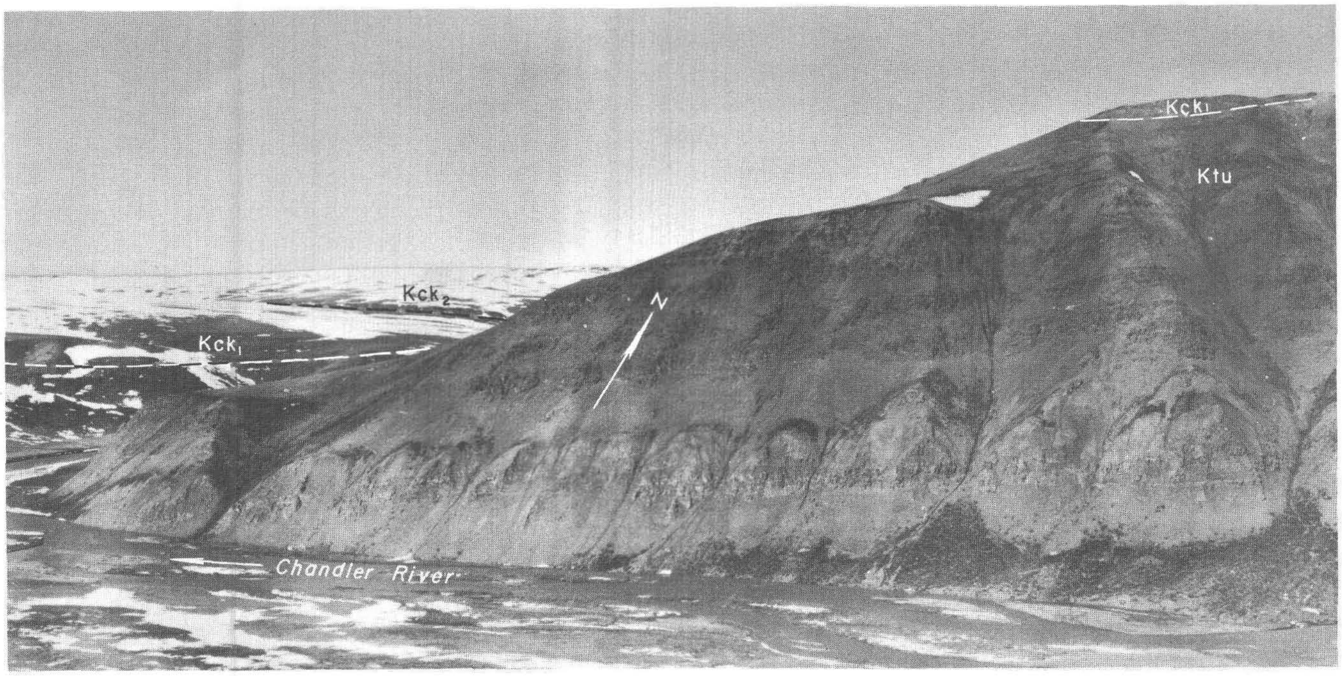

FIGURE 39.—Oblique view, looking north-northwest, of Tuktu Bluff showing type locality of the Tuktu formation. Kck_2, upper part, Killik tongue; Kck_1, lower part, Killik tongue; Ktu, Tuktu formation. Photograph by U.S. Navy.

province. The southern edge of the northern foothills is formed by the prominent Tuktu Escarpment of resistant clastic rocks at the base of the group.

The sedimentary rocks of the group include: subgraywacke sandstone (Krumbein and Sloss, 1951, p. 133–134), sandstone, conglomerate, siltstone, shaly siltstone, and clay shale. Coal, limestone and ironstone as concretions and beds, and bentonite (in the upper part) are intercalated with the clastic sediments. In the southern part of the mapped area the group is 4,800 feet thick; it becomes thinner toward the northeast with a minimum thickness of 2,340 feet.

TUKTU FORMATION

OCCURRENCE

The type locality for the Tuktu formation is at Tuktu Bluff on the northeast bank of the Chandler River, at its confluence with the Kiruktagiak River, lat 68°44′ N., long 152°18′ W. (fig. 39). Tuktu Bluff is part of the prominent south-facing Tuktu Escarpment that can be traced laterally for nearly 200 miles.

The escarpment is the highest topographic feature in the area with maximum relief of 1,000 to 1,800 feet; to the south are lowlands underlain by Torok formation, and on the north are high ridges of the resistant coarse clastic Chandler formation. The best exposures of the Tuktu formation are along and just to the north of the escarpment. Northward the Tuktu is exposed in isolated localities where it has been brought to the surface by faulting or folding. Several sections of the Tuktu formation, north of the escarpment, are significant to the discussion on facies changes within the formation. The formation has not been identified south of the escarpment, perhaps because of nondeposition or erosion. The former seems more probable because erosion is unlikely to account for the total absence of the formation.

In the southernmost exposures of the Tuktu formation the strata have a regional north dip of 10° to 25°. North of the escarpment, strata of the Tuktu formation are locally more highly deformed. The regional strike of the strata is from N. 80° W. to east-west.

CHARACTER AND THICKNESS

The Tuktu formation is a marine clastic unit composed primarily of dirty, green to gray-green medium to very fine grained sandstone, gray-green siltstone, and shaly siltstone. Subordinate amounts of clay shale are present in the more northeasterly exposures. Minor constituents include limestone, ironstone, and sandstone concretions and chert-pebble conglomerate. A few thin coal beds near the top of the formation along the Killik River represent a lagoonal facies.

At the type locality, the Tuktu formation is about 1,030 feet thick (pl. 27; pl. 29, column 2). Sandstone and siltstone constitute about 85 percent of the rocks. The siltstone is subordinate to the sandstone, but much of the latter is very fine grained. The sandstone is a subgraywacke, very fine to medium grained, medium-gray to olive-gray and green shaly-bedded to massive; it contains argillaceous material and is commonly calcareous. Most of the sandstone is soft, and unit 2, in the upper part of the type section, is very friable. A 4-inch bed of gray and black chert-pebble conglomerate occurs in unit 6 about 105 feet above the base. The conglomerate is intraformational, with as much as 10 percent shale fragments; it is probably a littoral or sublittoral deposit. However, pelecypods and worms in the conglomerate do not show evidence of abrasion by wave action. Some of the intercalated sandstone is crossbedded but no ripple marks were noted. The shaly-bedded sandstone and also some of the siltstone in the upper part of the formation locally have small crossbeds. These crossbeds were probably formed by current action rather than by wave or tidal action. The sandstone in the lower 460 feet is more massive and forms the base of the escarpment. Plant fragments are present in the basal part of the formation. Ironstone concretions are commonly associated with the shaly siltstone. The concretions are small, generally less than 2 inches in diameter, and the enclosing shale is iron stained.

Eastward along the escarpment the Tuktu formation is similar to the outcrop at the type locality; it is not well exposed in the intrastream areas but is best exposed where streams have cut the escarpment.

The Nanushuk River section (pl. 29, column 3) is about 940 feet thick. It was measured on the north flank of Arc Mountain anticline where there are better exposures than at the escarpment; consequently, it may not be quite representative of the rocks in the escarpment. Clay shale and shaly siltstone constitute about 40 percent of the rocks. Although the section is predominately sandstone, its rocks are finer grained, thinner bedded, and more argillaceous than those at the type locality. Ripple marks are common throughout. The entire section appears to have been deposited farther from shore than the rocks at the type locality.

Westward along the escarpment from the type locality the facies of the Tuktu formation becomes more littoral. The Killik River section (pl. 29, column 1) shows the westerly facies of the formation. The section is about 940 feet thick but is incomplete as the base is cut off by a fault. Sandstone near the top of the Killik River section is more lagoonal and littoral than the rock of any other observed occurrence of the formation. Several thin coal beds were seen near the top of the formation in the escarpment; the measured section, which is 5 miles north of the escarpment, includes several coal beds in the upper 80 feet. Carbonaceous material and plant fragments are also common throughout the section. The Killik River section has other features found only in the southwestern part of the area; near the top is a 150-foot section (unit 4) of fine-grained thin- to medium-bedded friable dark-green sandstone. Sandstone in other sections of the Tuktu formation are correlated with this, but in other outcrops this unit is not as distinctive. Below the friable sandstone is a section of about 710 feet of rhythmically interbedded siltstone, sandstone, and shaly siltstone. The unit is predominately a green thin-bedded (1/8- to 1/4-in. thick) siltstone. Intercalated with the siltstone is very fine grained medium-green to gray sandstone in beds as much as 1 foot thick and shaly siltstone units of similar thickness. This 710-foot section becomes progressively sandier toward the base. Minor constituents include sandstone concretions with shale inclusions.

The shale content of the Tuktu formation increases rapidly toward the north and, to a lesser extent, toward the east. In the more northerly exposures the sandstone units are much thinner than along the escarpment and are generally thin bedded, very fine to fine grained, and highly argillaceous.

The Fossil Creek section (pl. 29, column 5) is the northernmost exposure of strata mapped as Tuktu formation in northern Alaska. The incompletely exposed section is about 900 feet thick. Clay shale and shaly siltstone constitute about 50 percent of the exposed strata; siltstone is more abundant than sandstone, which is generally thin bedded, fine grained, and medium green to gray. The individual sandstone units, although considerably thinner, can be correlated with sandstone units at the escarpment.

The Rooftop Ridge section (pl. 29, column 4) is about 715 feet thick; it was measured in the bluff along the west bank of the Nanushuk River, where the river truncates the ridge. The section is incomplete and the base is missing. This section is about midway between the escarpment and the northernmost exposures of the formation and is an intermediate facies. Sandstone and shale are present in nearly equal proportions. This is the only section in which limestone was noted. A bed 1 foot thick was measured 480 feet below the top (unit 24).

The upper contact of the Tuktu formation over most of the area is well defined, sharp, and nongradational. The green and gray marine sandstone passes abruptly into light-yellowish "salt and pepper" appearing nonmarine sandstone and conglomeratic sandstone of the Chandler formation. Along the Killik River the contact is less well defined and is somewhat gradational. The upper 80 feet of the Killik River section contains some marginal marine strata, but the contact has been placed arbitrarily at the base of the first definitely nonmarine salt-and-pepper sandstone and conglomerate. In some outcrops the marine Tuktu formation is overlain by the marine Grandstand formation. The contact between the two marine formations is sharp, well defined, and nongradational; it is placed at the base of the first greenish-gray "salt and pepper" quartz sandstone. A small amount of white quartz is present in the sandstone of the Tuktu formation but is effectively masked by abundant argillaceous material. The sandstone at the base of both the Killik tongue of the Chandler formation and the Grandstand formation contains a great abundance of white quartz and less argillaceous material. This gives the sandstone a distinctive salt-and-pepper appearance. The sandstone is commonly clean, silica cemented, and well indurated, particularly just above the contact. In all outcrops the contact between the Tuktu formation and the overlying Chandler and Grandstand formations appears to be conformable.

Five field samples from the Tuktu formation were examined microscopically to determine the size and abundance of constituent minerals. The samples were selected from different localities and from different positions within the formation.

Field sample 48 ADt 159 (pl. 29, column 2) is from 50 feet below the top of the formation at the type locality on the Chandler River. The sandstone is thin to shaly bedded, fine to very fine grained, friable, and dark greenish gray; it weathers dark yellowish brown. Thin section examination showed the angular to subround grains to be 0.3 mm to less than 0.1 mm in diameter. A siliceous matrix comprises 40 to 50 percent of the rock. The constituent minerals are: quartz, 48 percent; chert, 27 percent; chlorite, 12 percent; rock fragments, 5 percent; calcite, 2 percent; plagioclase, 1 percent; carbonaceous material, 3 percent; the remaining 2 percent includes biotite, muscovite, tourmaline, limonite, and leucoxene. All percentage figures were determined by a grain count of 100.

Field sample 53 ADt 45 (pl. 29, column 1) from 210 feet below the top of the formation is similar to the first in general appearance; it contains 38 percent quartz, 14 percent chert, 9 percent calcite, 20 percent chlorite, 8 percent biotite, 7 percent rock fragments, 3 percent carbonaceous material, with minor amounts of plagioclase, limonite, magnetite, and leucoxene.

The rocks of the other three field samples are so nearly like the two already described that they do not warrant further discussion. In all samples the matrix composed 20 to 50 percent of the rock and was either quartz or calcite; pore space was generally less than 5 percent.

GEOLOGIC SECTIONS

The geologic sections of Tuktu formation are described in descending stratigraphic order and are presented in the same succession as on plate 29.

The Killik River section (pl. 29, column 1) was measured in the first bluff south of the axis of Kurupa anticline, on the east bank of the Killik at lat 68°51′ N., long 153°25′ W. At this locality the formation is exposed in a series of bluffs in which the strata are folded into numerous small east-plunging anticlines and synclines on the flanks of Kurupa anticline. The strata are cut by high-angle reverse faults that repeat the section several times. The faults are small and generally parallel the bedding; maximum displacement probably does not exceed 200 feet. The 940-foot measured section was taped in continuous south-dipping strata that lie between two faults. The dip decreases from 40° at the north end of the bluff to 28° at the south end. The contact with the overlying Killik tongue is normal.

Incomplete section of Tuktu formation, along the Killik River (pl. 29, column 1)

	Feet
Lower part of the Killik tongue.	
Tuktu formation:	
1. Siltstone and sandstone; thin- to heavy-bedded, fine-grained, dark-neutral to green; siltstone micaceous and carbonaceous	25
2. Covered; computed thickness	25
3. Shaly siltstone, and siltstone, sandstone, and coal; rubble; computed thickness	30
4. Sandstone, thin- to medium-bedded, fine-grained, dark-green, very friable; few siltstone interbeds and lenses. Scattered pelecypods in upper part (USGS Mesozoic loc. 24633). In part rubble; computed thickness	150
5. Siltsone, greenish, thin-bedded (1/8 to 1/4 in. thick); interbedded with sandstone beds and shaly siltstone units, both 1 foot thick. Sandstone very fine grained, silty, medium green to dark neutral; weathers gray to rusty brown; has few shale inclusions; worm trails and tubes, plant fragments, and sandstone concretions in lower part. Unit becomes progressively sandier toward base. Scattered fossils 200 ft above base (USGS Mesozoic loc. 24619) fossils 530 ft below top (USGS Mesozoic loc. 20464) and 160 ft above base (USGS Mesozoic loc. 20472). In part rubble; computed thickness	710
	940
Fault.	

The type section at Tuktu Bluff (pl. 29, column 2) was measured in the escarpment on the northeast bank of the Chandler River, near its confluence with the Kiruktagiak River. The upper 840 ft of the section was measured on the face of the bluff 1.4 miles upstream from the junction of the two rivers. The basal 190 ft was measured in a stream cut bank about 1 mile farther east. Some of the bluff section was inaccessible and the thickness was calculated from barometric measurement. The remainder was taped.

Type section of Tuktu formation at Tuktu Bluff on the Chandler River (pl. 29, column 2)

	Feet
Lower part of the Killik tongue.	
Tuktu formation:	
1. Sandstone, siltstone, and shaly siltstone, Sandstone, thin to shaly bedded, very fine grained, medium gray to olive gray, highly argillaceous; siltstone and shaly siltstone greenish gray, somewhat sandy; in part rubble; computed thickness	90
2. Sandstone, medium-bedded, fine- to medium-grained, medium-green; weathers medium yellow brown; iron-stained, slightly argillaceous, very friable; fractures into rectangular blocks	50
3. Sandstone, thin- to shaly-bedded, crossbedded, very fine to fine-grained, dark-neutral with greenish cast, argillaceous, calcareous; in places almost a siltstone. Ironstone concretions locally abundant. Gray shaly siltstone and siltstone interbedded with sandstone. A few fossils, pelecypods and worms near middle of section (USGS Mesozoic loc. 25122). In part rubble; computed thickness	430
4. Sandstone, thin- to thick-bedded, more massive than unit 3; cliff-forming; fractures into large rectangular blocks; fine-grained, medium- to dark olive-gray, argillaceous; interbeds of siltstone and shaly siltstone; ironstone concretions. Fossil collection from lower 80 ft. of section (USGS Mesozoic loc. 25121). In part rubble; computed thickness	270
5. Sandstone, medium-bedded, medium- to coarse-grained with some chert pebbles; medium yellow-red, friable; fractures into large slabs	10
6. Sandstone, siltstone, shaly siltstone and clay shale, with ironstone concretions. Sandstone thin to medium bedded, fine grained, dark neutral; weathers gray to rusty brown; argillaceous, crossbedded; a 4-in. seam of pebble-granule conglomerate near middle of section is 90 percent black and gray chert, the rest mainly shale fragments, well cemented, hard. Fossils associated with conglomerate, including *Inoceramus* cf. *I. cadottensis* McLearn (USGS Mesozoic locs. 25123 and 20454); fossils do not appear to be reworked; plant fragments common in upper part. The unit mainly rubble; computed thickness	180
	1, 030
Torok formation.	

The Arc Mountain section on the Nanushuk River (pl. 29, column 3; pl. 31, section 4) was measured on the north bank of a small tributary that enters the Nanushuk River at lat 68°40′ N., long 150°32′ W. The section is in north-dipping strata on the north flank of Arc Mountain anticline.

Section of Tuktu formation on the Nanushuk River South of May Creek (pl. 29, column 3)

	Feet
Killik tongue.	
Tuktu formation:	
1. Sandstone, thin- to heavy-bedded, very fine to medium-grained, medium-green to gray, argillaceous. Carbonized plant fragments and pyrite concretions; fossiliferous, ammonites and pelecypods. In part rubble; computed thickness	250
2. Silty shale, pyrite concretions, rubble; computed thickness	20
3. Sandstone, thin- to medium-bedded, very fine grained, medium-green to gray, argilliaceous; pyrite concretions. Fossiliferous, ammonites and pelecypods; carbonized plant fragments. Subordinate siltstone, mostly rubble; computed thickness	80
4. Clay shale and shaly siltstone; dark, with few siltstone interbeds; pyrite concretions, rubble; computed thickness	110
5. Sandstone, medium-bedded, very fine grained, light- to medium-gray, argillaceous, carbonaceous, ripple-marked; pyrite concretions. Scattered pelecypods. In part rubble; computed thickness	70
6. Clay shale and shaly siltstone; rubble; computed thickness	90
7. Sandstone; similar to unit 5; rubble; computed thickness	30
8. Clay shale and shaly siltstone; few siltstone interbeds; pyrite concretions; rubble; computed thickness	130
9. Sandstone; similar to unit 5; rubble; computed thickness	20
10. Clay shale and shaly siltstone rubble; computed thickness	40
11. Silty shale, siltstone, and sandstone similar to that in overlying units; fossiliferous at base, ammonites and pelecypods (USGS Mesozoic loc. 24427). Mostly rubble; computed thickness	100
	940

The Rooftop Ridge section (pl. 29, column 4) was measured on the west bank of the Nanushuk River, at lat 68°51′ N., long 150°31′ W. Rooftop Ridge was formed by thrust faults; part of the section has been repeated. The section measured lies at the north end of the bluff between two faults in strata dipping 42° S. to 52° S.

Incomplete section Tuktu Formation, at the east end of Rooftop Ridge on the Nanushuk River (pl. 29, column 4)

Grandstand and Ninuluk formations, undifferentiated.

Tuktu formation:	Feet
1. Sandstone, thin-bedded to massive, fine- to coarse-grained, greenish-neutral	10
2. Sandstone, thin-bedded, fine-grained, dark-neutral to green; thin siltstone interbeds	34
3. Silty shale and siltstone; medium-gray	8
4. Sandstone and siltstone	10
5. Silty shale and siltstone float in covered area; computed thickness	20
6. Sandstone, thin-bedded, very fine to fine-grained, dark-neutral to greenish-gray	20
7. Siltstone and sandstone; thin- to shaly-bedded, very fine grained, greenish-gray crossbedded; few large calcareous sandstone concretions; several 1-foot beds of ferruginous shaly siltstone. Scattered fossils near top (USGS Mesozoic loc. 24626)	33
8. Sandstone, siltstone, and shaly siltstone rubble; computed thickness	60
9. Sandstone and shaly siltstone, interbedded. Sandstone beds 2 feet thick, shaly siltstone beds 1 foot thick	30
10. Silty shale, with siltstone interbeds	10
11. Sandstone, massive, very fine to fine-grained, dark-neutral to green; weathers gray	30
12. Siltstone and sandstone; very thin bedded to shaly bedded	10
13. Silty shale and siltstone	8
14. Siltstone and shaly siltstone rubble; computed thickness	25
15. Sandstone, thin- to medium-bedded, very fine grained, medium-green, ferruginous, with subordinate siltstone	20
16. Siltstone, greenish-gray, ferruginous. Fossiliferous in upper part (USGS Mesozoic loc. 25132)	5
17. Sandstone, medium-bedded, very fine grained, dark-neutral to dark-green; siltstone interbeds. Fossils in lower part (USGS Mesozoic loc. 25131). Rubble; computed thickness	80
18. Sandstone, ledge-forming, thin- to medium-bedded, fine-grained, silty, dark-neutral to greenish gray; weathers rusty brown; hard, brittle; subordinate siltstone interbeds; carbonaceous; few ironstone concretions; fossiliferous (USGS Mesozoic loc. 24627)	15
19. Siltstone and sandstone	5
20. Silty shale with 1-inch siltstone interbeds	7
21. Sandstone, thin-bedded, flaggy, very fine to fine-grained, dark-neutral	10
22. Siltstone, hackly-fracturing	7
23. Sandstone, medium-bedded, fine-grained, dark-neutral with greenish cast; worm tubes	18
24. Limestone, thin, rusty-brown, hard	1
25. Sandstone; similar to unit 23	10
26. Sandstone rubble; few pelecypods (USGS Mesozoic loc. 25133); computed thickness	20

Tuktu formation—Continued	Feet
27. Siltstone and sandstone; thin- to medium-bedded, very fine grained, silty, dark-neutral with greenish cast, small crossbeds, ferruginous; ironstone concretions	40
28. Silty shale and siltstone	6
29. Siltstone and sandstone	5
30. Siltstone, dark-neutral; rusty weathering; carbonaceous, fossiliferous (USGS Mesozoic loc. 24625)	3
31. Silty shale, hackly-fracturing, dark-neutral; weathers rusty brown	5
32. Silty shale, siltstone, and sandstone rubble; computed thickness	65
33. Sandstone, thin-bedded, fine-grained, silty, dark-neutral; rusty weathering; ripple-marked; subordinate siltstone and shaly siltstone interbeds; carbonaceous. Fossils at top of unit (USGS Mesozoic loc. 24624)	35
34. Covered; computed thickness	15
35. Sandstone, thin- to medium-bedded, fine-grained, dark-neutral	15
36. Sandstone, thin- to medium-bedded, very fine grained, silty, dark-neutral to greenish gray; weathers rusty-brown; carbonaceous, with mud lumps. Worm tubes, scattered fossils (USGS Mesozoic locs. 24624 and 25135). In part rubble; computed thickness	20
	715

Fault.

The Fossil Creek section (pl. 29, column 5) was measured in a series of discontinuous cutbanks along the creek between lat. 69°13′30″ N., and lat. 69°14′30″ N., long 152°28′ W. The strata measured are on the south flank of Fossil Creek anticline. The dip decreases from 17° S. to 14° S. toward the Outpost Mountain syncline. A thrust fault obliterates the base of the formation.

Incomplete section of Tuktu Formation, along Fossil Creek (pl. 29, column 5)

Killik tongue.

Tuktu formation:	Feet
1. Sandstone, thin-bedded, fine-grained, light yellow-red, with few siltstone interbeds	20
2. Siltstone, shaly siltstone, and sandstone interbedded; rubble; computed thickness	30
3. Covered; computed thickness	30
4. Silty shale and siltstone, dark-brown; sandstone, thin-bedded, very fine grained, medium-green, and weathers yellow brown; rubble; computed thickness	40
5. Covered; computed thickness	40
6. Sandstone, siltstone, and shaly siltstone interbedded. Fossils in sandstone (USGS Mesozoic loc. 20433). Rubble; computed thickness	35
7. Covered; computed thickness	25

Tuktu formation—Continued

	Feet
8. Clay shale, dark blue-gray, hard; in part rubble; computed thickness	15
9. Siltstone and shaly siltstone; dark-brown	25
10. Covered; computed thickness	20
11. Siltstone and sandstone; fine-grained, dark-neutral; scattered fossils (USGS Mesozoic loc. 25129); rubble; computed thickness	10
12. Covered; computed thickness	10
13. Sandstone and siltstone rubble; computed thickness	20
14. Sandstone, medium-bedded, very fine to fine-grained, dark-neutral with greenish cast; fractures into large rectangular blocks; argillaceous; numerous fossils (USGS Mesozoic locs. 24622 and 20432); in part rubble; computed thickness	40
15. Siltstone rubble; computed thickness	10
16. Covered; computed thickness	110
17. Siltstone and shaly siltstone rubble; computed thickness	20
18. Sandstone, thin-bedded, fine-grained, silty, dark-neutral to greenish gray, argillaceous	15
19. Clay shale, shaly siltstone, siltstone, and sandstone interbedded; thin to shaly bedded, very fine grained, dark neutral, argillaceous fossiliferous; mostly rubble; computed thickness	70
20. Sandstone, thin- to medium-bedded, fine-grained, dark-neutral to brownish-yellow, crossbedded; few scattered chert and white-quartz pebbles	15
21. Covered; computed thickness	50
22. Siltstone, shaly siltstone, and sandstone; thin-bedded, very fine grained, light yellow-brown to greenish, crossbedded, calcareous, carbonaceous. Scattered fossils (USGS Mesozoic loc. 25128); mostly rubble; computed thickness	40
23. Covered; computed thickness	40
24. Siltstone and sandstone; thin, platy-bedded, very fine to fine-grained, medium-green, ripple-marked; unit contains mud lumps; fossiliferous (USGS Mesozoic loc. 24621)	35
25. Clay shale, dark blue-gray, hard to crumbly, with few interbeds of siltstone and sandstone; very fine grained, dark-neutral to greenish, crossbedded. Fossils in upper part (USGS Mesozoic loc. 24620) and in lower part (USGS Mesozoic loc. 20492). Lower part rubble; computed thickness	135
	900

Fault.

AGE AND CORRELATION

The Tuktu formation has a prolific and varied megafauna. The formation is entirely marine and fossils are found throughout; however, they are more abundant in certain well-defined zones. Of the 51 collections shown in table 3, 19 are from the upper 200 feet of the formation, and 11 are from a zone 670 to 770 feet below the top. The megafossils from the Tuktu formation listed in table 3 were identified by R. W. Imlay.

The genus *Inoceramus* is the most important pelecypod found in the formation; the species *I anglicus* Woods and *I.* cf. *I. cadottensis* McLearn have been identified. They are present throughout the formation but are more abundant in the lower half. Ammonites are present in 12 collections; 6 are from the lower half of the formation and 4 are from the upper 200 feet. The ammonites represent 4 genera: *Beudanticeras*, *Gastroplites*, *Pseudopulchellia*, and *Paragastroplites.* The ammonites are more important to the correlation and age of the formation than are the pelecypods. A new species of worm of the genus *Ditrupa* was identified by Imlay (1961); it is common throughout the formation. Gastropods were identified in 3 collections and echinoderms in 4.

Concerning the age and correlation of the megafauna, Imlay and Reeside (1954, p. 242) states:

> * * * the Tuktu formation is assigned to the basal part of the middle Albian because of the presence of *Gastroplites*, *Cleoniceras*, *Inoceramus anglicus* Woods, and *Inoceramus* cf. I. *cadottensis* McLearn * * *. The *Gastroplites* present occurs in the western interior of Canada associated with *Inoceramus cadottensis* in beds somewhat higher than those containing *Lemuroceras* * * *. *Inoceramus anglicus* Woods is common in the middle and upper Albian of the Boreal region.

In discussing some of the other pelecypods, Imlay further states (written communication, 1954):

> The pelecypods *Arctica?*, *Entolium*, *Panope?*, *Thracia*, and *Pleuromya* are probably identical with species from the Clearwater formation of Alberta, which formation on the basis of ammonites is equivalent to the Torok formation * * *. Experience has shown that most species of pelecypods have longer ranges than most species of ammonites and commonly range through an appreciable part of a stage. Therefore, we might expect to find the same species of pelecypods in the upper part of the Torok formation as in the Tuktu formation wherever a similar sandy facies exists.

Sixty-eight field samples were collected from outcrops of the Tuktu formation in the Chandler River region and examined for microfossils; 15 samples were barren. All microfossils from the formation, including two genera of Radiolaria, are listed on plate 30. The microfossils were identified by H. R. Bergquist, who reported (written communication, 1956):

> In the 53 fossiliferous samples, 28 species of Foraminifera were recorded, of which seven arenaceous species constitute 73 percent. Four of these, *Haplophragmoides topagorukensis* Tappan, *Verneuilinoides borealis* Tappan, *Ammobaculites fragmentarius* Cushman, and *Miliammina awunensis* Tappan, were common to very abundant in several samples, together totaling 76 of the 82 common to very abundant occurrences. *Verneuilinoides borealis* occurred in 41 samples and *Haplophragmoides topagorukensis* was found in 40. Ten species occurred very rarely and five species were rare to very rare. *Saccammina* sp. occurred in very rare numbers in 18 samples but was abundant in one. One species, *Gaudryina nanushukensis* Tappan, occurred in only one sample, where it was abundant. Many of

the 28 species found in the samples are characteristic of the faunal zone that I have designated the *Verneuilinoides borealis* zone, after the principal species. Several of the species are of known Albian age although some range into the Cenomanian. All are part of the same fauna that I have found in the upper part of the Torok formation and in the Grandstand formation.

CHANDLER FORMATION

The Chandler formation was first described by Gryc and others (1951, p. 164) as the nonmarine formation of the Nanushuk group. The formation was known to intertongue with and grade into the marine formations to the north, and two major tongues, Hatbox and Niakogon, were named and mapped. Since 1951, other sections of the Chandler formation have been mapped. With better sections available, the nomenclature was revised by Detterman (1956a, pp. 237–241). The Hatbox tongue was renamed Killik tongue, as that part of the formation is better exposed along the Killik River than it is at Hatbox Mesa on the Chandler River. The Niakogon tongue was redefined and the type locality changed from Niakogon Buttes to the Killik River, as recent study of the Niakogon Buttes indicated that the tongue is not exposed at that locality.

The Chandler formation is one of the more widespread and persistent mappable units in the area; it is exposed from the Tuktu Escarpment to Fossil Creek. The Chandler formation is the main ridge-forming unit in the northern foothills section. The magnitude of the escarpment is due more to the resistant sandstone cap rock of the Chandler formation than to the sandstone of the Tuktu formation. At the escarpment the formation occurs in broad, open folds; farther north it forms the faulted anticlinal ridges that are the predominant topographic features of the more northerly areas.

The Chandler formation is a thick unit that includes all the nonmarine strata of the Nanushuk group. In every outcrop of the Chandler within the area mapped the two named tongues, Killik and Niakogon, are separated by at least a thin section of marine Ninuluk formation (see fig. 35); this forms two distinct units within the Chandler and the tongues are mapped throughout most of the region.

KILLIK TONGUE

OCCURRENCE

The Killik tongue is the lower and thicker of the two tongues of the Chandler formation. The type locality (fig. 40) is along the east bank of the Killik River between lat 68°52′ N. and lat 68°55′ N. (pl. 27). At the type locality the incompletely exposed tongue is about 2,815 feet thick.

Northeastward from the type locality, the Killik tongue interfingers with and grades into its marine equivalent, the Grandstand formation. The numerous marine transgressions, many of which are relatively minor, cannot be mapped accurately at the scale used on plate 27; therefore, the Grandstand formation is mapped only where the strata are predominantly marine. Any outcrops in which there are minor units of marine strata are mapped with the Killik tongue. The Killik tongue by definition is nonmarine and marginal, so it should be borne in mind that marine strata were included with the Killik tongue only as a mapping convenience. The fence diagram (pl. 31) gives a more complete picture of the extent and nature of the intertonguing marine and nonmarine strata.

In the southern and southwestern parts of the Chandler River region the Killik tongue can be divided into lithologically distinct upper and lower parts. In some localities, however, the two parts of the tongue can be mapped only near the rivers where the strata are well exposed.

CHARACTER AND THICKNESS

Lower part.—At the type locality the lower part of the Killik tongue is 1,095 feet thick. Well-indurated ridge-forming sandstone composes the bulk of the exposed section. The sandstone is predominantly medium bedded to massive and fine to coarse grained; it is various shades of yellow red with a characteristic rusty-brown weathered surface; and it commonly has a salt-and-pepper appearance. Lenticular beds of pebble conglomerate occur locally in the lower part of the section. White quartz constitutes about 40 percent of the pebbles; this is the lowest known occurrence of white quartz as a conglomeratic constituent of the Cretaceous rocks of northern Alaska. The remainder of the pebbles are predominantly black, gray, and green chert. In addition to the sandstone and conglomerate, other constituents of the section are gray micaceous carbonaceous siltstone, shaly siltstone, and coal. Siliceous and ferruginous nodules commonly containing plant fossils occur in the siltstone and shaly siltstone beds.

Table 3.—*Megafossils*

[Identified by R. W. Imlay, 1961, p. 33. Collection made by L. A. Warner, C. E. Kirschner, R. L. Detterman,

Geographic area	Killik River						Chandler River (near Tuktu Bluff)			
Column (pl.2)	1	1	1	1						2
Stratigraphic position below top of formation (feet)	530	790	700	100	400-500	400-500	360-400	360	260	900-1000
USGS Mesozoic locality number	20464	20472	24619	24633	24634	24635	21827	25124	25125	20454
Crinoid stems and cirri	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Brittle star	-------	-------	-------	-------	-------	-------	-------	-------	-------	×
Starfish	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Worm? burrows	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Ditrupa cornu Imlay	-------	-------	-------	-------	-------	-------	-------	-------	-------	×
Nucula (Pectinucula) cf. *N. dowlingi* McLearn	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Yoldia cf. *Y. kissoumi* McLearn	-------	-------	-------	-------	-------	-------	-------	-------	-------	×
Dicranodonta dowlingi McLearn	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Astarte ignekensis Imlay	-------	-------	-------	-------	-------	-------	-------	-------	-------	×
Astarte portana McLearn	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Tancredia kurupana Imlay	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Arctica? sp	-------	-------	×	-------	-------	-------	-------	-------	-------	×
Flaventia? sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Solecurtus? *chapmani* Imlay	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Pleuromya sikanni McLearn	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Pleuromya sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Panope? *kissoumi* (McLearn)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
elongatissma (McLearn)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Panope? sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Homomya sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	×
Thracia stelcki McLearn	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
cf. *T. stelcki* McLearn	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Psilomya sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Isognomon? sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Inoceramus anglicus Woods	×	×	×	×	×	×	-------	-------	-------	-------
cf. *I. cadottensis* McLearn	-------	-------	-------	×	-------	-------	-------	-------	-------	×
Inoceramus sp	-------	-------	-------	-------	-------	-------	-------	×	×	-------
Entolium utokokense Imlay	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Entolium sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Placunopsis sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Modiolus archisikanni McLearn	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Modiolus sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Trochid? gastropods	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Cerithiid? gastropods	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Naticoid gastropods	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Beudanticeras? sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Gastroplites kingi McLearn	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
cf. *G. kingi* McLearn	-------	-------	-------	×	-------	-------	-------	-------	-------	-------
Paragastroplites flexicostatus Imlay	-------	-------	-------	-------	×	-------	-------	-------	-------	-------
Cleoniceras tailleuri Imlay	-------	-------	-------	-------	-------	-------	×	-------	-------	-------
Pseudopulchellia pattoni Imlay	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Xenohelix? sp	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

of the Tuktu Formation

R. S. Bickel, I. L. Tailleur, George Gryc, E. J. Webber, R. E. Fellows, W. W. Patton, Jr., A. S. Keller, and F. C. Schrader].

Chandler River (near Tuktu Bluff)			Fossil Creek									Chandler River (Grandstand and Big Bend anticlines)				
2	2	2	5	5	5	5	5	5	5	5	5					
770	360	920	320	180	860	760	730	670	280	540	320	Upper part	Upper part	Upper part	Upper part	75-100
25121	25122	25123	20432	20433	20492	24620	24621	25128	25129	25917	24622	24274	24293	24294	24295	24296
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Table 3.—*Megafossils of the*

Geographic area	Chandler River (Grandstand and Big Bend anticlines)				Anaktuvuk River						
Column (pl. 29)											
Stratigraphic position below top of formation (feet)	100-125	50-100	0-100	Upper part	Upper part	Upper part	0-150	Upper part	0-150	0-150	Middle
USGS Mesozoic locality number	24297	25126	25127	24299	20480	24637	3204	20484	24623	3203	20494
Crinoid stems and cirri					×						
Brittle star								×			
Starfish						×					
Worm? burrows						×				×	
Ditrupa cornu Imlay				×	×			×	×	×	
Nucula (*Pectinucula*) cf. *N. dowlingi* McLearn											
Yoldia cf. *Y. kissoumi* McLearn			×								
Dicranodonta dowlingi McLearn							×	×	×		
Astarte ignekensis Imlay							×				
Astarte portana McLearn											
Tancredia kurupana Imlay		×									
Arctica? sp			×	×					×		
Flaventia? sp											
Solecurtus? *chapmani* Imlay						×					
Pleuromya sikanni McLearn											
Pleuromya sp											
Panope? *kissoumi* (McLearn)	×	×			×						
elongatissma (McLearn)								×	×		
Panope? sp											
Homomya sp											
Thracia stelcki McLearn								×			×
cf. *T. stelcki* McLearn											
Psilomya sp											
Isognomon? sp											
Inoceramus anglicus Woods											
cf. *I. cadottensis* McLearn											
Inoceramus sp					×		×				
Entolium utokokense Imlay						×		×	×		
Entolium sp					×						
Placunopsis sp								×			
Modiolus archisikanni McLearn									×		
Modiolus sp		×									
Trochid? gastropods											
Cerithiid? gastropods											
Naticoid gastropods					×						
Beudanticeras? sp									×		
Gastroplites kingi McLearn								×			
cf. *G. kingi* McLearn						×					
Paragastroplites flexicostatus Imlay								×			
Cleoniceras tailleuri Imlay											
Pseudopulchellia pattoni Imlay											
Xenohelix? sp						×	×	×	×	×	

Tuktu Formation—Continued

Nanushuk River Rooftop Ridge								Nanushuk River and May Creek							
4	4	4	4	4	4	4	4	3		3					
710	570	110	420	400	350	500	720	900	830-930	0-70	Unknown	Unknown	Unknown	Unknown	Unknown
24624	24625	24626	24627	25131	25132	25133	25135	24427	25130	26140	24426	24428	24429	24430	24425
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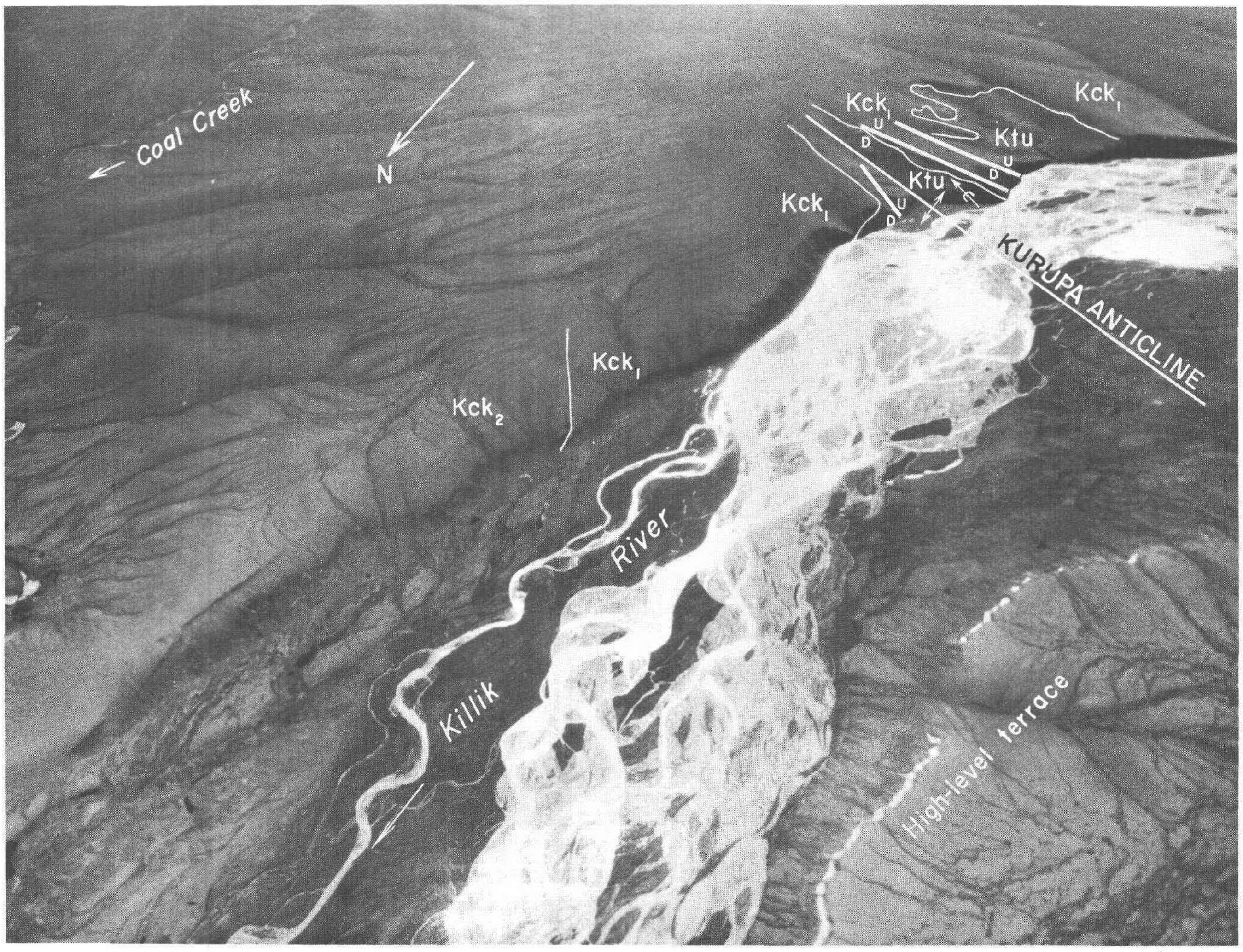

FIGURE 40.—Oblique view of the type locality of the Killik tongue. Kck2, upper part, Killik tongue; Kck1, lower part, Killik tongue; Ktu, Tuktu formation. Photograph by U.S. Navy.

The Chandler River section (pl. 32, column 2) was designated the type section for the now-abandoned Hatbox tongue of Gryc and others (1951, p. 164); it is exposed just north of the Tuktu Escarpment where the Chandler River cuts through the northern foothills. The lower part of the Killik tongue at this locality consists for the most part of sandstone rubble traces and is not well exposed, but it is similar to the type section in that the sandstone is massive to medium bedded. The basal conglomerate facies is similar to the Killik River section.

Upper part.—At the type locality the upper part of the Killik tongue is 1,720 feet thick. This part of the tongue is not so well exposed as is the lower part but has a distinct lithology characterized by massive ledge-forming conglomerate, whereas the lower part of the tongue is predominantly sandstone. White quartz pebbles constitute about 40 percent of the conglomerate. Most of the pebbles are well rounded, slightly oblong, and 1/4 to 1 3/4 inches in length, with an occasional cobble as much as 4 inches in length. Siltstone and shale siltstone are common. The sandstone is thinner bedded, finer grained, and more argillaceous than that in the lower part. Coal float was noted, but it is not abundant. Plant fossils are moderately abundant, particularly in ironstone beds and nodules.

A conglomerate bed, 23 of the type section, is well indurated and forms a resistant ridge that can be traced laterally for miles across the foothills. Another conglomerate bed (unit 30) 340 feet below unit 23 is lenticular, ranging from a massive conglomerate to a few pebbles in a coarse salt-and-pepper sandstone matrix. The contact between the upper and lower parts of the Killik tongue is placed at the base of this lower conglomerate bed.

The Chandler River section is similar to the type section but is somewhat more conglomeratic. Five conglomerate units about the same distance apart give the suggestion of a rhythmic deposition. Pebbles within individual conglomerate units are primarily of one size, and the size of the pebbles decreases progressively with each succeeding unit. White quartz, as a constituent, also decreases in abundance with each succeeding unit. The intervals between the conglomerate units commonly are composed of shaly siltstone, clay shale, siltstone, thin silty sandstone, and coal. These intervals are rarely well exposed.

The upper 1,300 feet of the Nanushuk River section is similar to the upper Killik tongue of the Chandler River section. The conglomerate beds can be correlated almost unit for unit. The remainder of the Nanushuk River section, however, is more closely related to the marine Grandstand formation.

Conglomerate is missing from the Killik tongue in the northern part of the area. The sandstone is thinner bedded, finer grained, and more argillaceous. The color, however, does not change, and the sandstone can be readily identified as belonging to the Killik tongue. A few coal beds are present, and ferruginous nodules are more common. A few thin beds of bentonite associated with the coal, siltstone, and shaly siltstone units in the northern part of the area mark the lowest known occurrence of bentonite in strata of Cretaceous age in northern Alaska.

Five thin section of samples from the Killik tongue were examined microscopically to determine the size, shape, and abundance of the constituent minerals. The samples were selected at different localities and from different positions within the tongue.

Field sample 53 ADt 32 is from the base of the tongue on the Killik River, near the type locality. The salt-and-pepper sandstone is fine grained, thin bedded to massive, friable, and crossbedded. In thin section the grains are rectangular to subround and 0.1 mm to as much as 2 mm in diameter. The matrix is calcite and forms about 30 to 40 percent of the specimen. The constituent minerals are: quartz, 42 percent; chert, 35 percent; calcite, 6 percent; chlorite, 3 percent; rock fragments, 5 percent; biotite, 5 percent; carbonaceous material, 3 percent; plagioclase, 1 percent. All percentages were determined by a grain count of 100. This was the only sample examined that has a calcite matrix.

Field sample 48 ADt 167 (pl. 32, column 2), from 1,780 feet below the top of the Chandler River section, is typical of the sandstone of the Killik tongue. In thin section the grains are subround to round, and 0.1 to 0.6 mm in diameter. The siliceous matrix composes about 20 to 30 percent of the specimen. The constituent minerals are: quartz, 58 percent; chert, 30 percent; calcite, 1 percent; biotite, 4 percent; rock fragments, 4 percent; carbonaceous material, 2 percent; limonite, 1 percent.

The percentage of limonite in rocks of the Killik tongue is commonly higher than in the above specimen, and it accounts for the yellow-red surface stain that is characteristic of the rocks of the Killik tongue. The remaining specimens are similar to the two described.

GEOLOGIC SECTIONS

The type section of the Killik tongue of the Chandler formation (pl. 32, column 1; pl. 31, section 6) was measured along the east bank of the Killik River between lat 68°53′ N. and 68°55′ N. The section is exposed along the bank in a series of discontinuous ledges and rubble piles. Quaternary terrace deposits cover most of the unexposed parts of the section, which is on the north flank of Kurupa anticline in strata that dip 13°–15° N. The exposed parts of the section were taped. Both the horizontal and vertical control were good, so the computed thickness should be accurate to within 10 percent.

Type section of Killik tongue, on the Killik River (pl. 32, column 1)

Ninuluk formation.	
Killik tongue, upper part:	*Feet*
1. Covered; computed thickness	40
2. Sandstone, medium-bedded, fine-grained, dark yellow-red, well-indurated; rubble; computed thickness	15
3. Covered; computed thickness	345
4. Siltstone, shaly siltstone, coal, and ironstone concretions; mostly rubble; computed thickness	40
5. Covered; computed thickness	20
6. Siltstone, shaly siltstone, and ironstone concretions; rubble; computed thickness	10
7. Covered; computed thickness	150
8. Sandstone, fine-grained, light yellow-red; abundant plant fossils. Siltsone, shaly siltstone, coal, carbonaceous shale, and ironstone concretions; mostly rubble; computed thickness	20
9. Covered; computed thickness	80
10. Shaly siltstone, and siltstone; rubble; computed thickness	10
11. Covered; computed thickness	110
12. Siltstone, dark-gray, shaly siltstone, coal float, and ironstone concretions; plant fossils (53 ADt 56); rubble; computed thickness	20
13. Covered; computed thickness	85
14. Sandstone, medium-bedded, fine- to medium-grained, salt-and-pepper grading to dark yellow red; siltsone, shaly siltstone and coal float; rubble in part; computed thickness	35
15. Covered; computed thickness	40

Killik tongue, upper part—Continued | Feet

16. Siltstone, shaly siltstone, coal, and ironstone concretions; all float; computed thickness — 20
17. Covered; computed thickness — 40
18. Siltstone, gray to gray-green, shaly siltstone, coal, and ironstone concretions; rubble; computed thickness — 20
19. Covered; computed thickness — 40
20. Sandstone, medium-bedded, medium-grained salt-and-pepper. Gray siltstone and shaly siltstone. Plant fossils, coal float. Computed thickness — 20
21. Covered; computed thickness — 160
22. Sandstone, massive, coarse-grained, salt-and-pepper, highly iron stained, friable — 14
23. Conglomerate, massive, with coarse salt-and-pepper sandstone matrix. Predominantly ¼- to ¾-in. pebbles; a few cobbles as much as 4 in. in diameter; 40 percent white quartz, rest black, green, and gray chert; all well rounded, oblong, well cemented, hard — 46
24. Sandstone, medium- to thick-bedded, fine- to coarse-grained, salt-and-pepper, iron-stained; few thin siltstone beds; in part rubble; computed thickness — 20
25. Covered; computed thickness — 20
26. Silstone rubble, gray; computed thickness — 20
27. Covered; computed thickness — 120
28. Sandstone, massive, salt-and-pepper, lenses of pebble conglomerate — 20
29. Covered; computed thickness — 140
30. Sandstone, medium-grained, crossbedded, salt-and-pepper; weathers rusty brown; conglomeratic, with pebbles as much as 1 in. in diameter; 40 percent white quartz, 60 percent black and gray chert — 20

Total: 1,740

Killik tongue, lower part:

31. Sandstone, thin- to medium-bedded, fine- to medium-grained; salt-and-pepper, grading to dark yellow-red; weathers gray to rusty brown; extremely crossbedded; plant fragments common (53 ADt 53). Siltstone, shaly siltstone, ironstone concretions, and coal float. In part covered and rubble; computed thickness — 120
32. Covered; computed thickness — 300
33. Series of ledge-forming sandstone beds, medium-bedded, fine-grained, dark yellow-red to salt-and-pepper. Siltstone, shaly siltstone, coal and ironstone concretions. Interval between ledges either covered or contains float of siltstone, shaly siltstone and coal. Computed thickness — 280
34. Sandstone, thin-bedded, fine-grained; becomes coarser near base; dark yellow-red to salt-and-pepper, crossbedded. Conglomeratic stringers 40 feet above base with chert and quartz pebbles as much as 2 in. in diameter, but mostly ½ in. or less. Siltstone, shaly siltstone, coal, and ironstone concretions interbedded with sandstone — 220
35. Covered interval with siltstone and sandstone rubble; computed thickness — 45

Killik tongue, lower part—Continued | Feet

36. Sandstone, thick- to medium-bedded, dark-neutral; weathers dark yellow red; thin bedded near base — 30
37. Cover; computed thickness — 40
38. Sandstone, thin-bedded to massive, dark yellow-red; shaly siltstone and siltstone with worm trails; microfossil-bearing beds — 20
39. Coal — 3
40. Sandstone, thin-bedded, medium yellow-red, and shaly siltstone — 15
41. Coal — 2
42. Sandstone, massive, salt-and-pepper to yellow-red, medium- to coarse-grained; lenses and stringers of pebble conglomerate, 50 percent white quartz, 50 percent dark chert; crossbedded, hard, with few ironstone concretions — 20

Total: 1,095

Tuktu formation.

The Chandler River section (pl. 32, column 2; pl. 31, section 5) was measured on the west side of the river at camp D–June 14–48. The section is not well exposed, consisting for the most part of ledges and rubble traces. The total thickness of the section may be in error by 10 percent. The strata dip 12° to 13° N. at this locality.

Section of Killik tongue, on the Chandler River (pl. 32, column 2)

Ninuluk formation.

Killik tongue, upper part: | Feet

1. Covered; computed thickness — 180
2. Siltstone and sandstone; thin-bedded, fine-grained, dark yellow-red, brown-weathering, agrillaceous, well-indurated; rubble; computed thickness — 20
3. Conglomerate, massive, pebble-granule; pebbles ¼ to ½ inch in length, few as much as 1½ in.; black and gray chert and subordinate white quartz, (10 percent); well-sorted, well-indurated — 20
4. Covered; computed thickness — 260
5. Siltstone, shaly siltstone, and coal float; computed thickness — 20
6. Conglomerate, massive, pebble-granule, ledge-forming, with few cobbles; mostly ½ in. or less; 30 percent white quartz, rest black and gray chert in coarse salt-and-pepper sandstone matrix — 20
7. Covered; computed thickness — 160
8. Sandstone, thin- to medium-bedded, medium-grained, dark yellow-red, argillaceous, somewhat friable; subordinate amount of siltstone above sandstone; rubble; computed thickness — 30
9. Siltstone float in covered area; computed thickness — 240
10. Sandstone, medium-bedded, medium-grained, salt-and-pepper to light yellow-red; weathers brown, slabby; siltstone above sandstone — 30

Killik tongue, upper part—Continued	Feet
11. Conglomerate, massive, pebble-cobble, ledge-forming; few cobbles as much as 4 inches long, pebbles ¾ to 1 in. long; 30 percent white quartz, 70 percent black, green, and gray chert; all well rounded, well indurated	20
12. Covered; computed thickness	50
13. Siltstone, shaly siltstone, and sandstone, interbedded; with four coal seams from 2 to 10 in. thick; abundant ironstone concretions. Sandstone thin bedded, fine to medium grained, dark yellow red, iron stained; rubble; computed thickness	110
14. Covered; computed thickness	30
15. Interbedded series similar to unit 13, has three coal seams; rubble; computed thickness	80
16. Conglomerate, massive, cobble-pebble, ledge-forming; cobbles as much as 5 in. long, pebbles predominately 1 inch long; 40 to 50 percent white quartz, remainder mostly black and gray chert; lenses of coarse-grained salt-and-pepper well-indurated sandstone	90
17. Siltstone, shaly siltstone, and coal float in covered area; few microfossil-bearing beds; computed thickness	310
18. Sandstone, thin-bedded, fine-grained, silty, dark yellow-red, soft, argillaceous, carbonaceous, ferruginous, ripple-marked; rubble; computed thickness	10
19. Covered; computed thickness	20
20. Sandstone, conglomeratic, medium-bedded, medium- to coarse-grained with scattered chert and quartz pebbles; salt-and-pepper, clean; subordinate shaly siltstone above the sandstone; in part rubble; computed thickness	40
	1, 740
Killik tongue, lower part:	
21. Covered; computed thickness	20
22. Sandstone, medium-bedded, medium-grained, salt-and-pepper to medium yellow-red, argillaceous, siliceous, hard, slabby, with subordinate siltstone	30
23. Covered; computed thickness	20
24. Sandstone, medium-bedded, medium-grained, salt-and-pepper to medium yellow-red; weathers brown; slabby; rubble; computed thickness	20
25. Covered; siltstone and shaly siltstone float; computed thickness	170
26. Sandstone; similar to unit 24; rubble; computed thickness	20
27. Covered; computed thickness	30
28. Sandstone, similar to unit 24; rubble; computed thickness	30
29. Covered; computed thickness	120
30. Sandstone, medium-bedded, fine-grained, dark yellow-red; weathers brown; argillaceous, well-indurated; fractures into rectangular blocks; rubble; computed thickness	60
31. Covered; computed thickness	360
32. Siltstone and sandstone; thin-bedded, fine- to medium-grained, dark yellow-red, hard, argillaceous	59
33. Coal	1

Killik tongue, lower part—Continued	Feet
34. Siltstone, shaly	10
35. Sandstone, medium-bedded, medium- to coarse-grained, salt-and-pepper to medium yellow-red, friable; crossbedded, with subordinate siltstone beds	120
36. Sandstone, conglomeratic; scattered chert and quartz pebbles in coarse salt-and-pepper sandstone matrix; well-indurated, ferruginous, crossbedded	30
	1,100

Tuktu formation.

The Nanushuk River section (pl. 32, column 3; pl. 31, section 4) was measured along the east side of the Nanushuk River, where it breaches Arc Mountain syncline. The lower part is moderately well exposed, but only the conglomerate ledges are well exposed in the upper part.

Section of Killik tongue, on the Nanushuk River (pl. 32, Column 3)

Killik tongue:	Feet
1. Sandstone, conglomeratic, coarse-grained; pebbles of chert and white quartz (10 to 20 percent)	20
2. Covered; sandstone, coal, and ironstone concretions; rubble; computed thickness	430
3. Conglomerate, massive; pebbles and granules of black and green chert and white quartz; coarse-grained salt-and-pepper sandstone matrix	20
4. Covered; computed thickness	40
5. Conglomerate and sandstone; similar to unit 3, except more sandstone	30
6. Covered; computed thickness	100
7. Conglomerate and sandstone; similar to unit 3; conglomeratic constituents all pebble size	30
8. Covered; ironstone concretions and coal float; computed thickness	280
9. Conglomerate and sandstone; similar to unit 3	40
10. Covered; sandstone, siltstone, shaly siltstone, and coal float; computed thickness	240
11. Conglomerate, chert and white quartz pebbles, and sandstone; fine grained, light neutral to yellow red	50
12. Covered; coal float; computed thickness	570
13. Sandstone, medium- to thick-bedded, fine-grained, light-gray; abundant plant fragments	60
14. Clay shale and shaly siltstone; dark-gray; interbeds of medium-gray siltstone and thin-bedded sandstone; in part rubble; computed thickness	360
15. Sandstone, thin-bedded to massive, very fine to fine-grained, light-gray to yellow-red, crossbedded; few scattered pelecypods in upper part; in part rubble; computed thickness approximately	300
	2,570

Tuktu formation.

The Fossil Creek section (pl. 32, column 4; pl. 31, section 1) was measured in a series of discontinuous cutbanks starting about 2.2 miles upstream from the Colville River valley and continuing upstream for

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about 1.4 miles. The section is on the south flank of Fossil Creek anticline in strata dipping 6° to 12° S. The exposed part of the section was measured by plane table and alidade. Any error in estimated thickness should be less than 5 percent. Approximately 425 feet at the top of the section is Grandstand formation, and the lower 730 feet is Killik tongue. Smaller units of Grandstand formation may be present within the Killik tongue, but they were not mapped. This section represents the northernmost occurrence of the Killik tongue in the Chandler River region.

Section of Killik tongue, on Fossil Creek (pl. 32, column 4)

Grandstand formation.

Killik tongue:	Ft.	In.
1. Covered; computed thickness	20	0
2. Clay shale, dark blue-gray, soft, crumbly, with interbeds of siltstone; 3-in. coal seam near base	20	0
3. Covered; computed thickness	20	0
4. Siltstone and sandstone; thin- to medium-bedded, fine-grained, medium yellow-red; rubble; computed thickness	10	0
5. Covered; computed thickness	120	0
6. Sandstone, medium-bedded, fine- to medium-grained, salt-and-pepper to medium yellow-red; thin siltstone at base; rubble; computed thickness	15	0
7. Covered; computed thickness	65	0
8. Sandstone, shaly to medium-bedded, coarse-grained, lenticular, with thin coal bed and shaly siltstone interbeds	18	0
9. Sandstone, massive, coarse-grained, salt-and-pepper, ripple-marked	6	0
10. Sandstone, shaly-bedded, fine-grained, medium yellow-red; ironstone concretions	5	0
11. Sandstone, lower part thick bedded, coarse grained; upper part shaly bedded, fine grained; wood fragments common; thin coal stringer in upper part; ripple marks common	14	0
12. Covered; shaly siltstone; rubble; computed thickness	37	0
13. Siltstone, shaly, microfossil-bearing, interbedded with siltstone and sandstone; very fine grained, thin bedded	57	0
14. Sandstone, thin-bedded, very fine grained, dark-neutral, ripple-marked	3	0
15. Clay shale, microfossil-bearing	12	0
16. Sandstone, very fine grained, light yellow-red	8	0
17. Covered; computed thickness	20	0
18. Sandstone, thin-bedded, very fine grained, light yellow-red, argillaceous	10	0
19. Siltstone, shaly, light-brown, fissile, microfossil-bearing	20	0
20. Coal		9
21. Siltstone, shaly siltstone, and sandstone, interbedded; unit thin bedded, very fine grained, light brown	15	6
22. Coal	5	0

Killik tongue—Continued	Ft.	In.
23. Bentonite	2	9
24. Siltstone and shaly siltstone; dark-brown, ripple-marked	8	6
25. Coal		3
26. Siltstone, sandy, thin-bedded, light-green	12	3
27. Covered; computed thickness	75	0
28. Sandstone, thin- to medium-bedded, coarse-grained, salt-and-pepper to light yellow-red; rubble; computed thickness	25	0
29. Covered; computed thickness	80	0
30. Siltstone and sandstone; medium-bedded, medium-grained, salt-and-pepper	10	0
31. Sandstone, medium- to heavy-bedded, medium-grained, salt-and-pepper, friable, crossbedded; plant fragments	15	0
	730	0

Tuktu formation.

The Chandler River section (pl. 32, column 5; pl. 31, section 2) was measured on the north side of the river, at camp D–July 12–48. The section is in the south flank of the faulted Big Bend anticline in strata dipping 15° to 18° S. This section shows the interfingering of marine and nonmarine units. Two units each of Grandstand formation and Killik tongue were measured, and smaller units may be present within the larger mapped units.

Section of Killik tongue, on the Chandler River (pl. 32, column 5)

Grandstand formation.

Killik tongue:	Feet
1. Coal	1
2. Siltstone, greenish-gray, micaceous, with abundant ironstone concretions	20
3. Coal	1
4. Siltstone; ironstone concretions abundant	19
Grandstand formation (interval described on p. 256).	
Killik tongue:	
5. Covered; computed thickness	30
6. Siltstone, shaly siltstone, and sandstone thin-bedded, very fine grained, dark-neutral; weathers brown; cross-bedded, argillaceous, hard, rubble; computed thickness	40
7. Covered; shaly siltstone float; computed thickness	75
8. Sandstone, medium- to heavy-bedded, fine- to medium-grained, greenish-gray to medium yellow-red, slabby, hard, argillaceous; few siltstone interbeds; rubble; computed thickness	30
9. Covered; computed thickness	55
10. Sandstone, thin-bedded, fine- to medium-grained, medium yellow-red, with siltstone and shaly siltstone rubble; computed thickness	35
11. Covered; computed thickness	85
12. Sandstone, thin-bedded, fine-grained, dark-neutral, argillaceous, platy; shaly siltstone and siltstone below sandstone; rubble; computed thickness	20
13. Covered; shaly siltstone float; computed thickness	90

Killik tongue—Continued	*Feet*
14. Siltstone and sandstone; medium- to heavy-bedded, fine- to medium-grained, medium yellow-red; rubble; computed thickness	20
15. Covered; computed thickness	90
16. Siltstone, shaly siltstone, and sandstone; thin-bedded, medium-grained, light yellow-red; plant fragments, coal float in middle of unit; in part rubble; computed thickness	30
17. Covered; computed thickness	100
18. Sandstone, thin-bedded, fine- to medium-grained, dark yellow-red, slabby, well-indurated; scattered plant fossils; rubble; computed thickness	20
19. Covered; computed thickness	65
20. Sandstone, thin-bedded, medium-grained, light yellow-red, argillaceous, laminated; abundant plant fragments; subordinate siltstone; rubble; computed thickness	25
21. Covered; computed thickness	95
22. Sandstone, medium- to thick-bedded, medium- to coarse-grained; light yellow-red to salt-and-pepper at base; slabby well-indurated siltstone and shaly siltstone between the sandstone beds; in part rubble; computed thickness	155
	1, 101

Tuktü formation.

The Anaktuvuk River section (pl. 32, column 6; pl. 31, section 3) was measured at the type locality for the Grandstand formation on the west side of the river. Two intertongues of nonmarine strata, 100 and 170 feet thick, were measured on the south flank of the structure in beds that dip 15° to 33° S.

Section of Killik tongue from type section of Grandstand formation on the Anaktuvuk River

Grandstand formation.

Killik tongue:	*Feet*
1. Sandstone, siltstone, and shaly siltstone unit with ironstone concretions; plant fossils and one thin coal seam. Sandstone thin bedded, fine grained, light yellow red. Mostly rubble; computed thickness	100
Grandstand formation (interval described on p. 256).	
Killik tongue:	
2. Sandstone, ledge-forming, thin- to medium-bedded, fine- to medium-grained, salt-and-pepper to medium yellow-red, crossbedded; few limy nodules and thin bentonite and coal beds	40
3. Sandstone, thin- to thick-bedded, fine-grained, light olive-gray, clean, friable, crossbedded; plant fossils. Few siltstone and shale interbeds; ironstone concretions and mud lumps common; coal and bentonite float near middle of unit; few limy nodules. Mostly rubble; approximately 40 percent exposed; computed thickness	130
	270

AGE AND CORRELATION

The age of the nonmarine-marginal strata of the Killik tongue cannot be determined precisely from fossils. Three collections contain invertebrate fossils that were identified by R. W. Imlay (1961). "*Unio*" sp., a long-ranging, brackish- to fresh-water type was identified in one collection. The other fossils are probably from an intertongue of marine Grandstand formation strata; *Panope? kissoumi* (McLearn) was identified in one, and a starfish cast in the other.

Plate 30 shows microfossils in the interval labeled Killik tongue and Grandstand formation; since all the genera shown are marine forms, they are from beds of the Grandstand formation. Sixty-eight samples from the Killik tongue in this interval are barren.

Plant fossils are common throughout most of the exposed rocks of the Killik tongue. The 13 collections made from strata of this tongue were identified by R. W. Brown; they are shown in table 4. Concerning the age and correlation of the plant fossils Brown stated (written communication, 1953) "All but the specimen from 53 ADt 79 represent species identified as Late Cretaceous of Alaska by Hollick. The specimen (*Dennstaedtia americana* Knowlton) represents a fern known hitherto only from the Tertiary. It is abundant in the Paleocene of the United States and Canada; but it must have had Cretaceous ancestors, of which this specimen may have been a representative." The nearest rocks of known Tertiary age are 115 miles northeast of the fossil locality. The fern was 500 to 600 feet stratigraphically above a collection of invertebrate fossils identified by R. W. Imlay as middle Albian and below mollusks identified as upper Cenomanian; it is thus apparent that the rocks cannot be Tertiary in age.

Plant fossils suggest a Late Cretaceous age for the Killik tongue. The tongue overlies the Tuktu formation, which is correlated with the lower middle Albian, and underlies the Ninuluk formation of late Cenomanian age; it intertongues with the marine Grandstand formation, which is also correlated with the middle Albian. Thus, in the absence of conclusive evidence, the Killik tongue is tentatively correlated with the middle Albian stage of the Early Cretaceous.

The contact with the Ninuluk formation is conformable in all observed outcrops; it is placed at the first occurrence of marine strata bearing *Inoceramus dunveganensis* McLearn. The lower contact with the Tuktu formation is also conformable.

TABLE 4.—*Plant fossils of the Killik tongue*

[Identified by: a, R. W. Brown; b, H. F. Knowlton; c, W. M. Fontaine. Initials in field numbers indicate collection made by: Bl, R. S. Bickel; Dt, R. L. Detterman S, P. S. Smith; no initial, F. C. Schrader]

Geographic area	Killik River				Colville River					Ayiyak River		Chandler River	Anaktuvuk River	
Stratigraphic position	Upper part		Lower part		Lower part					Upper part		Upper part	Lower part	
Field sample No.	53 ABl 18	53 ADt 56	53 ADt 53	53 ADt 40	53 ADt 79	53 ABl 24	53 ABl 25	53 ABl 126	24 AS 29	52 ADt 37	52 ABl 55	52 ABl 113	544	545
Podozamites lanceolatus (Lindlay and Hutton) Braun.		a							b					
Dennstaedtia americana Knowlton					a									
Cephalotaxopsis heterophylla Hollick	a					a								
C. intermedia Hollick		a												
Cephalotaxopsis sp.									b			a		
Sequoia reichenbackia (Geinitz) Heer												a		
Ginkgo concima Heer						a								
Cladophlebis septentrionalis Hollick						a	a							
Cladophlebis sp.									b					
Stems			a										c	c
Woody impressions										a	a			
Coniferous wood				a										
Fragment of dicotyledonous leaves								a						

GRANDSTAND FORMATION

OCCURRENCE

The Grandstand formation was defined by Detterman (1956a, p. 235–237) as the marine and lagoonal facies that are, at least in part, the age equilvalents of the Killik tongue of the Chandler formation. The type locality for the formation is a bluff along the west side of the Anaktuvuk River, 22 miles upstream from its junction with the Tuluga River (fig. 41). The bluff is formed where the strata on the south flank of Grandstand anticline are breached by the Anaktuvuk River.

The formation is mapped only in the northeastern part of the Chandler River region, where it attains its maximum thickness. Thin units of nonmarine Killik tongue were mapped in all outcrops of the formation; two units are present at the type locality. The formation thins rapidly toward the south and west accompanied by a corresponding thickening of the Killik tongue. As the Grandstand formation becomes thinner it splits into numerous units that wedge out in the Killik tongue. Some of these units extend across the entire mapped area and are present as microfossil-bearing beds at the type locality of the Killik tongue.

In addition to the section at the type locality, the Grandstand formation was measured with the Killik tongue in outcrops along Fossil Creek and along the

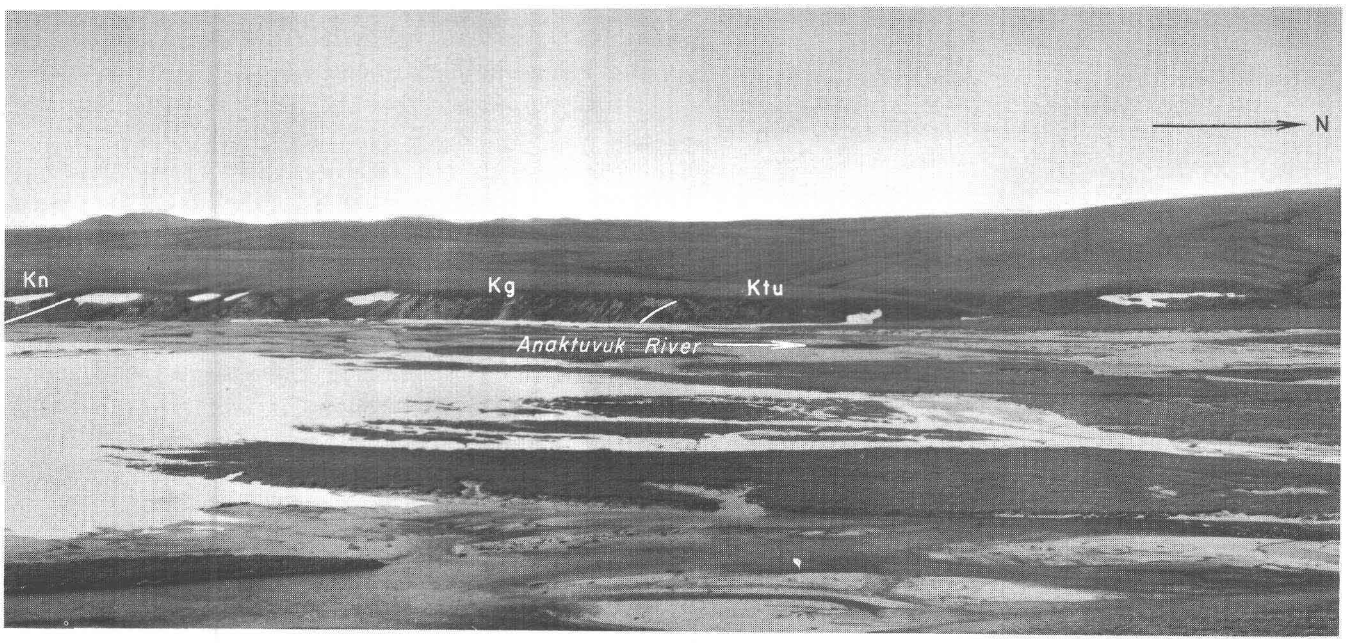

FIGURE 41.—Oblique view of part of the type locality of the Grandstand formation. The high ridges in the distance are part of the Tuktu Escarpment. Kn, Ninuluk formation; Kg, Grandstand formation; Ktu, Tuktu formation. Photograph by U.S. Navy.

Chandler River at Big Bend anticline; however, at both these localities the strata are mapped as Killik tongue. In regions where the Killik tongue and Grandstand formation are interbedded it is virtually impossible to map each at the scale used on plate 27; consequently, the thickest unit is mapped. Where the formation is present as thin interbeds in other geologic sections (pl. 32) of the Killik tongue, it is mentioned only as microfossil-bearing beds.

CHARACTER AND THICKNESS

The Grandstand formation is a marine and lagoonal clastic unit primarily composed of dirty olive-gray to greenish-gray fine-grained thin-bedded sandstone, greenish-gray siltstone, and shaly siltstone. Subordinate amounts of clean, salt-and-pepper sandstone are present in the lower part of the formation, particularly near the contact with Tuktu formation. Minor constituents include limestone nodules, ironstone concretions, and clay shale.

At the type locality, the section is 1,700 feet thick; this includes 270 feet of nonmarine Killik tongue (pl. 32, column 6). The section is incompletely exposed, part of it being rubble. Sandstone and siltstone compose about 80 percent of the rocks. Most of the sandstone is a subgraywacke. The salt-and-pepper sandstone has a greenish cast that is not found in similar sandstone units of the Killik tongue. The siltstone is commonly micaceous and carbonaceous. Shaly siltstone constitutes about 15 percent of the rocks. Limestone nodules are present in the upper part of the section, a few of which are fossiliferous; *Panope? kissoumi* McLearn and *Arctica?* sp. were the only fossils found in the nodules. Ironstone concretions are scattered throughout the entire formation but are generally more abundant in the siltstone and shaly siltstone units. Some of the sandstone beds in the upper part of the the formation form ledges similar to the conglomerate ledges of the upper part of the Killik tongue, and they are probably the equivalent of the conglomerate beds farther south. Coal and other nonmarine material is associated with some of the ledge-forming sandstone and is mapped as part of the Killik tongue.

A section of Grandstand formation, totaling 589 feet and divided by a 41-foot section of Killik tongue, was measured along the south flank of Big Bend anticline on the Chandler River at lat 69°04′ N., long 151°53′ W. The Grandstand overlies an additional 1,060 foot section of Killik tongue (pl. 32 column 5). Unit 1 of this section consists of only a small quality of rubble, so it is possibly Killik tongue instead of Grandstand formation. The sandstone at this locality is predominantly medium bedded, medium grained, and medium to dark neutral with a greenish cast. Unit 9 is medium to coarse grained and massive and has a clean salt-and-pepper appearance. The remainder of the sandstone is moderately argillaceous. Well-indurated siltstone and shaly siltstone are interbedded with the sandstone. Ironstone concretions are common features of these interbeds. Plant fossils are locally abundant in the sandstone, and mollusk fossils were collected from unit 9 (USGS Mesozoic locs. 25136 and 24298).

The other measured section of the Grandstand formation is from Fossil Creek (pl. 32, column 4), where 425 feet was mapped overlying 730 feet of Killik tongue. Unit 7 of this section is a thin coal and carbonaceous-shale bed that should be included with the Killik tongue. The Fossil Creek section has a high percentage of fine clastic rocks in which clay shale and shaly siltstone are predominant. The sandstone is thin bedded, very fine grained, silty, calcareous, and dark neutral. The sandstone units are thin and often occur with siltstone as interbeds in the shale. Minor constituents of the formation at this locality include ironstone concretions and a dark blue-gray dense limestone 2 feet thick 3 feet above the base. Fossils are more abundant in this section than in any other section of the Grandstand formation.

GEOLOGIC SECTIONS

Following are the details of the geologic sections.

Section of Grandstand formation, on Fossil Creek (pl. 32, column 4)

	Ft.	In.
Ninuluk formation.		
Grandstand formation:		
1. Covered; computed thickness	40	0
2. Clay shale and shaly siltstone with interbeds of siltstone and sandstone. Sandstone very fine grained, dark neutral; weathers medium gray; calcareous, hard, brittle, with abundant ironstone concretions; fossils in upper sandstone (USGS Mesozoic loc. 25139). In part rubble; computed thickness	100	0
3. Covered; computed thickness	80	0
4. Siltstone and sandstone; thin-bedded, very fine grained, dark-neutral; rubble; computed thickness	20	0
5. Covered; computed thickness	60	0
6. Siltstone, shaly siltstone, and clay shale; fissile, soft, black, carbonaceous: siltstone and shaly siltstone in beds several inches thick; hackly-fracturing. A few pelecypods near top (USGS Mesozoic loc. 25138)	40	0
7. Coal and carbonaceous shale		7
8. Siltstone	2	5
9. Covered; computed thickness	17	0
10. Sandstone, thin- to thick-bedded, very fine grained, dark-neutral	15	0
11. Siltstone, greenish-brown	28	0

Grandstand formation—Continued

	Ft.	In.
12. Sandstone, shaly-bedded, very fine grained, silty	2	0
13. Siltstone and shaly siltstone; gray-brown, hard, hackly-fracturing	15	0
14. Limestone, dark blue-gray; weathers rusty-brown	2	0
15. Sandstone, thin-bedded, very fine grained, light-green	3	0
	425	0

Killik tongue.

Section of Grandstand formation on the south flank of Big Bend anticline on the Chandler River (pl. 32, column 5)

Ninuluk formation

Grandstand formation:

	Feet
1. Covered; sandstone, siltstone, and shaly siltstone float. Fossils 100 feet below top (USGS Mesozoic loc. 20457); computed thickness	280
2. Siltstone, shaly siltstone, and sandstone; medium-bedded, medium-grained, light yellow-red, argillaceous, hard; in part rubble; computed thickness	40
3. Sandstone, thin- to medium-bedded, very fine grained, dark-neutral with greenish cast, argillaceous, hard; plant fossils common; in part rubble; computed thickness	30
4. Siltstone and shaly siltstone; ironstone concretions common; in part rubble; computed thickness	50
5. Sandstone, thin-bedded, very fine grained, silty, dark-neutral, argillaceous	20
6. Siltstone, shaly, gray, hard	19
Killik tongue (interval described on p. 252).	
Grandstand formation:	
7. Sandstone, thin- to medium-bedded, medium-grained, hard, medium-neutral with greenish cast; plant fossils common; in part rubble; computed thickness	20
8. Siltstone and shaly siltstone; ironstone concretions abundant; rubble; computed thickness	20
9. Sandstone, thin-bedded to massive, medium- to very coarse-grained, salt-and-pepper with greenish cast to medium-neutral, friable to well-indurated; few plant fragments; siltstone interbeds; fossils in lower part of unit (USGS Mesozoic locs. 25136 and 24298); in part rubble; computed thickness	110
	589

Killik tongue.

Type section of Grandstand formation on the Anaktuvuk River (pl. 32, column 6)

Ninuluk formation.

Grandstand formation:

	Feet
1. Sandstone, siltstone, and shaly siltstone with ironstone concretions. Sandstone thin bedded, dark gray green, fine grained; siltstone beds micaceous. Mostly rubble; computed thickness	100
Killik tongue (interval described on p. 253).	
Grandstand formation:	
2. Sandstone, thin- to heavy-bedded, dusky yellow-green to greenish-gray salt-and-pepper, argillaceous, crossbedded; maroon-weathering in part. Few pelecypods in limy nodules (USGS Mesozoic loc. 24301)	20
3. Sandstone, siltstone, and shaly siltstone; similar to unit 1. Rubble; computed thickness	110
Killik tongue (interval described on p. 253).	
Grandstand formation:	
4. Sandstone, siltstone, and shaly siltstone. Sandstone thin to heavy bedded, fine grained, greenish gray; mud lumps and limy nodules; mostly rubble; computed thickness	140
5. Siltstone and shaly siltstone, greenish-gray, with few limy nodules	40
6. Sandstone, with few interbeds of siltstone and shaly siltstone, mainly in lower part. Sandstone mostly thin bedded, fine grained, light olive gray with greenish cast to dark yellow red, crossbedded, somewhat argillaceous; ripple marked; plant fossils, ironstone concretions. Salt-and-pepper sandstone just above contact. Mostly rubble; computed thickness	1,020
	1,430

Tuktu formation.

AGE AND CORRELATION

The marine Grandstand formation does not have as diverse a megafauna or microfauna as does the Tuktu formation. Twelve megafossil collections were made from the formation; the fossils were identified by R. W. Imlay and are shown in table 5. The fossils include six genera of pelecypods, of which the most important is the species *Inoceramus anglicus* Woods; one genus of worm, *Ditrupa cornu* Imlay, and a starfish cast. The meager Grandstand megafauna all represent genera found in the Tuktu formation; therefore, the Grandstand, at least in part, is also probably of middle Albian age. No ammonites were found in the Grandstand formation of the Chandler River region, so the exact position of the formation within the middle Albian cannot be determined.

The presence of *Inoceramus anglicus* Woods about 100 feet below the top of the formation at Big Bend anticline on the Chandler River (see table 5) is of special interest to the age determination of the Grandstand formation. This is the highest stratigraphic occurrence of a species that is common in the Tuktu formation and also is found in rare occurrences in the Torok formation. The age of the Tuktu and Torok formations is early Albian to middle Albian. *I. anglicus* Woods, according to R. W. Imlay, is common in the Albian of the Boreal region and is not known in the Cenomanian.

TABLE 5.—*Megafossils of the Grandstand formation and the Killik tongue of the Chandler formation*

[Identified by R. W. Imlay, 1961, p. 35]

Geographic area	Colville River						Fossil Creek		Chandler River				Anaktuvuk River
Column (pl. 32)							4	4	5		5	5	6
Stratigraphic position below top	Lower part	Near top		850–950	950–1050		320	80	100	Lower part	540		240
USGS Mesozoic locality No	20435	20473	20474	20477	20478	25137	25138	25139	20457	24273	24298	25136	24301
Starfish		×											
Ditrupa cornu Imlay	×			×									
Tancredia kurupana Imlay					×								
Tancredia sp	×										×		
Arctica? sp	×							×			×	×	×
Panope? *kissoumi* (McLearn)	×		×										×
Panope? sp					×	×	×			×		×	
Thracia stelcki (McLearn)				×									
Inoceramus anglicus Woods									×				
Inoceramus sp											×		
Entolium utukokense Imlay	×				×	×					×		
Entolium sp										×			
Xenohelix? sp					×								

The microfossils also support an Early Cretaceous age determination for the Grandstand formation. Seventy-six samples from the formation were examined for microfossils; 28 were barren. The microfossils are shown on plate 30; they were identified by H. R. Bergquist, who reported (written communication, 1956):

No calcareous species of Foraminifera were found and only 12 arenaceous species were identified. Most of the 12 species however, are characteristic of the *Verneuilinoides borealis* faunal zone and also occur in beds in the Tuktu formation as well as in the upper part of the Torok formation. Five of the species comprise 75 percent of the fauna found in these samples. In order of abundance these species are: *Verneuilinoides borealis* Tappan, *Saccammina. sp. Miliammina awunensis* Tappan, *Trochammina rutherfordi* Stelck and Wall, *Gaudryina canadensis* Cushman. *Verneuilinoides borealis* was found most frequently and in greatest abundance and comprised 52 percent of all common to very abundant occurrences of the total species. *Haplophragmoides topagorukensis*, which is the second most abundant species in the Detterman samples from the Tuktu formation, was noted in only very rare occurrences in 5 samples from the Grandstand formation. Three species that were found in the Grandstand formation but not in the samples from the Tuktu formation are *Psamminopelta subcircularis* Tappan, *Miliammina ischnia* Tappan, and *Gaudryinella irregularis* Tappan. In samples from Early Cretaceous rocks in other parts of nothern Alaska these species are part of the *Verneuilinoides borealis* faunal zone.

The Grandstand formation is in apparent normal-contact relation with the underlying Tuktu formation and the overlying Ninuluk formation; it grades laterally into the nonmarine Killik tongue of the Chandler formation. A fence diagram (pl. 31) of the Tuktu and Grandstand formations and the Killik tongue of the Chandler formation shows the relation of these units. The diagram shows the intertonguing of nonmarine and marine rocks, the northeastward facies change of the strata, and a general thinning of the units in that direction. The sections used to construct the diagram are included on plates 30 and 32. The sides of the diagram were constructed from sections not shown on the above plates.

UPPER CRETACEOUS ROCKS

NANUSHUK GROUP

CHANDLER FORMATION

NIAKOGON TONGUE

OCCURRENCE

The Niakogon tongue was redefined by Detterman (1956a, p. 240–241) as the upper nonmarine tongue of Chandler formation; it is, at least in part, the age equivalent of the Ninuluk formation. The type locality is on the northeast bank of the Killik River (fig. 42), 10 miles upstream from it confluence with the Colville River (pl. 27); the tongue is named after Niakogon Buttes, lat 69°02′ N., long 151°41′ W., 40 miles east of the type locality.

Rocks of the Niakogon tongue are present only in the western part of the mapped area. The tongue was recognized only as far east as Wolverine Creek, where a few thin nonmarine beds were mapped in the marine Ninuluk formation. A section 540 feet thick was measured on Mammoth Creek, 28 miles southeast of the type locality. Two sections, 124 and 138 feet thick, were measured at Ninuluk Bluffs on the Colville River, 12 miles northeast of the type locality. Thus, the tongue is more persistent in a southeasterly direction from the type locality than it is toward the northeast.

At the type locality a 40-foot section of Ninuluk formation separates the Niakogon from the Killik tongue. East of the type locality the Niakogon intertongues with and grades into the Ninuluk formation, making differentiation between the marine and nonmarine strata difficult particularly in the interstream areas. For con-

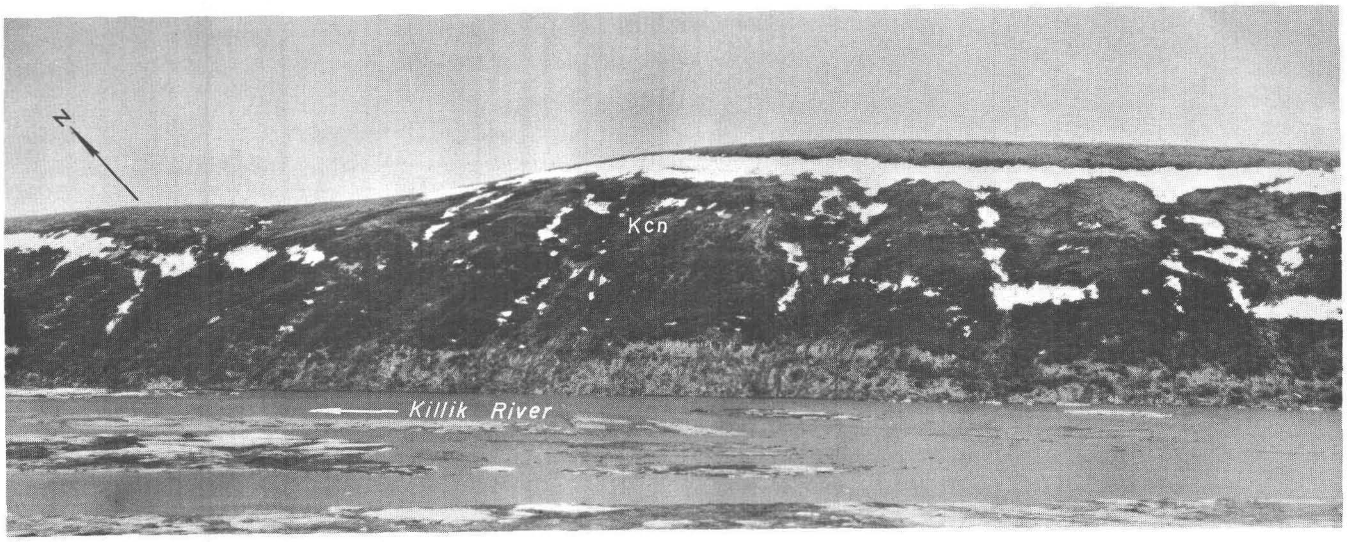

FIGURE 42.—Oblique view of part of the type locality of the Niakogon tongue. Kcn, Niakogon tongue. Photograph by U.S. Navy.

venience in mapping, therefore, in areas of intertonguing sediments, the Niakogon tongue has not been differentiated from the Ninuluk formation.

CHARACTER AND THICKNESS

At the type locality the Niakogon tongue is about 652 feet thick and overlies 40 feet of Ninuluk formation; however, the tongue may have originally been somewhat thicker as the upper contact is eroded. The sandstone of the tongue is predominantly of salt-and-pepper type with some yellow-red, highly iron stained beds in the upper part of the section. The sandstone is fine to coarse grained, thin bedded to massive, and generally well indurated; it contains numerous plant fragments and has a high concentration of limonitic material, particularly in the upper part. Some of the heavier bedded, coarser grained sandstone contains pebbles and thin lenticular beds of conglomerate. The pebbles are approximately 90 percent dark chert and 10 percent white quartz; they are well rounded, oblong, and ¼ to ½ inch in length. Siltstone, shaly siltstone, and clay shale compose about 50 percent of the section. Several thin coal seams occur in the section, and ironstone concretions and beds are locally abundant.

Bentonite is present in the upper part of the tongue. This is the lowest known major occurrence of bentonite found in the mapped area; bentonite is common in the Colville group but characteristically absent in the Nanushuk group. Thin seams of plastic gray-green bentonite are associated with the clay-shale units. Volcanism was apparently associated with a renewed tectonic activity in the land mass to the south; there is no indication of a source for the bentonite within the mapped area.

The Mammoth Creek section (pl. 33, column 2) is 541 feet thick and is similar to the strata at the type locality. The basal part above the marine Ninuluk formation is predominantly sandstone but is incompletely exposed. The sandstone is predominantly thin bedded, fine grained, and dark neutral to yellow red. Unit 15 is the one exception; it is thick bedded, medium to coarse grained, and salt and pepper appearing with scattered chert and quartz pebbles. Clay shale is more common than at the type locality; in association with shaly siltstone and siltstone it constitutes a higher percentage of the unit than at the type locality. Several coal beds are present in the upper middle part of the section; they are generally about 1 foot thick and are associated with the shale units. Thin bentonite seams also are found with the shale.

The section at Ninuluk Bluffs on the Colville River (pl. 33, column 3) consists of two thin nonmarine tongues in a predominantly marine section. The lower tongue is 124 feet thick, and the upper tongue is 137 feet thick. Clay shale, shaly siltstone, and siltstone constitute the bulk of the section. Several thick sandstone units are present, one of which, unit 29, is probably in part marine, as it contains megafossils. Both coal and bentonite beds are more numerous and the individual units are considerably thicker than at the type locality. The section at Ninuluk Bluffs is the farthest north occurrence of the Niakogon tongue in the mapped area.

Two rock samples from the Niakogon tongue were examined in thin section to determine the size, shape, and abundance of constituent minerals; both samples are from the lower of the two tongues measured at the type locality of the Ninuluk formation.

Field sample 47 ADt 23 (pl. 33, column 3) is a salt-and-pepper sandstone with a black chert grit on the bedding planes; it is fine grained and well indurated. In thin section the grains are subangular to subround and 0.1 to 0.6 mm in diameter; a siliceous clay and silt matrix constitutes 20 to 30 percent of the rock. The constituent minerals are: quartz, 35 percent; chert, 45 percent; calcite, 5 percent; plagioclase, 6 percent; orthoclase, 1 percent; biotite, 3 percent; rock fragments, 3 percent; carbonaceous material, 2 percent. All percentage figures are based on a grain count of 100.

Field sample 47 ADt 27 is very fine grained, light olive gray; it weathers to moderate yellow brown and is well indurated and carbonaceous. Thin section examination shows the grains to be subround to round and 0.1 to 0.2 mm in diameter; a cryptocrystalline calcite cement constitutes about 30 percent of the rock. The constituent minerals are: quartz, 31 percent; chert, 19 percent; calcite, 35 percent; plagioclase, 6 percent; orthoclase, 2 percent; biotite, 1 percent; rock fragments, 3 percent; carbonaceous material, 2 percent; limonite, 1 percent.

GEOLOGIC SECTIONS

The columar sections for the Niakogon tongue are included with the Ninuluk formation (pl. 33) to show better their intertonguing relation.

The type section of the Niakogon tongue (pl. 1; pl. 33, column 1; pl. 34, section 7) is on the northeast bank of the Killik River, between camps D–June 27–53 and W–July 12–45, and on the south flank of the east-plunging Killik Bend anticline in strata that dip 4° to 5° S. Error in compilation should be less than 10 percent and probably is no greater than 5 percent. The upper contact was not seen, but the 652 feet measured probably represents almost the total thickness for the tongue.

Type section of Niakogon tongue, on the Killik River (pl. 33, column 1)

	Feet
Niakogon tongue:	
1. Sandstone, thin-bedded, fine-grained, hard, dark yellow-red, in part conglomeratic; pebbles 90 percent dark chert, 5 percent gray and green chert, and 5 percent white quartz. Few thin brittle rusty brown limy sandstone beds with limonite specks. For the most part rubble; computed thickness	20
2. Siltstone, shaly siltstone, and clay shale, interbedded; bentonite stringers, ironstone concretions, and one 6-inch coal seam near base. Rubble; computed thickness	50
3. Sandstone, thin- to thick-bedded, mostly thin; fine-grained, crossbedded, medium-gray; weathers reddish brown, friable; few ironstone concretions; coal float, plant fragments	25
Niakogon tongue—Continued	
4. Sandstone, thin- to medium-bedded, fine-grained, dark-gray, conglomeratic in part; pebbles 90 percent chert, 10 percent white quartz; few ironstone concretions, siltstone and shaly siltstone interbeds. Entire unit highly iron stained; contains limonite specks	35
5. Clay shale, thin, fissile, dark blue-gray, with several thin bentonite stringers	40
6. Sandstone, massive, fine- to coarse-grained, salt-and-pepper; pebbles common, 90 percent dark chert, 5 percent gray and green chert, and 5 percent white quartz. A 15-in. bed of grit conglomerate in the middle; plant fragments common	10
7. Clay shale with numerous ironstone concretions; rubble; computed thickness	30
8. Sandstone, thin-bedded, fine- to medium-grained, light-gray to light yellow-red; with few chert pebbles and a little shaly siltstone; rubble; computed thickness	25
9. Covered; computed thickness	15
10. Sandstone, thin-bedded, fine-grained; upper part salt-and-pepper, lower part medium yellow-red; few chert and quartz pebbles in upper part; ironstone concretions and siltstone interbeds; plant fossils common. In part rubble; computed thickness	30
11. Covered; computed thickness	40
12. Sandstone, siltstone, and coal float. Sandstone thin bedded, fine grained, medium yellow red; weathers rusty brown; rubble; computed thickness	12
13. Covered; siltstone float near middle of unit; computed thickness	70
14. Sandstone, thin-bedded, fine- to medium-grained, light greenish-yellow; in part rubble; computed thickness	10
15. Siltstone and shaly siltstone with a 4-inch coal seam in middle of unit; mostly rubble; computed thickness	10
16. Covered; computed thickness	30
17. Sandstone, thin-bedded, fine- to medium-grained, medium yellow-red; plant fossils common; in part rubble; computed thickness	10
18. Covered; computed thickness	15
19. Sandstone, siltstone, and shaly siltstone; sandstone fine to medium grained, light greenish yellow; ironstone concretions abundant; in part rubble; computed thickness	10
20. Covered; computed thickness	15
21. Sandstone, siltstone, and shaly siltstone; ironstone concretions, plant fossils; 4-in. coal seam near top; in part rubble; computed thickness	15
22. Covered; computed thickness	35
23. Sandstone, thin- to medium-bedded, fine-grained, medium yellow-red, friable; plant fragments and fossile casts; rubble; computed thickness	10
24. Sandstone, siltstone, and shaly siltstone, interbedded; coal float, ironstone concretions, plant fragments. Sandstone fine grained, greenish gray; rubble; computed thickness	40

Niakogon tongue—Continued	Feet
25. Sandstone, thin- to medium-bedded, fine-grained, medium-neutral with red cast, crossbedded; few ironstone concretions, mud balls, and plant fossils	20
26. Siltstone, sandstone, shaly siltstone, clay shale, and coal. One 15-in. coal seam 10 ft. from bottom. Siltstone micaceous, carbonaceous, and shows mud flow marks; ironstone concretions and plant fossils common	30
	652

Ninuluk formation.

The Mammoth Creek section (pl. 33, column 2; pl. 34, section 6) was measured along the east bank of the creek 2 miles southeast of camp D–June 27–52. The tongue is exposed in a series of discontinuous cutbanks along the stream, on the south flank of Canyon syncline.

Section of Niakogon tongue, on Mammoth Creek (pl. 33, column 2)

Ninuluk formation.	Feet
Niakogan tongue:	
1. Sandstone, siltstone, shaly siltstone, and clay shale, interbedded; sandstone very fine grained, dark-neutral; bentonite bed near base; in part rubble, computed thickness	90
2. Covered; computed thickness	20
3. Clay shale, dark blue-gray to black; thin bentonite stringer	12
4. Coal and carbaceous shale	1
5. Clay shale, shaly siltstone, and siltstone; few ironstone concretions	10
6. Sandstone, thin-bedded, very fine grained, silty, argillaceous, micaceous, ripple-marked	8
7. Sandstone, thin, siltstone, shaly siltstone, and clay shale with thin bentonite stringer, interbedded; in part rubble; computed thickness	75
8. Coal	1
9. Clay shale	3
10. Coal	1
11. Sandstone, siltstone, and clay shale; mostly rubble; computed thickness	60
12. Covered; computed thickness	40
13. Sandstone, thin- to medium-bedded, fine-grained, dark-neutral to yellow-red; thin siltstone at base; rubble; computed thickness	10
14. Covered; computed thickness	70
15. Sandstone, conglomeratic, predominantly black chert pebbles, less than 10 percent white quartz; thick-bedded, medium- to coarse-grained, salt-and-pepper, clean, hard	25
16. Covered; computed thickness	25
17. Sandstone, siltstone, and shaly siltstone; rubble; computed thickness	15
18. Covered; computed thickness	75
	541

Ninuluk formation.

The Ninuluk Bluffs section (pl. 33, column 3, pl. 34, section 8) was measured on the south flank of Little Twist anticline in strata dipping 41° to 45° S. The section is completely exposed.

Section of Niakogon tongue, at Ninuluk Bluffs on the Colville River (pl. 33, column 3)

Ninuluk formation.	Ft.	In.
Niakogon tongue:		
1. Bentonite	0	2
2. Shale, carbonaceous	0	4
3. Clay shale, bentonite stringers, ironstone concretions; yellow salt efflorescence	21	0
4. Coal	0	4
5. Bentonite	0	4
6. Shale, carbonaceous	0	8
7. Sandstone, fine-grained, dark-neutral, with mud lumps, wood fragments	6	0
8. Sandstone and siltstone; hackly fracturing	11	0
9. Bentonite	0	2
10. Sandstone, fine- to medium-grained, dark-neutral, argillaceous, carbonaceous, ripple-marked; ironstone concretions	17	0
11. Siltstone and clay shale; ironstone concretions, bentonite stringer	10	0
12. Coal, lignite to subbituminous	3	9
13. Clay shale and shaly siltstone; ironstone concretions	10	0
14. Bentonite	2	3
15. Coal, lignite, and carbonaceous shale		10
16. Sandstone, thin- to medium-bedded, very fine to fine-grained, dark-neutral, argillaceous, crossbedded; ironstone concretions	25	0
17. Coal, bituminous	3	0
18. Siltstone; ironstone concretions	3	0
19. Coal, subbituminous	1	2
20. Clay shale and sandstone; fine-grained, dark-neutral, hard, argillaceous, carbonaceous, with coal lenses	21	0
21. Coal	1	0
Ninuluk formation (interval described on p. 264).		
Niakogon tongue:		
22. Coal	2	1
23. Shale, carbonaceous	2	4
24. Clay shale, bentonitic	14	0
25. Bentonite	2	1
26. Sandstone, fine-grained, dark-neutral	14	0
27. Clay shale, crumbly, light-gray; few siltstone interbeds	24	0
28. Coal	0	5
29. Sandstone, fine-grained, medium-gray; few chert pebbles and fossils	22	0
30. Granule conglomerate, predominantly chert	0	6
31. Sandstone, thin-bedded, fine- to medium-grained, brownish-gray, crossbedded, noncalcareous; ironstone concretions	24	0
32. Clay shale, crumbly, dark-gray	16	6
33. Coal	0	8
34. Bentonite	0	7
35. Coal, subbituminous	1	0
	261	2

Ninuluk formation.

AGE AND CORRELATION

Plants are the only fossils found in the Niakogon tongue. Three collections from the Ayiyak River and one from the Colville River were identified by R. W. Brown (table 6). Included in the table is a collection from the type locality made by Mertie in 1924 (Smith and Mertie 1930, p. 222) and identified by F. H. Knowlton. The plants are all assigned to the Late Cretaceous (R. W. Brown, written communication, 1953).

TABLE 6.—*Plant fossils of the Niakogon tongue*

[Identified by: a, F. J. Knowlton; b, R. W. Brown. Initials in field numbers indicate collection made by: Mt, J. B. Mertie, Jr.; Bl, R. S. Bickel; Dt, R. L. Detterman]

Geographic area	Killik River	Ayiyak River	Wolverine Creek		Colville River
Stratigraphic position	Upper	Middle	Lower	Lower	Middle
Field sample No.	24 AMt 64	52 ABl 23	52 ABl 11	52 ABl 13	53 ADt 87
Ginkgo sp	a				
Podozamites sp	a				
Sequoia sp	a				
Pterospermites sp	a				
Anemia supercretacea conformis Hollick					b
Pseudoprotophyllum crassum Hollick					b
Cephalotaxopsis intermedia Hollick		b			
Cephalotaxopsis sp		b			
Coniferous wood					b
Woody impressions		b	b	b	

The Niakogon tongue overlies at least a thin section of marine Ninuluk formation in all outcrops in the Chandler River region. The Ninuluk formation is abundantly fossiliferous; consequently, it is possible to determine indirectly the age of the Niakogon tongue. One of the diagnostic fossils from the base of the Ninuluk formation is *Inoceramus dunveganensis* McLearn, which is indicative of an upper Cenomanian age (Imlay and Reeside, 1954, p. 243). Thus, the beds cannot be older than the earliest part of the Late Cretaceous.

The contact between the Niakogon tongue and the Ninuluk formation is well defined; the rusty-weathering yellow-red sandstone, with abundant coal and bentonite interbeds, changes abruptly to a greenish-gray marine fossiliferous sandstone. The Niakogon tongue is similar in general character to the Killik tongue. However, there are two distinguishing features for the Niakogon: The most important is the abundance of bentonite; the second is the increase of limonitic material in the sandstone.

NINULUK FORMATION

OCCURRENCE

The Ninuluk formation was first described by Detterman (1956a, p. 241–244) as the upper marine formation of the Nanushuk group; it is at least in part the age equivalent of the Niakogon tongue of the Chandler formation. Outcrops of the formation are widespread in the Chandler River region. The southernmost exposures are almost parallel to, and about 5 miles north of, the Tuktu escarpment. In the Killik River area the southernmost exposure is about 10 miles north of the Tuktu Escarpment.

Near the escarpment the Ninuluk crops out in broad gently folded synclines; to the north, owing to the regional monoclinal north dip of the strata, the formation is exposed in low rounded hills on the flanks of higher ridges of the Chandler formation and is present on all the major anticlines. In the area under discussion the Ninuluk does not crop out north of lat 69°15′ N. Along the Nanushuk River the formation is not as well defined as it is elsewhere; the resistant ridge-forming sandstone in the upper part has been eroded.

The type locality of the Ninuluk formation is at Ninuluk Bluffs on the southeast bank of the Colville River (fig. 43), 20 miles downstream from the

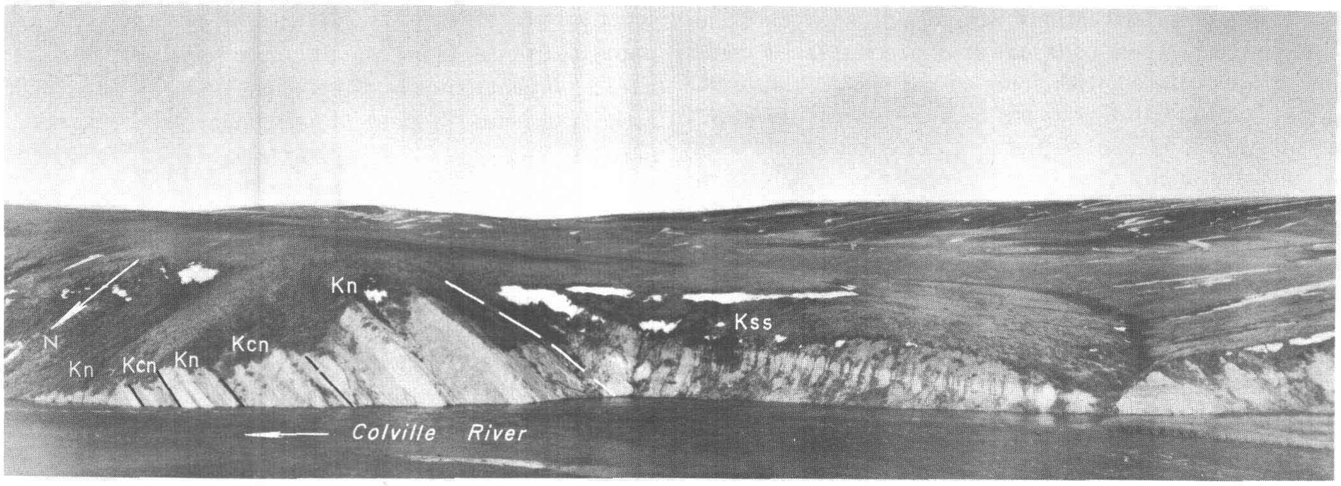

FIGURE 43.—Oblique view, looking southeast, of the type locality of the Ninuluk formation showing the unconformity between the Nanushuk and Colville groups. Kss, Shale Wall member; Kcn, Niakogon tongue; Kn, Ninuluk formation. Photograph by U.S. Navy.

junction of the Killik and Colville Rivers. Five columnar sections in addition to the type section are shown on plate 33. These sections were taken from different parts of the region to show the facies change within the formation, the extent of the intertonguing of marine and nonmarine strata, and the magnitude of the unconformity at the top of the formation.

The columnar sections on plate 33 include sections of the Niakogon tongue that are intercalated with the Ninuluk formation. As the marine Ninuluk formation has a greater areal distribution, it is used as the major mapping unit, and the Niakogon tongue is mapped only at its type locality.

CHARACTER AND THICKNESS

At the type locality the Ninuluk formation is 657 feet thick.

Sandstone and conglomeratic sandstone constitute about 40 percent of the formation. The sandstone is thin bedded to massive, commonly laminated, very fine to fine grained, soft to moderately well indurated and argillaceous; it grades through various shades of greenish gray to olive brown. In the lower 50 feet of the section several beds of salt-and-pepper sandstone were mapped. The sandstone is commonly crossbedded, ripple marked, calcareous, and carbonaceous; in places it contains small ironstone concretions. Thin lenticular beds of pebble-granule conglomerate are scattered throughout the formation. White quartz constitutes about 10 percent of the conglomeratic material; the remainder is mainly varicolored chert.

Greenish-gray finely laminated shaly siltstone and dark blue-gray clay shale constitute the major part of the formation. The siltstone and shaly siltstone are well indurated and show hackly fracturing. The clay shale is soft, fissile, and crumbly; commonly the weathered surface is covered with yellow or white crystals. Ironstone concretions also occur with the fine clastic rocks. Thin beds of gray-green plastic bentonite are associated with some of the clay-shale units.

The Ninuluk Bluffs section has the overall appearance of a cyclic-bedded sequence. Thick sandstone beds are abruptly terminated by a clay shale, which in turn grades into shaly siltstone and siltstone and then into sandstone again. The thickness of a cycle may vary from 50 feet to about 200 feet, and occasionally smaller oscillations occur within the cycle.

A gradual facies change in a northeasterly direction indicates deposition in progressively deeper water. The sandstone becomes progressively finer grained, thinner bedded, and more argillaceous and calcareous. Limestone beds are present and some of the sandstone is almost an arenaceous limestone. The limestone has a characteristic rusty-brown weathered surface. Bentonite, common in the nearshore facies and in the nonmarine Niakogon tongue, was not seen in any of the deeper water sedimetary rocks. Likewise, ripple marks and crossbedding, common in the Killik River area and at the type locality, disappear from the strata in the rest of the area.

Two rock samples from the Ninuluk formation were examined microscopically to determine the size, shape, and abundance of the constituent minerals.

Field sample 52 ADt 97 is from 350 feet above the base of the formation on the Ayiyak River; it is moderate yellowish brown, fine grained, well indurated, and argillaceous. In thin section the grains are subangular to subround and 0.4 to less than 0.1 mm in diameter; they commonly are elongated; a siliceous clay and silt groundmass composes 30 to 40 percent of the specimen. Twinning is common in the calcite, some of which is altered to siderite. Inclusions are common in the quartz, and there are albite inclusions in microcline. The constituent minerals are: quartz, 42 percent; chert, 20 percent; calcite, 17 percent; plagioclase, 4 percent; chlorite, 3 percent; biotite, 6 percent; rock fragments, 4 percent; limonite, 3 percent; carbonaceous material, 1 percent. All percentage figures are based on a grain count of 100.

Field sample 52 ABl 238 is from 250 feet above the base of the formation on Trouble Creek; it is thin bedded, fine grained, light olive gray, well-indurated, and calcareous. In thin section the grains are subangular to subround and 0.05 to 0.2 mm in diameter. A calcareous and limonitic clay matrix constitutes 30 to 40 percent of the specimen. Twinning is common in the calcite, some of which is altered to siderite. Inclusions are present in the quartz and microline. The constitutent minerals are: quartz, 30 percent; chert, 13 percent; calcite, 43 percent; plagioclase, 2 percent; chlorite, 2 percent; biotite, 3 percent; limonite, 3 percent; rock fragments, 3 percent; carbonaceous material, 1 percent.

GEOLOGIC SECTION

Measured sections of the Ninuluk formation, including sections of Niakogon tongue, are shown on plate 33. The columns are arranged roughly in a southwest-northeast direction to show the interfingering of the Niakogon tongue and the general facies change in that direction. The Killik River section was measured at the type locality of the Niakogon tongue.

Section of Ninuluk formation, on the Killik River (pl. 33, column 1; pl. 34, section 7)

Niakogon tongue.

Ninuluk formation:	Feet
1. Sandstone, medium- to thick-bedded, fine- to medium-grained	10
2. Shaly siltstone, clay shale, siltstone, and thin-bedded sandstone; ironstone bed near top; in part rubble; computed thickness	20
3. Sandstone, conglomeratic, and pebble conglomerate with 85 percent dark chert, 5 percent with quartz, 5 percent green and gray chert, and 5 percent broken-shell and shale fragments. Sandstone hard, rusty brown. Conglomerate almost a coquina of broken shells (USGS Mesozoic loc. 24629)	10
	40

Killik tongue.

The Mammoth Creek section (pl. 33, column 2; pl. 34, section 6) was measured along the east bank of the creek 2 miles southeast of camp D–June 27–52. The formation is exposed in a series of discontinuous cutbanks for 0.6 mile along the stream. The section is on the south flank of Canyon syncline, and the dip of the strata increases from 7° N. to 16° N. at the contact with the Killik tongue. About 280 feet of Ninuluk formation were measured or inferred in these exposures. Both the upper and lower contacts are exposed. The angularity between the Ninuluk and Seabee formations is about 5° at this point. Total thickness may be in error by as much as 5 percent.

Section of Ninuluk formation, along Mammoth Creek (pl. 33, column 2)

Seabee formation.
Unconformity.

Ninuluk formation:	Feet
1. Sandstone, thin- to medium-bedded, very fine grained, silty, dark-neutral to yellow-red; weathers gray to maroon; fractures into long slabs. Fossiliferous in lower part (USGS Mesozoic Loc. 24277). Mud lumps and ironstone concretions common; few siltstone and shaly siltstone interbeds; in part rubble; computed thickness	40
2. Covered; computed thickness	20
3. Sandstone, thin- to shaly-bedded, very fine grained, dark-neutral; weathers rusty brown; highly argillaceous; in part rubble; computed thickness	20
Niakogon tongue (interval described on p. 260).	
Ninuluk formation:	
4. Sandstone, thin- to medium-bedded, fine- to medium-grained, dark-neutral to yellow-red with greenish cast; interbeds of siltstone and shaly siltstone; mostly rubble; computed thickness	55
5. Covered; computed thickness	90
Ninuluk formation—Continued	
6. Conglomerate and conglomeratic sandstone; massive; 95 percent black and gray chert, 5 percent white quartz pebbles. Sandstone medium grained, medium yellow red; contains *Inoceramus dunveganensis* McLearn. In part rubble; computed thickness	55
	280

Killik tongue.

The type section at Ninuluk Bluffs (pl. 27; pl. 33, column 3; pl. 34, section 8) is the only completely exposed section of Ninuluk formation seen. The section was measured on the south flank of Little Twist anticline. The exposure is bisected by a normal fault with vertical displacement of about 300 feet; key beds can be correlated across the fault. A total of 828 feet were measured south of the fault in strata dipping 41° to 45° S. This includes 261 feet of Niakogon tongue. North of the fault the strata dip about 4° to 6° S. and in general are not as well exposed. In all, 90 feet were measured north of the fault. The lower contact with the Killik tongue is normal. The Seabee formation unconformably overlies the Ninuluk with angular discordance of 41°.

Type section of Ninuluk formation, at Ninuluk Bluffs on the Colville River (pl. 33, column 3)

Seabee formation.
Unconformity.

Ninuluk formation:	Ft.	In.
1. Sandstone, siltstone, clay shale, and bentonite, interbedded. Sandstone and siltstone beds less than 2 in. thick, fine grained, dark gray, ripple marked, and carbonaceous; clay shale dark blue gray, fissile, with bentonite beds as much as 3 inches thick	42	4
2. Sandstone; massive at base to thin bedded at top; fine- to very fine-grained, medium-neutral; several bands of black-chert pebbles in middle; few small ironstone concretions	48	0
3. Siltstone, dense, hackly-fractured, dark-neutral	10	8
4. Sandstone, thin-bedded, noncalcareous, brownish-buff, very fine grained	7	0
5. Clay shale, dark, fissile	2	4
6. Sandstone, thin-bedded, very fine grained, silty, dark-neutral with greenish cast, calcareous	4	0
7. Siltstone and shaly siltstone; dark-gray, hard, ironstained	39	0
8. Covered in part; siltstone, shaly siltstone, clay shale, and bentonite float; computed thickness	25	0

Ninuluk formation—Continued	Ft.	In.
9. Sandstone, fine-grained, thin-bedded, dark-neutral, few scattered pebbles; extremely fossiliferous (USGS Mesozoic loc. 25147)	5	0
10. Clay shale and siltstone, interbedded	10	0
11. Sandstone, thin- to thick-bedded, very fine to fine-grained, medium-gray, hard, calcareous, argillaceous, carbonaceous	47	0
12. Sandstone, siltstone, and shaly siltstone, interbedded; dark- to medium-neutral with greenish cast. Fossil zone 10 ft. from base (USGS Mesozoic loc. 25146)	36	0
13. Sandstone, conglomeratic, granule size; 90 percent chert, 10 percent white quartz	3	0
14. Clay shale, very thin bedded, with yellow salt efflorescence	3	6
15. Siltstone and sandstone; bottom 5 ft. siltstone with fossil zone; ferruginous; sandstone beds very fine grained, greenish yellow, crossbedded	13	8
16. Clay shale, paper-thin and fissile to thick with hackly fracture	11	4
Niakogon tongue (interval described on p. 260).		
Ninuluk formation:		
17. Sandstone, fine-grained, dark-neutral, fossiliferous	5	0
18. Clay shale, with few siltstone interbeds; very thin bedded, fissile, yellow salt efflorescence. Fossil zone in base (USGS Mesozoic loc. 25145)	26	8
19. Siltstone, reddish-brown, hard, brittle	2	6
20. Siltstone and sandstone; fine-grained, light-yellow; fossiliferous (USGS Mesozoic loc. 25144)	18	8
21. Clay shale, dark-gray, crumbly; bentonite stringers	21	6
Niakogon tongue (interval described on p. 260).		
Ninuluk formation:		
22. Clay shale with siltstone interbeds	21	6
23. Sandstone, fine-grained, thin-bedded, brownish-gray, argillaceous, carbonaceous, laminated, crossbedded, ripple-marked	10	0
24. Siltstone and shaley siltstone, dark-neutral	19	0
25. Sandstone, medium-bedded, fine- to medium-grained, hard, light yellow-red, carbonaceous; *Inoceramus dunveganensis* McLearn cast (USGS Mesozoic loc. 25157)	14	0
26. Siltstone and sandstone; carbonaceous	7	0
27. Sandstone, very fine grained, dark-neutral, crossbedded, carbonaceous	4	0
28. Clay shale and shaly siltstone; dark-gray, with interbeds of sandstone and siltstone; sandstone concretions 4 ft. in diameter 60 ft. above base	94	0
29. Sandstone with shale interbeds; very fine grained, medium-neutral, argillaceous. Fossiliferous (USGS Mesozoic locs. 25148 and 25149)	20	0
30. Rubble of sandstone, siltstone and shaly siltstone; computed thickness	35	0
31. Sandstone and conglomerate; granule to pebble; 90 percent dark chert, 10 percent white quartz. Sandstone fine- to medium-grained, salt and pepper; wood fragments; rusty-weathering limestone lenses near top; hard; *Inoceramus dunveganensis* McLearn (USGS Mesozoic loc. 25156)	40	0
32. Siltstone and sandstone	10	0
	656	8

Killik tongue.

The Tuluga River section (pl. 33, column 4; pl. 34, section 5) which is not well exposed, was computed on the north flank of Gunsight anticline along the west fork of Tuluga River. The strata dip north at about 16° to 20°. Only a few of the thicker sandstone and conglomerate units are exposed in the lower part of the formation. This 1,160-foot section is believed to be the thickest sequence of the Ninuluk formation but may be in error by as much as 20 percent.

Section of Ninuluk formation, on the West Fork Tuluga River (pl. 33, column 4)

Seabee formation.

Unconformity.

Ninuluk formation:	Feet
1. Siltstone, greenish-gray with thin interbeds of sandstone and shaly siltstone; rubble; computed thickness	35
2. Sandstone; upper part medium bedded, medium grained, light yellow red; lower part thin bedded, fine grained, medium neutral; ironstone concretions; in part rubble; computed thickness	25
3. Siltstone, shaly, and clay shale, with few thin greenish-gray sandstone beds in upper part; few fossils in sandstone	110
4. Covered; computed thickness	70
5. Sandstone, thin-bedded, fine- to medium-grained, and siltstone; rubble; computed thickness	15
6. Covered; computed thickness	45
7. Sandstone, medium-bedded, fine- to medium-grained, light-red to medium yellow-red; little siltstone at top; rubble; computed thickness	20
8. Covered; computed thickness	410
9. Sandstone, thin-bedded, fine-grained, medium- to dark-neutral; siltstone interbeds; rubble; computed thickness	30
10. Covered; computed thickness	70
11. Sandstone, medium-bedded, fine-grained, dark-neutral to yellow-red; subordinate greenish-gray siltstone; rubble; computed thickness	30
12. Covered; computed thickness	250
13. Sandstone and conglomerate. Conglomerate predominantly black and gray chert pebbles and grit; less than 10 percent white quartz pebbles, all well rounded. Sandstone medium bedded, fine to coarse grained, tan to medium yellow red, slabby	50
	1,160

Killik tongue.

The Chandler River section (pl. 33, column 5; pl. 34, section 10) was measured along the west side of the Chandler River just south of camp D–Aug. 17–52. The strata dip 6° to 12° S. on the south flank of Big Bend anticline. Only the basal 250 feet of the formation are present. The upper part was either eroded or never deposited. The Seabee formation unconformably overlies the Ninuluk, but the degree of angularity is small.

Section of Ninuluk formation, on the south side of Big Bend anticline on the Chandler River (pl. 33, column 5)

Seabee formation.
Unconformity.

Ninuluk formation:	Feet
1. Sandstone, thin-bedded, very fine grained, and greenish-gray siltstone; rubble; computed thickness	10
2. Covered; computed thickness	60
3. Siltstone rubble; computed thickness	5
4. Sandstone, thin-bedded, very fine grained, light-green, argillaceous, soft; in part rubble; computed thickness	25
5. Siltstone, shaly siltstone, clay shale, and sandstone, interbedded; thin- to shaly-bedded, very fine grained, dark-neutral to yellow-red, all with greenish cast; argillaceous, soft. Fossils scattered throughout (USGS Mesozoic loc. 25142)	100
6. Limestone, blue-gray; weathers rusty brown; hard, dense, fossiliferous (USGS Mesozoic loc. 24287)	8
7. Clay shale, dark blue-gray, crumbly	18
8. Sandstone, conglomeratic, medium- to thick-bedded, medium-grained, salt-and-pepper; few pebbles of dark chert and white quartz	25
	250

Grandstand formation.

The Fossil Creek section (pl. 33, column 6; pl. 34, section 9) of the Ninuluk formation was measured in a series of cutbanks along Fossil Creek. A 240-foot section is almost completely exposed on the south flank of Fossil Creek anticline. The strata dip 4° to 5° S. The contact with the underlying Grandstand formation is not clearly exposed, but the relation is apparently normal. The angular discordance with the overlying Seabee formation is relatively small, although most of the Ninuluk appears to be missing at this locality.

Section of Ninuluk formation, on Fossil Creek (pl. 33, column 6)

Seabee formation.
Unconformity.

Ninuluk formation:	Feet
1. Sandstone, fine-grained, light-neutral, argillaceous	10
2. Clay shale, dark blue-gray, fissile, soft	20
3. Sandstone, conglomeratic, medium-bedded, medium-grained, light yellow-red; scattered chert and quartz pebbles	10
4. Covered; computed thickness	10
Ninuluk formation—Continued	
5. Sandstone, thin- to medium-bedded, fine- to medium-grained, greenish-gray to salt-and-pepper; weathers rusty brown; few thin siltstone interbeds; fossiliferous (USGS Mesozoic locs. 20434 and 24269)	20
6. Siltstone and shaly siltstone; medium-gray to greenish-gray	15
7. Sandstone, thin- to medium-bedded, very fine grained, light-green, argilaceous; silica-cement; few thin greenish-gray siltstone interbeds; fossiliferous in upper part (USGS Mesozoic loc. 24270)	45
8. Siltstone and shaly siltstone	20
9. Siltstone, shaly siltstone, clay shale, and sandstone. Sandstone thin bedded, very fine grained, dark neutral, silty, soft, argillaceous; grades upward into a medium-grained well-indurated carbonaceous sandstone with hackly fracture. A 6-ft. yellow-brown limestone near base contains scattered pelecypods, including *Inoceramus dunveganensis* McLearn	90
	240

Grandstand formation.

AGE AND CORRELATION

Sixty-five megafossil collections were made from beds of the Ninuluk formation; of this number 36 are from the lower 100 feet. Twelve genera of pelecypods and one gastropod were identified by R. W. Imlay and D. L. Jones. No ammonites were found in beds of the Ninuluk formation in the Chandler River region. *Inoceramus dunveganensis* McLearn is the most important pelecypod for the purpose of correlation; it was identified in 27 collections from the lower 400 feet of the formation. Megafossils of the Ninuluk formation are listed in table 7.

Concerning the age and correlation of these fossils Imlay and Reeside (1954, p. 243) state:

> The common species include *Inoceramus athabaskensis* McLearn and *I. dunveganensis* McLearn. These have been identified elsewhere in Alaska in the lower part of the Upper Cretaceous sequence in the Kuskokwin region. In northwestern Alberta and northeastern British Columbia they are associated with the ammonite *Dunveganoceras* in the Dunvegan formation. *I. athabaskensis* likewise occurs at the base of the LaBiche shale on the Athabaska River. All the occurrences in Canada are in beds that underlie the lowest ammonite zone of the Turonian. The stratigraphic position of *Dunveganoceras* in Montana, Canada, and England is upper Cenomanian.

D. L. Jones subsequently restudied the genus *Inoceramus* and came to the conclusion that no morphologic basis is present for dividing the genus into the species *I. athabaskensis* and *I. dunveganensis* (written communication, 1957). The name *I. dunveganensis* was established first (McLearn, 1926); consequently, all specimens of *Inoceramus* from the Ninuluk formation

Table 7.—*Megafossils of*

[Identified by R. W. Imlay and D. L. Jones. Collections made by L. A. Warner, R. L. Detterman, R. S. Bickel,

Geographic area	Killik River		Ninuluk Creek										Coal Creek
Stratigraphic position above base of formation; includes thickness of Niakogon Tongue beds where present (feet)	Basal 10	Basal 10	Base	Base	10-30	Lower part	Lower part	Lower part	Lower part	Lower part	Middle	Middle	Base
Column (pl. 33)	1	1											1
USGS Mesozoic locality number	20466	24629	25154	24280	24300	25151	24271	24290	24289	24288	24278	24279	24628
Inoceramus dunveganensis McLearn	×	×	×	×	×	-----	×	-----	-----	×	×	×	-----
Inoceramus sp. juv	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	×
Inoceramus? sp	-----	-----	-----	-----	-----	×	-----	-----	-----	-----	-----	-----	-----
Arctica? *dowlingi* McLearn	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
cf. *A. dowlingi* McLearn	-----	×	-----	-----	-----	×	-----	-----	-----	-----	-----	-----	-----
Arctica? sp	-----	-----	-----	-----	-----	-----	-----	×	-----	-----	-----	-----	-----
Panope? *dunveganensis* Warren	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
cf. *P. dunveganensis* Warren	-----	-----	-----	-----	×	-----	-----	-----	-----	-----	-----	-----	-----
Panope? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Volsella cf. *V. silentiensis* McLearn	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Volsella sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Brachydontis multilnigera Meek	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Psilomya? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Tellina? sp	-----	-----	-----	-----	-----	-----	-----	-----	×	-----	-----	-----	-----
Mactra? sp	-----	-----	-----	-----	-----	-----	-----	×	-----	-----	-----	-----	-----
Corbula? sp	-----	-----	-----	-----	-----	-----	-----	×	-----	-----	-----	-----	-----
Thracia? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Tancredia? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Astarta n. sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gastropod	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Table 7.—*Megafossils of the*

Geographic area	Colville River												
Stratigraphic position above base of formation; includes thickness of Niakogon Tongue beds where present (feet)	10-30	10-30	40	Basal 50	Basal 100	Basal 100	100	100	135	220	420	420	420
Column (pl. 33)							3	3		3	3	3	3
USGS Mesozoic locality number	20469	24631	24618	25156	20476	25152	25148	25149	25153	25157	12412	20475	25144
Inoceramus dunveganensis McLearn	-----	×	-----	-----	×	-----	×	×	-----	-----	-----	×	-----
Inoceramus sp. juv	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Inoceramus? sp	-----	-----	-----	×	-----	-----	-----	-----	-----	-----	×	-----	-----
Arctica? *dowlingi* McLearn	-----	-----	-----	-----	-----	-----	-----	×	-----	×	-----	-----	×
cf. *A. dowlingi* McLearn	-----	×	×	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Arctica? sp	×	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Panope? *dunveganensis* Warren	-----	×	-----	-----	-----	-----	-----	-----	×	-----	-----	-----	-----
cf. *P. dunveganensis* Warren	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Panope? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Volsella cf. *V. silentiensis* McLearn	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Volsella sp	×	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Brachydontis multilnigera Meek	-----	-----	-----	-----	-----	-----	-----	×	-----	-----	-----	-----	-----
Psilomya? sp	-----	×	-----	-----	-----	×	-----	-----	-----	-----	-----	-----	-----
Tellina? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Mactra? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Corbula? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Thracia? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Tancredia? sp	-----	-----	-----	-----	-----	×	-----	-----	-----	-----	-----	-----	-----
Astarta n. sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	×	-----	-----
Gastropod	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

the Ninuluk Formation

C. E. Kirschner, D. E. Mathewson, J. B. Mertie, Jr., George Gryc, R. E. Fellows, and F. S. Schrader]

Wolverine Creek		Mammoth Creek	Ayiyak River											Colville River						
Base	780	Upper Part	10-30	10-30	10-30	10-30	100-150	100-150	Lower part	Middle	Middle	Upper part	Basal 10	Basal 10	10-30	10-30	10-30	10-30	10-30
	2																		
24276	24277	24275	24263	24264	24266	24281	24283	24267	24262	24261	24265	24282	20468	24630	20465	20467	25150	25155	25159
X	-----	-----	-----	X	X	-----	X	-----	-----	-----	-----	-----	X	X	X	X	X	X	-----
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Ninuluk Formation—Continued

Colville River			Fossil Creek				Chandler River								Anaktuvuk River				
450	670	750	Base	150	180	180	10-30	40-50	50-150	Basal 100	100	150	Middle	Middle	Base	10-30	10-30	30	40
3	3	3		6	6	6	5	5	5										
25145	25146	25147	24291	24270	24269	20434	20456	24287	25142	20455	25140	25141	25143	24286	24268	20486	24285	3206	24284
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are referred to it. The restricting of all specimens of *Inoceramus* to the one species does not affect the age determination of the Ninuluk formation, as the age is based on an association of faunas similar to the faunas in Canada, western United States, and England.

The species *Panope? dunveganensis* Warren and *Arctica? dowlingi* McLearn are also common in the Dunvegan formation of Canada. Imlay, in a written communication, 1953, further stated:

The occurrence of these species at the base of the Ninuluk formation shows that no part of it is older than the Cenomanian, provided the corresponding Dunvegan formation is not older than Cenomanian.

The age of the Dunvegan formation is based on the presence of the ammonite *Dunveganoceras*, in its highest beds and in the basal part of the overlying Kaskapau formation beneath beds of early Turonian age (Warren and Stelck, 1940, p. 149; McLearn 1945b). Furthermore the genus *Dunveganoceras*, including the same species as in Canada, occurs in Montana and Wyoming associated with other ammonites of late Cenomanian age beneath beds of earliest Turonian age (Cobban, 1953, p. 46, 47). Consequently, that part of the Dunvegan formation underlying the beds containing *Dunveganoceras* should correspond with the middle Cenomanian. Whether the formation includes beds of early Cenomanian age remains to be proven. In that regard Henderson (1954, p. 2282, 2286) states that some beds beneath the Dunvegan formation contain ammonites of Cenomanian age. However, if the Dunvegan formation does not include the earliest Cenomanian, then the Ninuluk formation, which contains the same pelecypod faunule, may not include the earliest Cenomanian either.

Eighty-one samples from beds of the Ninuluk formation were examined for microfossils; 29 samples, or nearly 36 percent, were barren. The fossils were identified by H. R. Bergquist (pl. 30). Concerning these fossils Bergquist states (written communication):

The fauna in the samples is very small, as only 8 species of Foraminifera and 1 species of charophyite oogonia were found. Three species of Foraminifera constitute the bulk of the fauna. One species, *Trochammina rutherfordi* Stelick and Wall, dominates the fauna and is common to very abundant in 25 samples and rare to very rare in 12. Second in significance is *Gaudryina canadensis* Cushman, although the occurrence of the species are exceeded by *Saccammina* n. sp. However, the latter is a long-ranging species found in nearly all the Cretaceous formations of northern Alaska, and as most of its occurrences in samples from the Ninuluk formation are very rare or rare, the species has no value for correlation. Additional species of Foraminifera include specimens of *Trochammina rainwateri* Cushman and Applin, which are common in 5 samples and rare to very rare in 2 others, and about 10 occurrences of a few other species in rare to very rare numbers. An exception is the common occurrence of *Bulimina* sp. in one sample. * * * Although all the species found in these samples from the Ninuluk formation also occur in older, Early Cretaceous formations in northern Alaska, only 2 species, *Trochammina rutherfordi* and *Gaudryina canadensis* are prominent. Because these two species are the dominant and often exclusive Foraminifera in the samples from the Ninuluk formation, and because they have the same status in samples from equivalent outcropping sections in other areas and from equivalent subsurface sections of the formation, I consider that they constitute a faunal zone that is more or less synonymous with Ninuluk formation. This faunal zone, the *Gaudryina canadensis-Trochammina rutherfordi* zone, is younger than and distinct from the *Verneuilinoides borealis* faunal zone of the upper part of the Torok formation and the Tuktu and Grandstand formations. Most of the species of the latter faunal zone do not range into the Ninuluk formation.

The above discussion shows that although the age of the beds cannot be determined exactly from the microfossils, the *Gaudryina canadensis-Trochammina rutherfordi* faunal zone is younger than the *Verneuilinoides borealis* faunal zone, which has been correlated with the early to middle Albian stage (see p. 236 and 242). There is no faunal evidence that beds of late Albian age ever were deposited in the Chandler River region; however, there is no apparent unconformity between beds of Early Cretaceous and Late Cretaceous age. The contact between the Ninuluk formation and older rocks was observed at numerous localities throughout the mapped area; in all occurrences the contact appears to be conformable. The upper contact with the Seabee formation is marked by a major unconformity. The degree of angularity is not consistent but is greatest in the southern part of the mapped area; it is 41° at the type locality for the Ninuluk formation.

COLVILLE GROUP

The Colville "series", named after the Colville River, was defined by Schrader (1904, p. 81–84) from exposures along the Colville River north of its junction with the Anaktuvuk River. Schrader concluded that these rocks are of Oligocene and Pliocene age. In their analysis of the early exploratory work in Naval Petroleum Reserve No. 4, Smith and Mertie (1930, p. 232–233) concluded that "* * * from the fossil evidence obtained in the apparent continuation of these rocks farther west * * *" at least the lower part of the Colville "series" is Late Cretaceous in age." The present evaluation of the microfauna and megafauna indicates the rocks defined by Schrader as Colville "series" are entirely of Late Cretaceous age.

The Colville "series" was redefined in 1951 by Gryc and others (p. 164–167) as the Colville group; the term "* * * applied to type exposures along the Colville River from approximately the junction with Prince Creek east and north to the 70th parallel." At that time the Colville group was subdivided into the nonmarine Prince Creek formation with the Tuluvak and Kogosukruk tongues, and the marine Schrader Bluff formation with three members, Seabee, Tuluga, and Sentinel Hill. Data obtained since 1951 has necessitated further changes of nomenclature within the Colville group. Whittington (1956, p. 249–253) redefined the Schrader Bluff formation to include the Rogers Creek, Barrow Trail, and Sentinel Hill members. He raised the former Seabee member to formational status (p. 246–249). The Ayiyak member of the Seabee formation was defined and described by Detterman (1956b, p. 253–254); the Shale Wall member (new) is named and defined in this paper. The designation of the Prince Creek formation with the two named tongues is unchanged.

The Colville group is confined to the northern foothills section of the Arctic Foothills province and adjoining parts of the Arctic Coastal Plain province. In the Chandler River region the group is not exposed south of lat 68°42′ N. along the Nanushuk River or south of 68°53′ N. near the Killik River. Thus, the strike of the southern boundary of the group is about N. 75° W., which is roughly parallel to that of the Nanushuk group. Elsewhere in northern Alaska, the Colville group has been mapped from the Sagavanirktok River west at least as far as the Utukok River; gross lithologic characteristics can be carried even farther. Beds with similar lithologic characteristics have been mapped as the upper part of the Ignek formation east of the Sagavanirktok River (Keller and others, 1961, p. 203) and as part of the Kukpowruk formation in the Utukok-Corwin area (Sable, 1956). Megafossils indicate that the upper part of the Ignek formation is at least in part equivalent to the Colville group.

The topographic expression of the Colville group is distinct and readily recognizable. In the southernmost exposures, mesas formed by the coarse conglomerate at the base of Prince Creek formation rise abruptly from the broad featureless lowlands underlain by the nonresistant shale of the Seabee formation. These mesas occur along the axes of Ayiyak Mesa, Niakogon, Racetrack, and Outpost Mountain synclines. The sandstone in the basal part of the Barrow Trail member of the Schrader Bluff formation is the ridge-forming unit in the Colville group. These sandstone beds form Outpost Mountain, and other topographic features in the northern part of the northern foothills section.

The rocks of the Colville group include conglomerate, sandstone, siltstone, shaly siltstone, clay shale, bentonite, and tuff. The primary distinguishing feature of the group is the abundance of tuff and tuffaceous material as detritus in the clastic rocks. Thick beds of bentonite are associated with the tuff and are also characteristics of the group. Minor constituents include limestone, both as beds and as concretions, coal, and low-grade oil shale. Ironstone occurs sporadically throughout the strata. Within the area of this report the Colville group attains a maximum thickness of about 4,890 feet; local variations in thickness of the group are common. The minimum thickness of strata measured was 3,085 feet.

SEABEE FORMATION

The Seabee formation, named after Seabee Creek, which flows into the Colville River at Umiat, was first described as a member of the Schrader Bluff formation by Gryc and others (1951, p. 166). The member was redefined by Whittington (1956, p. 246–249). During the fieldwork south of Umiat, a coarse clastic unit in the upper part of the formation was recognized and mapped. This unit was defined as the Ayiyak member of the Seabee formation by Detterman (1956b, p. 253–254). The lower unit is predominantly a shale sequence that has wide areal distribution in the Arctic Foothills and Coastal Plain provinces; it is readily recognized and mapped. The authors herein name this lower unit the Shale Wall member, after Shale Wall Bluff. The type section is designated as the west bank of the Nanushuk River at camp W–June 25–47 (fig. 44). The section is 1,385 feet thick and is exposed in an outcrop that extends for 2.5 miles along the river. The base of the type section is missing as the beds have been cut by a thrust fault; however, this is the thickest and most completely exposed section of the member.

SHALE WALL MEMBER

OCCURRENCE

The southernmost exposures of the Shale Wall member are 7 miles north of the Tuktu Escarpment. In the Nanushuk River area the southernmost exposure was mapped at lat 68°42′ N.; just east of the Killik River, exposures occur at lat 68°53′ N. The strike of the southern limit of the member is approximately N. 75°W., which is roughly parallel to the strike of the escarpment. Farther north the member is exposed in broad synclinal valleys between ridges of resistant strata of the Nanushuk group.

The Shale Wall member of the Seabee formation is a weak, incompetent clay shale unit that does not form ridges. The member occurs in ridges only where the resistant clastics of the Ayiyak member and the nonmarine Prince Creek formation overlie the shale; consequently, the member is not well exposed. Although there are few good exposures of the Shale Wall member, it is nonetheless a readily mappable unit. The broad featureless lowlands are cut by numerous small deeply entrenched streams that are a characteristic topographic expression of the member. Associated with this topographic expression are the peculiar light-gray surficial shale "boils" produced as a weathering phenomenon of the bentonitic clay shales. These shale

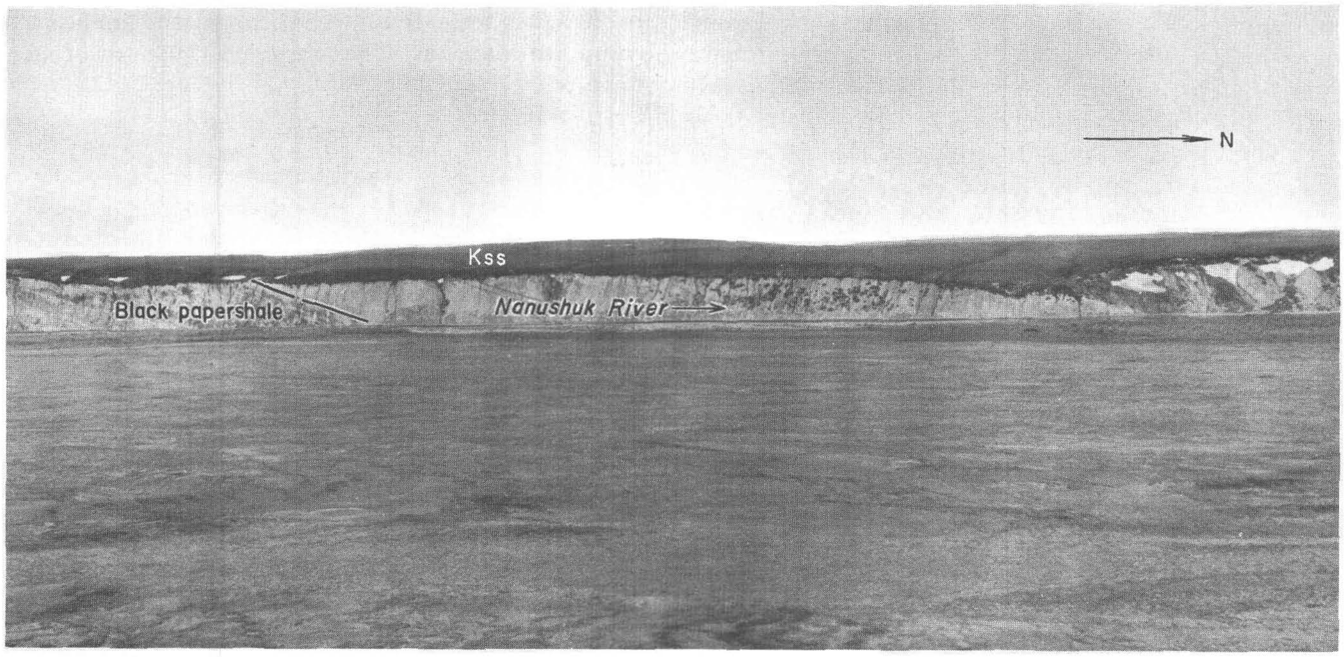

FIGURE 44.—Oblique view of part of the type locality of the Shale Wall member. The black paper shale is at the left. Kss, Shale Wall member. Photograph by U.S. Navy.

"boils" are found only in the shale of the Shale Wall member of the Seabee formation and appear as gray patches on photographs (fig. 45).

Beds of the Shale Wall member of the Seabee formation are not as structurally complex as are the beds of the underlying Nanushuk group. In most places the dip of the strata is less than 10°. Along the Nanushuk River, however, the folding was more severe and the strata dip as much as 31° N. on the flank of the faulted Shale Wall anticline and 27° S. at Rooftop Ridge. Most occurrences of the member are in synclines. The Seabee formation unconformably overlies the Ninuluk formation. The degree of angularity ranges from a few degrees to 41° at Ninuluk Bluffs.

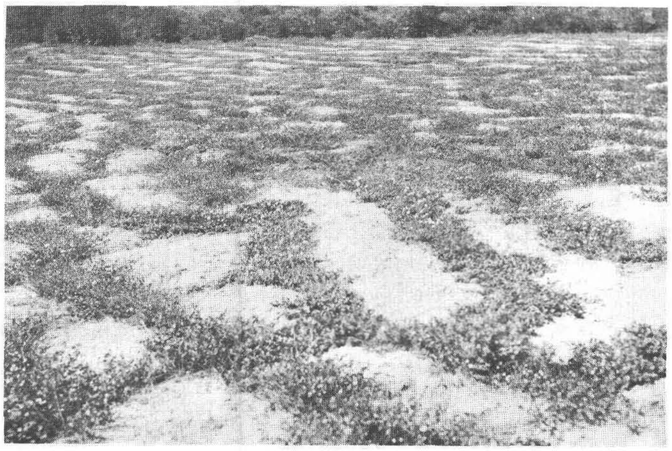

FIGURE 45.—Shale "boils" characteristic of the Shale Wall member in Lahnan syncline on the Chandler River.

CHARACTER AND THICKNESS

The type section of the Seabee formation is predominantly medium-gray, fissile to well-indurated, bentonitic clay shale. Laminated siltstone and shaly siltstone are generally intercalated with the clay shale (Whittington, 1956, p. 246–248). The type section of the formation differs from most of the outcrop sections of the member in that it contains several thick sandstone units. The sandstone is very fine to fine grained, medium light gray, calcareous, and laminated in part. Siltstone, shaly siltstone, and clay shale are intercalated with the sandstone.

The surface exposures of the Shale Wall member of the Seabee formation are predominantly soft, fissile to crumbly, dark blue-gray bentonitic clay shale. A black ferruginous paper shale, or low-grade oil shale, is present in most sections. The paper shale is soft, fissile, and noncalcareous and has a strong organic odor. Yellow, green, and white crystals commonly coat the surface of exposures. Dark blue-gray sublithographic limestone concretions, oblate in shape and ranging in size from 6 inches to 8 feet, are associated with the paper shale (fig. 46). These concretions are commonly fossiliferous. Fossils also occur in the paper shale beds.

Limestone concretions and beds are present in other parts of the member but are rarely fossiliferous. Intercalated with the clay shale are thin micaceous carbonaceous laminated siltstone and shaly siltstone beds.

Sandstone is a subordinate constituent in the surface section of the member, although several beds were mapped in the section at Ninuluk Bluffs. At that locality the sandstone is thin bedded to massive, very fine grained, dark neutral to yellow brown, calcareous, argillaceous, and in places laminated. Sandstone is not present in any of the other sections within the area but has been reported by Brosgé and Whittington (oral communication) in areas north of the Colville River.

Bentonite and bentonitic material are diffused throughout the member. Associated with the shale, it produces the peculiar shale "boils" that are a surface expression of the member. Generally the bentonite is in beds ¼ to ½ inch thick that occur every few feet in the more fissile parts of the section, but it is included also as a constituent of the rocks. The clay shale is more compact and less fissile where the bentonite is missing from the section. Thick beds of gray-green plastic bentonite are present in the mapped area. Two such beds, each 5 feet thick, were mapped on Fossil Creek, and beds 2 feet thick were noted in other sections.

A slight northeastward facies change is present in the Shale Wall member. Siltstone and shaly siltstone in the southwestern parts of the mapped area grade into limestone beds along the Nanushuk River. An important feature of the member is its rapid thickening in an easterly direction. West of the Chandler River the Shale Wall member is generally less than 400 feet thick; on the Chandler River 630 feet was inferred from poor exposures. The greatest amount of thickening is along the Nanushuk River, where 1,385 feet was measured at the type locality on the north flank of Shale Wall anticline; this section is incomplete, as the base of the member is faulted. Farther south along the Nanushuk River, at Rooftop Ridge, approximately 1,000 feet was measured, and an interval equivalent to about 800 feet of section is covered by tundra. If it is assumed that the beds in this interval are continuous, and all evidence indicates that they are, then the Rooftop Ridge section would be the thickest known section of the member. The thickening of the Shale Wall member of the Seabee formation is probably indicative of a structural basin east of the Nanushuk River, though it may represent a submarine-canyon deposit similar to the one present at Cape Simpson, Alaska (T. G. Payne, oral communication).

Two samples from the Shale Wall member of the Seabee formation were studied in thin section with the petrographic microscope to determine the size, shape, and abundance of the constituent minerals.

Field sample 47 ADt 98 (pl. 35, column 3) is a massive very fine grained hard laminated calcareous olive-gray sandstone from 220 feet below the top of the member at Ninuluk Bluffs. In thin section the grains are subround to round and about 0.05 mm in diameter. The matrix constitutes about 50 percent of the rock and is calcite and calcareous clay; much of the calcite is altered to siderite. Glass shards are common in the matrix. The sample contains quartz, calcite, glauconite, biotite, montmorillonite, muscovite, limonite, and carbonaceous material.

Field sample 52 ADt 63 is a thin-bedded hard dark-green siltstone from 110 feet above the base of the member on the Ayiyak River. Thin-section examination shows the round grains to be less than 0.05 mm in diameter. The matrix is siliceous and contains abundant glass shards. The constituent minerals include quartz, plagioclase, biotite, tourmaline, and montmorillonite.

GEOLOGIC SECTIONS

Seven columnar sections of the Shale Wall member of the Seabee formation are shown on plate 35. Columns 1 and 2 are from the southernmost exposures; columns 3, 4, 5, and 6 are roughly along a west to east line 20 to 25 miles north of columns 1 and 2. Column 7 is approximately in line with columns 1 and 2 but was placed next to column 6 to show the thickening of the formation along the Nanushuk River.

The Ayiyak River section (pl. 35, column 1; pl. 34, section 6) was measured in a series of cutbanks along the east side of the Ayiyak River, at camp D–June 26–52. A nearly complete section is exposed in a bluff about 1 mile downstream from camp. The strata are gently inclined into the east-plunging Canyon syncline.

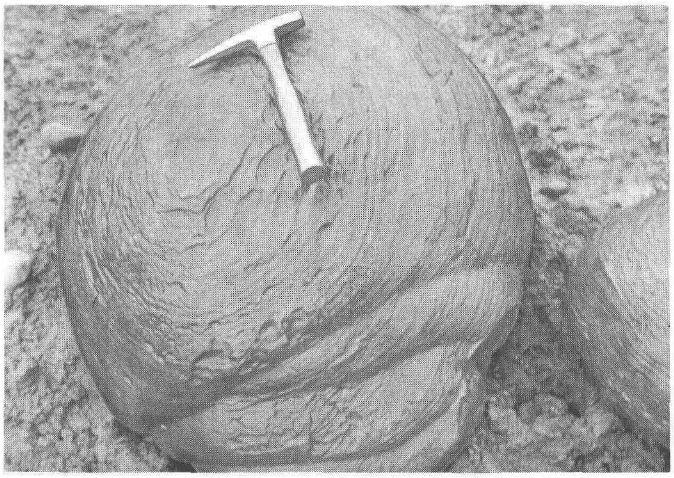

FIGURE 46.—Limestone concretion from the Shale Wall member.

Section of Shale Wall member, Seabee formation, on the Ayiyak River (pl. 35, column 1)

	Feet
Ayiyak member.	
Shale Wall member:	
1. Clay shale with 4- to 5-inch interbeds of siltstone and shaly siltstone; interbeds more numerous in upper part. Siltstone, dark-neutral and carbonaceous. Clay shale, dark blue-gray, crumbly to hard, somewhat ferruginous; few small limestone concretions. Scattered pelecypods in middle and upper parts (USGS Mesozoic locs. 24641, 26564, and 26565). In part rubble; computed thickness	285
2. Covered; computed thickness	15
3. Clay shale, black, and paper shale, soft, crumbly, ferruginous, with yellow-and-white salt efflorescence; yellow-green bentonite stringers in upper part and a 2-foot bed near base; few thin rusty-weathering limestone beds with cone-in-cone structure	100
	400
Unconformity.	
Ninuluk formation.	

The Tuluga River section (pl. 35, column 2; pl. 34, section 5) was measured in a cutbank 3 miles east of camp D–July 22–52. An additional 850 feet of section can be inferred for the interval between the exposed part and the uppermost beds of the Ninuluk formation.

Section of Shale Wall member, Seabee formation, along the East Fork Tuluga River (pl. 35, column 2)

	Feet
Ayiyak member.	
Shale Wall member:	
1. Clay shale, dark blue-gray, soft, crumbly, ferruginous; yellow-and-white salt efflorescence; few thin (½-in.) stringers of bentonite; occasional limestone and marcasite concretion. Few thin (1-in.) beds of gray siltstone interbedded with the shale	48
2. Clay shale, black, fissile, and soft ferruginous paper shale; yellow-and-white salt efflorescence and thin bentonite beds. Numerous limestone concretions as much as 8 ft in diameter throughout the shale section. Concretions contain many fossils, some with original shell material (USGS Mesozoic locs. 26567, 26557, and 26563). Nonfossiliferous concretions contain pebbles and wood fragments	40
3. Clay shale and bentonite float in partially exposed area; computed thickness	100
	188

The Colville River section at Ninuluk Bluffs (pl. 35, column 3; pl. 34, section 8) was measured in the bluffs on the south bank of the Colville River at Camp D–July 19–47. Rubble of the Ayiyak member was mapped on a ridge about 1 mile south of the river, but there is insufficient data to compute the stratigraphic interval between the two points. However, a maximum of 150 to 200 feet of additional section is indicated by projecting into Ninuluk Creek syncline the 4° S. dip measured in the bluff. The contact with the underlying Ninuluk formation is exposed in a gully near the south end of the bluffs (fig. 43). The angularity between the two formations was 41° at this point, the maximum observed in the mapped area. A difference of 34° was measured about 2 miles farther east where Ninuluk Creek has exposed beds near the contact.

Section of Shale Wall member, Seabee formation, at Ninuluk Bluffs on the Colville River (pl. 35, column 3)

	Ft.	In.
Shale Wall member:		
1. Sandstone, thin-bedded, very fine grained, silty, dark-neutral, poorly cemented, iron-stained	5	0
2. Clay shale, dark blue-gray, ferruginous, and interbedded shaly siltstone and siltstone	14	6
3. Clay shale, dark blue-gray, hard, brittle, ferruginous; one 4-inch bentonite bed and numerous thin stringers. A 5-ft. zone near base contains pelecypods and ammonites (USGS Mesozoic loc. 26555)	20	0
4. Clay shale with bentonite interbeds and few small limestone concretions containing pelecypods; in part rubble; computed thickness	89	0
5. Clay shale and black paper shale; ferruginous, fissile, soft, with thin bentonite stringers	45	9
6. Sandstone, thin-bedded, very fine grained, dark-neutral, and dark blue-gray silty clay shale; limestone concretions as much as 7 ft in diameter contain pelecypods (USGS Mesozoic loc. 26554)	10	9
7. Sandstone, massive, very fine grained, yellow-brown, hard, calcareous, argillaceous	4	0
8. Clay shale, laminated, light-brown, argillaceous, calcareous, with 1-in. sandstone interbeds	9	0
9. Sandstone, massive, very fine grained, brownish-gray, argillaceous, calcareous	2	6
10. Clay shale, thin sandstone interbeds	19	6
11. Clay shale, light- to dark-gray, crumbly, soft, with numerous small ironstone concretions	45	0
12. Covered; computed thickness	15	0
13. Clay shale	2	0
14. Bentonite		3
15. Clay shale	1	6
16. Clay shale, dark-gray, fissile, crumbly, ferruginous	18	9
17. Bentonite, gray-green, with large striated carbonate crystals	1	6

Shale Wall member—Continued	Ft.	In.
18. Clay shale, dark-gray, soft, crumbly, ferruginous; bentonite interbeds as much as 3 in. thick	40	0
	344	0

Unconformity.
Ninuluk formation.

The Fossil Creek section (pl. 35, column 4; pl. 34, section 9) was measured on the south flank of Outpost Mountain syncline in strata dipping 2° to 3° N. The beds are incompletely exposed in a series of stream cuts downstream from camp D–August 22–52. The upper part of the member is missing. The contact with the underlying Ninuluk formation is exposed, showing an angularity of 12° at this locality. In all, 370 feet was measured and inferred for this section.

Section of Shale Wall member, Seabee formation, on Fossil Creek (pl. 35, column 4)

Shale Wall member:	Feet
1. Clay shale. dark blue-gray to black; fissile, soft, very thin bedded paper shale, ferruginous in part; numerous thin beds and two 5-foot beds of yellow-green bentonite; limestone concretions as much as as 4 feet in diameter containing pelecypods and ammonites (USGS Mesozoic locs. 26570 and 26751)	210
2. Clay shale, bentonitic; rubble; computed thickness	130
3. Clay shale, dark blue-gray to black, fissile, soft; thin bentonite interbeds	30
	370

Unconformity.
Ninuluk formation.

The Chandler River section (pl. 35, column 5; pl. 34, section 10) was computed on the west side of the river 1 to 1.5 miles southwest of camp D–August 17–52. The Shale Wall member occurs predominantly as float and shale "boils" on the surface. About 628 feet was computed for this interval and may be in error by as much as 20 percent.

Section of Shale Wall member, Seabee formation, from Big Bend anticline on the Chandler River (pl. 35, column 5)

Ayiyak member.

Shale Wall member:	Feet
1. Siltstone, shaly siltstone, and clay shale rubble; computed thickness	20
2. Clay shale float, bentonitic; subordinate amounts of siltstone; computed thickness	390
3. Clay shale, dark blue-gray, fissile, soft; thin interbeds of bentonite and a few fossiliferous limestone concretions (USGS Mesozoic loc. 26569). In part rubble; computed thickness	58
4. Covered; computed thickness	115
5. Clay shale float; bentonitic; computed thickness	45
	628

Unconformity.
Ninuluk formation.

The type section for the Shale Wall member at Shale Wall Bluff on the Nanushuk River (pl. 27; pl. 35, column 6; pl. 34, section 3) was measured in a continuous exposure along the west bank of the river at camp W–June 25–47. The section is exposed along the stream for about 2.5 miles. The 1,385 feet of the member is almost completely exposed. Unit 2 was only partly exposed, but the computed stratigraphic interval is believed to be accurate. The remainder of the section was taped and sampled in 10-foot intervals.

The section is on the north flank of the faulted Shale Wall anticline. The inclination of the beds decreases toward the north from 31° to 10° N. Near the axis of the anticline the beds are folded into many small east-plunging drag folds with the strata inclined as much as 70°. Individual beds can be traced through these minor folds. The section is terminated at the south end by a thrust fault.

Type section of Shale Wall member, Seabee formation, at Shale Wall Bluff on the Nanushuk River (pl. 35, column 3)

Ayiyak member.

Shale Wall member:	Feet
1. Clay shale with few thin interbeds of shaly siltstone, siltstone, and very fine grained light-neutral sandstone. Shale well indurated, calcareous, ferruginous; contains abundant *Haplophragmoides rota* Nauss and rare *Trochammina ribstonensis* Wickenden	35
2. Clay shale, dark blue-gray, soft, ferruginous; abundant salt efflorescence, a few bentonite beds, and limestone concretions in lower part; in part rubble; computed thickness	330
3. Clay shale, dark blue-gray, hard, hackly-fracturing, calcareous; a few thin (3- to 6-in.) hard blue-gray limestone beds. Unit resistant to weathering and barren of microfossils	150
4. Clay shale, gray, soft, crumbly; very few limestone beds; abundant salt efflorescence; less resistant to weathering than unit 3; a few Foraminifera and Radiolaria	90
5. Clay shale, dark blue-gray, hard, hackly-fracturing, with a few thin limestone interbeds with cone-in-cone structures. Shell fragments of *Inoceramus* sp. in lower part and rare occurrences of radiolarians *Zonodiscus* sp. and *Dictyomitra* sp	320
6. Clay shale, medium dark-gray, soft, crumbly; many thin bentonite beds and small limestone concretions; no fossils; unit not resistant to weathering; has fetid odor	60
7. Clay shale and black paper shale; fissile, soft; many thin bentonite beds; calcareous; yellow salt efflorescence; strong fetid odor; thin brown limestone beds and small concretions. Radiolarians *Dictyomitra* sp. and *Cenosphaerea* sp. *abundant;* no Foraminifera; pelecypod *Inoceramus labiatus* Schlötheim common in upper part	170

Shale Wall member—Continued	Feet
8. Clay shale, dark blue-gray, hard, calcareous, resistant to weathering; many thin (1- to 4-in.) silty limestone interbeds and concretions; thin aragonite veins; many thin (½- to 1-in.) bentonite beds. Unit contains the Foraminifera *Trochammina ribstonensis* Wickenden, *Trochammina whittingtoni* Tappan, and *Gaudryina irenensis* Stelck and Wall; no Radiolaria; pelecypod collections from 20 feet above base (USGS Mesozoic loc. 26547) and 130 ft above base (USGS Mesozoic loc. 26548)	230
	1,385

Fault.

The Nanushuk River section south of Rooftop Ridge (pl. 35, column 7; pl. 34, section 4) was measured along the west bank of a small tributary that joins the Nanushuk River at Camp W–June 8–47. The stream cuts are just south of the main bluff formed by Rooftop Ridge. A 990-foot section was measured and inferred for the exposed part of the section; in addition, 800 feet was inferred for the unexposed part.

Section of Shale Wall member, Seabee formation, at Rooftop Ridge on the Nanushuk River (pl. 35, column 7)

Ayiyak member.

Shale Wall member:	Feet
1. Siltstone, shaly siltstone, and clay shale; rubble; computed thickness	30
2. Covered; computed thickness	800
3. Clay shale with interbeds of siltstone near top. Shale dark blue gray to black near base; moderately indurated to fissile; paper shale at base. Sublithographic limestone concretions from 2 in. to 4 ft in diameter common throughout; a few thin limestone beds near middle of unit; bentonite as thin stringers, with one 3-ft bed near base; yellow and white salt efflorescence common; a few marcasite concretions in upper part. Ferruginous weathering common to upper part. Fossiliferous in upper middle part (USGS Mesozoic loc. 26544 and 26545). In part rubble; computed thickness	440
4. Clay shale float, bentonitic, with few sublithographic limestone concretions containing pelecypods and ammonites; computed thickness	230
5. Clay shale, dark blue-gray to black; in part ferruginous; better indurated than upper part of section; thin bentonite stringers ½- to 1-in. thick; limestone as concretions and thin beds; thin veins of dogtooth spar common. In part rubble; computed thickness	290
	1790

Unconformity.

Ninuluk and Grandstand formations undifferentiated.

AGE AND CORRELATION

The Shale Wall member of the Seabee formation has a distinct and readily identifiable magafauna in the outcrop area. The fauna is commonly associated with the limestone concretions and beds in the fissile black paper-shale intervals and also, locally, in shaly siltstone and siltstone beds. When found in concretions the fossils are well preserved and still retain much of their original shell material. They form the center of the concretion that may contain hundreds of specimens. Not all the concretions are fossiliferous, however, and some have plant fossils rather than mollusks. The mollusks, where found in shale, are almost impossible to remove as the shale fractures into small fragments when disturbed. In the near-shore facies of the southwestern part of the mapped area only pelecypods were collected. Ammonites become more abundant in collections from areas farther north and east. In collections from the Nanushuk River both ammonites and pelecypods are present, but the ammonites are much more abundant than are the pelecypods.

Collections from the Shale Wall member of the Seabee formation were identified by George Gryc and D. L. Jones. The more common fossils, considered to be characteristic of the Seabee formation, are: *Inoceramus labiatus* Schlötheim, *I. cuvieri* Sowerby, *Watinoceras* sp., *Scaphites delicatulus* Warren, and *Borissjakoceras* n. sp. These fossils indicate a possible early Turonian age for the Seabee formation (Jones and Gryc, 1960, p. 160).

Concerning the age of the *Inoceramus*, D. L. Jones stated (written communication, 1957): "*Inoceramus labiatus* in England is found mainly in the zone of *Rhynochonella cuvieri* (Early Turonian) but is also present in the zone of *Terebratulina lata* (Late Turonian) * * *, thus, evidence indicates that *Inoceramus labiatus* is typically a Turonian species and perhaps is confined to lower Turonian beds."

Inoceramus cuvieri is found in several collections from the upper part of the member and also is present in the overlying Ayiyak member. In England, *I. cuvieri* ranges from Late Turonian to Early Santonian (D. L. Jones, oral communication).

One hundred and eighty-two samples collected from beds of the Shale Wall member were examined for microfossils; eighty-five samples were barren. Apparently the environmental conditions were not conducive to a widespread distribution of microfauna; this is particularly true of the deeper parts of the basin in the Nanushuk River area. An examination of the microfossil chart (pl. 30) will show that the preponderance of specimens is confined to the lower 400 feet of the member. In areas west of the Chandler River, the total thickness of the member is approximately 400 feet and most beds are fossiliferous throughout. However, in the thicker section, particularly in the Nanushuk River area, that part of the sequence above the basal

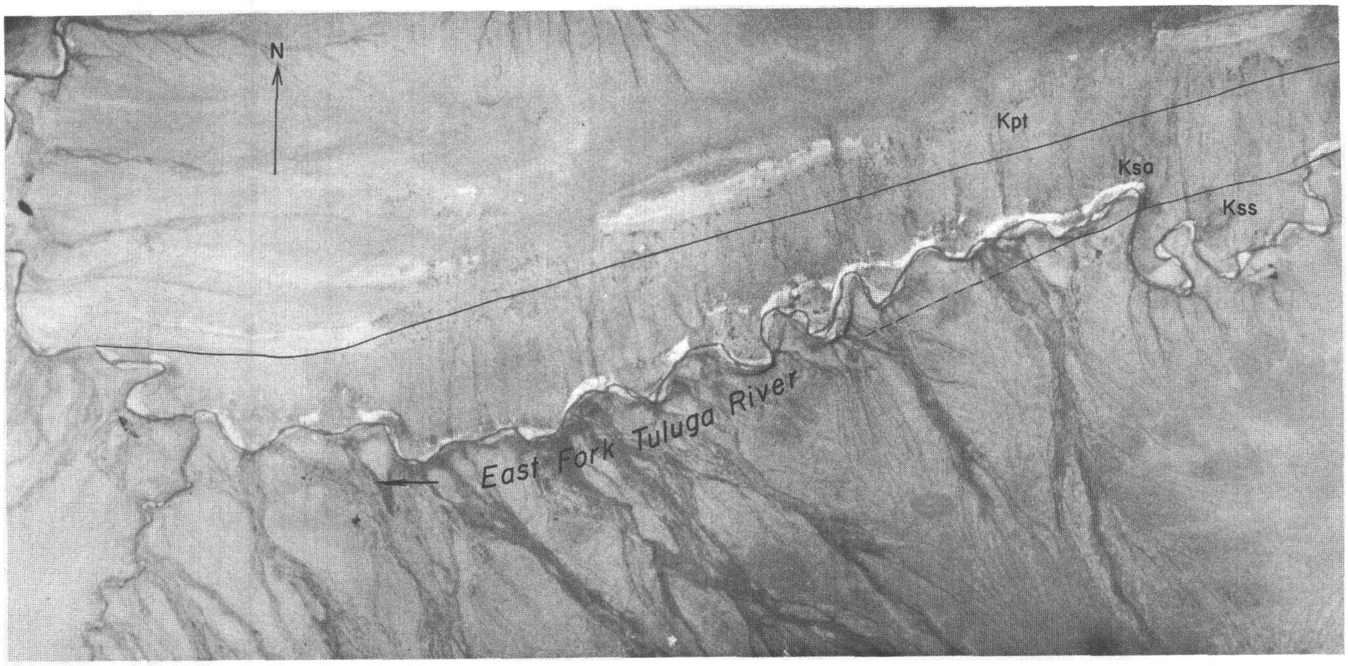

FIGURE 47.—Vertical view of part of the type locality of the Ayiyak member. Kpt, Tuluvak tongue; Ksa, Ayiyak member; Kss, Shale Wall member. Photograph by U.S. Navy.

400 feet is largely barren. This probably indicates that the environmental conditions presents during the deposition of the basal 400 feet were consistent over the entire area and also that these conditions were conducive to a widespread distribution of microfauna.

The microfossils were identified by H. R. Bergquist, who reported (written communication, 1956):

A few samples from the lower 300 or 400 feet of the member along the Colville River and along the Nanushuk River are barren, but 44 yielded a small formaminiferal fauna consisting mostly of crushed or flattened specimens of three species of *Trochammina* (*T. diagonis* (Carsey), *T. ribstonensis* Wickenden, and *T. whittingtoni* Tappan), *Gaudryina irenensis* Stelck and Wall, and *Saccammina* n. sp. One or more of these species were common to abundant in each of 17 samples. In most of the other fossiliferous samples in the collection more or less the same species occurred, but occurrences were scattered and the number of specimens were few.

Although present throughout the Colville group, specimens of *Haplophragmoides rota* Nauss are abundant only in the Ayiyak member of the Seabee formation. But the species occurred in 9 samples from beds of the Shale Wall member immediately below the Ayiyak member along the Nanushuk River and in two or three samples from Trouble Creek and was common in three samples from the Nanushuk River collection and abundant in one. Thus its distribution in those samples is similar to that in the Ayiyak beds. A few specimens of *Trochammina ribstonensis* were present in some samples. In 11 samples from the Webber collection from the Nanushuk River area the only fossils were pyritic casts of Radiolaria. Most of these are medially depressed, biconvex discoidal casts of *Zonodiscus* sp., but in two or three samples ribbed conical pyritic casts of *Dictyomitra cf. D. multicostata* Zittel were common to abundant.

The pyritic casts of *Zonodiscus* sp. are known to be limited to the Seabee formation and are not found in the rest of the Colville group, but other Radiolaria and all the Foraminifera found in the Chandler River samples range throughout the Colville group. No one of these species can therefore be used for correlation purposes, but from observations of many surface and subsurface samples throughout northern Alaska it is known that the assemblage found in the Chandler River samples is indigenous to the Seabee formation. From other species in other collections a Turonian age of the fossils is indicated.

AYIYAK MEMBER

OCCURRENCE

The Ayiyak member of the Seabee formation is named after the Ayiyak River, along which the member is exposed at a number of localities. The type section is on the north bank of the East Fork Tuluga River near camp D–July 22–52 (fig. 47).

The southernmost exposures of the Ayiyak member are at the same localities as exposures of the Shale Wall member of the Seabee formation. The two units commonly are exposed at the same localities. The member is usually exposed under the conglomerate and above the Shale Wall member in the synclinal mesas capped by resistant basal conglomerate of the Tuluvak tongue of the Prince Creek formation. At some places the conglomerate has been eroded and the Ayiyak member forms the ridges; this has happened at Niakogon Buttes, where the cap rock is sandstone of the Ayiyak member. The member is generally confined to a narrow band between the featureless lowlands underlain by shale of the Shale Wall member and the ridges and mesas of the Prince Creek formation. The Ayiyak member has not been mapped north of lat 69°12′ N.; beds that may be in part equivalent to the Ayiyak member occur north of the Colville River at Umiat (W. P. Brosgé and C. L. Whittington, oral communication) but have been mapped as part of the Seabee formation, undifferentiated.

CHARACTER AND THICKNESS

The Ayiyak member is primarily composed of greenish-brown siltstone and shaly siltstone. Sandstone, thin- to medium-bedded, fine-grained, red-brown to greenish-gray is present in the upper 100 feet of the member in the southwestern part of the mapped area. The amount of coarse clastic material increases toward the Nanushuk River, where thin lenticular beds of black chert- and white quartz-pebble conglomerate occur. The sandstone associated with the conglomerate is heavy bedded to massive, medium to coarse grained, salt and pepper to medium yellow red. A medium-grained chocolate-brown sandstone with specks of yellow tuffaceous material is commonly found in the upper 20 to 30 feet of the member. Minor constituents include thin, rusty-brown-weathering limestone beds and concretions, clay shale, and ironstone concretions. Some of the limestone beds are fossiliferous. Bentonitic material was observed only in the section on the Nanushuk River at the Shale Wall anticline. A minor amount of tuffaceous material is also present, mainly in the chocolate-brown sandstone.

At the type locality the Ayiyak member is approximately 360 feet thick. The lower 230 feet are greenish-gray siltstone and shaly siltstone with a few intercalated sandstone beds. The sandstone is thin bedded, very fine grained, and dark neutral. Limestone concretions occur at 110 and 160 feet above the base. Clay shale and a few limestone beds occur from 230 to 290 feet above the base. The upper 90 feet is predominantly a sandstone section with interbeds of clay shale, shaly siltstone, and siltstone.

A facies change is present in the Ayiyak member, but the direction of change is opposite to that of the older units of the Cretaceous, including the Shale Wall member. In older units the most marked change was in a north to northeasterly direction, with the sediments becoming more marine in that direction. The Ayiyak member appears more marine in the southwestern part of the area with an increase in coarse clastic near-shore material in the Nanushuk River region. This might indicate a change in source areas, but more likely it indicates a change in the configuration of the basin. In either case an unconformity could exist between the two members, but wherever they were exposed the contact appears to be conformable, as does the contact with the overlying Prince Creek formation. The thickness of the member is fairly consistent across the area, although the sections along the Nanushuk are slightly thinner and are also the ones in which the coarse clastics increase.

One field sample (52 ADt 46, pl. 35, column 1) from the Ayiyak member was studied microscopically to determine the size, shape, and abundance of the constituent minerals. The specimen, from 50 feet below the top of the member, is a fine-grained hard calcareous limonitic sandstone. In thin section the grains are subround, less than 0.1 mm in diameter, and predominantly of one size. The matrix is a calcareous clay with considerable limonite. The constituent minerals are: quartz, 46 percent; chert, 19 percent; calcite, 17 percent; plagioclase, 1 percent; biotite, 6 percent; limonite, 5 percent; carbonaceous material, 2 percent; rock fragments, 4 percent. All percentage figures are based on a grain count of 100.

GEOLOGIC SECTIONS

The Ayiyak River section (pl. 35, column 1; pl. 34, section 6) was measured in a series of river cutbanks and ridges on the south flank of Ayiyak Mesa syncline, between the mouth of Wolverine Creek and camp D–June 26–52. The strata dip 5° to 6° N.

Section of Ayiyak member, Seabee formation, along the Ayiyak River upstream from its junction with Wolverine Creek (pl. 35, column 1)

	Feet
Tuluvak tongue.	
Ayiyak member:	
1. Sandstone, fine- to medium-grained, thin- to medium-bedded, dark yellow-red, slabby	10
2. Sandstone, thin-bedded, very fine grained, dark yellow-brown; weathers rusty brown; calcareous. Interbeds of siltstone, shaly siltstone, and clay shale; rusty-weathering thin limestone. Fossils scattered in lower part (USGS Mesozoic loc. 26538). Mostly rubble; computed thickness	80
3. Covered; siltstone, shaly siltstone, and clay shale talus; computed thickness	110
4. Sandstone, siltstone, shaly siltstone and clay shale. Sandstone fine grained, greenish to yellow red; thin interbeds of sandstone in the shale	30
5. Covered; sandstone, siltstone, and clay shale rubble; computed thickness	110
6. Sandstone, thin-bedded, fine-grained, greenish-gray; interbeds of shaly siltstone and clay shale	30
	370
Shale Wall member.	

The Tuluga River section (pl. 27; pl. 35, column 2; pl. 34, section 5) was measured in a series of almost continuous stream cuts along the north bank of the East

Fork Tuluga River near camp D–July 22–52. The cutbanks extend about 4.2 miles along the stream. This is the type locality for the Ayiyak member of the Seabee formation. Except for two small partly covered areas, 360 feet of the member is completely exposed.

Type section of Ayiyak member, Seabee formation, on the East Fork Tuluga River (pl. 35, column 2).

Tuluvak tongue.

Ayiyak member:	Feet
1. Sandstone, medium-bedded, fine-grained, clean, somewhat tuffaceous, light-tan	10
2. Siltstone and sandstone; medium-bedded, fine-grained, tan to light chocolate-brown, clean, noncalcareous; rubble; computed thickness	20
3. Siltstone and shaly siltstone; abundant ironstone concretions	8
4. Sandstone, medium-bedded, very fine grained, dark-neutral, crossbedded, ripple-marked; worm trails, one fossil (USGS Mesozoic loc. 26539)	7
5. Sandstone, siltstone, shaly siltstone, clay shale, and ironstone concretions; sandstone thin bedded, very fine grained, dark-neutral	35
6. Shaly siltstone, siltstone, and clay shale, interbedded; several 1-ft. limestone beds, somewhat tuffaceous; in part rubble; computed thickness	65
7. Shaly siltstone, and thin siltstone; greenish-gray; worm tubes, few fossils (USGS Mesozoic loc. 26540)	60
8. Shaly siltstone and siltstone; few limestone concretions as much as 3 ft. in diameter	75
9. Shaly siltstone, siltstone, and a thin very fine grained dark-neutral sandstone	25
10. Siltstone, shaly siltstone, and a few thin sandstone beds	55
	360

Shale Wall member.

The Chandler River section (pl. 35, column 5; pl. 34, section 10) was measured on the side of a mesa 2.5 miles southwest of camp D–August 17–52.

Section of Ayiyak member, Seabee formation, on the Chandler River south of Big Bend anticline (pl. 35, column 5)

Tuluvak tongue.

Ayiyak member:	Feet
1. Sandstone, thin-bedded, very fine grained, greenish-yellow	10
2. Sandstone, conglomeratic, siltstone, and shaly siltstone; sandstone medium bedded, medium grained, medium yellow red, with black chert pebbles as much as ¼ inch long; in part rubble; computed thickness	75
3. Sandstone, siltstone, and shaly siltstone rubble; sandstone medium bedded, fine grained, light tan to yellow red; computed thickness	125
4. Sandstone, ledge-forming, medium- to heavy-bedded, medium- to coarse-grained, light yellow-red; siltstone and shaly siltstone below sandstone; rubble; computed thickness	25

Ayiyak member—Continued	Feet
5. Covered; sandstone, siltstone, and shaly siltstone; rubble; computed thickness	105
6. Sandstone, thin-bedded, very fine grained, greenish-brown; few plant fossils; rubble; computed thickness	10
	350

Shale Wall member.

The Nanushuk River section (pl. 35, column 6; pl. 34, section 3) at Shale Wall Bluff is continuously exposed in a series of river bluffs on the west bank of the river, about 1 mile downstream from camp W–June 25–47.

Section of Ayiyak member, Seabee formation, at Shale Wall Bluff, Nanushuk River (pl. 35, column 6)

Tuluvak tongue.

Ayiyak member:	Feet
1. Sandstone, massive, very fine to fine-grained, medium- to light-neutral, argillaceous, well-indurated to friable	25
2. Siltstone, shaly siltstone, clay shale, and a few ironstone concretions	30
3. Sandstone, similar to unit 1, except coarser grained	35
4. Clay shale; interbeds of sandstone and siltstone; thin bentonite stringers in clay shale	32
5. Sandstone, thin- to medium-bedded, very fine grained, medium- to dark-gray, laminated, crossbedded, silty, argillaceous; lenses of siltstone and shale; a thin coquina of pelecypod shell fragments near top (USGS Mesozoic loc. 26533)	32
6. Shaly siltstone, dark-neutral, hackly-fracturing, calcareous	15
7. Sandstone, lenticular, very fine grained, silty	3
8. Clay shale, and shaly siltstone, interbedded with thin very fine grained dark-neutral sandstone near base	60
9. Clay shale, shaly siltstone, and siltstone, interbedded with sandstone at base; bentonite and a thin coal stringer	43
	275

Shale Wall member.

The Nanushuk River section (pl. 35, column 7; pl. 34, section 4) is partly exposed in the side of a mesa about 1 mile southwest of camp W–June 8–47. The computed thickness may be in error by 15 percent.

Section of Ayiyak member, Seabee formation, south of Rooftop Ridge on the Nanushuk River (pl. 35, column 7)

Tuluvak tongue.

Ayiyak member:	Feet
1. Sandstone, medium- to heavy-bedded, fine- to coarse-grained; conglomeratic; few chert and quartz pebbles; salt-and-pepper to yellow-red and chocolate-brown; ironstone concretions, mud lumps, and plant fossils common; interbedded greenish-gray siltstone near middle of unit. In part rubble; computed thickness	30

Ayiyak member—Continued	Feet
2. Shaly siltstone and limestone; chocolate-brown, thin, hard, brittle; rubble; computed thickness	20
3. Covered; computed thickness	30
4. Sandstone and siltstone; rubble; computed thickness	10
5. Covered; computed thickness	20
6. Sandstone, conglomeratic, medium-bedded, medium- to coarse-grained, salt-and-pepper to yellow-red; black chert and white quartz pebbles ¼ inch or less in length; rubble; computed thickness	10
7. Covered; subordinate siltstone, sandstone, and shaly siltstone float; few ironstone concretions; computed thickness	145
8. Sandstone, conglomeratic, massive; fine- to coarse-grained in upper part, lower part fine-grained; salt-and-pepper to light-buff and greenish-yellow; soft, friable, clean; pebbles ¼ inch long in lenses; ironstone concretions common. Greenish-yellow sandstone is fossiliferous (USGS Mesozoic loc. 24632)	35
	300

Shale Wall member.

AGE AND CORRELATION

Megafossils were collected at 12 localities from beds of the Ayiyak member. The fossils are generally poor, consisting of internal and external molds. Some of the fossils are present only in the more shaly parts of the stratigraphic sequence, while others are found only in the coarse clastic parts of the member. The best preserved and only diagnostic fossils identified were large specimens of *Inoceramus cuvieri* Sowerby; this species was identified by R. W. Imlay from a collection (USGS Mesozoic loc. 24632) from the coarse clastic part of the member along the Nanushuk River, south of Rooftop Ridge. Concerning this fossil he reported (written communication, 1953): "The *I. cuvieri* is reported to range from the zone of *Terebratulina lata* to the zone of *Micraster coranguinum* inclusive; i.e., middle Turonian through Coniacian". *Inoceramus cuvieri* was associated with *I. labiatus* in a few collections from the upper part of the Shale Wall member but occurs alone in beds of the Ayiyak member.

The megafauna may indicate almost continuous deposition during Seabee time. Fossils from the Shale Wall member are of early Turonian age, and the fauna present only in the Ayiyak member are middle Turonian through Coniacian in age. The Ayiyak member cannot be correlated with other formations in Alaska, because the diagnostic fossil *Inoceramus cuvieri* Sowerby has not been reported previously from any other part of Alaska.

Twenty-nine samples of microfossils were collected from beds of the Ayiyak member. The fossils were studied by H. R. Bergquist (written communication, 1956), who reported as follows on the fossils.

A small microfauna of a few species of Foraminifera and one species of Radiolaria was found in the samples that were collected by Detterman, Webber, and Bickel from the Ayiyak member of the Seabee formation in the Chandler River region. Two species in the collection that are characteristic of the Ayiyak member and are apparently entirely restricted to these beds are *Pseudoclavulina hastata* (Cushman) and *Arenobulimina torula* Tappan. Almost all the specimens of *Arenobulimina torula* are crushed, and only rare specimens occurred in a few samples; broken and entire specimens of *Pseudoclavulina hastata* were common to abundant in four samples, and one or two specimens occurred in each of 14 other samples. *P. hastata* is the only species of *Pseudoclavulina* found in Mesozoic sedimentary rocks of northern Alaska and is easily recognized, even when in fragments.

Of the 29 samples in the collection, 24 were fossiliferous, and flattened or crushed specimens of *Haplophragmoides rota* Nauss were found in all but one. This species is very abundant in 9 samples, abundant in 3, and common in 6. Thus its significance is in its abundance and frequency in the Seabee formation, as the species ranges throughout the Colville group. In Canada, however, the species has been reported only from the Belly River formation * * * which is of Senonian age and probably equivalent to the upper part of the Colville group in Alaska.

Two other Foraminifera that were found in several samples are *Trochammina ribstonensis* Wickenden and *Gaudryina irenensis* Stelck and Wall. Flattened specimens of the former occurred in more than half the samples; they were abundant in one sample and common in three. Specimens of *Gaudryina irenensis* occurred in 6 samples from the area east of the Tuluga River and in a few other scattered samples. Most of the specimens of *G. irenensis* are flattened or crushed and twisted, but a few are cylindrical and fairly well preserved. Specimens of *Saccammina lathrami* Tappan, a long-ranging species, occur in scattered samples. One or two specimens each of three or four other nondiagnostic Foraminifera were found in scattered occurrences.

Two samples yielded one specimen each of a medially depressed biconvex pyritic disc. These are the pyritic casts of a Radiolaria (*Zonodiscus* sp.) which occurs in several samples from the Shale Wall member.

Ten of the samples are from beds at the type locality; 4 from the upper 190 feet of the section were barren. The samples from the basal 170 feet of the member contained the following microfossils: *Haplophragmoides rota* Nauss, rare to common in 6; *Gaudryina irenensis* Stelck and Wall, rare to common in 6; *Pseudoclavulina hastata* (Cushman) rare in 5; *Trochammina ribstonensis* Wickenden, common to abundant in 3; and one specimen of the Radiolaria (*Zonodiscus* sp.) in one sample. All the fossils from the Ayiyak member are shown on plate 30.

PRINCE CREEK FORMATION

The Prince Creek formation was defined by Gryc and others (1951, p. 166–167). By definition the formation is nonmarine and "* * * includes all the non-

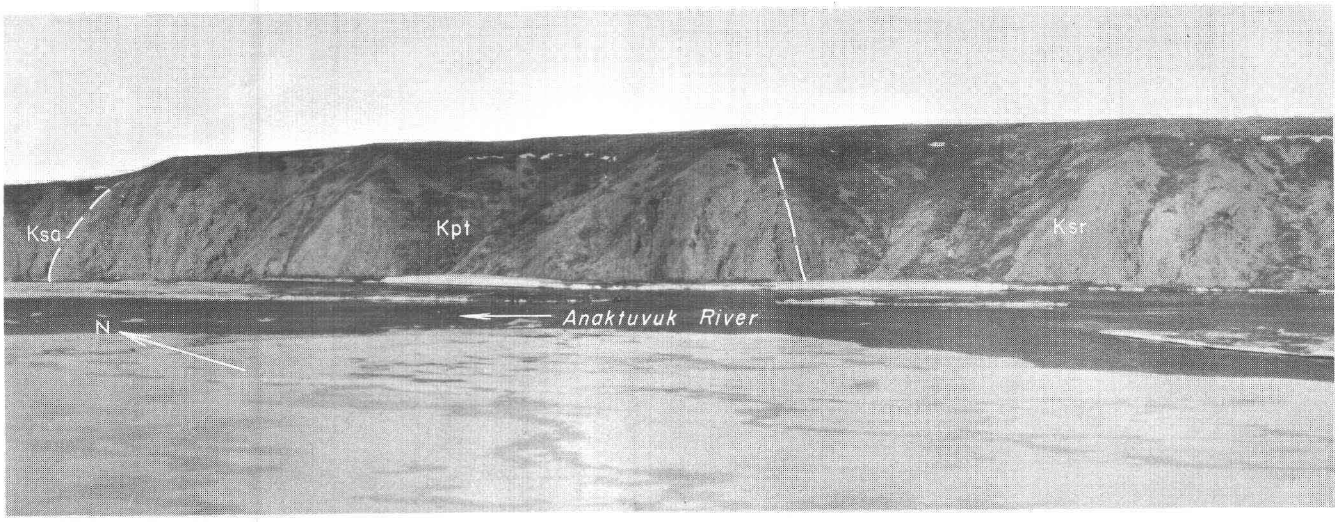

FIGURE 48.—Oblique view, looking east-northeast, of part of Schrader Bluff, showing the type locality of the Tuluvak tongue and part of the type locality of the Schrader Bluff formation; Ksr, Rogers Creek member; Kpt, Tuluvak tongue; Ksa, Ayiyak member. Photograph by U.S. Navy.

marine beds above the top of the Niakogon tongue of the Chandler formation * * *." The type locality is 9 miles upstream from Umiat on Prince Creek, a tributary of the Colville River. The formation was subdivided into the Tuluvak tongue and the Kogosukruk tongue.

The Tuluvak tongue was named after Tuluvak Bluffs, which are along the Chandler River between lat 69°10′ N. and lat 69°15′ N. The section exposed at this locality was designated the type section by Gryc and others (1951). A better section is exposed at Schrader Bluff (fig. 48) on the northeast bank of the Anaktuvuk River 5 miles upstream from the mouth of the Tuluga River, and the Schrader Bluff section is herein established as a reference locality of the Tuluvak tongue. The Tuluvak is, at least in part, the age equivalent of the Rogers Creek and Barrow Trail members of the Schrader Bluff formation.

The Kogosukruk tongue was also defined by Gryc and others (1951, p. 166–167) and was named after the Kogosukruk River, along which it is well exposed. The Kogosukruk tongue is the age equivalent of the marine Sentinel Hill member of the Schrader Bluff formation. The two tongues are readily recognized and mapped as individual units. In all exposures within the mapped area the two tongues are separated by a section of marine Schrader Bluff formation.

TULUVAK TONGUE

OCCURRENCE

The southernmost exposures of the Tuluvak tongue are in May Creek syncline at lat 68°43′ N. in the eastern part of the mapped area. North of May Creek syncline the tongue is more widespread; it is present in structural lows along Ayiyak Mesa and Niakogon synclines and in the structural basin at Racetrack syncline. The tongue is not present in any anticlines south of lat 69° N. and is not extensively present in anticlines north of that latitude except at Schrader Bluff.

Mesas and ridges formed by the resistant basal conglomerate of the tongue rise above the featureless lowlands underlain by the nonresistant shale of the Shale Wall member along the Ayiyak Mesa and Niakogon synclines (fig. 49). In general these mesas have a gentle lower slope formed by sandstone of the Ayiyak member; near the top the basal Tuluvak conglomerate rises nearly vertically for 30 to 60 feet. These ridges and mesas are a topographic expression of the tongue that make it readily identifiable. West of the Chandler River the ridges are relatively small; farther east the belt underlain by beds of the Tuluvak tongue is much wider, owing to regional east plunge. In general the tops of the ridges have very low relief; the beds in the mesas dip less than 4°.

In addition to those in the synclinal ridges and mesas, there are exposures of the Tuluvak tongue in isolated cutbanks along small streams that transect the ridges and mesas. Only the more resistant sandstone and conglomerate beds are exposed in the interstream areas.

CHARACTER AND THICKNESS

At the type locality at Schrader Bluff the Tuluvak tongue is 575 feet thick. Sandstone constitutes about 50 percent of the section; it is predominantly thin to medium bedded, fine grained, and light to medium gray The color may range from pale yellow to ash white and light brownish gray, largely depending on the amount

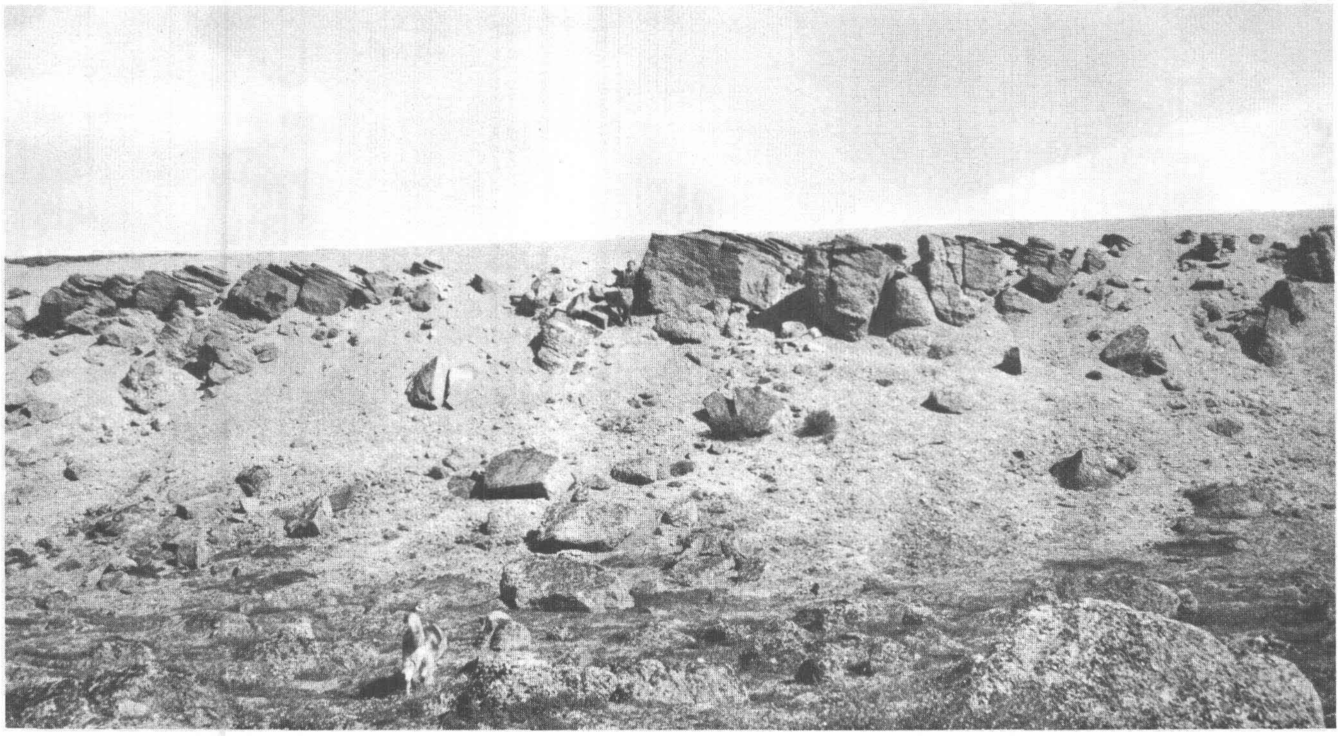

FIGURE 49.—Basal conglomerate of the Tuluvak tongue near Ayiyak Mesa. This conglomerate caps the mesas in the Chandler River region.

of tuffaceous material present. Some coarse-grained salt-and-pepper sandstone is present also. Coal fragments occur in some of the lower sandstone beds. The massive basal conglomerate characteristic of the exposures in the southern part of the mapped area is represented by a few scattered black chert and white quartz pebbles in a fine-grained sandstone. As much as 15 feet of basal conglomerate was measured on the south flank of Outpost Mountain, 6 miles southwest of Schrader Bluff.

Minor amounts of clay shale and claystone are present in the section. The clay shale is thin bedded to fissile and gray to black; some is bentonitic. Other subordinate constituents include shaly siltstone, green to gray siltstone that is commonly tuffaceous and micaceous, coal, tuff and bentonite. Ironstone nodules occur in sandstone and siltstone beds. The sandstone from unit 43 has a strong petroleum odor on newly fractured surfaces, and a brown stain was noted on the surface of the rock. Plant fragments are common throughout.

The type section at Schrader Bluff is in the northern part of the mapped area and is representative of the northerly facies. The Ayiyak River section near the mouth of Wolverine Creek can be considered characteristic of the southern coarser facies. This section is incompletely exposed but has a computed thickness of 822 feet. The unexposed part is probably composed of shale, siltstone, and coal beds similar to those of the type section. Massive conglomerate and sandstone constitute the bulk of the exposures. The basal conglomerate caps the mesas and synclinal ridges in the southern area; it is 40 feet thick along the Ayiyak River and consists of pebbles and cobbles, as much as 6 inches in length, with a coarse-grained salt-and-pepper sandstone matrix. The rock fragments are 60 percent black and gray chert and 40 percent white quartz and gray quartzite. The basal conglomerate is separated by 17 feet of shaly siltstone, siltstone, coal, and bentonite from another 25 feet of massive grit to pebble conglomerate (unit 14). The constitutents of this unit are black and gray chert and white quartz. Two other conglomerate beds occur above this; one is near the middle of the section (unit 8) and the other, a 40-foot section (unit 3) of grit- and pebble-size fragments with 90 percent black chert and 10 percent white quartz, is near the top. The associated sandstone is predominantly medium bedded, medium to coarse grained, and salt and pepper to medium yellow red. A thin-bedded dark chocolate-brown sandstone is near the top of the section. The sandstone is commonly crossbedded and friable. Other sections from the southern part of the mapped area are similar to the Ayiyak River section.

One section at Tuluvak Bluffs, along the Chandler River, is on the same structure (pl. 1) as the Schrader Bluff section; it is predominantly clay shale, coal, and bentonite. Only minor amounts of sandstone are present in the upper part; it is thin bedded, very fine grained, light gray to pale yellow red, and tuffaceous. The conglomerate is restricted to a 1-foot bed that contains black chert granules.

One sample of sandstone (52 ADt 81) from the Tuluvak tongue was examined microscopically. The buff very fine grained hard clean sandstone is from 580 feet above the base of the tongue along the South Fork Ninuluk Creek.

In thin section the grains are subround to round and less than 0.1 mm in diameter. A siliceous matrix constitutes about 10 percent of the rock. The constituent minerals are: quartz, 52 percent; chert, 28 percent; calcite, 2 percent; chlorite, 2 percent; biotite, 10 percent; carbonaceous material, 2 percent; and rock fragments, 4 percent. All percentages are based on a grain count of 100.

GEOLOGIC SECTIONS

Sections of the Tuluvak tongue are included on plate 36 in columns 1, 2, 3, 5, 6, 7, and 8. Sections shown in columns 1, 2, and 3 are from the southern part of the area.

The Ninuluk Creek section (pl. 36, column 1) was measured on ridges about 1 mile east of the South Fork Ninuluk Creek and about 10 miles west of camp D–June 26–52. The section was computed to be 760 feet thick, but only the more resistant sandstone and conglomerate beds are exposed on the south flank of Niakogon syncline. The total thickness may be in error by as much as 10 percent.

Incomplete section of Tuluvak tongue, Prince Creek formation, on the South Fork Ninuluk Creek (pl. 36, column 1)

	Feet
Tuluvak tongue:	
1. Conglomerate, grit to pebble; 70 percent black and gray chert, 30 percent white quartz; all well rounded, poorly cemented; minor amount of tuffaceous rock fragments; weathers light tan; in part rubble; computed thickness	30
2. Sandstone, medium-bedded, very fine grained, light-tan to medium-green, hard, brittle; somewhat tuffaceous; little siltstone; few plant fragments; rubble; computed thickness	30
3. Covered; computed thickness	40
4. Sandstone, medium- to coarse-grained, salt-and-pepper to medium yellow-red; weathers brown; rubble; computed thickness	15
5. Covered; computed thickness	45
6. Sandstone, medium-bedded, very fine grained, light-gray to tan, hard, brittle; few chert and quartz pebbles; plant fragments; somewhat tuffaceous; minor amount of siltstone; rubble; computed thickness	30
7. Covered, computed thickness	180
8. Sandstone, thin- to medium-bedded, medium- to coarse-grained, light yellow-red; rubble; computed thickness	20
Tuluvak tongue—Continued	
9. Covered; computed thickness	340
10. Conglomerate with salt-and-pepper sandstone lenses. Conglomeratic constituents predominantly black and gray chert and minor white quartz that are grit to pebble size and subangular to subround; crossbedded; moderately cemented; in part rubble; computed thickness	30
	760

Ayiyak member.

The Ayiyak River section (pl. 36, column 2; pl. 34, section 6) was computed and measured along the east bank of the Ayiyak River near its junction with Wolverine Creek. The section is about 822 feet thick and probably represents the complete Tuluvak tongue at this locality; it is on the south flank of Ayiyak Mesa syncline in beds that dip 3° to 6° N. The beds are moderately well exposed.

Section of Tuluvak tongue, Prince Creek formation, on the Ayiyak River near its junction with Wolverine Creek (pl. 36, Column 2)

	Ft.	In.
Tuluvak tongue:		
1. Sandstone, medium-bedded, fine-grained, light-gray to tan, clean, hard, brittle	10	0
2. Siltstone and sandstone; medium-bedded, medium- to coarse-grained, salt-and-pepper to dark-chocolate-brown; tuffaceous material in dark sandstone	10	0
3. Conglomerate; grit to ½-in. pebbles, 90 percent black chert, 10 percent white quartz and tuffaceous rock fragments, all well-rounded	40	0
4. Sandstone, medium- to thick-bedded, coarse-grained, salt-and-pepper; in part rubble; computed thickness	20	0
5. Covered; computed thickness	70	0
6. Siltstone and sandstone; medium-bedded, medium- to coarse-grained, salt-and-pepper to medium yellow-red; rubble; computed thickness	20	0
7. Covered; computed thickness	170	0
8. Sandstone, conglomeratic, with chert and white quartz pebbles, and medium-bedded crossbedded coarst-grained salt-and-pepper clean friable sandstone; in part rubble; computed thickness	40	0
9. Covered; computed thickness	110	0
10. Siltstone and shaly siltstone rubble; computed thickness	30	0
11. Covered; computed thickness	130	0
12. Sandstone, siltstone, and shaly siltstone rubble; sandstone fine grained, medium yellow red; computed thickness	20	0
13. Covered; computed thickness	70	0
14. Conglomerate; grit to pebble, black and gray chert and white quartz; sandstone lenses fine to medium grained, salt and pepper	25	0
15. Siltstone and shaly siltstone, thin-bedded, gray to black	10	0

Tuluvak tongue—Continued	Ft.	In.
16. Coal	0	4
17 Siltstone, shaly	5	0
18. Coal	1	6
19. Bentonite	0	2
20. Conglomerate; coarse salt-and-pepper matrix, with pebbles and cobbles as much as 6-in. long; 60 percent black and gray chert, 40 percent white quartz and gray quartzite; iron-stained	40	0
	822	0

Ayiyak member.

The Tuluga River section (pl. 36, column 3; pl. 34, section 5) was measured on the east side of the East Fork Tuluga River, between camps D–July 19–52 and D–July 22–52; it is on the south flank of the Ayiyak Mesa syncline in beds dipping 7° to 13° N. The section is exposed in the stream bank and on ridges just east of the river;

Incomplete section of Tuluvak tongue, Prince Creek formation, on the East Fork Tuluga River (pl. 36, column 3)

Tuluvak tongue:	Ft.	In.
1. Sandstone, conglomeratic, in upper part, predominantly dark chert pebbles; siltstone and sandstone in lower part. Sandstone thin to medium bedded, very fine to fine grained, light yellow red, clean. Mostly rubble; computed thickness	60	0
2. Covered; computed thickness	90	0
3. Siltstone, shaly siltstone, and sandstone; shaly- to medium-bedded, fine-grained, light-neutral to medium yellow-red, rusty-weathering; unit contains abundant plant fossils (52 ADt 127)	50	0
4. Covered; computed thickness	45	0
5. Siltstone, shaly; mostly rubble	4	0
6. Coal	0	6
7. Siltstone and sandstone; medium-bedded, fine-grained, dark-neutral to yellow-red; ironstone concretions, mud lumps	10	0
8. Coal	1	6
9. Siltstone, shaly siltstone, and ironstone concretions; float in covered area; computed thickness	69	0
10. Sandstone, thin-bedded, fine-grained, tan, argillaceous	8	0
11. Siltstone, shaly siltstone, and coal; rubble; computed thickness	12	0
12. Covered; computed thickness	35	0
13. Conglomerate, pebble; 70 percent black and gray chert, 30 percent white quartz and gray quartzite; sandstone, medium-bedded, fine-grained, light-tan; in part rubble; computed thickness	30	0
14. Covered; computed thickness	60	0
15. Siltstone, shaly siltstone, and sandstone; medium-grained, dark-neutral to chocolate-brown; abundant ironstone concretions; rubble; computed thickness	15	0
16. Covered; computed thickness	55	0

Tuluvak tongue—Continued	Ft.	In.
17. Sandstone, siltstone, shaly siltstone, clay shale, coal, and bentonite; plant fossils in sandstone; ironstone nodules common; rubble; computed thickness	20	0
18. Covered; computed thickness	40	0
19. Sandstone, thin- to medium-bedded, medium- to coarse-grained, medium-neutral to yellow-red, slabby; few plant fragments; rubble; computed thickness	20	0
20. Covered; computed thickness	125	0
21. Sandstone, medium-bedded, medium- to coarse-grained, medium yellow-red, slabby	10	0
22. Conglomerate, massive, grit to 6-in. cobbles; 40 percent gray quartzite, 5 percent white quartz, 55 percent black and gray chert; all conglomeratic constituents well rounded and elongated	30	0
	790	0

Ayiyak member.

The Chandler River section (pl. 36, column 5; pl. 34, section 1) was measured along the east bank of the river just downstream from camp D–July 25–48. The section is exposed in a series of almost continuous bluffs (Tuluvak Bluffs) on the north flank of Fossil Creek anticline in beds dipping 9° to 10° N. Only the upper 261 feet of the tongue is exposed; lower beds are truncated by a fault along the north flank of the anticline.

Incomplete section of Tuluvak tongue, Prince Creek formation, along the Chandler River (pl. 36, column 5)

Rogers Creek member.

Tuluvak tongue:	Ft.	In.
1. Bentonite, green, plastic	1	0
2. Sandstone, very fine grained, light-gray to yellow-red, argillaceous, tuffaceous	10	0
3. Clay shale, claystone, tuffaceous siltstone and sandstone, interbedded; rusty-weathering limestone lenses; in part rubble; computed thickness	75	0
4. Bentonite	2	0
5. Clay shale, blue-gray, crumbly; thin stringers of bentonite; in part rubble; computed thickness	73	0
6. Sandstone, conglomeratic; black chert granules, well-rounded	1	0
7. Clay shale	29	0
8. Lignite and carbonaceous shale	0	8
9. Clay shale and sandstone, interbedded; light yellow-red, fine- to medium-grained, friable	13	0
10. Coal (lignite)	1	4
11. Clay shale	6	0
12. Coal	0	8
13. Clay shale	10	0
14. Coal	3	4
15. Clay shale	15	0
16. Bentonite	2	0
17. Clay shale	18	0
	261	0

Fault.

The Outpost Mountain section (pl. 36, column 6) was computed on the south flank of Outpost Mountain syncline about 6 miles west of Schrader Bluff. The mountain is the highest point in the northern part of the mapped area. The syncline plunges east and the beds dip 13° to 17° NE. The east end of Outpost Mountain has been truncated by the Tuluga River. The tongue is represented by numerous rubble lines but is not well exposed. The section was computed to be 680 feet thick, but this thickness may be in error by as much as 10 percent.

Section of Tuluvak tongue, Prince Creek formation, at Outpost Mountain (pl. 36, column 6)

Rogers Creek member.

Tuluvak tongue:	Feet
1. Siltstone, tuffaceous, and dark-gray to yellowish-gray tuff with waxy luster; siltstone dark green gray with fragments of tuff; rubble ridges; computed thickness	50
2. Rubble traces with float of shaly siltstone, clay shale and a little greenish-gray siltstone; computed thickness	500
3. Sandstone and conglomerate ledge. Sandstone thin bedded, lenticular, medium to coarse grained, salt and pepper with greenish cast, friable. Conglomerate fragments grit to pebble size, pebbles mostly ¼ to 1 in.; 60 percent black chert, 37 percent gray and green chert, 3 percent white quartz; well-sorted; all well rounded	20
4. Covered; computed thickness	80
5. Sandstone, in part conglomeratic with black chert pebbles. Sandstone thin bedded, medium grained, friable, buff to dark brown; weathers brown with metallic surface; ironstone nodules common. In part rubble; computed thickness	30
	680

Aylyak member.

The type section of the Tuluvak tongue is 575 feet thick at Schrader Bluff (pl. 27; pl. 36, column 7; pl. 34, section 2). The section is almost completely exposed near the north end of the bluff in beds that dip 37° to 60° S. south of the faulted anticlinal axis.

Type section of Tuluvak tongue, Prince Creek formation, at Schrader Bluff (pl. 36, column 7)

Rogers Creek member.

Tuluvak tongue:	Feet
1. Sandstone, fine-grained, light-gray, soft	35
2. Sandstone, massive, medium-grained, light olive-gray to salt-and-pepper; weathers light brown: hard; concretionary weathering; moderately calcareous	13
3. Sandstone, fine-grained, light-gray soft	23
4. Benonite, sandy, varicolored; intermittent 1-in. coal beds	3
5. Bentonite, yellow; thin coal beds	3
6. Covered; computed thickness	12
Tuluvak tongue—Continued	
7. Coal	3
8. Sandstone, massive, coarse-grained, salt-and-pepper; weathers grayish yellow; crossbedded, ⅛-in. coal seams	13
9. Clay shale grading into siltstone	4
10. Sandstone, fine grained, light-gray, soft; 2-in. coal bed	2
11. Sandstone, fine-grained, medium greenish-gray, ripple-marked; coaly material and ironstone concretion band at base	4
12. Clay shale, grayish-brown, fissile, deeply weathered	6
13. Clay shale, black, fissile, crumbly	7
14. Sandstone, fine-grained, pale yellowish-brown; weathers brick-red; hard, dense, slightly calcareous; contains spindly brown remnants of carbonaceous material as much as 1 in. long	2
15. Sandstone, medium-grained, light olive-gray to salt-and-pepper; weathers tan; poorly sorted; soft	9
16. Sandstone, medium-grained, medium light-gray to salt-and-pepper, hard, moderately calcareous	7
17. Sandstone, fine-grained, light-gray, hard	16
18. Sandstone, very fine grained, pale yellowish-brown; weathers tan	4
19. Covered; computed thickness	42
20. Siltstone, thin-bedded, medium light-gray; ironstone beds	8
21. Sandstone; similar to unit 17; crossbedded	4
22. Clay shale, silty; light- and dark-layered	3
23. Covered; computed thickness	110
24. Sandstone, fine-grained, light-brown; weathers dark red; soft	8
25. Sandstone, fine-grained, medium greenish-gray; poorly sorted	10
26. Sandstone, fine-grained, light-gray, soft	7
27. Sandstone, fine-grained, light brownish-gray; well-sorted	1
28. Sandstone; similar to unit 25	14
29. Sandstone, very fine grained, pale yellowish-brown, moderately indurated, blocky, slighty calcareous	17
30. Marcasite concretions in unconsolidated sand	1
31. Siltstone, medium light-gray, laminated; interbedded along ironstone layers; carbonaceous	36
32. Covered; computed thickness	14
33. Sandstone, massive, fine-grained, light-gray to salt-and-pepper, moderately indurated; small coal inclusions as much as 1 inch in diameter; plant fossils	4
34. Coal	3
35. Claystone, dark-brown, silty; pencil fracture	1
36. Bentonite, yellow and gray; 3-in. coal seam	5
37. Sandstone and coal fragments; mostly covered; computed thickness	14
38. Clay shale, greenish-black, hard, fissile	1
39. Covered; computed thickness	7
40. Siltstone shaly, sandy	2
41. Sandstone; similar to unit 25	15

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Tuluvak tongue—Continued	Feet
42. Sandstone, fine-grained, light brownish-gray friable, soft	63
43. Sandstone, medium-grained, light olive-gray to salt-and-pepper; weathers light brown; well-sorted, hard, moderately calcareous; clay galls	10
44. Sandstone, very fine to fine-grained, silty, light olive-gray, dense, hard, blocky; threadlike plates of organic material	11
	575

Ayiyak member.

The Racetrack Basin syncline section (pl. 36, column 8) was computed on the west side of the basin about 3 miles northeast of camp D–July 26–52. The section is represented for the most part by a series of rubble lines around the basin. Only the resistant conglomerate (unit 7) is well exposed. The section is complicated by intensive folding and minor faulting where the Grandstand anticline plunges under the syncline. The conglomerate bed dips 83° NE, but the upper part of the section is flatter and dips 35° NE. Lack of control and steep dips of the beds may have caused error in estimating the total thickness of the section; however, the error probably does not exceed 100 feet.

Incomplete section of Tuluvak tongue, Prince Creek formation, at Racetrack Basin syncline on the Anaktuvuk River (pl. 36, column 8)

Rogers Creek member.

Tuluvak tongue:	Feet
1. Siltstone, tuffaceous, and tuff; gray; weathers brown; hackly-fracturing; in part rubble; computed thickness	40
2. Covered; computed thickness	200
3. Siltstone, medium-neutral, carbonaceous; rubble; computed thickness	15
4. Covered; computed thickness	90
5. Sandstone, fine-grained, light yellow-red, and siltstone rubble; rubble; computed thickness	15
6. Covered; computed thickness	260
7. Conglomerate; 95 percent black chert, 4 percent gray-green chert, 1 percent white quartz; pebbles as much as ¼-inch in diameter; all well rounded; coarse salt-and-pepper sandstone lenses	20
8. Siltstone, shaly siltstone, and coal; rubble; computed thickness	10
9. Sandstone, massive, fine-grained, buff, hard; few black chert pebbles; in part rubble; computed thickness	20
	670

Ayiyak member.

Age and correlation.—A few fossil leaves were collected from rocks of the Tuluvak tongue. They were identified by Roland W. Brown as *Pseudoprotophyllum magnum* Hollick; *Ginkgo laramiensis* Ward; and *Populites platanoides* Hollick. Concerning the fossils Brown stated (written communication, 1953): "All the species listed are also found at other localities in the Upper Cretaceous of Alaska and western United States."

The Tuluvak tongue is nonmarine, but it intertongues with and grades into its marine equivalent, the Rogers Creek and Barrow Trail members of the Schrader Bluff formation. In the northern part of the Chandler River region, beds that are mapped as Tuluvak tongue contain marine microfossils and are part of the Schrader Bluff formation; however, it is impossible to differentiate these beds at the scale used on plate 27. The microfossils from these marine beds are shown (pl. 30) with the Tuluvak tongue. They are characteristic of the Colville group and are similar to fossils found in the Schrader Bluff formation and to some of the fossils of the Ayiyak members of the Seabee formation. Thus, the microfossils support indirectly a postulation of Late Cretaceous age for the Tuluvak tongue.

SCHRADER BLUFF FORMATION

The marine Schrader Bluff formation is named after Schrader Bluff, which is on the east bank of the Anaktuvuk River about 5 miles upstream from the mouth of the Tuluga River. The formation was first described by Gryc and others (1951, p. 164–166); they subdivided it into three members: Seabee, Tuluga, and Sentinel Hill. The formation has since been studied in greater detail; Whittington (1956, p. 246–253) and Detterman (1956b, p. 253–254) revised the designation of the members of the formation. The name Tuluga was abandoned and the sequence of beds that was formerly considered part of that member was subdivided into the newly defined Rogers Creek and Barrow Trail members. The name Sentinel Hill was retained, but the type section was redefined.

ROGERS CREEK MEMBER

OCCURRENCE

The Rogers Creek member is poorly exposed in the Chandler River region. The soft shale and siltstone that are the main constituents of the member do not form good exposures; however, both the uppermost bed of the underlying Tuluvak tongue and the lowermost bed of the overlying Barrow Trail member are recognizable beds and the interval between is mapped. In some of the mapped area the Rogers Creek cannot be differentiated from the Barrow Trail and the two are mapped together.

The southernmost occurrence of strata mapped as Rogers Creek member is in Racetrack Basin syncline east of the Anaktuvuk River, at lat 68°55′30″ N. At this locality the member consists of several bentonitic clay shale and siltstone rubble traces in an otherwise covered interval between beds of the Tuluvak tongue and Barrow Trail member. A similar-appearing unit is mapped on the flanks of Outpost Mountain syncline. The only good exposures of the member are in Schrader Bluff and along the east bank of the Chandler River about 1 mile upstream from camp D–July 28–48.

The Rogers Creek member accurs only in the northern and eastern parts of the mapped area. In addition to the areas previously mentioned the member crops out along the Chandler and Colville Rivers north of lat 69°15′ N. These exposures are primarily in bluffs along the rivers and in cutbanks on small tributary streams. The interstream areas are covered by Quaternary deposits that effectively mask all older rocks.

CHARACTER AND THICKNESS

The type section in the Gubik test wells (Whittington, 1956, p. 250) is predominantly medium light-gray clay shale and medium-gray claystone. Two sandstone units, very light gray, medium hard, argillaceous, and tuffaceous, occur in the type section. The upper sandstone unit is about 50 feet below the top and the lower about 250 feet below the top. Bentonite, tuffaceous siltstone, shaly siltstone, tuff, and limestone are minor constituents of the sections. Bentonitic and tuffaceous material which is dispersed throughout the member and forms the matrix for the various rock types gives the overall light-gray color to the sediments. The correlation between the two well sections is good. The drilled section of Gubik test well 1 has a little more sandstone and a little less tuff than that of Gubik test well 2, but otherwise the well logs are almost identical. The four measured outcrop sections of the Rogers Creek member (pl. 36, columns 5–8) are slightly thicker than the 585 to 595 feet described by Whittington from the logs of the Gubik wells. The difference in computed thickness is in part due to use of different criteria to determine the contact between the Rogers Creek and Barrow Trail members. On the surface the contact is placed at the base of a conspicuous sandstone unit between 50 and 60 feet above the contact established in the well sections. The location of the contact in the wells is based in part on lithology and in part on the microfaunal assemblage present; that of the surface contact is based entirely on lithology. The section exposed at Schrader Bluff is 680 feet thick; on the Chandler River the section is 613 feet thick. Both sections can be correlated with the well sections. The section at Racetrack Basin syncline and the one at Outpost Mountain syncline are insufficiently exposed to be correlated.

The lithologic characteristics of the surface exposures of the Rogers Creek member are similar to those of the subsurface sections. Medium-gray fissile bentonitic clay shale and hard medium-gray claystone are the characteristic rock types. Fine-grained laminated light-gray to pale yellow-red sandstone with muscovite and biotite flakes are present locally. Subordinate constituents include green plastic bentonite, creamy-white to greenish-black tuff, bentonitic tuffaceous gray siltstone and shaly siltstone, and dense limestone with biotite flakes. Individual bentonite beds are as much as 4 feet thick on the Chandler River.

A thin section of laminated tuff was examined under the petrographic microscope. In the hand specimen the alternating light and dark laminae are somewhat lenticular and crossbedded, with irregularly shaped dark blotches; the rock is well indurated and conchoidally fractured. In thin section the angular grains are 0.01 to 0.2 mm in diameter. The siliceous matrix constitutes about 70 percent of the rock and contains abundant jagged glass shards. The laminae were formed by bands of light chert and dark biotite. The larger grains are concentrated along boundaries of the laminae; the grains in the laminae are generally less than 0.1 mm in diameter. The specimen contains a high percentage of orthoclase and plagioclase feldspars.

GEOLOGIC SECTIONS

The following sections describe the surface exposures of the Rogers Creek member. The standard subsurface sections from Gubik test wells 1 and 2 were described by F. M. Robinson (1958a).

The Chandler River section (pl. 36, column 5; pl. 34, section 1) was measured in a series of cutbanks along the east side of the river about 1 mile upstream from camp D–July 28–48. The section is 613 feet thick and on the south flank of Prince Creek syncline in beds inclined 6° to 8° N.

Section of the Rogers Creek member, Schrader Bluff formation, along the Chandler River (pl. 36, column 5)

	Ft.	In.
Barrow Trail member.		
Rogers Creek member:		
1. Clay shale, bentonite, thin limestone, tuffaceous siltstone, and silty tuffaceous sandstone, interbedded; mostly rubble; computed thickness	380	0
2. Tuff, creamy white		8
3. Clay shale, claystone, tuffaceous siltstone, bentonite, and tuff, interbedded; in part rubble; computed thickness	180	0
4. Bentonite, yellow-green, plastic	3	4
5. Claystone, hard, brittle	2	0
6. Clay shale, crumbly, black	3	0
7. Bentonite	3	0
8. Claystone	5	0
9. Bentonite	4	0
10. Clay shale, crumbly, black; thin stringers of bentonite	32	0
	613	0
Tuluvak tongue.		

The Outpost Mountain section (pl. 36, column 6) was computed on the south flank of Outpost Mountain syncline about 6 miles southwest of Schrader Bluff. The section is 670 feet thick, which compares favorably with the section at Schrader Bluff. However, the member is poorly exposed and is defined simply as the interval between the uppermost unit of the underlying Tuluvak tongue and the lowermost bed of the overlying Barrow Trail member.

Incomplete section of Rogers Creek member, Schrader Bluff formation, at Outpost Mountain (pl. 36, column 6)

	Feet
Barrow Trail member.	
Rogers Creek member:	
1. Covered; computed thickness	370
2. Sandstone, tuffaceous, siltstone, and shale rubble; sandstone very fine grained, greenish gray; computed thickness	20
3. Covered; computed thickness	280
	670
Tuluvak tongue.	

The Schrader Bluff section (pl. 36, column 7; pl. 34, section 2) was measured in Schrader Bluff, on the east bank of the Anaktuvuk River. The section is 680 feet thick.

Section of the Rogers Creek member, Schrader Bluff formation, at Schrader Bluff (pl. 36, column 7)

	Ft.	In.
Barrow Trail Member.		
Rogers Creek member:		
1. Clay shale, shaly siltstone, and bentonite; mud covered; computed thickness	105	0
2. Siltstone	1	0
3. Covered; computed thickness	3	0
4. Limestone, light olive-gray, dense, blocky	1	0
5. Mud-covered; computed thickness	16	0
6. Tuff, pale yellowish-green, dense	3	0
7. Siltstone	2	0
8. Bentonite, yellow	2	0
9. Siltstone, tuff, and bentonite, interbedded	19	0
10. Sandstone, fine-grained, light brownish-gray, well-sorted; with mica and biotite; ripple-marked	11	0
11. Clay shale and bentonite	2	0
12. Sandstone; similar to unit 10	17	0
13. Shaly siltstone, and siltstone; one 2-in. bed of bentonite; small concretions	7	0
14. Bentonite, yellow	0	2
15. Limestone, light-gray, dense, hard; pyrite and biotite crystals; short spindly dark blebs as much as ¼ in. long	4	10
16. Clay shale, medium-gray, and bentonite; in part mud covered; computed thickness	76	0
17. Clay shale, medium dark-gray; weathers olive gray; soft	4	0
Rogers Creek member—Continued		
18. Mud-covered; two bentonite beds 2 feet thick, one near base, other near top; computed thickness	23	0
19. Tuff, silty, medium-gray, dense, hard; carbonaceous fragments	2	0
20. Tuff, white; weathers yellowish gray; conchoidal fracture, dense	3	0
21. Covered; computed thickness	95	0
22. Limestone, silty, dark yellowish-brown, dense, hard, blocky; biotite flakes	1	0
23. Sandstone, thin-bedded, very fine grained, pale-yellow	36	0
24. Clay shale and bentonitic mud; in part covered; computed thickness	17	0
25. Limestone, light-gray, hard, dense, blocky	2	0
26. Similar to unit 24; computed thickness	7	0
27. Siltstone, medium light-gray; weathers rusty-brown; conchoidal fracture; concretions on bedding planes	8	0
28. Sandstone, fine-grained, light-gray, hard	17	0
29. Limestone, dense, hard, blocky; weathers tan; organic particles	2	0
30. Sandstone, fine-grained, light-gray, hard, bentonitic; siltstone interbedded with sandstone	12	0
31. Siltstone, medium light-gray, calcareous, crossbedded; concretions as much as 1½ in. in diameter	10	0
32. Siltstone, thin-bedded, sandy, soft	16	0
33. Covered; computed thickness	155	0
	680	0
Tuluvak tongue.		

The Racetack Basin syncline section (pl. 36, column 8) was measured on the west side of the basin, about 3.8 miles northeast of camp D–July 26–52 on the Anaktuvuk River. The member is poorly exposed, being represented by a few shale rubble traces. A total of 680 feet was computed at this locality, but the control is poor and the thickness may have been overestimated by 10 to 20 percent, giving a thickness in excess of what is actually present. The exposed rocks consist entirely of bentonitic clay shale.

AGE AND CORRELATION

Molluscan megafossils have not been found in any of the surface exposures of the Rogers Creek member. However, *Inoceramus patootensis* de Loriol was reported from the upper sandstone unit in both Gubik test wells. The presence of this fossil would indicate a correlation with the upper part of the Santonian and the lower part of the Campanian stages. This would be roughly equivalent to part of the Telegraph Creek formation and Eagle sandstone of the western interior of the United States.

The microfossils collected from the shale of the Rogers Creek member were identified by H. R. Bergquist (pl. 30). Concerning these fossils Bergquist stated (written communication, 1956):

Some of these samples were collected from strata which are interbedded with the Tuluvak tongue of the Prince Creek formation. A few species of arenaceous Foraminifera comprise the fauna and generally one or two species are common or abundant in a sample. Almost all the specimens are crushed and distorted.

Haplophragmoides rota Nauss occurred in about one third of the samples and was abundant in 5. Specimens identified as *Haplophragmoides bonanzaense* Stelck and Wall occurred in four or five samples. In two of the six samples in which it occurred, *Verneuilinoides fischeri* Tappan was common. Specimens of *Gaudryina irenensis* Stelck and Wall were common in three samples and a few were found in each of 5 other samples. *Saccammina* n. sp. was found in several samples and specimens of *Trochammina ribstonensis* Wickenden were found in six samples but were abundant in only two. In a few samples from lower beds in the member there were a few specimens of *Trochammina whittingtoni* Tappan.

Abundant specimens of *Flabellammina chapmani* Tappan in one sample (47 AWb 456) are unusual, as this coarsely arenaceous species of Foraminifera was not found in any other surface or subsurface sample from the entire Colville group. Most of the arenaceous Foraminifera in these samples are species that range throughout the Colville group; however, a few calcareous species in a few samples from the upper part of the Rogers Creek member suggest a Senonian age. These are *Anomalinoides talaria* (Nauss) and *Quinqueloculina sphaera* Nauss, which occur in the Lea Park shale of Alberta, and *Nonionella austinana* Cushman in the Austin Chalk of Texas and the Belly River group of Canada. No typical Turonian fossils occur in the section.

BARROW TRAIL MEMBER

OCCURRENCE

The areas in which the Barrow Trail member of the Schrader Bluff formation was mapped are in general the same as were delineated for the Rogers Creek member. The southernmost exposure with beds of definitely known Barrow Trail member is in Racetrack Basin syncline at lat 68°56′ N. The member is also present along the flanks of Twin Bluffs and Outpost Mountain synclines. Along the Chandler River the member occurs north of lat. 69°13′ N., in both anticlines and synclines, and along some of the tributaries of the Chandler, particularly the Kutchik River. The westernmost mapped occurrence in the Chandler River region is on the south flank of Prince Creek syncline about 8 miles upstream from Umiat.

The strata of the Barrow Trail member are generally not severely folded. An average dip of about 10° or less is maintained over most of the area west of the Anaktuvuk River. Post-Cretaceous uplift was strongest east of the Anaktuvuk River and it is there that the beds are most deformed. The strata are inclined from 60° to 72° S. in Schrader Bluff. The dip is less at Twin Bluffs syncline, being as much as 19° S., but it indicates moderate post-Cretaceous folding.

CHARACTER AND THICKNESS

The Barrow Trail member is distinguished by the abundance of tuff and bentonite intercalated with the clastic rocks of the sequence; tuffaceous and bentonitic material, which is admixed with the sandstone, siltstone, and shale, imparts a uniform medium-gray color to the rocks that is characteristic of the member.

Thin-bedded hard brittle tuffaceous fine-grained sandstone, light- to medium-gray and various shades of greenish- to brownish-gray, is a major constituent of the member. The sandstone is commonly laminated and may contain blebs and threads of organic material. The laminae commonly are composed of alternating layers of light- and dark-colored materials. Some of the sandstone in the lower part of the member contains white quartz and black chert pebbles as much as 1½ inches in diameter and also shell fragments, claystone, and coal fragments as much as 10 inches long. The pebbles may form clusters along the bedding planes. The Colville River section (pl. 36, column 4) is predominantly sandstone, but the sandstone facies becomes thinner toward the east and is largely replaced by a siltstone and shale sequence. The sandstone is restricted to the upper and lower parts of the section along the Chandler River (pl. 36, column 5); farther east at Outpost Mountain and Schrader Bluff (pl. 36, column 6 and 7) the section is more sandy. The sections that contain more shale and siltstone probably represent small localized basins of deposition. Thin coal seams (less than ½ inch thick) and finely dispersed carbonaceous material are commonly associated with the thick sandstone units.

Siltstone that is tuffaceous, bentonitic, medium light gray, laminated, and well-indurated to fissile is another major component of the Barrow Trail member. The siltstone is different from all other siltstone of the Cretaceous sequence seen in northern Alaska in that dark-gray spindle or lens-shaped particles as long as ⅜ inch occur along the bedding planes. These particles show up readily against the gray background of the rock. Most of the siltstone is noncalcareous, and the beds in the upper part of the section weather purple or maroon.

Other rock types in the Barrow Trail member are limestone and tuff. Limestone is more abundant in this member than in any other part of the Cretaceous sequence in northern Alaska. The limestone is light gray, hard, brittle, dense, and conchoidally fractured. All the limestone has abunant biotite flakes and finely disseminated pyrite crystals throughout. The impure limestone, when treated with acid, yields a considerable amount of insoluble residue. Some of the limestone is sandy and has a sugary texture. Organic blebs and blotches are common, and one bed has the appearance of an oolite. The tuff is white, yellowish gray, and greenish gray to green, hard, dense, and conchoidally fractured; it has a greasy feel. Oriented biotite flakes and specks of pyrite occur throughout the aphanitic groundmass. Boundaries between different color phases are interfingering and irregular, as well as gradational. The tuff is thin bedded and in some places laminated. One unit at Schrader Bluff is 13 feet thick.

Bentonite is admixed with most of the rock types of the member, particularly in the clay-shale intervals; it occurs generally in beds less than 6 inches thick, although a few individual beds may be as much as 3 feet thick. When not mixed with other rocks it is gray green and very plastic.

Subordinate constituents of the member include clay shale, shaly siltstone, claystone, clay galls, and a few concretions of ironstone and of limestone. The claystone is hard, almost like a slate, and medium gray; it fractures conchoidally. The clay galls are small rounded masses of clay material commonly incorporated in the sandstone and siltstone. Ironstone concretions occur sparsely in the lower part of the section.

An over-all eastward gradation into shale and an eastward thinning of the Barrow Trail member are apparent from the columnar sections (pl. 36), although there is a reversal in the trend between the Chandler River and the Outpost Mountain sections. The contact with the overlying Sentinel Hill is gradational; it cannot be picked precisely in all sections. However, the upper contact appears to become lower in an easterly direction; thus, the thinning is largely in the upper part of the member. The member also becomes thinner northward. All the measured sections from this area are thicker than the 575 feet measured at the type locality along the Colville River (Whittington, 1956, p. 250–251). The thickest section is along the Chandler River, where 1,042 feet was measured. This section is about 18 miles south of the type locality, indicating a thinning of about 25 feet per mile.

Three rock specimens from the Barrow Trail member were examined in thin section with the petrographic microscope. Rock sample 47 AWb 133 (pl. 36, column 9) is a yellowish-gray tuff with greenish-yellow amygdule-like structures; it is well indurated and conchoidally fractured. In thin section the angular grains are less than 0.1 to 0.3 mm in diameter and are randomly scattered throughout the amorphous chert groundmass, which contains abundant angular glass shards. The amygdule-like structures are filled with anhedral masses of calcite 1 to 1.5 mm in diameter. A few aragonite crystal growths are partly altered to calcite. Grains of oligoclase, bytownite, and andesine feldspars are abundant.

Rock sample 52 ABl 200 (pl. 36, column 6) is a tuffaceous siltstone from 400 feet above the base of the member at Outpost Mountain. In thin section the subangular grains are 0.02 to 0.1 mm in diameter. A siliceous clay matrix composes about 60 percent of the rock. Pyrite and limonite are scattered throughout the specimen.

The third specimen is also a tuffaceous siltstone similar to sample 52 ABl 200.

GEOLOGIC SECTIONS

The six geologic sections of the Barrow Trail member are included on plate 36. All the sections are from the northern part of the mapped area. The southernmost section is from Racetract Basin syncline; although the member is present farther south, the beds are insufficiently exposed to measure a section. The sections on plate 36 are arranged from west to east to show the transition to shale and the thinning of the member.

The Colville River section (pl. 36, column 4) was measured on the south bank of the Colville River about 4 miles upstream from Umiat. The section, the westernmost exposure of the Barrow Trail member measured in the area, is on the north flank of Prince Creek syncline in beds that dip 6° S.

Section of Barrow Trail member, Schrader Bluff formation, on the Colville River (pl. 36, column 4)

	Ft.	In.
Sentinel Hill member.		
Barrow Trail member:		
1. Sandstone, thin-bedded, light- to medium-neutral, banded in part, well-indurated to friable, somewhat carbonaceous	33	0
2. Coal	1	0
3. Siltstone, banded, light-gray, somewhat tuffaceous	2	6
4. Sandstone, thin-bedded, medium-neutral, banded, hard, carbonaceous	20	0
5. Siltstone, medium-neutral, banded	5	0
6. Sandstone, thin-bedded to massive, light-gray, somewhat tuffaceous	14	0
7. Covered; computed thickness	10	0
8. Siltstone, medium-gray, finely laminated; pencil fracture; somewhat tuffaceous	36	0
9. Sandstone talus, few shale pebbles; computed thickness	20	0
10. Sandstone, finely laminated, fine-grained; carbonized wood fragments	7	0
11. Clay shale, black, with bentonite stringers	5	0
12. Sandstone, medium-grained, light- to medium-gray, slabby to cliff-forming at the top; some bentonitic and tuffaceous material	53	0
13. Covered; computed thickness	10	0

Barrow Trail member—Continued	Ft.	In.
14. Sandstone, fine- to medium-grained, medium-neutral; ironstone nodules common	9	0
15. Sandstone talus and bentonite; computed thickness	17	0
16. Sandstone, medium-neutral, very hard	1	0
17. Siltstone	1	4
18. Covered; computed thickness	5	0
19. Sandstone, massive, fine-grained, light- to medium-gray, cliff-forming, tuffaceous, friable in spots	23	0
20. Covered, talus of sandstone; computed thickness	17	0
21. Bentonite, yellow-green	2	6
22. Sandstone, very fine grained, well-indurated; few sandstone concretions with fossil fragments	4	0
23. Bentonite, yellow-green	2	6
24. Sandstone, fine-grained, light- to medium-gray, banded, crossbedded, cliff-forming, somewhat tuffaceous	20	0
25. Covered; sandstone and bentonite talus; computed thickness	52	0
26. Siltstone, medium-neutral	5	0
27. Sandstone, bentonitic, poorly exposed; computed thickness	30	0
28. Sandstone, fine-grained, medium-neutral, crossbedded	5	0
29. Covered, bentonite float; computed thickness	10	0
30. Sandstone, massive, fine-grained, light-neutral, banded, well-indurated	4	6
31. Covered; computed thickness	8	0
32. Sandstone, fine-grained, medium-neutral, slabby	1	0
33. Covered; computed thickness	3	6
34. Bentonite, green-yellow	1	0
35. Sandstone, massive, fine-grained, light-gray, tuffaceous	2	6
36. Bentonite	1	3
37. Tuff	1	0
38. Covered; computed thickness	2	0
39. Bentonite		6
40. Tuff		3
41. Bentonite	1	0
42. Tuff		5
43. Bentonitic sandstone		8
44. Siltstone, well-indurated		3
45. Bentonitic sand		10
46. Sandstone, massive, fine-grained, light-neutral, crossbedded, banded, slabby, fossiliferous	5	0
47. Clay ironstone	0	3
48. Sandstone, fine-grained, medium-neutral; carbonaceous laminae	0	6
49. Siltstone, medium-neutral; weathers brown; fossil fragments	0	9
50. Sandstone, fine-grained, light-neutral, hard, crossbedded, slabby	7	6
	463	6

The Chandler River section (pl. 36, column 5; pl. 34, section 1) was measured in a series of bluffs along the east bank of the Chandler River at camp D–July 28–48. The bluffs are part of Tuluvak Bluffs. The section is on the south limb of Prince Creek syncline in strata dipping 6° to 10° N. The lower part of the section is incompletely exposed.

Section of Barrow Trail member, Schrader Bluff formation, along the Chandler River (pl. 36, column 5)

Sentinel Hill member.		
Barrow Trail member:	Ft.	In.
1. Sandstone, thin-bedded, fine- to medium-grained, medium-neutral to light yellow-red, argillaceous, tuffaceous, crossbedded. Few fossils, starfish and pelecypods included with (USGS Mesozoic loc. 26512)	15	0
2. Siltstone, shaly siltstone, and somewhat bentonitic clay shale, interbedded. Ten feet of very fine grained, dark-gray, argillaceous sandstone near middle of unit. Poorly exposed; computed thickness	120	0
3. Sandstone, thin-bedded, fine-grained, dark-gray, argillaceous, tuffaceous; few fossils (USGS Mesozoic loc. 26512)	15	0
4. Siltstone and clay shale, interbedded with thin bentonite stringers; poorly exposed; computed thickness	85	0
5. Siltstone and shale; light-gray to greenish-gray, tuffaceous; bentonite stringer at top	8	0
6. Sandstone, fine-grained, medium yellow-red, friable, carbonaceous, argillaceous, calcareous. Contains *Inoceramus patootensis* (USGC Mesozoic loc. 26510)	2	0
7. Siltstone and shale; light- to dark-gray, tuffaceous; 4-inch bentonite bed at base	30	0
8. Siltstone and shale, interbedded; predominantly siltstone near top; medium- to dark-gray, with white (tuffaceous) and dark (carbonaceous) splotches; hard, brittle. Few small coal lenses containing amber. Fossils throughout, many with original shell material intact; ammonites and pelecypods (USGS Mesozoic loc. 26510)	80	0
9. Clay shale, dark blue-gray, poorly consolidated; numerous bentonite stringers. Two 6-inch dark yellow-red siltstone interbeds, one at top, other 20 feet below top	70	0
10. Tuffaceous siltstone, shaly, siltstone and clay shale, interbedded. Predominantly medium-gray siltstone with circular light and dark rings. Hard, hackly-fracturing shale. Several 1- to 2-inch coquina layers. Fossils (USGS Mesozoic loc. 26509)	60	0

Barrow Trail member—Continued	Ft.	In.
11. Tuffaceous siltstone and claystone, interbedded; shaly siltstone and clay shale. Siltstone light gray with circular ring structures (carbonized plant stems); clay shale black. All hard, brittle, hackly-fracturing, fossiliferous (USGS Mesozoic loc. 26509)	90	0
12. Clay shale and claystone	34	0
13. Siltstone, tuffaceous, light-gray; cross laminations, hard, brittle, fossiliferous	20	0
14. Clay shale	20	0
15. Siltstone, tuffaceous, light-gray; circular ring structures	10	0
16. Claystone and clay shale; hard, brittle	60	0
17. Siltstone, tuffaceous, light-gray; weathers brown	6	0
18. Siltstone, tuffaceous; shaly siltstone, and clay shale float, mostly covered; computed thickness	150	0
19. Sandstone, light-gray to light yellow-red, thin-bedded, very fine grained, tuffaceous, carbonaceous, argillaceous, hard, brittle	30	0
20. Conglomerate, intraformational, sandstone and shale fragments		6
21. Clay shale rubble, bentonitic; computed thickness	50	0
22. Sandstone, thin-bedded, medium-gray to light-green, tuffaceous, hard, brittle, conchoidally fracturing; 3-inch coquina zone near base (USGS Mesozoic loc. 26508)	12	0
23. Clay shale and shaly siltstone, tuffaceous siltstone, and sandstone, interbedded	55	0
24. Conglomerate, chert-pebble grit; silica cement, hard		6
25. Sandstone, thin-bedded, fine-grained, light- to medium-gray, tuffaceous	19	0
	1,042	0

Rogers Creek member.

The Outpost Mountain section (pl. 36, column 6) is on the south flank of Outpost Mountain syncline. The section is 800 feet thick, and the upper part of the member is missing. The beds dip as much as 11° N. The thickness may be in error by as much as 5 to 10 percent.

Section of Barrow Trail member, Schrader Bluff formation, at Outpost Mountain on the Tuluga River (*pl. 36, column 6*)

Barrow Trail member:	Feet
1. Sandstone, tuffaceous, thin-bedded, very fine grained, light olive-gray to greenish-gray, banded; with darker olive gray, greenish-gray siltstone fragments below sandstone. Mostly rubble; computed thickness	23
2. Covered; thickness	40
3. Siltstone, light olive-gray, tuffaceous, and yellowish-gray to greenish-gray vitric tuff. Rubble; computed thickness	17
4. Covered; computed thickness	50
5. Siltstone rubble traces, tuffaceous, light olive-gray, hard, brittle, siliceous; interbeds of yellowish-buff tuff. Fossil fragments throughout (USGS Mesozoic loc. 26519); computed thickness	45
6. Covered; computed thickness	65
7. Series of tuffaceous sandstone and siltstone traces. Sandstone very thin bedded, fine grained, dusky yellow, siliceous, hard, brittle. Unit fossiliferous throughout; computed thickness	60
8. Covered; computed thickness	50
9. Sandstone and siltstone, interbedded; tuffaceous; sandstone very fine grained, thin bedded, light greenish gray, siliceous, hard, brittle. Fossil fragments throughout. Rubble; computed thickness	60
10. Covered; computed thickness	20
11. Sandstone and siltstone; tuffaceous, very thin bedded, very fine grained, light-gray to greenish; circular splotches of dark organic material; fossiliferous (USGS Mesozoic 26523). In part rubble; computed thickness	70
12. Covered; computed thickness	40
13. Siltstone and sandstone; tuffaceous, very fine grained, thin-bedded, light-gray, siliceous, hard, brittle; circular dark splotches. Rubble; computed thickness	60
14. Series of ledges and traces. Sandstone, siltstone, and tuff. Predominantly very fine grained thin-bedded light greenish gray tuffaceous siliceous hard brittle sandstone, with circular dark splotches. Greenish-gray siltstone and pinkish-gray tuff. Minor amounts of coal float; plant fossils common. In part rubble and covered; computed thickness	200
	800

Rogers Creek member.

The Schrader Bluff section (pl. 36, column 7; pl. 34, section 2) was measured in Schrader Bluff on the east bank of the Anaktuvuk River, about 5 miles upstream from the junction with the Tuluga River. The section is 894 feet thick and is almost completely exposed in a series of beds dipping 65° to 70° S. on the south flank of the faulted Schrader Bluff anticline.

Section of Barrow Trail member, Schrader Bluff formation, at Schrader Bluff (*pl. 36, column 7*)

Sentinel Hill member.

Barrow Trail member:	Ft.	In.
1. Bentonite	0	6
2. Clay gouge zone; clay shale, bentonite, and tuff	16	6
3. Bentonite	0	6
4. Siltstone	26	6
5. Clay gouge zone; similar to unit 2	5	0
6. Siltstone, medium-dark gray; fossiliferous	17	0
7. Mud-covered, similar to unit 2	4	0
8. Siltstone, thin-bedded (2 to 6 in.), light-gray; weathers purple	40	0

Barrow Trail member—Continued	Ft.	In.
9. Covered; computed thickness	18	0
10. Clay shale, medium-gray; weathers dusky yellow; silty	4	0
11. Siltstone, coarse-grained, medium light-gray, dense, noncalcareous; scarce muscovite and hornblende recognizable along with predominant light minerals. Unit contains clay galls and is locally cross-bedded and fissile	58	0
12. Siltstone, medium dark-gray, massive, hard, conchoidally fractured; weathers yellowish-red and purple; numerous fossils; similar to unit 8	64	0
13. Covered; computed thickness	3	0
14. Sandstone, thin-bedded, very fine grained, light greenish-gray; light salt-and-pepper matrix; well-indurated, tuffaceous; few gray-clay blebs; grades into pale yellowish-brown fine-grained sandstone. Three-inch bed of bentonite near base	68	0
15. Mud-covered; computed thickness	8	0
16. Limestone, light-gray, dense, hard; weathers purple; concretions as much as 2 inches in diameter on bedding planes; fossiliferous; contains dark blebs as much as ¼ inch long, biotite flakes, and pyrite crystals	22	0
17. Bentonite	2	0
18. Siltstone, medium dark-gray, massive; little bentonite; similar to unit 11	30	0
19. Limestone; similar to unit 16	7	6
20. Tuff, gray to yellowish-green	0	2
21. Tuff, blue, dense	0	2
22. Bentonite	0	2
23. Limestone; similar to unit 16	5	0
24. Bentonite	2	0
25. Siltstone; similar to unit 8	14	0
26. Mud-covered; computed thickness	7	0
27. Sandstone, thin-bedded, laminated, very fine grained to fine-grained, medium-gray to greenish-gray, hard, silty; fossiliferous	38	0
28. Siltstone, laminated; medium-gray, with light yellowish-gray laminae; weathers yellowish gray; abundant biotite	1	0
29. Limestone, laminated, conchoidally fractured	2	0
30. Conglomerate; constituents include coal, sandstone, shell fragments, and black chert, all angular; salt-and-pepper sandstone matrix; moderately calcareous	1	0
31. Tuff, sandy, fine-grained, medium-gray; biotite flakes	40	0
32. Covered; computed thickness	2	0
33. Sandstone, thin-bedded, laminated, very fine grained, silty, medium-gray; traces of dark organic threads; biotite flakes, noncalcareous; fossiliferous	21	0
34. Sandstone, fissile, laminated, very fine to fine-grained, silty, medium-gray to greenish-gray, hard, noncalcareous; concretionary weathering	6	0
35. Siltstone; similar to unit 8; mostly mud covered	24	0
36. Tuff, silty, medium-gray, dense; abundant biotite and pyrite; gradational color banding from gray to yellow and white	9	0
37. Bentonite	0	6
38. Tuff; similar to unit 36	4	6
39. Covered; computed thickness	19	0
40. Sandstone; similar to unit 34	2	0
41. Covered; computed thickness	9	0
42. Sandstone; similar to unit 34	3	0
43. Mud-covered; computed thickness	6	0
44. Siltstone, shaly, light-green, weathered, plastic	0	6
45. Sandstone; similar to unit 34; fossiliferous	0	6
46. Siltstone; brown, deeply weathered	1	0
47. Sandstone; similar to unit 34	3	0
48. Shaly siltstone, light-gray, sandy, coaly; thin bentonite beds	4	0
49. Siltstone, coarse-grained, medium light-gray, dense, massive; muscovite and hornblende; concretions as much as 2 inches in diameter	22	0
50. Sandstone; similar to unit 34; fossiliferous	6	0
51. Covered with bentonitic mud; computed thickness	34	0
52. Siltstone; similar to unit 6	17	0
53. Covered with bentonitic mud; computed thickness	33	0
54. Limestone, dense, dusky-yellow; weathers purple; biotite and hornblende flakes common; aphanitic	1	0
55. Covered with bentonitic mud; computed thickness	39	0
56. Sandstone, thin-bedded, laminated, fine-grained, medium-gray, poorly consolidated; with pebbles	76	0
57. Conglomerate; milky quartz and black chert pebbles as much as 1½ inches in diameter	0	6
58. Sandstone, fine-grained, moderate yellowish-brown, well-indurated, porous, well-sorted, noncalcareous	7	6
59. Coal, sand, and bentonite zone	1	0
60. Sandstone; similar to unit 34	1	0
61. Sandstone, very fine grained; light-gray, with dark-gray laminae; weathers moderate yellowish brown; poorly cemented, noncalcareous	2	0
62. Shaly siltstone, almost slate, light-gray; micaceous surface	0	6
63. Tuff, greenish-gray; flecks of organic remains	1	6
64. Sandstone, medium-bedded, very fine grained, pale yellowish-brown, with reddish cast; slightly calcareous	32	0
	894	0

Rogers Creek member.

The section at Racetrack Basin syncline (pl. 36, column 8) was computed on the west side of the basin about 4 miles northeast of camp D–July 26–52. The member is poorly exposed, consisting of a series of rubble traces that enclose the basin. The thickness was computed from measurement of questionable dips; consequently, it may be in error by as much as 15 percent. However, the gross lithologic units appear to be correlative with the other measured sections, so the column is included because it is the southernmost exposed section of the member in the mapped area.

Section of Barrow Trail members, Schrader Bluff formation, at Racetrack Basin syncline (pl. 36, column 8)

	Feet
Sentinel Hill member.	
Barrow Trail member:	
1. Sandstone and siltstone; tuffaceous, fine-grained, buff, hard; unit fractures into small fragments; rubble; computed thickness	20
2. Covered; computed thickness	270
3. Siltstone and sandstone; tuffaceous, very fine grained, thin- to shaly-bedded, tan to light-gray; unit weathers brown; rubble; computed thickness	35
4. Covered; shaly siltstone float; computed thickness	245
5. Sandstone, fine-grained, medium-bedded, gray, hard, brittle, slabby, somewhat tuffaceous; siltstone interbeds; mostly rubble; computed thickness	25
6. Clay shale and shaly siltstone float; computed thickness	220
7. Sandstone and siltstone, tuffaceous, very fine grained, medium-bedded, gray, hard; rubble and cover; computed thickness	45
	860
Rogers Creek member.	

The Nanushuk River section at Twin Bluffs (pl. 36, column 9) was measured in a bluff on the north bank of the Nanushuk River about 1 mile upstream from camp W–June 26–47. The beds are on the south flank of Twin Bluffs syncline and the dip is 6° to 19° N.

Section of Barrow Trail member, Schrader Bluff formation, at Twin Bluffs (pl. 36, column 9)

	Feet
Sentinel Hill member.	
Barrow Trail member:	
1. Siltstone, tuffaceous, gray-green to gray-brown; weathers red brown to maroon; laminated, thin-bedded, well-indurated, bluff-forming; rectangular fracture; petroliferous odor on fresh surface; a few fossils 40 feet from top (USGS Mesozoic loc. 26499)	71
2. Sandstone and siltstone; tuffaceous, very fine grained, thin-bedded; two 1-foot beds of tuff near middle of unit	36
3. Siltstone float, tuffaceous; unit mostly covered; computed thickness	52
Barrow Trail member—Continued	
4. Siltstone and limestone; tuffaceous, light-gray to greenish-gray, laminated; dark splotches on surface; hard, brittle	83
5. Siltstone and sandstone, tuffaceous; light-neutral to gray-green limestone, and white tuff. Sandstone very fine grained, thin to medium bedded, crossbedded; a thin coquina in upper part of sandstone (USGS Mesozoic loc. 26500)	60
6. Claystone, light-gray, calcareous, carbonaceous; several thin tuff interbeds	27
7. Sandstone, very fine grained, thin to medium-bedded, crossbedded, laminated, gray-green, calico-weathering, calcareous, carbonaceous; and light-gray tuffaceous siltstone with several thin coquina zones (USGS Mesozoic loc. 26497)	91
8. Covered; shaly siltstone and clay shale float; computed thickness	18
9. Siltstone and sandstone; tuffaceous, light-gray; unit weathers white; laminated, well-indurated, with conchoidal fracture; dark lenses and splotches, organic odor; pelecypods and ammonites in sandstone at base of unit (USGS Mesozoic loc. 26501)	52
10. Covered; clay shale float; computed thickness	190
11. Sandstone, very fine grained, medium-gray, slabby to thin-bedded, calcareous; grades into conchoidally-fracturing tuffaceous siltstone; *Inoceramus* sp. shell fragments common	14
12. Claystone, light-gray, and tuff, green; weathers deep maroon to purple	4
13. Claystone, dark-neutral, calcareous, carbonaceous, hard, brittle; shell fragments locally abundant	26
14. Sandstone, very fine grained, silty, medium-neutral with greenish cast, slabby to thin-bedded, commonly crossbedded, hard, with conchoidal fracture; petroliferous	12
15. Covered; clay shale and bentonite float; computed thickness	15
16. Sandstone, very fine grained, silty, medium- to thick-bedded, laminated; large scale crossbedding; medium-gray; weathers brown; somewhat tuffaceous, calcareous, hard, rectangular-fracturing. At base, sandstone grades into siltstone. Fossils scattered throughout (USGS Mesozoic loc. 26498)	75
17. Claystone, dark-neutral, highly calcareous, carbonaceous, hard, brittle; few scattered fossils	13
18. Sandstone, very fine grained, thin- to medium-bedded, light-neutral; few scattered black and gray chert pebbles; small scale crossbedding: highly calcareous and argillaceous; fractures into rectangular slabs; several coquina lenses with abundant pelecypods and gastropods	17
	856

AGE AND CORRELATION

The Barrow Trail member contains the largest number of megafossils of any unit in the Cretaceous of northern Alaska, both as to the number of genera represented and the number of individual specimens. The diversified molluscan megafauna has a widespread areal distribution and is most abundant in the sandstone units of the member. The siltstone beds are locally fossiliferous. The conglomerate, 430 feet above the base at Schrader Bluff, contains large quantities of broken shells such as might be found in a beach deposit. Most of the fossils of the member are well preserved and some of the specimens still retain the original shell material.

Among the more common fossils are: *Inoceramus patootensis* de Loriol, *I. steenstrupi* de Loriol, *Protocardium* cf. *P. borealis* Whiteaves, *Glycymeris* sp., *Panope* sp., *Tellina* sp., *Mytilus* sp., *Volsella* sp., *Corbula* sp., *Yoldia* sp., and the gastropod *Gyrodes* sp. The *Inoceramus* is considered diagnostic and is correlated with similar species from Canada and the western interior of the United States. This indicates a correlation with the upper part of the Santonian and lower part of the Campanian stages (Jones and Gryc, 1960, p. 153).

The shale sections of the Barrow Trail member were sampled for microfossils. The fossils were identified by H. R. Bergquist and are shown on plate 30. Sixty-one rock samples were collected from the Barrow Trail member; 30 were barren of microfossils. Concerning the age and correlations of the microfossils, Bergquist stated (written communication, 1956):

> The only fossils found are from the Chandler River section; samples from the lowest bed of that section provided only a couple specimens of Foraminifera and a few well preserved specimens of Radiolaria (*Archicorys* sp., two species of *Spongodiscus*, and *Dictyomitra* cf. *D. multicostata* Zittel).
>
> Two-thirds of the samples from 500 to 810 feet above the base of the member in the Chandler River section each yielded from one to six specimens of crushed and distorted arenaceous Foraminifera (*Haplophragmoides rota* Nauss and *Verneuilinoides fischeri* Tappan) and dark-colored calcareous Foraminifera (*Anomalinoides talaria* (Nauss) and *Gavelinella tumida* Brotzen).
>
> The samples from the interval from 810 to 1,100 feet above the base of the member provided the largest number of Foraminifera in the collection. At least 10 species are calcareous and the specimens are fairly well preserved, although most are stained red by iron oxide. *Neobulimina canadensis* Cushman and Wickenden, *Anomalinoides talaria*, *Quinqueloculina sphaera* Nauss, *Nonionella austinana* Cushman, *Gavelinella tumida*, Brotzen and *Praebulimina seabeensis* Tappan were recognized, but specimens of each are relatively rare. Arenaceous species from the same interval all are crushed and distorted, but *Haplophragmoides rota* Nauss, which occurs throughout the Colville group, was found in every sample, and specimens of it were abundant in one sample and common in three. In scattered samples were a few specimens questionably identified as *Trochammina stefanssoni* Tappan, a species that is common in some sections of the Sentinel Hill member but occurs only rarely in beds below it.
>
> Most of the microfossils found in the samples from the Barrow Trail member range throughout the Colville group, but, outside Alaska, three of the calcareous Foraminifera have been found only in beds of Senonian age. These are *Anomalinoides talaria*, *Quinqueloculina sphaera*, and *Nonionella austinana*, which also occurred sparingly in the Rogers Creek member.

SENTINEL HILL MEMBER

OCCURRENCE

The Sentinel Hill member of the Schrader Bluff formation is the uppermost Cretaceous marine unit exposed in the mapped area. Exposures of the member are scarce and occur mostly along the flanks of Prince Creek syncline where the structure is breached by the Colville, Chandler, and Kutchik Rivers. The interstream areas are covered by Quaternary deposits that unconformably overlie the Cretaceous rocks. The southernmost occurrence of the Sentinel Hill member is at lat. 68°56′30″ N. in the center of Racetrack Basin syncline. The lower part of the member is exposed on the flanks of Twin Bluffs syncline east of the Nanushuk River, 6 miles northeast of Racetrack Basin syncline. These exposures probably represent deposits in local embayments of the sea. The member is better exposed and is thicker in the region north and west of the Colville River (W. P. Brosgé and C. L. Whittington, oral communications).

The type locality of the Sentinel Hill member is along the west bank of the lower Colville River, from near Sentinel Hill to about the latitude of Ocean Point, 40 miles north of the mapped area (Whittington, 1956, p. 251–252). At that locality the member is represented by a lower unit 389 feet thick and an upper unit 316 feet thick. A section of the nonmarine Kogosukruk tongue 336 feet thick separates the two units of the marine Sentinel Hill member, and a thicker unit of the Kogosukruk overlies the upper unit of the Sentinel Hill. In the Chandler River region only the lower units of the Sentinel Hill member and the Kogosukruk tongue are present. The upper two units apparently were eroded during the time represented by the unconformity between the Cretaceous and Quaternary, or else they were never deposited.

Over much of the mapped area beds of the Sentinel Hill member are gently folded; for the most part the strata are inclined 8° or less, except at Schrader Bluff where they dip 70° S. The dip of the beds between the Chandler and Colville River is 5° or less, indicating less severe post-Cretaceous folding there than in the eastern part of the mapped area adjacent to the sedimentary basin east of the Nanushuk River.

Table 8.—*Megafossils of the Sentinel Hill and*

[Identified by George Gryc and D. L. Jones. Collections made by R. L. Detterman,

Geographic area	Colville River					Chandler River			
Stratigraphic position above base of member (feet)	820	Unknown	Unknown	Unknown	Unknown	Basal 180	80-150	200-300	250-350
Column (pl. 36)	4					5	5		
USGS Mesozoic locality number	26504	26503	19433	19434	19437	20458	26508	20462	20461
Undetermined echinoderms	-	-	-	-	-	-	-	-	-
Gyrodes sp	-	-	×	×	×	×	-	×	×
Haminea? sp	-	-	-	-	-	-	-	-	-
Turritella? sp	-	-	-	-	-	-	-	-	-
Worm borings	-	-	-	-	-	-	-	-	×
Arctica cf. *A. ovatus* (Meek and Hayden)	-	-	-	-	×	-	-	-	-
Brevicardium sp	×	×	-	-	-	-	×	-	-
Corbus? (Corbula?) sp	×	-	-	×	-	-	-	-	-
Gervillia? sp	-	-	-	-	×	-	-	-	-
Glycimeris? sp	-	-	-	-	-	-	-	-	×
Goniomya cf. *G. americana* (Meek and Hayden)	-	-	-	-	-	-	-	×	-
Homomya cf. *H. concentrica* Gabb	-	-	-	-	-	-	-	-	-
cf. *H. americana*	-	-	-	-	-	-	-	-	-
Homomya sp	-	-	-	-	-	-	-	-	-
Inoceramus patootensis deLoriol	-	-	-	×	-	-	×	×	×
steenstrupi deLoriol	×	-	-	-	-	-	-	-	-
cuvieri Sowerby	-	-	-	-	-	-	-	-	-
Inoceramus sp	-	-	-	-	-	×	-	-	-
Laternula? sp	-	-	-	-	-	-	-	-	-
Legumen? sp	-	-	-	×	-	-	×	-	-
Leptosolen? sp	-	-	-	-	-	-	-	-	-
Lima? sp	-	-	-	-	-	-	-	-	-
Lucina? sp	-	-	×	×	-	-	×	-	-
Mytilus? sp	-	-	-	-	-	-	-	-	-
Nemodon? sp	-	-	-	-	-	-	-	-	-
Panope sp	×	-	×	×	×	-	-	-	×
Ostrea sp	-	-	-	-	-	-	-	-	-
Pecten (*Camptonectes*) sp	-	-	×	-	-	-	-	-	-
Pecten cf. *P. simplicius* Conrad	-	-	-	-	-	-	-	-	-
Pecten sp	-	-	×	-	×	-	×	-	-
Pholadomya sp	-	-	-	×	-	-	-	-	-
Protocardium? sp	-	-	×	-	-	-	×	×	-
Protocardium cf. *P. borealis* (Whiteaves)	-	-	-	×	×	×	-	-	×
Tancredia cf. *T. americana*	-	-	×	×	-	-	×	-	-
Tellina sp	-	-	-	-	-	×	-	×	×
Unio? (Elliptio)?	-	-	-	-	-	-	-	-	×
Unio? sp	-	-	-	-	-	-	-	-	×
Volsella cf. *V. wrighti* (Warren)	-	-	-	×	-	-	-	-	-
cf. *V. meeki*	-	-	-	-	×	-	-	-	-
Xylophagella cf. *X. whitmeyi*	-	-	-	-	-	-	-	-	-
Yoldia sp	×	×	×	-	-	-	-	-	-
Fish remains (teeth, scales, vertebrae)	-	-	-	-	-	-	-	-	-

Barrow Trail Members of the Schrader Bluff Formation
R. R. Coats, George Gryc, R. S. Bickel, R. E. Fellows, and E. J. Webber]

Chandler River							Outpost Mountain							
540-600	300-700	730-800	750-810	900-920	900-1040	Unknown	400	400-450	430-450	430-450	500-520	500-520	530-560	550-560
5	5	5	5	5			6	6	6	6	6	6	6	6
26509	20459	20460	26510	26512	26511	20463	26522	26524	26525	26521	26526	26515	26527	26516
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Table 8.—*Megafossils of the Sentinel Hill and Barrow Trail Members of the Schrader Bluff Formation*—Continued

Geographic area	Outpost Mountain			Anaktuvuk River		Schrader Bluff		Nanushuk River		
Stratigraphic position above base of member (feet)	630	650-670	670	Upper	Unknown	Unknown	Unknown	Basal 120	500	30
Column (pl. 36)	6	6	6					9	9	
USGS Mesozoic locality number	26519	26517	26518	20483	26502	20481	20482	26498	20487	26495
Undetermined echinoderms	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gyrodes sp	-----	X	-----	X	-----	X	X	X	X	-----
Haminea? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Turritella? sp	-----	-----	-----	-----	-----	-----	X	-----	-----	-----
Worm borings	-----	-----	-----	-----	-----	-----	-----	X	-----	-----
Arctica cf. *A. ovatus* (Meek and Hayden)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Brevicardium sp	-----	-----	-----	-----	-----	X	-----	-----	-----	-----
Corbus? (Corbula?) sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Gervillia? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Glycimeris? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Goniomya cf. *G. americana* (Meek and Hayden)	-----	-----	-----	-----	-----	X	-----	-----	-----	-----
Homomya cf. *H. concentrica* Gabb	-----	-----	-----	-----	-----		-----	-----	-----	-----
cf. *H. americana*	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Homomya sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Inoceramus patootensis deLoriol	X	-----	X	-----	-----	-----	-----	X	X	-----
steenstrupi deLoriol	-----	-----	-----	-----	-----	X	-----	X	-----	-----
cuvieri Sowerby	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Inoceramus sp	-----	X	X	-----	X	X	-----	-----	-----	-----
Laternula? sp	-----	-----	-----	-----	-----	-----	X	-----	-----	-----
Legumen? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Leptosolen? sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Lima? sp	X	-----	-----	-----	-----	-----	-----	-----	-----	X
Lucina? sp	-----	-----	-----	-----	-----	X	X	-----	-----	-----
Mytilus? sp	-----	-----	-----	-----	-----	X	-----	-----	-----	-----
Nemodon? sp	-----	-----	-----	-----	-----	-----	-----	X	-----	-----
Panope sp	-----	-----	-----	X	-----	X	X	-----	X	-----
Ostrea sp	-----	-----	-----	-----	-----	X	-----	-----	-----	-----
Pecten (*Camptonectes*) sp	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pecten cf. *P. simplicius* Conrad	-----	-----	-----	-----	-----	X	-----	-----	-----	-----
Pecten sp	-----		-----	-----	-----	X	-----	X	X	-----
Pholadomya sp	-----	-----	-----	-----	-----	-----	-----	X	-----	-----
Protocardium? sp	X	X	X	-----	-----	-----	-----	-----	-----	X
Protocardium cf. *P. borealis* (Whiteaves)	-----	-----	-----	X	-----	-----	-----	X	X	-----
Tancredia cf. *T. americana*	-----	-----	-----	-----	-----	X	-----	X	X	-----
Tellina sp	X	X	-----	X	-----	X	-----	X	X	-----
Unio? (Elliptio)?	-----	-----	-----	X	-----	-----	-----	-----	-----	-----
Unio? sp	-----	-----	-----	-----	-----	X	-----	-----	-----	-----
Volsella cf. *V. wrighti* (Warren)	-----	-----	-----	X	-----	-----	-----	-----	-----	-----
cf. *V. meeki*	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Xylophagella cf. *X. whitmeyi*	-----	-----	-----	-----	-----	-----	-----	X	-----	-----
Yoldia sp	-----	X	-----	-----	-----	-----	-----	-----	-----	-----
Fish remains (teeth, scales, vertebrae)	-----	-----	-----	-----	-----	X	X	X	-----	-----

CHARACTER AND THICKNESS

The main lithologic features of the Sentinel Hill member are the poor consolidation and the abundance of tuff and bentonite. In addition to tuff and bentonite, the member is composed predominantly of medium dark-gray siltstone that is thin bedded to massive, laminated, and noncalcareous. Dark-gray spindle or lens-shaped particles as much as 3/8 inch long are alined along the bedding planes. Vague blotches of this dark material, similar to those in the siltstone of the Barrow Trail member, are common throughout the beds. The siltstone is weathered in part to a dark maroon and ripple marks are common. Medium dark-gray to black fissile clay shale is also a constituent of the member. A few laminated fossil-bearing limestone nodules occur in the clay shale of the Twin Bluffs section.

A definite relation appears to exist between the pyroclastic material and the clastic sediments. Sections that are composed of clay shale have only bentonite intercalated with the shale, and the tuff appears to be restricted to the siltstone and sandstone units. This seems to indicate that the tuff was formed from ash deposited in the near-shore shallow-water zone and the bentonite from ash that was deposited in deeper water farther from shore.

A minor amount of thin-bedded very fine-grained silty tuffaceous light-gray sandstone occurs in Racetrack Basin syncline. This is the southernmost section and represents a near-shore deposit, as plant fragments are present in the standstone.

A section 455 feet thick, the thickness in the mapped area, was inferred from rubble traces at Racetrack Basin syncline. The exposure from the east bank of the Chandler River, 1 mile downstream from camp D–July 28–48, is the only one in which the member is overlain by the Kogosukruk tongue; the Sentinel Hill is inferred to be 220 feet thick there. At Schrader Bluff the member is unconformably overlain by terrace deposits of Quaternary age; however, the 315 feet measured is probably a nearly complete section.

GEOLOGIC SECTIONS

Five sections of the member are shown on plate 36. All sections except the one from the Chandler River are incomplete, as the overlying Kogosukruk is not exposed.

The Colville River section (pl. 36, column 4) is 140 feet thick and is on the north flank of Prince Creek syncline on the south side of the Colville River, about 4 miles upstream from Umiat. There the exposed part of the Sentinel Hill member is composed entirely of clay shale and bentonite. As the exposures are poor, the thickness could not be accurately measured. Additional strata of the Sentinel Hill may be present between the exposed area and the center of the syncline, but if so, they are covered by terrace deposits and tundra. Some nonmarine beds of the Kogosukruk tongue occur in the center of the syncline, but the contact could not be placed accurately.

The Chandler River section (pl. 36, column 5; pl. 34, section 1) was measured on the east side of the river, about 1 mile downstream from camp D–July 29–48. The section, which consists of bentonitic clay shale float, is poorly exposed; it was computed from a stadia traverse by using an average dip obtained from the underlying and overlying beds. The section is important only insofar as it helps to show a facies pattern within the member. The computed thickness of 220 feet may be in error by 10 percent.

The Schrader Bluff section (pl. 36, column 7; pl. 34, section 2) is exposed at the south end of the bluff, along the east bank of the Anaktuvuk River. The section is incomplete in that the upper contact with the Kogosukruk tongue was not seen; however, the 315 feet measured at this locality is well exposed.

Section of the Sentinel Hill member, Schrader Bluff formation, at Schrader Bluff (pl. 36, column 7)

Terrace deposits.
Unconformity.

Sentinel Hill member:	Feet
1. Siltstone, thin-bedded to massive; gray background with darker gray spindle or lens-shaped particles as much as 3/8 inch long alined along the bedding planes; hard, brittle, noncalcareous; interbedded with olive-gray dense flinty massive greasy-appearing tuff; ripple-marked; mica flakes scattered throughout	59
2. Mud-covered	8
3. Siltstone and tuff; interbedded; similar to unit 1. Tuff less than 10 percent of unit. Indications of bentonite seen in mud	136
4. Covered; computed thickness	9
5. Siltstone; similar to unit 1; weathers purple; well-developed ripple marks	103
	315

Barrow Trail member.

The Racetrack Basin syncline section (pl. 36, column 8) is in the center of the basin about 2.5 miles northeast of camp D–July 26–52. It was computed to be 455 feet thick, which is considerably thicker than other sections of the Sentinel Hill in the mapped area. The lithology was determined from rubble traces. The thickness may be in error by 10 to 20 percent. This is the southernmost section measured and is important to an understanding of the facies pattern of the member.

Incomplete section of Sentinel Hill member, Schrader Bluff formation, at Racetrack Basin syncline on the Anaktuvuk River (pl. 36, column 8)

Sentinel Hill member:	*Feet*
1. Siltstone and sandstone; tuffaceous, very fine grained, light-gray, thin-bedded; fractures into small fragments; slightly calcareous, hard; rubble; computed thickness	25
2. Covered; computed thickness	15
3. Same as unit 1; rubble; computed thickness	20
4. Siltstone and shaly siltstone float; computed thickness	60
5. Sandstone, very fine grained, thin-bedded, light-gray; tuffaceous siltstone and shaly siltstone; rubble; computed thickness	15
6. Siltstone, shaly, float; computed thickness	70
7. Sandstone, siltstone, and shaly siltstone; sandstone very fine grained, silty, thin-bedded, somewhat tuffaceous; plant fragments; rubble; computed thickness	20
8. Siltstone, sandstone, and shaly siltstone float in covered area; computed thickness	230
	455
Barrow Trail member.	

The Twin Bluffs section (pl. 36, column 9) was computed at the west end of the upstream bluff, about 1 mile from camp W–June 15–47. Clay shale representing the basal 40 feet of the member is exposed at this locality. Additional beds are undoubtedly present between the end of the exposure and the center of the syncline but are covered by tundra.

Incomplete section of Sentinel Hill member, Schrader Bluff formation, at the southern bluff of Twin Bluffs syncline on the Nanushuk River (pl. 36, column 9)

Sentinel Hill member:	*Feet*
1. Clay shale, dark blue-gray to black, fissile, paper-thin; thin bentonite interbeds ½ to 1 inch thick; a few laminated limestone nodules in upper part. Fossils present in nodules (USGS Mesozoic loc. 26495). Mostly rubble; computed thickness	40
Barrow Trail member.	

AGE AND CORRELATION

Molluscan faunal remains are scarce in the Sentinel Hill member. A few megafossils were collected from limestone concretions in the Twin Bluffs section (pl. 36, column 9). They are similar to species identified from the underlying Barrow Trail member. In addition to the mollusks a few fragments of fossil fish were collected. The fragments were insufficiently complete to be identifiable.

Fifteen samples were collected for examination for microfossils. The Foraminifera and Radiolaria were identified by H. R. Bergquist who reported (written communication, 1956):

A small microfauna was found in 13 of the 15 samples examined from the Sentinel Hill member, but nearly all the Foraminifera are crushed and distorted and thus many specimens are questionably identified. In contrast, the specimens of the few species of Radiolaria are well preserved.

Haplophragmoides rota Nauss and *Dictyomitra* cf. *D. multicostata* Zittel each were common in two of the five fossiliferous samples from the Colville River section below the mouth of Fossil Creek. In one sample, specimens of *Saccammina* sp. were common and specimens of *Trochammina ribstonensis* Wickenden were abundant. In another sample, specimens of *Anomalinoides talaria* (Nauss) were common and *Neobulimina canadensis* Cushman and Wickenden was abundant. Rare to very rare specimens of *Verneuilinoides fischeri* Tappan, *Psamminopelta* sp., *Spiroplectammina mordenesis*? Tappan, and *Trochammina ribstonensis*? were found. Pyritic casts of *Zonodiscus* sp. occurred in each of the samples.

Haplophragmoides rota is abundant in one of the samples from Schrader anticline, but only a few specimens of it were found in the samples from the Gubik anticline. The dominant species in those samples is *Trochammina stefanssoni* Tappan which is common to very abundant in three samples. This species is more or less diagnostic of the Sentinel Hill member and is rarely found below it.

A Senonian age is suggested for the Sentinel Hill member because *Anomalinoides talaria* is known in Canada only from beds of Senonian age and in Alaska seems to be limited to beds above the Turonian (Seabee formation).

PRINCE CREEK FORMATION

KOGOSUKRUK TONGUE

OCCURRENCE

The nonmarine Kogosukruk tongue of the Prince Creek formation is limited to the northern part of the mapped area; it does not occur south of lat 69°14″ N. The exposures are restricted almost exclusively to the Prince Creek and Kutchik synclines. One area along the Prince Creek syncline is on the south bank of the Colville River about 5 miles upstream from Umiat. Two sections of the tongue were measured; one on the east bank of the Chandler River about 15 miles upstream from its mouth and the other on the east bank of the Nanushuk River about 6 miles upstream from the junction with the Anaktuvuk River. In the interstream areas the tongue is largely covered by Quaternary deposits or mapped as undifferentiated with beds of the Sentinel Hill member of the Schrader Bluff formation.

At the type locality along the Colville River, north of this area, the Kogosukruk tongue is 1,496 feet thick (W. P. Brosgé and C. L. Whittington, oral communications). The thickest section measured in the area is 150 feet thick along the Nanushuk River. At that locality the tongue is unconformably overlain by the Gubik formation of Pleistocene age. The section along the Chandler River is 145 feet thick; the two sections may not be entirely correlative. An unexposed interval approximately equivalent to 125 feet of section overlies the Chandler River section and may be in part equivalent to the Nanushuk River section. Regardless of the correlation between the two sections, the Kogosukruk tongue is apparently much thinner in the Chandler River region than it is farther north along the Colville River.

CHARACTER AND THICKNESS

The distinguishing features of the Kogosukruk tongue are the poor consolidation and bright colors. The two sections measured exhibit different lithologies. The Nanushuk River section is predominantly thin lenticular crossbedded sandstone that is light yellow, red, buff, maroon, cream, and greenish-gray. A few chert pebbles are present near the base. Minor constituents include siltstone, shaly siltstone, clay shale, coal, limy ironstone concretions, tuff, and logs. A few small brackish-water pelecypods and gastropods were found throughout the section.

The Chandler River section is mainly a coal, clay shale, and bentonitic unit. Nine coal beds with an aggregate thickness of 23 feet occur in the basal 75 feet of the section. The thickest individual bed is 5 feet and the thinnest is 8 inches. Clay shale, fire clay, and bentonite are intercalated with the coal. Three sandstone units and a conglomerate bed are also included in the coal section. The sandstone is thin bedded to massive, medium to coarse grained, salt and pepper, crossbedded, and friable. The intraformational pebble-cobble conglomerate includes shale and coal fragments in addition to varicolored chert and quartz. The constituents are poorly sorted and almost unconsolidated. Associated with the uppermost sandstone unit are clinkers and residue of a burnt coal bed. The clinkers are covered by moss, tundra, and gravel at the top of the exposure which would seemingly indicate that the fire was not of recent origin. Sandstone and shale adjoining the coal bed were burned to a brick red color.

The contact with the underlying Sentinel Hill member of the Schrader Bluff formation is not well exposed. Consequently, the contact is arbitrarily placed at the base of the lowest nonmarine bed. The upper contact, as seen on the Nanushuk River, is marked by an unconformity. Beds of the Gubik formation of Pleistocene age overlie the Kogosukruk tongue with an angular discordance of 5° to 8°. An 8-inch zone of weathered blue plastic clay marks the unconformity at this locality.

The 55 feet of dark fissile clay shale (unit 2) of the Chandler River section may be an intertongue of the Sentinel Hill member. One shale sample collected from this unit contains microfossils. The Kogosukruk is generally barren or microfossils; however, the genera represented were the arenaceous long-ranging forms, *Saccammina lathrami* Tappan and *Trochammina* sp., that are found in marginal sedimentary rocks of the Nanushuk and Colville groups. Other samples from the same unit were barren of microfossils, so, lacking conclusive evidence to the contrary, this unit has been retained as part of the Kogosukruk tongue.

GEOLOGIC SECTIONS

Both sections given below were measured on the south limb of the Prince Creek syncline where the gently dipping beds are inclined 4° to 10° toward the north. The Chandler River section (pl. 36, column 5; pl. 34, section 1) was measured about 0.8 mile downstream from camp D–July 28–52. The Nanushuk River section (pl. 36, column 10) was measured about 0.5 mile upstream from camp W–July 6–47.

Incomplete section of the Kogosukruk tongue, Prince Creek formation, on the Chandler River downstream from Trouble Creek (pl. 36, column 5)

	Ft.	In.
Kogosukruk tongue:		
1. Sandstone, siltstone, shaly siltstone, and burnt coal; sandstone medium grained, medium bedded, light gray, tuffaceous, carbonaceous; burnt coal as clinkers; rubble; computed thickness	15	0
2. Clay shale, dark blue-gray, fissile to crumbly; thin bentonite stringers	55	0
3. Coal (lignite)	2	8
4. Bentonite	1	1
5. Coal	3	9
6. Siltstone, shaly gray, with thin interbeds of carbonaceous siltstone	11	0
7. Coal	2	6
8. Bentonite, plastic, green, and green tuff	4	2
9. Sandstone, thin-bedded, medium-grained, salt-and-pepper to dark yellow-red, carbonaceous	6	0
10. Coal	3	0
11. Fire clay	1	0
12. Clay shale	1	0
13. Coal and carbonaceous shale	1	4
14. Bentonite	1	0
15. Coal	1	0
16. Clay shale	0	8
17. Coal	0	8
18. Clay shale and bentonite	1	0
19. Coal	3	0
20. Sandstone, medium- to thick-bedded, medium- to coarse-grained, clean, friable, salt and pepper; large-scale crossbedding; plant fossils	20	0
21. Conglomerate; intraformation pebble to cobble, including shale and coal fragments; poorly cemented	5	0
22. Coal (lignite)	5	2
	145	0

Sentinel Hill member.

Incomplete section of Kogosukruk tongue, along the Nanushuk River (pl. 36, column 10)

Gubik formation.
Unconformity.

Kogosukruk tongue:	*Feet*
1. Sandstone, siltstone, shaly siltstone and clay shale, bentonite, limestone, and coal, interbedded; rocks generally very poorly consolidated; sandstones varicolored light yellow red, buff, maroon, cream, and greenish gray; beds lenticular and crossbedded. Several thin coal seams, numerous logs, and limy ironstone concretions. Strong petroliferous odor in lower sands. Few chert pebbles near base. Pelecypods scattered throughout the section. (USGS Mesozoic loc. 26493)	150
	150

AGE AND CORRELATION

The age of the Kogosukruk tongue cannot be determined directly from faunal evidence. A few nondiagnostic long-ranging brackish- to fresh-water pelecypods and gastropods were collected from the outcrop on the Nanushuk River. The only Foraminifera found in the Chandler River section, *Saccammina* n. sp. and *Trochammina* sp., are also long ranging; both have been found throughout the Nanushuk and Colville groups (H. R. Bergquist, written communication, 1956).

The age of these beds can be ascertained indirectly from their relation to beds of known age. The Kogosukruk tongue is the youngest sequence of beds in the upper Cretaceous rocks of northern Alaska; it intertongues with and overlies strata of the Schrader Bluff formation that contains a diversified megafauna including *Inoceramus patootensis* de Loriol and *I. steenstrupi* de Loriol. This fossil indicates a correlation with the upper part of the Santonian and lower part of the Campanian stages (Imlay and Reeside, 1954, p. 242). Thus, the Kogosukruk tongue is not older than lower Campanian, for it overlies beds containing fossils of that age.

QUATERNARY SYSTEM

Some of the most extensive deposits in the mapped area are those that were formed in Recent time or that are still in the process of formation. About 20 percent of the region has been mapped as Quaternary. A combination of two processes, fluviatile or glacial, account for most of these deposits. Marine and eolian processes were involved to a lesser extent in the formation of the Quaternary deposits. In some localities deposits of different origin merge in to one another so intricately as to make their identification virtually impossible. In general, however, they have been subdivided and mapped according to their origin. The following four classifications were used in mapping the Quarternary: Gubik formation, primarily of marine origin, but including some fluviatile and terrestrial material; glacial deposits; fluviatile deposits, subdivided into high-level terraces and alluvium; eolian deposits or loess.

These unconsolidated deposits mantle the underlying bedrock to varying depths. The deposits of glacial origin are perhaps as much as 200 feet thick locally, but in general they are only a few tens of feet thick. The terrace deposits are 20 to 30 feet thick, as is the silt of eolian origin that mantles the terraces in many places. The thickness of the alluvium varies but is known to be as much as 110 feet at Grandstand test well 1 on the Chandler River.

GUBIK FORMATION

The term "Gubik sand" was first used by Schrader (1904, p. 93) to describe "* * * a surficial deposit of brownish sand or loam about 10 to 15 feet in thickness * * *" which is exposed along the Colville River in the Arctic Coastal Plain province.

The Gubik sand was later redefined by Gryc and others (1951, p. 167) as the Gubik formation. The type locality is the same as that Schrader described as "* * * the bluffs along the west side of the Colville River from the mouth of the Anaktuvuk River to Ocean Point." The Gubik is the only surficial deposit of Quaternary age in this area to be defined as a formation.

OCCURRENCE

The only section of the Gubik formation that was measured in the mapped area is on the Nanushuk River, 5 miles upstream from its confluence with the Anaktuvuk River. This is the most southerly occurrence of the formation reported. At that locality the Gubik unconformably overlies strata of Late Cretaceous age and is in turn comformably overlain by terrace deposits of Pleistocene age.

The Gubik formation was also mapped along the east side of the Nanushuk and Anaktuvuk Rivers as far as the northern limit of the Chandler River region; it probably underlies the high-level terrace throughout most of the northern part of the region, but it has been so completely covered by the terrace that it is not recognizable.

CHARACTER AND THICKNESS

The unconsolidated to partly consolidated sediments exposed on the Nanushuk River consist primarily of yellow-red to brown sand and conglomerate. Coal and sandstone of Cretaceous age constitute the bulk of the conglomeratic constituents; chert, quartz, and limestone are also present. The conglomeratic constituents are all well rounded except for coal and sandstone fragments. The section exposed on the Nanushuk is composed of larger rock fragments than is the type section along the Colville River north of the mapped area. The bedding is not well defined. An 8-inch bed of plastic blue clay occurs between the base of the sand and the underlying Cretaceous strata. The Gubik formation in the mapped area is primarily of nonmarine origin.

GEOLOGIC SECTION

A section 28 feet 8 inches thick was measured on the east bank of the Nanushuk River about 1 mile upstream from camp W–July 6–47.

Section of Gubik formation, on the Nanushuk River

	Ft.	In.
Terrace deposits.		
Gubik formation:		
1. Chert pebbles and cobbles with partly consolidated yellow-red sand matrix	10	0
2. Sand, clean, moderately cemented, well-sorted, buff to yellow-red; few chert cobbles (wind-polished dreikanters); thin stringers of marl and coal ½ inch thick	10	0
3. Sand, yellow-red, with intraformational conglomerate pebbles and cobbles including chunks of coal, Upper Cretaceous sandstone, and a small percentage of older rocks, mainly chert, quartz, and limestone	8	0
4. Clay, blue, plastic	0	0
	28	8
Uncomformity.		
Kogosukrok tongue.		

AGE AND CORRELATION

The Gubik formation unconformably overlies strata of Late Cretaceous age and is in turn overlain by terrace deposits derived, at least in part, from glacial deposits. Therefore, the Gubik is at least younger than the Cretaceous and older than the last glacial advance. The section exposed on the Nanushuk River was unfossiliferous, but freshwater ostracods of Pleistocene age have been reported by W. P. Brosgé and C. L. Whittington (written communication, 1960) from similar beds north of Umiat.

GLACIAL DEPOSITS

The recent Geological Survey parties in the Chandler River region were primarily concerned with mapping the stratigraphy and structure, as they applied to the exploration of Naval Petroleum Reserve No. 4. Field observations of glacial geology were made during 1952 and 1953; morainal areas were delineated on vertical aerial photographs at a scale of 1:20,000. This rather limited study of the glacial history of the area is the basis of the present interpretation.

Quaternary glaciation in northern Alaska was not of the same magnitude as it was in southern Alaska and the United States; however, it was more widespread than was once believed. Most of the major river valleys in the central and eastern Brooks Range and southern foothills section, as well as many of the smaller tributary valleys, were glaciated at least once. Ice occupied some of the valleys several times, and it coalesced to form piedmont lobes at least twice (Detterman, 1953, p. 11–12).

Only the southern part of the Chandler River region was glaciated. In all, 290 square miles along the Killik, Anaktuvuk, Kanayut, Nanushuk, and Itkillik Rivers are covered by glacial deposits, including outwash. Over most of the area these deposits occur as a thin mantle, which is from a few tens to a hundred feet thick and which partially obscures the original topographic features. Near the terminal edges of the glacier the morainal deposits may be several hundred feet thick where the ice dropped its burden before retreating.

Two stages of glaciation have been mapped in the area. The older stage has been called Anaktuvuk glaciation and the later stage Itkillik glaciation (Detterman, 1953, p. 11–12). The general appearance of the morainal remnants indicate that a considerable amount of time elapsed between the two stages. The morainal deposits of the older stage are subdued, well rounded, and dissected by numerous streams; many of the kettle lakes have been filled or drained. Moraines of the younger stage are still relatively fresh and retain sharp knob-and-kettle topography. Few of the lakes have been filled, and only a few streams cut the moraines.

As only limited studies have been made of glaciation in northern Alaska, it is impossible to correlate positively the advances there with the major episodes in the United States. They undoubtedly occurred during the Pleistocene, when ice covered much of the northern hemisphere. Little is known about the weathering characteristics produced by the semi-arid Arctic climate, and how they correspond to morainal weathering in more moderate climates. Based on a tentative correlation with glaciations in southern Alaska, which have been dated by carbon-14 analysis, Karlstrom (1957, p. 73–74) correlated the Anaktuvuk stage with the Nebraskan, and the Itkillik stage with the Illinoian. However, the authors believe that the Anaktuvuk glaciation should be correlated as pre-Wisconsin and the Itkillik as early Wisconsin. On the Killik, Anaktuvuk, and Nanushuk Rivers, scattered glacial erratics and gravel deposits that may be glacial or glacial-fluviatile in origin occur north of the limit of definitely recognizable glacial features. This may indicate deposits of an older glacial advance that have been nearly covered

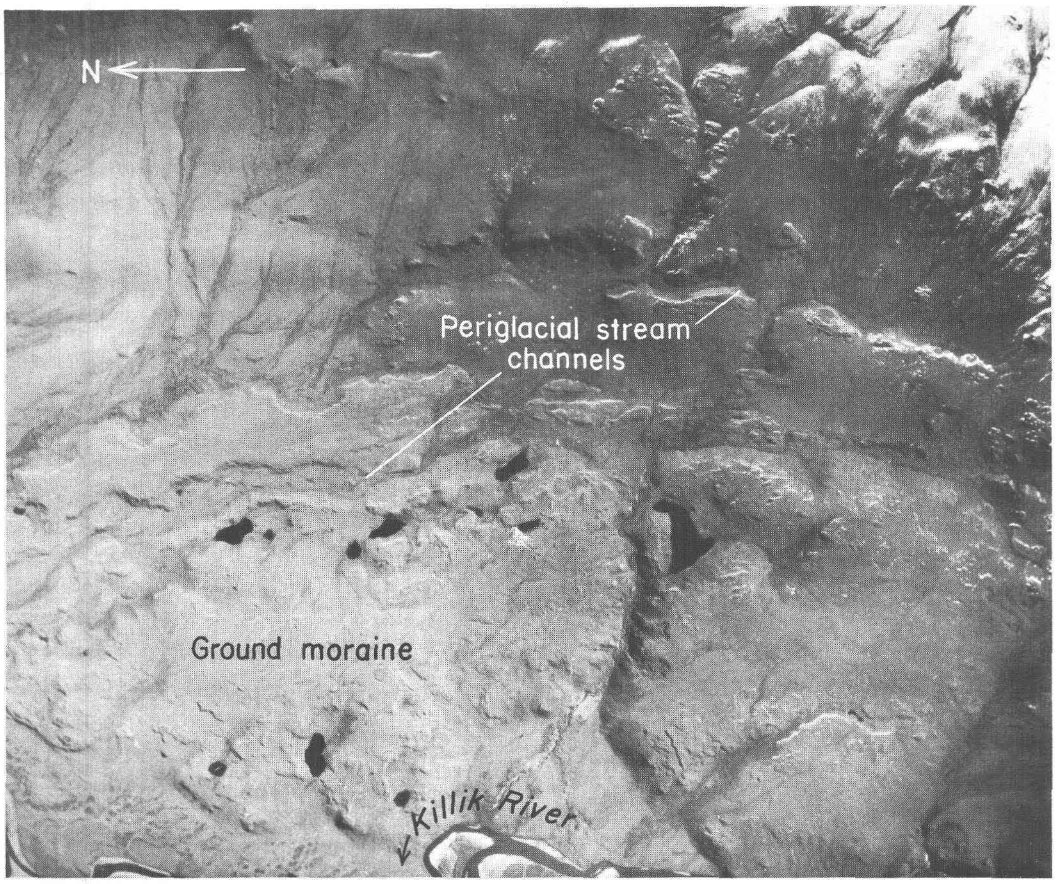

FIGURE 50.—Vertical view of periglacial stream channels and ground moraine formed by the Itkillik glaciation on the east wall of the Killik River valley. Photograph by U.S. Navy.

by outwash from later advances. On top of a bluff 10 miles above the mouth of the Anaktuvuk, Schrader (1904, p. 88) found sand and gravel that he inferred to be deposited by glacial waters. If his inference is correct, one advance must have extended nearly to that point. The oldest recognized stage of glaciation, the Anaktuvuk, was more widespread in the mapped area than was the Itkillik stage. Deposits of the Anaktuvuk stage cover about 235 square miles. Isolated morainal remnants between the Anaktuvuk and Nanushuk Rivers indicate that the valley glaciers coalesced to form a piedmont lobe, at least in that part of the area. The Itkillik stage was confined to the major river drainages, and in the area discussed in this report did not form a piedmont lobe.

KILLIK RIVER

Two distinct stages of glaciation covered an area of about 50 square miles in the Killik River area. Erratics that are found over an additional 100 square miles may indicate a third, older stage, or they may have been deposited by the Anaktuvuk glaciation, morainal remnants of which are extremely weathered. Lateral and terminal moraines are no longer identifiable, and the drainage is well integrated. In contrast to that of the older glaciation, the drift of the Itkillik glaciation is relatively fresh. Terminal moraines consist of arcuate zones of slightly modified knob-and-kettle topography in which lakes are present, undrained depressions are abundant, and drainage is poorly integrated. Well-developed lateral moraines are present along the sides of the valley 800 to 900 feet above the present river level, and scattered glacial remnants occur as high as 1,200 feet above the river. There are arcuate recessional moraines behind the terminal moraine at intervals of 1.5 to 2 miles. Two of the recessional moraines are present within the area mapped, and several more, about the same distance apart, are south of the mapped area. The time lapse between the formation of the terminal and recessional moraines was relatively short, as there is no apparent difference in the amount of weathering or in the surficial modifications.

An ice-marginal stream channel parallels the east wall of the Killik River valley (fig. 50), at an altitude of 450 feet above the present river level; it parallels the side of the ridge for several miles before disappearing.

The maximum width of the channel is 200 yards and at several places it has cut 80 to 90 feet through solid bedrock. This channel was probably cut during the recession of the glacier; Tarr (1909, p. 101) showed that marginal drainage is more vigorous during the shrinkage of glaciers than during their expansion, because there is more water and a greater rock load during melting. Several other marginal channels were noted south of the area included in this report. Many of the small tributary streams in the glaciated part of the Killik River valley are controlled by lateral and terminal moraines. The streams are comparatively recent. Instead of cutting through the moraines, they follow along the perimeter. Thus, they are somewhat arcuate in outline.

ANAKTUVUK, KANAYUT, AND NANUSHUK RIVERS

Morainal remnants of the Anaktuvuk glaciation cover about 150 square miles in the Anaktuvuk-Kanayut-Nanushuk River area. Most of the deposits are on the Anaktuvuk, but the ice sheet apparently coalesced and spread over the interstream areas. The morainal features on the Kanayut and Nanushuk Rivers are so subdued as to make their identification difficult. The drift is somewhat better defined on the west side of the Anaktuvuk, and extends for 40 miles north of the Brooks Range. Glacial erratics cover many of the hills outside of the morainal areas and extend 10 miles farther north than any of the true glacial drift. At Rooftop Ridge the erratics are found at an altitude of 500 to 600 feet above the present river level. They may have been dropped by glaciers of the Anaktuvuk glaciation or may represent an older stage.

Till of the Itkillik glaciation is found at the southern edge of the area on the Anaktuvuk River; it covers approximately 15 square miles. As on the Killik, moraines of this advance are relatively fresh and unaltered. The terminal and lateral moraines are well defined, as are the ground moraines and the knob-and-kettle topography. A few lakes are present and the drainage is not well integrated, being controlled by the moraines rather than transecting them. The maximum advance of the Itkillik glaciation was about 20 miles north of the Brooks Range; it was apparently stopped by high ridges flanking the river at this point. Morainal remnants of the Anaktuvuk glaciation are obscured by outwash of the younger glaciation in the southern part of the mapped area.

ITKILLIK RIVER

As only a small part of the Itkillik River is mapped in this report, the true extent of the glaciation is not shown. The Itkillik was more extensively glaciated than any of the other rivers in the mapped area. About 75 square miles of drift was mapped, and in general it has the same features as were described for the drift in the other river areas. The older till (the Anaktuvuk) is considerably weathered; that of the Itkillik advance is comparatively fresh with well-developed moraines. The northernmost limit of deposits of definite glacial origin is about 40 miles north of the Brooks Range. Data on the area covered by erratics north of the drift area is not available.

FLUVIATILE DEPOSITS

Terrace gravels of Quaternary age occur along all the major streams in the mapped area. Those mapped as Quaternary terrace gravels (pl. 27) are the high-level terraces, which are about 250 feet above the present stream levels. There is also a well-developed system of low-level terraces between the stream level and 30 feet above the stream level. The latter are above the gravels of the present streams but have been mapped as Quaternary alluvium.

HIGH-LEVEL TERRACES

High-level terrace gravels cover an area of about 760 square miles. The main concentration is along the Colville River and in the northeastern part of the mapped area that falls within the Arctic Coastal Plain province. An almost continuous blanket of gravel extends from Fossil Creek to the Itkillik River. Along the Chandler River the terrace is 20 miles upstream from the Colville, and on the Anaktuvuk and Itkillik Rivers it extends even farther south. A similar, but smaller, deposit of gravel is located on the west side of the lower Killik River, where it extends 6 to 8 miles upstream. The deposit on the Killik can be correlated directly with the deposit south of Umiat.

The areas covered by terrace gravels are regions of almost uniformly low relief. The upper surface is a flat plain, broken only by occasional monadnocks that protrude up through the gravel and by lakes and streams that have cut through the deposits. Bedrock is exposed under the gravel in cutbanks along all the major streams. In most occurrences, the gravel unconformably overlies strata of Cretaceous age; the one exception is along the lower Nanushuk River, where it conformably overlies the Gubik formation of Pleistocene age. This is within the Arctic Coastal Plain province; it is possible that the gravel also overlies the Gubik in other parts of that province. The occurrence of the gravel overlying the Gubik indicates that the gravel was deposited in late Pleistocene, probably contemporaneously with one of the major glaciations. Further proof of this is seen in the southern part of the area where the terraces contain material that is definitely of glacial-fluviatile origin.

The high-level terraces maintain a constant gradient similar to the modern streams. The gradient is toward the north, away from the mountains. Along the Anaktuvuk River, from just north of Rooftop Ridge to the Colville River, the gradient is 17 feet per mile; from Trouble Creek, on the Chandler River to the Colville it is 5 feet per mile. This is almost exactly the gradient of the modern rivers (see table 2). The data used to compute the terrace gradients was taken from altitudes at triangulation stations established on the terraces. The fact that the stations were on top of the terraces, and thus on surfaces subject to erosion, does not appreciably affect the validity of the gradient measurements. In all cases where noted, the terrace was 20 to 30 feet thick; consequently, a variation of 10 feet or less will not greatly affect the gradient when measured over a distance of 20 to 30 miles.

The terraces are composed predominantly of well-rounded cobbles 4 to 6 inches in diameter with a considerable amount of smaller rock fragments 1 to 3 inches in diameter. Pebbles and silt are present locally, but in general are not an important part of the terrace. White quartz, gray quartzite, and varicolored chert constitute the bulk of deposits. Limestone may be present, but it is usually extremely weathered. Other constituents are laminated tan limonitic quartzite, graywacke, and quartz-pebble conglomerate. The deposits are a light to medium gray with a buff to rusty-brown weathered zone. A loess deposit 25 to 30 feet thick overlies the terrace deposit in most places.

ALLUVIUM

Those deposits mapped as Quaternary alluvium include all low-level terraces and gravels that occur on the flood plains of the modern streams. Some of the low terraces may be submerged during periods of high water, but submergence is not an essential criterion in mapping alluvium. The larger rivers may have four or five distinct terrace levels on their flood plains, each level being about 5 feet higher than the preceding terrace. The rivers may be actively cutting one or all of these various levels. Oxbow lakes, cutoff meanders, and abandoned channel scars are common features of flood-plain areas.

The alluvial deposits consist of all rock types found along the stream. Most rock fragments are water worn and well rounded except for material recently added from cutbank exposures of bedrock. The rock fragments range in size from 2 to 8 inches long; silt and small pebbles occur as lenses in lagoons and along the downstream end of bars. Mud, muck, and peat gradually fill in the lakes and cutoff meanders.

The thickness of Quaternary alluvium of only three locations is known, but these are probably representative of other parts of the mapped area. The following measurements of alluvium were obtained from test wells: Umiat test well 2, Colville River, 65 feet (Collins, 1958, pl. 12); Gubik test well 1, Chandler River, 67 feet (Robinson, 1958a, p. 209); Grandstand test well 1, Chandler River, 110 feet (Robinson, 1958b, pl. 19). The deposits were unconsolidated and similar to the surface alluvial deposits.

The thick deposits of Quaternary alluvium in the stream valleys may have been formed in one of several ways, or by a combination of several processes. The fluctuation of sea level due to large quantities of water contained as ice in the glaciers, land adjustments after the melting of the ice, and subsidence or uplift of the land area are but a few of the possibilities. Regardless of how the deposits were formed, deep canyons were cut and subsequently filled with alluvium. The rivers aggraded their channels to a position slightly higher than at present; the top of the low-level terraces on the flood plains, 25 to 30 feet above stream level, probably represents the maximum aggradation. The streams are now degrading their channels and the different terrace levels on the flood plain represent minor adjustments. The thick deposits of alluvium in the river valleys suggest that preglacial drainage followed the same general courses as the modern rivers.

LOESS DEPOSITS

Loess, or windblown silt, overlies the high-level terraces in the northern and northeastern part of the mapped area. These deposits were mapped from Fossil Creek to the Itkillik River. The terraces extend farther westward, but the loess could not be identified beyond Fossil Creek. One of the criteria used in identifying areas covered by loess is the presence of numerous large thermokarst lakes (fig. 51); lakes of this type attain their maximum development in areas of unconsolidated silt that contains large quantities of interstitial ice. Another important criterion is that the area must be nearly level with a poorly integrated drainage system. Both of these conditions are present in the northeastern part of the area mapped.

The unconsolidated deposits were classified as loess mainly because of the extremely small, almost microscopic size of the silt particles and the complete absence of large regoliths. The silt has a uniform grain size and has no apparent stratification where exposed. At present there is insufficient information to determine the source and the prevailing wind direction at the time of deposition. Presumably, however, the loess deposits

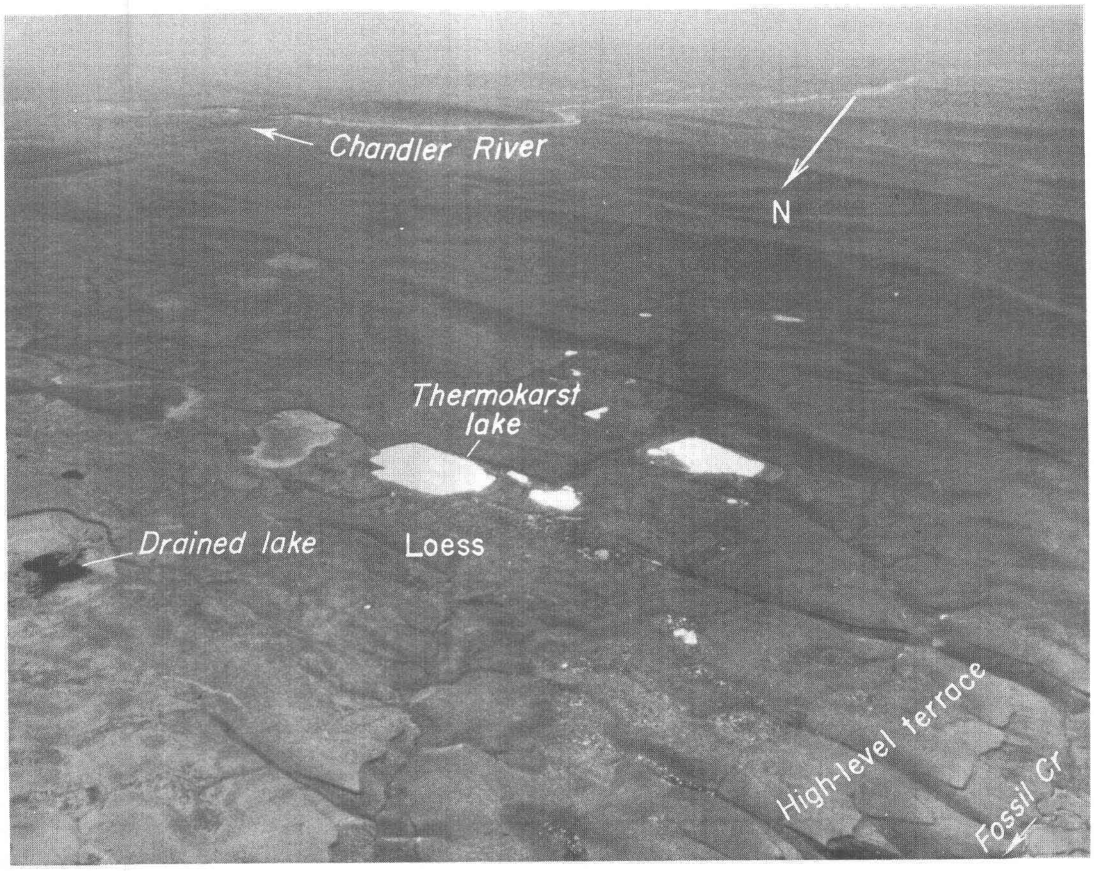

FIGURE 51.—Oblique view of the thermokarst lakes developing in the loess overlying the high-level terrace south of Umiat. Lake in left foreground is partly drained. Photograph by U. S. Navy.

were formed during one of the early glacial episodes. Strong currents of air blowing off the glaciers could have transported the silt.

The loess is 25 to 35 feet thick in most areas, except where the poorly integrated streams have eroded the deposit; it is stripped completely from the terraces along the river valleys. The regular featureless surface of the loess is broken only by thermokarst lakes, drained depressions, and poorly integrated streams.

There are many drained or partly drained thermokarst lakes in the loess. The only streams near the lakes are small and have very low gradients; consequently, it seems highly unlikely that they could have drained all the lakes. However, streams do drain some of the lakes. The distance between the floor of the depression and the top of the bank surrounding the depression is always about the same; that is, the lakes seem to drain when they reach a certain level. Porous zones in the material in or on which the lakes are developing could cause the lakes to drain; the terrace gravel would form such a zone. Permafrost is less well developed in gravel in which the constituent material is all moderately large; therefore the lakes may deepen until they reach the top of the gravel terrace and then drain out through the porous gravel. This theory would account for nearly all the lakes draining at about the same stage of development.

VERTEBRATE REMAINS

Many land animals apparently roamed northern Alaska during Quaternary time. Some of the species no longer exist; others have migrated to more favorable climates. Remains of these animals were noted by members of the Geological Society. Perhaps the most abundant remains were bones and tusks of the extinct mammoth or elephant. Several tusks were found by W. W. Patton, Jr., on Ivory Creek, a tributary of the Kiruktagiak, and by the authors on the Chandler and Colville Rivers. A tooth found on a gravel bar at camp D–June 26–52, on the Ayiyak River, was in perfect condition, as if it had only recently been transported to that spot. Another tooth was found on the Nanushuk near camp W–June 27–47. In addition to the mammoth teeth, bones of musk ox, bison, beaver, horse, and deer have been reported from adjacent areas.

The tusks and bones commonly are found on gravel bars. However, some are found embedded in the ice and muck of the stream banks. A tusk estimated to be 8 feet long and completely embedded in an ice wedge along the Colville was noted in 1947. The finding of mammal remains in muck near the present stream level indicates that the animals roamed the area in post-glacial time, or at least in one of the later inter-glacial periods. Complete skeletons were never seen, but the bones and tusks do not show signs of abrasions, as they would if they had been weathered out of older sediments and redeposited. Tusks that have been exposed to the weather for only a few years show signs of exfoliation; sometimes they splinter after a few months' exposure, so it must be inferred that the tusks and bones were originally deposited at the place where they were found.

GEOLOGIC HISTORY

The Chandler River region includes or is adjacent to nearly all the type localities of Cretaceous units in northern Alaska (Gryc and others 1956, fig. 5). The Cretaceous geologic history of the Arctic Slope as interpreted by T. G. Payne (1951, 1955) is based to a large extent on the geology of this region. Pre-Cretaceous rocks are not exposed in the mapped area and thus only the Cretaceous and post-Cretaceous history is here discussed.

The major tectonic elements of the Chandler River region were established sometime during the Jurassic period. By the beginning of the Cretaceous, the Brooks Range geanticline (Payne, 1955) was established as the dominant positive element and the source area of the Cretaceous rocks that were deposited in the Colville geosyncline to the north. The Okpikruak formation, of Neocomian age, forms the base of the Cretaceous sequence and includes about 2,400 feet of predominantly greenish-gray sandstone of graywacke type (Gryc and others, 1951). It is not exposed in the mapped area but is exposed a few miles to the south.

In late Neocomian and Aptian time the geosyncline was apparently moderately deformed and emergent, as both the Torok and Fortress Mountain formations of Albian age unconformably overlie the Okpikruak and older formations. Although the two formations are, at least in part, of the same age, they differ lithologically and are now exposed as two distinct mappable belts "separated by a zone of intense thrusts faults in a band in which there are no exposures" (Patton, 1956, p. 219). The Fortress Mountain includes between 10,000 and 11,000 feet of poorly sorted flysch-type marine graywacke sandstone and conglomerate. The Torok formation includes more than 6,000 feet of predominantly marine shale, with subordinate graywacke sandstone and chert-grit conglomerate (Patton, 1956, pp. 219-223).

The Tuktu formation (early middle Albian age) includes about 1,000 feet of ripple-marked sandstone, siltstone, and shale and apparently overlaps the Torok formation at an angle of 3° to 20°. This relation is well shown in the seismic profiles as anomalous dips that probably represent primary sedimentation features. These anomalous dips are interpreted to be foreset bedding on a continental shelf that was being built northward across the Colville geosyncline in Albian time.

The Tuktu formation has not been identified south of the Tuktu Escarpment. Lithologic and faunal characteristics indicate a sublittoral to neritic environmental area of deposition; they also indicate that the shore of the Tuktu sea was very near to the position of the present escarpment. The accumulation of 1,000 feet of uniform marine sediment indicates sedimentation in a slowly submerging geosyncline.

Near the end of Tuktu time the continental shelf slowly emerged from the sea. This gradual uplift first affected the Killik River area where a few thin marginal beds have been noted in the marine sequence. By the beginning of Chandler time the southern part of the mapped area was generally emergent, and a thick sequence of nonmarine and marginal strata were deposited. The remainder of Early Cretaceous time and the Cenomanian stage of the Late Cretaceous were marked by repeated marine transgressions and regressions. Two major marine transgressions covered a large part of the mapped area and are recorded as the Grandstand formation of late Early Cretaceous age and the Ninuluk formation of early Late Cretaceous age.

In late Cenomanian time the region was again uplifted; it was gently folded and the Ninuluk formation was partly eroded. This hiatus marks the top of the Nanushuk group, which is unconformably overlain by the Colville group. The areal extent of the latter, "is considerably less than that of the underlying Nanushuk * * * and extends to the west only to about the latitude of the Ikpikpuk River" (Whittington, 1956, p. 244). The restricted areal extent of the Colville group apparently reflects a change in the configuration of the Colville geosyncline and a separation into the Umiat and Chukchi basins (Payne, 1955). In the Umiat basin, which includes part of the Chandler River region, the character of the sediments and the rate of sedimentation were also markedly different. The rocks of the Colville group are characterized by greater vertical and lateral variation, apparently a slower rate of deposition, and a more normal marine environment as indicated by a more abundant and diversified fauna. Volcanic sediments and debris are rare in the Nanushuk but very common in the Colville group, giving evidence of extensive volcanism during Colville time. The site of this volcanism has not been determined.

The Turonian seaway covered all but possibly the extreme southern and southwestern part of the Chandler River region. The thickest section of the Seabee formation, which includes dark clay shale and black paper shale, was measured in the Nanushuk River area. According to Imlay and Reeside (1954), megafossils from this section indicate an early Turonian age. By middle Turonian time the region was again gently uplifted, first in the area of the Nanushuk River and then farther west. Although Imlay and Reeside (1954, p. 242) state that "The unconformity between the Seabee member and Tuluvak member could represent the late Turonian and part of the Coniacian," there is little evidence of a major hiatus at this stratigraphic interval in the Chandler River region.

Rocks of late Senonian (upper Campanian, Maestrichtian, and Danian) and Tertiary age have not been identified in the mapped area. The only exposure of the Gubik formation mapped in the Chandler River region is in the northeast corner of the area, where it unconformably overlies strata of Late Cretaceous age. Elsewhere other Quaternary sediments unconformably overlie the differentially eroded surface of the folded and faulted Cretaceous rocks. Thus the last orogeny to effect the region is pre-Quaternary and, as suggested by evidence in adjoining areas (Payne and others, 1951), was probably post-Paleocene. The extent and history of glaciation in the mapped area is discussed elsewhere (p. 301–303).

STRUCTURE

CHANDLER RIVER STRUCTURAL HIGH

A north-trending structural high, or line of culmination, is present just west of the Chandler River. The line of culmination is reflected in the Hawk, Grandstand, Big Bend, Fossil Creek, and Umiat anticlines; it is present in the area to the south, as reported by W. W. Patton, Jr. (written communication, 1960), and continues into the Brooks Range, between the Siksikpuk and Anaktuvuk Rivers, where W. P. Brosgé (written communication, 1960) reported that the anticlinal structures are doubly plunging. In the Chandler River region, all anticlinal folds crossing this high are doubly plunging, with closure indicated. West plunge is somewhat lessened by regional east plunge of the strata; conversely, east plunge is increased by the regional plunge.

The age of the high cannot be determined precisely from present field evidence; however, in all probability the line of culmination preceded the deposition of the oldest rocks exposed in the mapped area. There is a greater abundance of coarse-grained clastic rock along the line of culmination than is present in the rest of the mapped area; this seemingly indicates a growing structural high at the time the sediments were deposited. To the east and west of this mapped area, lines of culmination similar to the one along the Chandler River have been mapped.

CHANDLER SYNCLINORIUM

The main structural feature of the Chandler River region is a large east-plunging synclinorium that encompasses more than one-half of the area mapped. The synclinorium is more than 100 miles long and extends beyond both the east and west boundaries of the area. The maximum width of the synclinorium is between 35 and 40 miles. The south limb of this large structure is the north limb of the Ayiyak anticlinorium and the Tuktu Escarpment; the north limb is the east-trending Killik Bend and Big Bend anticlines. These anticlines are, in effect, one structure, although separated by the small Houston syncline along Ninuluk Creek.

The amount of east plunge on the synclinorium between the Killik and Anaktuvuk Rivers is 6,500 to 7,000 feet or about 100 feet per mile. East of the Anaktuvuk River the amount of plunge is less and a reversal may be indicated by the northeastward swing of the Tuktu Escarpment near the Itkillik River. The area east of the Itkillik River has been covered so completely with glacial debris and Quaternary alluvium that the east end of the structure is not discernible; however, the east end of the syncliorium is probably just east of the Itkillik River. There are several reasons for this supposition: the Tuktu Escarpment swings northeastward near the Itkillik River; the anticlinal and synclinal axes also swing northeastward between the Nanushuk and Itkillik Rivers; the structure increases in complexity in the Nanushuk River region; and finally, Big Bend anticline, which is part of the north limb of the synclinorium, swings slightly southeastward in the Nanushuk River area. All these structural features seemingly point to a reversal of plunge and a termination of the synclinorium east of the Itkillik River.

Many en echelon doubly plunging folds are present within the synclinorium. Without exception, these folds die out against the south limb of the structure. Some of the folds are 50 to 60 miles long and have several well-defined structural highs and lows. Two anticlines, Hawk and Grandstand, within the synclinorium have been contoured as has a part of Big Bend anticline (pl. 37).

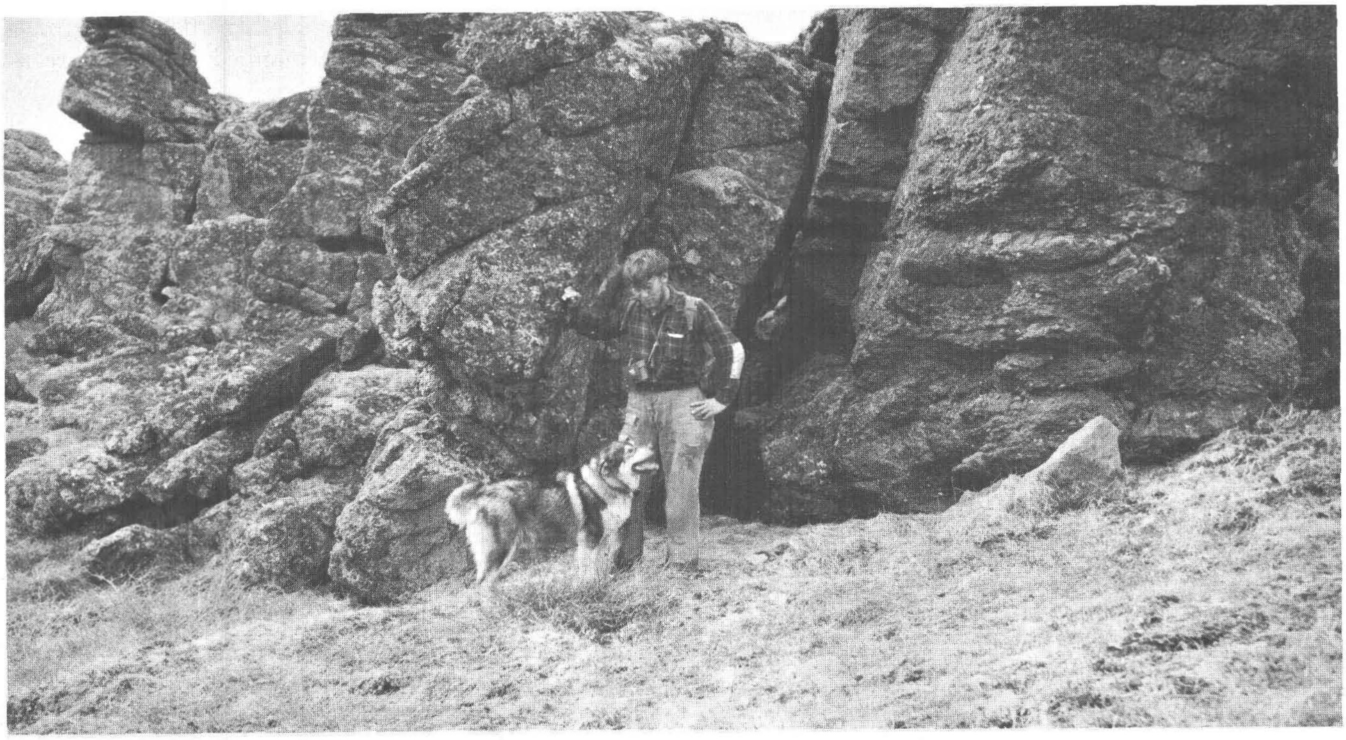

FIGURE 52.—Basal conglomerate bed of the Ninuluk formation at Hawk anticline.

The north limb of the synclinorium is not as high, structurally or topographically, as the south limb; this is to be expected with a northerly dissipation of orogenic forces and an initial north dip of the beds. North of the synclinorium, the strata apparently are folded into east-plunging anticlines and synclines.

HAWK ANTICLINE

Hawk anticline is a small fold, approximately 11 miles long, on the south limb of the synclinorium. The anticline was formed by the gentle upwarping of strata on the flank of the synclinorium and in addition to being doubly plunging, the entire anticline is titled gently toward the north with the south limb, at the structural high, being somewhat higher structurally and topographically than the north limb. Beds at both ends of the anticline flatten out and merge with the monoclinal north dip of the synclinorium. South of the anticline is the shallow Canyon syncline. Just east of the West Fork Tuluga River are Gunsight anticline and Tabletop syncline. These small folds may have been originally part of Hawk anticline and Canyon syncline; they were subsequently offset by the normal fault along the south bank of the Siksikpuk River. Movement along this fault appears to have been somewhat pivotal, with maximum displacement at the southeast end. The correlation of the two anticlines is partly substantiated by seismic line 4-52-144 (pl. 42), which was run by United Geophysical Co. between the Siksikpuk and Tuluga Rivers. A slight reversal is interpreted between shot points 5 and 8. As the line is close to Gunsight anticline, this reversal may be a reflection of that fold. Surface data from the area between the two anticlines do not indicate any correlation between the structures.

The anticline is slightly asymmetrical with the beds dipping more steeply on the north flank. Plunge on the east end of the structure is 12° to 14° steeper than the west plunge; this is probably a reflection of the regional east plunge. A longitudinal low-angle thrust fault with a dip of 26° is present about 1 mile south of the axis at the east end of the structure. The fault is approximately 5 miles long and extends to just east of the Chandler River. Stratigraphic displacement along this fault probably does not exceed 200 feet. The movement was somewhat pivotal in nature and decreases westward toward the end of the fault. A local steepening of dip about 1 mile north of the structural high could indicate another fault in that area; however, it was interpreted as only a local flexure, as adjacent structural traces do not appear to be offset and there is no lateral continuation of a fault trace.

Hawk anticline has a minimum of 600 feet of closure. The proven closed part of the structure encompasses an area approximately 7 miles long and 3 miles wide with a maximum of 600 feet of structural relief. The contour horizon (pl. 37) is the basal bed of the Ninuluk formation (fig. 52); a 200-foot contour interval was used. The four points of elevation on the map, like the contour lines, indicate structural and not topographic relief. They were listed to show the maximum structural relief on the crest of the structure and also to show that the 1,500-foot contour does not open up on the syncline but closes on the anticline.

GRANDSTAND ANTICLINE

Grandstand anticline is about 52 miles long and 5 miles wide at its widest point on the contour horizon between the Chandler and Tuluga Rivers; it occupies the center of the Chandler synclinorium. The strata at the west end of the anticline flatten and merge with the north-dipping beds on the south flank of the synclinorium about 3 miles west of the South Fork Ninuluk Creek.

The anticline is doubly plunging with the structural high about 5 miles east of the Chandler River. Small reversals in plunge probably occur along the structure; there is a slight suggestion of this both east and west of the high. However, the amount of reversal and the size and extent of any subsidiary highs cannot be determined exactly from present field information. Grandstand anticline is similar to Hawk anticline, in that the east plunge is greater than the west plunge. The east plunge under Racetrack Basin syncline was measured as 83°. This is probably abnormally high; the 23° east plunge recorded 1.5 miles farther west may be close to the true plunge of the east end of the structure.

A pivotal low-angle thrust fault cuts the anticlinal axis about 5 miles east of the South Fork Ninuluk Creek. From a point just east of Ninuluk Creek the fault is arcuate toward the north and continues in a northeasterly direction for 10 miles, terminating about 1 mile west of the Ayiyak River. Maximum stratigraphic displacement near the east end is probably 500 to 700 feet. A longitudinal axial fault extends from a point about 2 miles west of the Ayiyak River, eastward for 10 miles where it enters a structurally complex zone. This zone extends for 8 miles eastward along the anticline and is cut by the Chandler River near its east end (see pl. 37, section *B–B′*). The zone is about 1 mile wide at the river. A high-angle reverse fault cuts the strata about 1,000 feet north of the axis. A normal fault occurs 1,000 feet farther north; between the two faults are many small steeply plunging drag folds. Another high-angle reverse fault, which brings beds of the Tuktu formation to the surface, is present about 800 feet farther north. An escarpment formed by a low-angle thrust fault bounds the complex zone on the north. The faults apparently merge about 2.5 miles east of the river and continue east for another 4 miles; they form a low escarpment 1,000 feet north of the axis.

A small transverse fault offsets both the axis and the low-angle thrust faults a short distance east of the east end of the complex zone. The low-angle thrust fault may or may not exist for a distance of 2.5 miles west of the Tuluga River; bedrock traces as well as any trace of the fault scarp are missing in this interval. A high-angle reverse fault with a dip of 82° is present 1,000 feet north of the axis on the east bank of the Tuluga River. This high-angle fault joins the axis about 1 mile farther east and continues along the axis to the east end of the anticline. On the west bank of the Anaktuvuk River the dip is 69°. A pair of transverse faults offset some of the beds on the south limb of the anticline 1 to 2 miles west of the Chandler River. A pair of oblique slip faults, joining at the south end to form a triangular fault block, occur about 4 miles west of the Anaktuvuk River; the oblique slip faults are also on the south flank of the structure. Stratigraphic throw on the axial thrust fault west of the complex zone is interpreted as being between 300 and 400 feet; a minimum of 1,000 feet of stratigraphic throw is probably present on the low-angle thrust fault in the complex zone, and 200 to 300 feet of throw is indicated for the axial fault at the east end of the structure. Displacement on the other faults could not be accurately determined.

Grandstand anticline is a closed structure with a minimum of 2,000 feet of closure (pl. 37). The proven closed part encompasses an area approximately 40 miles long and 4.5 miles wide at the structural high; closure on the faulted structural high is between 500 and 600 feet. The structure is breached by the Ayiyak, Chandler, Tuluga, and Anaktuvuk Rivers. Structural relief is about 3,800 feet at the high.

Structure contours were drawn on a massive conglomeratic sandstone at the base of the Ninuluk formation; this same bed was used in contouring Hawk anticline. This horizon may be slightly lower stratigraphically at Grandstand than at Hawk anticline, owing to a northeast thinning of beds in the Chandler and Tuktu formations. The contours in the complex zone on the west side of the Chandler River are somewhat conjectural.

BIG BEND ANTICLINE

Big Bend anticline is one of the major structures of the area; with Killik Bend anticline, which is part of the same structural pattern, it forms the north flank of the synclinorium. The two anticlines are separated near Ninuluk Creek by the small Houston syncline. Killik Bend anticline within the area of this report has an indicated east plunge of about 125 feet per mile. The area just west of the western boundary of the map is known to be a structural high, and the anticline presumably has west plunge beyond that point.

Big Bend anticline is about 60 miles long. East of the Tuluga River the structural traces are covered by deposits of Quaternary age, but from data gained from exposures in stream cuts the anticline can be projected at least to the Nanushuk River. The apparent slight southeast swing of the axis near the latter point may indicate a closing out of the synclinorium in that direction. West of the Nanushuk River the west-trending structure continues in an almost straight line to Ninuluk Creek. A prevailing east plunge, common in other structures in the area, is also present on Big Bend anticline. This east plunge is reversed near Fossil Creek, with the resulting formation of a structural high near the Chandler River. The structural high occurs where the anticline crosses the north-trending Chandler River structural high.

Big Bend anticline is complexly folded and faulted as far east as Trouble Creek. East of Trouble Creek the anticline is apparently a slightly asymmetrical structure with beds dipping 15° to 33° N. on the north flank and 12° to 24° S. on the south flank. Two small oblique faults join at the north end to form a triangular fault block on the north flank 3 miles west of the Tuluga River. The faults are less than a mile long and stratigraphic displacement is relatively minor. An arcuate high-angle reverse fault cuts the axis about 5 miles east of Ninuluk Creek. A second high-angle reverse fault, starting north of the axis, joins it about 14 miles east of Ninuluk Creek. From the latter point the fault continues along the axis to a point 7 miles west of the Chandler River. The fault then continues north of the anticlinal crest to a point 1 mile east of the river, where it again cuts the axis and continues east to within 1 mile of Trouble Creek. Numerous steeply plunging drag folds are present between the fault and the anticlinal axis on the west bank of the Chandler River.

Lahnan syncline, near the Chandler River, and Ninuluk Creek syncline, near the Colville River, are in grabens resulting from normal faulting on the north flank of the anticline. The normal fault on the Chandler starts south of the river near Trouble Creek and continues northwest across the river before turning due west; the fault extends 8 miles before dying out. Lahnan syncline has a steep west plunge with beds of the Seabee formation in the graben in juxtaposition with beds of the Tuktu formation. Near the west end the syncline has a reversal in plunge as it dies out. The graben forming Ninuluk Creek syncline is about 15 miles long with continuous west plunge along the entire length. The normal fault forming the western graben is offset in two places by small transverse faults; continuation of the fault north of the Colville was not proved.

Structure contours of part of Big Bend anticline are included on plate 37. Only that part of the structure between the Chandler and Tuluga Rivers was contoured. Insufficient information and structural complexity made it impossible to contour the remainder of the anticline. A closure of 400 feet on the fault is indicated at the Chandler River, and additional closure may be present. The contoured horizon, the basal bed of the Ninuluk formation, will close on the east end of the structure as the east plunge continues at least as far as the Nanushuk River. West plunge on the structure between the Chandler River and Fossil Creek probably would give an additional 500 to 700 feet of closure. The proven closed part of the structure encompasses an area 10 miles long and 1 mile wide. Structural relief is about 3,400 feet.

FOSSIL CREEK, UMIAT, AND GUBIK ANTICLINES

Structural traces in the area from Fossil Creek anticline to the northern boundary of the mapped area are largely obscured by unconsolidated Quaternary deposits. The part of Fossil Creek anticline on the Anaktuvuk River was referred to by United Geophysical Co. as Schrader anticline. The general trend of the folds can be delineated from exposures in stream cutbanks, and regional east plunge can be proved; however, the structural picture is shown best by subsurface data obtained from seismic lines. A subsurface structure-contour map (pl. 38) was compiled by United Geophysical Co. from the seismic reflection records of fourteen lines run on the three anticlines (pls. 39–41). The anticlinal axes shown on the map are surface structures; they were added by the authors to show the relative positions of the surface axial trends with respect to the subsurface. The surface axes are slightly north of the indicated subsurface axes, and, because the orogenic forces responsible for the folding were supplied from the south, a south inclination of the axial plane should be expected. In brief, the map shows east plunge on all three anticlines, similar to the east plunge of the surface structures. Closure is indicated on Gubik anticline north of the Colville River; although no closure is shown on plate 38, Umiat anticline is known to have a minimum of 500 feet of closure north of the Colville River (W. P. Brosgé and C. L. Whittington, written communication, 1957).

SEISMIC REFLECTION PROFILES

The seismic profiles run by United Geophysical Co. are presented on plates 39–42. Data from these profiles were used by United Geophysical Co. in the compilation of the subsurface structure contour map (pl. 38). In the preparation of this map a phantom horizon (A) was used. The phantom horizon cannot be located definitely in the stratigraphic column, but it is probably the basal conglomeratic unit of the Tuluvak tongue of the Prince Creek formation. In Gubik test well 1, the top of the basal unit of the Tuluvak tongue was placed at 1,670 feet (Robinson, 1958a). The test well is 1,500 feet east of line 1–51–144 (pl. 39). By projecting the phantom horizon from shot points 6 to 8, on line 1–51–144, the phantom horizon would fall at 1,660 feet at the well site. Thus, it seems reasonable to assume that the phantom horizon is the top of the basal unit of the Tuluvak tongue.

GUBIK ANTICLINE

Line 1–51–144 (*pl. 39*).—There is good correlation between surface and subsurface structure; gently south dipping beds are indicated in both. There is no apparent surface evidence for the postulated fault in the seismic profile. By projecting the phantom horizon to shot point 8 it would fall at the proper position as shown in Gubik test well 1 (Robinson, 1958a).

Line 2–51–144 (*pl. 39*).—Gentle east plunge is indicated in both surface and subsurface beds. A slight reversal of plunge is indicated at shot point 8, but the phantom horizon has an overall east plunge of 125 feet. Plunge in the surface structure is perhaps a little steeper.

Line 3–51–144 (*pl. 39*).—The record is missing for shot points 12, 13, and 14 over the anticlinal axis. A possible fault is postulated in this interval, but there is no surface evidence of the fault. A projection of the reflectors across this area would form a gentle arch at the point where the axis should fall.

Line 4–51–144 (*pl. 39*).—Reflectors in the subsurface appear to be consistent with surface structure. The high point on the phantom horizon falls under shot point 11, which is about 1 mile south of the indicated surface axis, but the discrepancy may be due to the difficulty of accurately locating the surface axis. At shot point 11 the high point on the phantom horizon is at 2,410 feet; thus, an east plunge of 750 feet is indicated between lines 1 and 4.

Line 5–51–144 (*pl. 39*).—East plunge of 550 feet is indicated on the phantom horizon, with a slight indication of a fault between shot points 5 and 6. There is close agreement between surface and subsurface structures.

Line 6–51–144 (*pl. 39*).—Reflectors in the subsurface appear to be consistent with surface structure. There is total east plunge of 800 feet between lines 1 and 6. Gentle south dip of the phantom horizon is similar to surface structure.

UMIAT ANTICLINE

Line 1–52–145 (*pl. 40*).—On the Umiat anticline there is close correlation between surface and subsurface structures between shot points 10 and 18. The absence of any reflectors between shot points 5 and 10 make correlation practically impossible in that interval. The cause of the two anomalous reflections between 8,000 and 9,000 feet below shot point 4 is unknown, but they may be from a fracture plane.

Line 2–52–145 (*pl. 40*).—Reflectors in the subsurface appear consistent with surface structure, with east plunge of 200 to 300 feet. The origin of the anomaly at shot point 36 is unknown, but it may be a reflection from a fracture plane. The reflections between 7,000 and 8,000 feet below shot point 45 may be from a thrust fault. The anticline is faulted near Umiat, but surface indications of a fault are lacking in the mapped area. The dip of the subsurface strata is consistent with the dip of the surface strata.

Line 3–52–145 (*pl. 40*).—Reflectors in the subsurface appear consistent with the surface structure to a depth of 11,000 feet. The high point on the structure is between shot points 13 and 14, at a point about 1,000 feet north of the surface axis. The south dips in the subsurface between shot points 9 and 12 are somewhat steeper than those over the rest of the structure. These steeper dips may be a reflection of the fault trace that exists farther west along the anticline.

Line 4–52–145 (*pl. 40*).—There is close correlation between surface structure and subsurface reflectors, with gentle dips on both the anticline and Kutchik syncline. The anticlinal axis at the surface is 800 to 1,000 feet north of the subsurface axis. The surface axis of the syncline is about 1 mile north of the subsurface axis. East plunge of about 250 feet is indicated between lines 3 and 4.

Line 5–52–145 (*pl. 40*).—Reflectors in the subsurface appear consistent with surface structure, with a gentle reversal on the anticline at shot point 8. The dip of the beds is consistent between surface and subsurface. East plunge of about 1,200 feet is indicated between lines 4 and 5.

FOSSIL CREEK ANTICLINE

Line 5–52–144 (*pl. 41*).—Reflectors in the subsurface appear consistent with the surface structure over the anticlinal axis. The subsurface synclinal axis is about 2,500 feet north of the reversal on the surface. A fault mapped on the surface about 1,200 feet north of the axis can be projected into the subsurface between shot points 9 and 10. The asymmetrical surface structure is reflected at depth by steeper dips on the north flank of the anticline.

Line 6–52–144 (*pl. 41*).—There is close correlation between surface structure and subsurface reflectors to a depth of 5,000 feet. Below that point there is little connection between the reflectors and the surface structure. The reverse fault mapped on the surface about 2,000 feet north of the axis is questionably reflected at depth below shot point 8. The subsurface structure is steeply asymmetrical toward the north. East plunge of about 400 feet is indicated between lines 5 and 6.

Line 7–52–144 (*pl. 41*).—Reflectors in the subsurface appear consistent with surface structure. East plunge is indicated on the anticline.

GRANDSTAND ANTICLINE AREA

Line 4–52–144 (*pl. 42*).—Line 4, starting just north of the Tuktu Escarpment and continuing north across Grandstand anticline, is not tied into the seismic lines farther north; consequently, no direct comparison can be made between this profile and the one previously described. Reflectors in the subsurface appear consistent to a depth of 9,000 feet, with surface structure in Ayiyak Mesa syncline.

Reversal on Grandstand anticline is reflected to a depth of 6,000 feet. North of Grandstand anticline the surface structure is reflected to a depth of about 7,000 feet. Below 10,000 feet the beds are almost flat lying and probably represent pre-Cretaceous to Lower Cretaceous rocks. None of the reflections are believed to have originated from rocks of Paleozoic age. An unconformity probably exists between the upper and lower zones of reflections. The loss of persistent reflectors north of shot point 23, indicates a northward facies change in the subsurface beds. Local unconformities can be interpreted within the upper zone of reflections between shot points 10 and 23. These unconformities probably were formed by the offlap of sediments along the shelf area of the geosynclinal trough. Some of the unconformities are in the lower part of the Nanushuk group, others may be a reflection of the angular break between the Tuktu and Torok formations; this break is evident all along the Tuktu Escarpment and probably extends northward into the geosynclinal trough. There is an indication of a reverse fault beneath shot points 52 and 53. The reflections appear to be offset across the crest of the anticline, and two anomalous reflections near the surface between shot points 53 and 54 may be reflected from the fault plane. An intersection of the fault plane with the surface near shot point 54 would place it near the fault mapped on the surface.

AYIYAK ANTICLINORIUM

Line 2–52–144 (*pl. 42*).—The subsurface reflections show little resemblance to the surface structure south of shot point 12. The poor reflections indicate nearly flat lying beds with no indication of the surface anticlinorium mapped by W. W. Patton, Jr. and I. L. Tailleur (written communication, 1960). North of shot point 12 the steep north-dipping strata measured by the senior author in 1948 are reflected to a depth of 4,000 feet. Below this point the reflections indicate south-dipping beds, which may be either an unconformity or a low-angle bedding-plane thrust fault. Field evidence for either the unconformity or fault is lacking (p. 27), but either one could be present in the covered interval 2,000 to 3,000 feet below the top of the Torok formation. The absence of good reflectors to a depth of 24,000 feet beneath line 2 indicates that the stratigraphic sequence is largely shale. If more resistant sandstone and limestone beds are present, they are probably discontinuous or shattered by faulting and folding.

Line 3–52–144 (*pl. 42*).—A reversal over the anticlinorium is indicated to a depth of 12,000 feet, below which the reflections show little resemblance to the surface structure. An unconformity may exist at that depth. The anomalous reflections north of shot point 23 are probably from minor folds in the incompetent shale since there is little conformity with surface structure. The lack of good reflectors indicates a shale sequence to a depth of 22,000 feet.

Considering both the seismic and surface data, it appears that a close relation exists between the surface and subsurface structures north of the Tuktu Escarpment. South of the escarpment a thick shale section and the lack of good reflectors make it impossible to correlate exactly the surface and subsurface in that part of the area. Additional geophysical data might make correlation possible. A tie line between lines 4–52–144 and 5–52–144 (pl. 41) would make possible correlation of all rocks of the Nanushuk and Colville groups within the area.

ECONOMIC GEOLOGY

PETROLEUM

Three test wells were drilled in the Chandler River region in 1951 and 1952; two of the wells, drilled on Gubik anticline, produced gas. The third well was drilled on Grandstand anticline; it was abandoned as a dry hole. The gas-producing horizons are in the

Colville and Nanushuk groups, with most of the production coming from rocks of the Tuluvak tongue of the Prince Creek formation.

GUBIK GAS FIELD

Two test wells were drilled on the south flank of Gubik anticline on the west bank of the Chandler River. Gubik test well 1 is on a low gravel terrace 20 feet above the river and 1 mile upstream from its confluence with the Colville River. Gubik test well 2 is also on the west bank of the river, about 6,000 feet southeast of test well 1. At the points where the wells are located, seismic phantom horizon A indicates a closure of between 400 and 500 feet; this closure encompasses an area 12 miles long and 2.5 miles wide. The average dip of the strata on either side of the axis is 3°.

The following figures on daily production and the possible gas reserves of the field were taken from the completion report on Gubik test well 2 by Arctic Contractors, Inc.: The wells established the presence of 10 gas-producing zones; production tests were run on 3 zones. The production capacity of Gubik test well 2 was estimated at 50 million cubic feet per day. Recoverable gas reserves from the 3 zones tested were estimated at 222 billion cubic feet, with a possible 295 billion cubic feet if all 10 zones are productive. The producing zones appear to cover an area of 3,800 acres; by locating wells on 100-acre spacing an estimated 600 million cubic feet of gas per day might be produced from the Gubik structure.

TABLE 9.—*Producing zones in Gubik test wells 1 and 2*

Depth (feet)	Stratigraphic unit	Lithology	Type of occurrence
		Gubik test well 1	
1,085–1,105	Tuluvak tongue	Sandstone and conglomerate.	Gas odor.
1,210–1,240	do	Sandstone	Gas in ditch sample.
1,438–1,485	do	Sandstone and conglomerate.	Gas-producing.
1,681–1,738	do	Conglomeratic sandstone.	Do.
3,250–3,260	Seabee formation	Sandstone and siltstone.	Pale oil cut.
3,355–3,375	Chandler and Ninuluk formations.	Sandstone	Gas odor.
3,488–3,519	do	do	Gas-producing.
3,519–3,615	do	do	Do.
4,260–4,305	Grandstand formation	Claystone	Gas odor, oil cut.
5,440–5,463	Topagoruk formation	Clay shale	Do.
		Gubik test well 2	
1,145–1,201	Tuluvak tongue	Sandstone	Gas show.
1,308–1,351	do	Conglomeratic sandstone.	Gas and oil cut.
1,355–1,402	do	do	Do.
1,431–1,502	do	Sandstone	Gas cut.
1,792–1,841	do	do	Gas-producing.
1,844–1,876	do	Sandstone and conglomerate.	Do.
1,876–1,885	do	Sandstone	Do.
1,928–1,984	do	do	Gas and oil cut.
3,496–3,540	Seabee formation	Sandstone and siltstone.	Gas odor.
3,630–3,675	Chandler and Ninuluk formations.	do	Gas odor, oil cut.
3,755–3,880	do	do	Do.
4,039–4,060	Grandstand formation	Sandstone and shaly siltstone.	Oil odor and cut.
4,232–4,261	do	Sandstone	Oil cut.
4,325–4,340	do	do	Oil odor and cut.

A complete analysis of the Gubik wells is contained in a report by Florence Robinson (1958a). The stratigraphy of the well cores, as logged and described by Robinson, is included in that report. The formational units used in describing the subsurface lithology were established by Robinson, Rucker, and Bergquist (1956, p. 223–233).

Table 9 shows the depth, stratigraphic position, and lithology of the producing zones and the zones with a show of gas and oil.

The table shows that the main producing zones in the two Gubik wells are in the nonmarine-marginal formations of the Colville and Nanushuk groups.

UMIAT ANTICLINE

The major part of Umiat anticline, including the Umiat oil field, lies north of the Colville River. Seismic lines 1–52–145 through 5–52–145 (pl. 40) indicate east plunge south of the Colville River. The structure has not been drilled within the mapped area, but it seems entirely possible that production could be attained by drilling in the area enclosed by the −2,500-foot contour (pl. 38). Production in the Umiat field comes from two zones in the Grandstand formation (Collins, 1958). Any production from the anticline south of the Colville River would probably be from the same two zones because the higher producing zones in the Gubik wells are breached.

FOSSIL CREEK ANTICLINE

Data on the structure of Fossil Creek anticline is rather meager because the anticline is largely covered by surficial deposits. Seismic lines 5–52–144 through 7–52–144 (pl. 42), shot just east of the Chandler River, indicate east plunge. The river has cut through the structure, exposing rocks of the Seabee formation at the axis. A structural high is 10 miles west of the river over which rocks of the Chandler and Grandstand formations are exposed, but the exact thickness of the exposure is not known. Slight west plunge probably is present west of the high, but it is minor, for the Chandler and Grandstand formations are exposed over the axis at Fossil Creek. A reverse fault exposes rocks of the Tuktu formation south of the axis on Fossil Creek. The fault apparently cuts the axis under the surficial deposits west of the high, because reverse faults have been mapped north of the axis on both the Chandler and Anaktuvuk Rivers; in all likelihood they are the same fault. Any closure on the structure would probably be against the fault; therefore, a potential drill site would have to be east of the structural high and also would have to be governed by the extent to which the Chandler and Grandstand formations were breached over the high. Rocks below the Chandler and Grandstand formations in this part of the mapped area are predominantly shale and very fine grained sandstone. Further field and seismic work are necessary to evaluate the petroleum potential of the anticline; however, from the data available at present the anticline does not appear very promising.

BIG BEND ANTICLINE

Big Bend anticline is a major structure about 60 miles long. Only that part between the Chandler and Tuluga Rivers has been structure contoured. The structural high is just west of the Chandler River. A minimum of 400 feet of closure is indicated near the Chandler River, with an additional 200 to 300 feet of closure on the axis within the fault graben 3 miles west of Trouble Creek.

The anticline is breached to the Tuktu formation by both the Chandler River and Trouble Creek, thus lessening the producing potential of the structure, since all the proved producing zones at Gubik and Umiat have been breached. An estimated 600 to 700 feet of dirty graywacke sandstone and shale of the Tuktu formation lies below the breached zone. The next 6,000 to 18,000 feet of section below the Tuktu formation would consist almost entirely of shale with a few siltstone interbeds.

GRANDSTAND ANTICLINE

Grandstand test well 1 (lat 68°58′01″ N., long 151° 55′10″ W.) was drilled on a low river terrace, 15 feet above river level, on the west bank of the Chandler River. The well was spudded in May 1, 1952, and completed as a dry hole on August 8, 1952. The total depth drilled was 3,939 feet. The well was logged by Florence Robinson; a complete description of the rocks in the drill core and the formational breakdown of the strata are included in her report (1958b). Several slight oil and gas shows were found in the well (table 10).

TABLE 10.—*Oil and gas shows in Grandstand test well 1*

Depth (feet)	Stratigraphic unit	Lithology	Type of occurrence
790–930	Chandler and Grandstand formations.	Sandstone	Oil cut.
865–899	do	do	Gas cut mud.
1,938–1,971	Tuktu formation	Shaly siltstone and clay shale.	Slight gas flow.
2,150–2,160	do	Sandstone	Pale oil cut.
3,843–3,939	Torok formation	Clay shale	Slight gas flow.

Grandstand test well 1 was drilled on the north side of a complex structure zone, about 1.5 miles north of the anticlinal axis. The well is about 1,500 feet north of a low-angle thrust fault. Twelve hundred and fifty feet of the beds in the well are exposed within the complex zone at the base of the fault scarp 2,000 feet south of the well. A well drilled south of the axis would start about 800 feet lower in the section, but would be in an area of greater closure than would one drilled north of the faulted zone.

Grandstand anticline has a minimum of 2,000 feet of closure on the contour horizon, encompassing an area 40 miles long and 4.5 miles wide; however, the possible producing zones have been breached. The major producing zones in both the Gubik and Umiat fields have been eroded in Grandstand anticline by the Anaktuvuk, Tuluga, Chandler, and Ayiyak Rivers. This fact limits the possible reservoir beds in this structure to the dirty marine graywacke and shale section of the Tuktu formation and the siltstone and shale section of the upper part of the Torok formation.

The structure could be tested further by a series of shallow wells drilled in the breached zones on either the Chandler or the Tuluga River. The one test, Grandstand 1, on the north side of the fault block did not, in the authors' estimation, test all the structure. The depth of any beds drilled in the future probably would not exceed 3,000 feet since the rocks below 3,000 are thought to be predominantly shale. The absence of good reflectors over the axis in seismic line 4–52–144 (pl. 42) strengthens this conclusion.

HAWK ANTICLINE

Hawk anticline is a relatively small structure with a minimum of 600 feet of closure in an area 7 miles long by 3 miles wide. Inasmuch as the anticline is a minor bulge on the south flank of the synclinorium, it is possible that the reversal does not continue at depth. The only geophysical data available is line 4–52–144 (pl. 42), which was shot 11 miles east of the structural high. The profile suggests a reversal to a depth of about 3,000 feet. Reversal at the structural high is probably in excess of that amount and would be sufficient to make possible an adequate test of any potentially producing zones at the base of the Nanushuk group. A deep test would be impractical at Hawk anticline for the same reasons given for Grandstand anticline, namely, no indicated reversal at depth and the estimated 10,000 to 12,000 feet of shale believed to underlie rocks of the Nanushuk group.

Hawk anticline is the best locality for testing the coarse clastic southern facies of the lower part of the Nanushuk group. A shallow test well similar to

Grandstand test well 1 would penetrate all potential zones. The structure is breached about 550 feet into the upper part of the Killik tongue. A test in the breached zone on the structural high would penetrate at least 1,200 feet of course clastic sandstone, conglomerate, siltstone, shale, and coal of the upper part of the Killik tongue. About 1,100 feet of moderately clean, friable, quartz sandstone, siltstone, shale, and coal of the lower part of the Killik tongue would be found below the upper part of the Killik tongue. Sandstone would form about 50 percent of the total section. The 2,300 feet of nonmarine Killik tongue rocks are possible reservoirs.

Below the nonmarine Killik tongue is at least 1,000 feet of the marine Tuktu formation. The Tuktu should consist of about 30 percent graywacke sandstone at Hawk anticline; in addition to the sandstone the bulk of the Tuktu formation would be siltstone and shaly siltstone. The depth to the base of the Tuktu formation would be about 3,400 feet, and for all practicable purposes that would be the extent to which a test well need be drilled. The Torok formation underlying the Tuktu is predominantly a shale facies. Production might possibly be attained from some of the siltstone interbeds. The conglomeratic graywacke sandstone facies of the Torok formation 4,000 feet below the top of the formation at the type locality may or may not be present at Hawk anticline; some of the deeper reflections shown on line 4–52–144 (pl. 42) may be from that coarse clastic facies.

AYIYAK ANTICLINORIUM

W. W. Patton, Jr., (written communication 1958) reported the probability of the existence of Ayiyak anticlinorium. The association of drag folds and other structural features indicates a large anticlinorium. On the other hand seismic line 2–52–144 (pl. 42) does not show any reversal at depth but may indicate a thrust fault. The minor structures at the surface which suggest an anticlinorium could have been formed by thrust faulting at depth.

The rocks in the anticlinorium(?) are probably predominantly shale to a depth of 24,000 feet; the type of reflections in seismic lines 2–52–144 and 3–52–144 (pl. 42) supports this interpretation.

COAL

The localities of coal-bearing strata are shown on figure 53. On this sketch map all exposures seen of beds 3 feet thick or over are noted. Numerous other beds are 2 to 2.5 feet thick. Coal from the Chandler formation is generally of better quality than coal from the Prince Creek formation. Following is a list of samples taken from some of the coal seams. Those samples preceded by an asterisk (*) have been analyzed by the U.S. Bureau of Mines.

52 ADt 69 Tributary of Ayiyak River; 1-ft bed in sandstone and clay shale section. Niakogon tongue. Lat 68°49′30″ N., long 152°37′ W.

52 ADt 128 East Fork Tuluga River; 18-in. bed in 10 ft of mudstone and sandstone. Tuluvak tongue. Lat 68°51′ N., long 151°35′ W.

48 ADt 140 Chandler River; 8-in. bed in sandstone, siltstone, and shaly siltstone section. Torok formation. Lat 68°41′ N., long 152°18′ W.

48 ADt 162 Chandler River; 6- to 8-in. bed in sandstone, siltstone, and shaly siltstone section 140 feet thick. Lower part of the Killik tongue. Lat 68°45′ N., long 152°18′ W.

48 ADt 250 Chandler River; 6-in. bed in 3 ft of carbonaceous shale. Upper part of the Killik tongue. Lat 68°57′ N., long 151°53′ W.

48 ADt 255 Chandler River; 18-in. coal bed with 1 ft of shale in middle in 42-ft section of shale, sandstone, and siltstone. Same locality as 48 ADt 250, 60 ft higher stratigraphically.

*48 ADt 275 Chandler River; 3-ft coal bed in interbedded sandstone, siltstone, and shaly siltstone section in Big Bend anticline. Upper part of the Killik tongue. Lat 69°04′ N., long 151°52′ W.

48 ADt 330 Chandler River; two beds, each 1 ft thick, and one bed 6 in. thick in 85-ft section of sandstone, siltstone, shaly siltstone, and clay shale. Upper part of Killik tongue. Lat 69°08′ N., long 151°45′ W.

*48 ADt 375 Chandler River; 6 ft in 4 beds separated by several feet of clay shale in 85-ft section of clay shale, shaly siltstone, sandstone, and bentonite in Fossil Creek anticline. Tuluvak tongue. Lat 69°11′30″ N., long 151°29′ W.

*48 ADt 433 Chandler River; 62-in. bed in 15-ft section of sandstone and conglomerate. Kogosukruk tongue. Lat 69°14′30″ N., long 151°23′ W.

*48 ADt 434 Chandler River; four coal beds totaling 6 ft (3 ft, 8 in., 1 ft, and 16 in.) separated by thin (as much as 1 ft) beds of fire clay and clay shale in a 10-ft section of shale and coal 25 ft higher than 48 ADt 433 and 24 ft lower than 48 ADt 439. Same locality.

*48 ADt 439 Chandler River; 6 ft in two beds with 2 ft of fire clay and clay shale between them in a shale-coal section. Kogosukruk tongue. Same locality as 48 ADt 433.

*48 ADt 443 Chandler River; 8 ft in 3 coal beds (2 ft 6 in., 3 ft, 2 ft 6 in.) in 55-ft section of clay shale and shaly siltstone. About same horizon as 48 ADt 439. Kogosukruk tongue. Lat 69°16′ N., long 151°22′ W.

48 ADt 454 Chandler River; 6 in. in a 60-ft section of shale, sandstone, and bentonite. Barrow Trail member. Lat. 69°19′ N., long 151°25′ W.

47 ADt 2 Colville River; 2-ft bed in a 30-ft section of sandstone, siltstone, and shaly siltstone. Niakogon tongue. Lat 69°08′N., long 153°24′W.

47 ADt 20 Colville River; 20 in. with 7 in. of bentonite between the two beds. Niakogon tongue. Lat 69°08′ N., long 153°18′ W.

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47 ADt 25 Colville River; 5-in. bed between sandstone and clay shale, 62 ft stratigraphically higher than 47 ADt 20. Same locality.

*47 ADt 31 Colville River; 25 in. of coal and 28 in. of carbonaceous shale, 49 ft above 47 ADt 25. Same locality.

47 ADt 43 Colville River; 1 ft of coal and carbonaceous shale, 65 ft above 47 ADt 31. Same locality.

*47 ADt 45 Colville River; 3 ft in two beds with 30 in. of siltstone betwen the two beds, 27 ft above 47 ADt 43. Same locality.

47 ADt 48 Colville River; 10 in. of coal and carbonaceous shale, 25 ft above 47 ADt 45. Same locality.

*47 ADt 50 Colville River; 45-in. bed, 10 ft above 47 ADt 48. Same locality.

47 ADt 118 Ninuluk Creek; 14-in. bed in clay shale and fire clay section. Niakogon tongue. Lat 69°08′N., long 153°13′W.

47 ADt 200 Colville River; 14-in. bed in sandstone, siltstone, shaley siltstone, and clay shale section 38 ft thick. Ninuluk formation. Lat 69°17′N., long 152°35′W.

*47 ADt 251 Fossil Creek; 5-ft bed and a 1-ft bed with 13 ft of shaly siltstone and sandstone between them. Chandler formation. Lat 69°13′N., long 152° 28′W.

47 AWb 18 Nanushuk River; 2-ft bed in siltstone and shale section. Tuluvak tongue. Lat 68°44′N., long 150°33′W.

47 AWb 279 Nanushuk River; 17-in. bed in 50-ft section of clay shale, siltstone, sandstone. Tuluvak tongue. Lat 69°04′N., long 150°49′W.

45 AWa 73A Killik River; 8-in. bed in sandstone and shaly siltstone shale section. Lower part of Killik tongue. Lat 68°52′N., long 153°25′W.

*45 AWa 99 Colville River; 3-ft bed in sandstone and siltstone section. Upper part of Killik tongue. Lat 69°04′N., long 153°42′W.

45 AFs 21 Anaktuvuk River; 30-in. bed in sandstone and siltstone. Numerous other coal seams above and and below 45 AFs 21. Lower part of Killik tongue. Lat 68°44′N., long 151°63′W.

*45 AFs 225 Kanayut River; 3-ft bed in clay shale and sandstone section. Chandler formation. Lat 68°43′N., long 150°55′W.

*45 AFs 85 Anaktuvuk River; 3-ft bed in sandstone and siltstone at Schrader Bluff. Tuluvak tongue of Prince Creek formation. Lat 69°10′15″ N., long 150°59′45″ W.

*24 AMt 65 Killik River; 2-ft bed in sandstone, siltstone, and shaly siltstone section. Niakogon tongue of Chandler formation. Lat 68°59′N., long 153° 36′W.

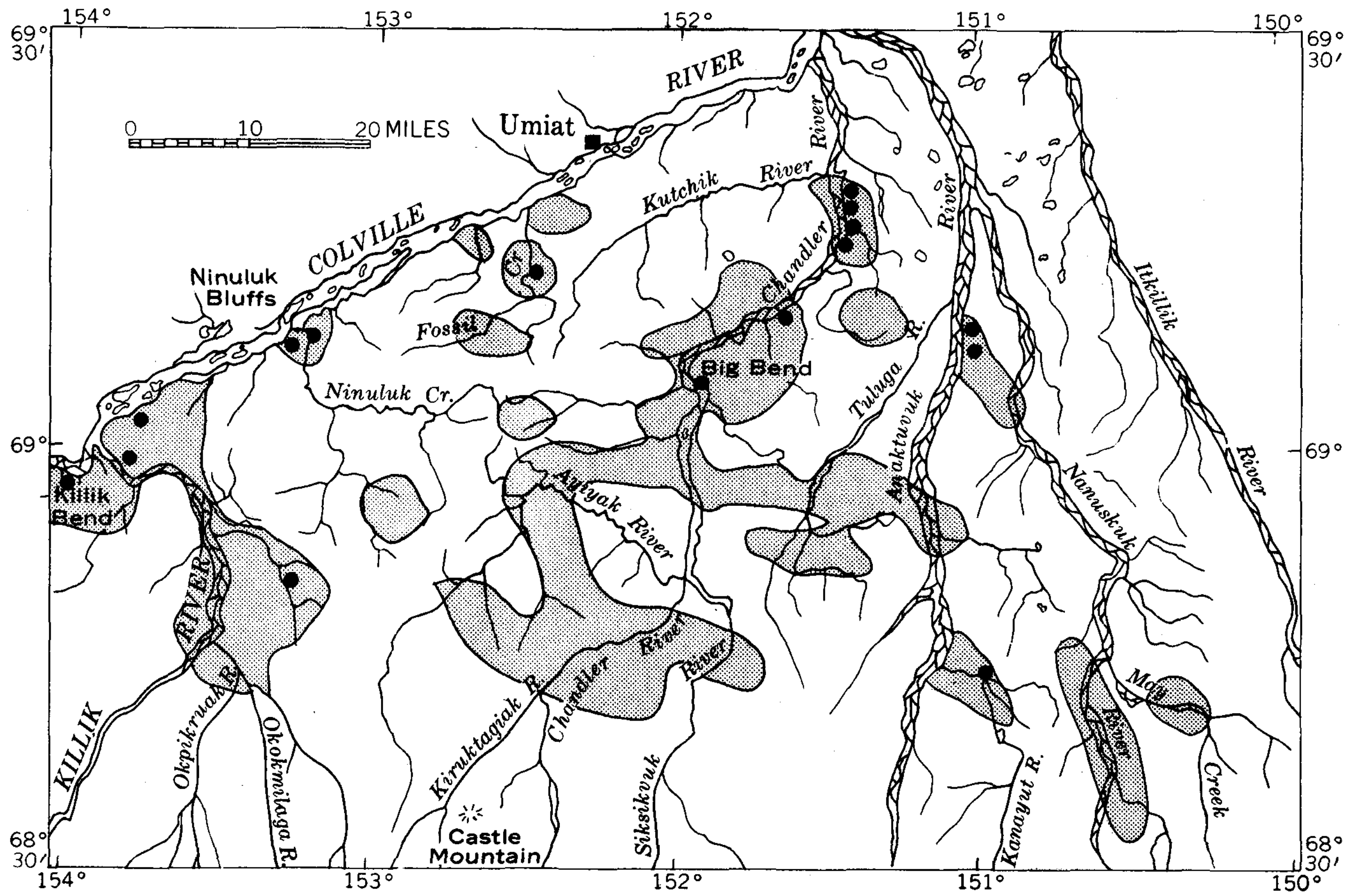

Figure 53.—Index map of the Chandler River region, showing geographic occurrence of coal-bearing strata (shaded). Dots indicate exposures of beds 3 feet or more in thickness.

KILLIK RIVER

Coal is present along the Killik River from about 3 miles above the junction with the Okpikruak River to the Colville River. Coal beds without shale or bone partings are locally as much as 4 feet thick. One 15-foot coal bed with numerous shale and bone partings was seen on Coal Creek about 10 miles upstream from its junction with the Killik River. A coal sample collected by Mertie (Smith and Mertie, 1930, p. 314) from a 2-foot coal bed at the mouth of Coal Creek (pl. 33, column 1) was analyzed by H. M. Cooper, chemist at the Pittsburgh laboratory of the Bureau of Mines.

Analysis A-6848 (24 AMT 65)

	Coal (as received)	Coal (moisture free)	Coal (moisture and ash free)
Moisture	16. 4		
Volatile matter	29. 9	35. 7	41. 6
Fixed carbon	41. 9	50. 2	58. 4
Ash	11. 8	14. 1	
Sulfur	. 3	. 3	. 4
Btu value	8, 450	10, 110	11, 770

Most of the coal beds along the Killik River are in strata dipping 12° or less, except those near the axis of Kurupa anticline.

COLVILLE RIVER

A sample of coal obtained by L. A. Warner from a bluff on the south side of the Colville about 7 miles downstream from the Killik River was analyzed as follows by Roy F. Abernethy, chemist at the Pittsburgh laboratory of the Bureau of Mines:

Analysis E-73994 (45 AWa 99)

	Coal (as received)	Coal (moisture free)	Coal (moisture and ash free)
Moisture	5. 3		
Volatile matter	31. 1	32. 8	44. 2
Fixed carbon	39. 3	41. 5	55. 8
Ash	24. 3	25. 7	
Total	100. 0	100. 0	100. 0

Several coal beds that ranged in thickness from 1 to 4 feet were noted at this locality. Most of the beds were associated with siltstone, shaly siltstone and sandstone. Numerous logs and parts of trees are embedded in the sandstone beds above and below. The coal, on the north flank of Killik Bend anticline in strata dipping 8° to 10° N., is in the upper part of the Killik tongue of the Chandler formation.

In all, 12 beds of coal, ranging in thickness from a few inches to 4 feet, were seen in Ninuluk Bluffs on the south side of the Colville River, 18 miles downstream from the mouth of the Killik River. The beds were on the south flank of the faulted Little Twist anticline in strata dipping 45° S. Three samples from this locality were analyzed by Roy F. Abernathy, chemist at the Pittsburgh laboratory of the Bureau of Mines (pl. 33, column 3), as follows:

Three samples from south flank of Little Twist anticline

	Coal (as received)	Coal (moisture free)	Coal (moisture and ash free)
Analysis E-73996 (47 ADt 31)			
Moisture	5. 9		
Volatile matter	35. 0	37. 2	43. 3
Fixed carbon	45. 8	48. 6	56. 7
Ash	13. 3	14. 2	
	100. 0	100. 0	100. 0
Analysis E-73997 (47 ADt 45)			
Moisture	3. 5		
Volatile matter	28. 3	29. 4	41. 2
Fixed carbon	40. 4	41. 8	58. 8
Ash	27. 8	28. 8	
	100. 0	100. 0	100. 0
Analysis E-73998 (47 ADt 50)			
Moisture	4. 4		
Volatile matter	30. 1	31. 4	40. 1
Fixed carbon	44. 8	46. 9	59. 9
Ash	20. 7	21. 7	
	100. 0	100. 0	100. 0

Field sample 47 ADt 31 is from a bed 25 inches thick overlain by 28 inches of carbonaceous shale in a clay shale section. This sample has the highest percentage of fixed carbon and volatile matter and the least amount of ash of the three samples tested from this locality. The three samples are from the Niakogon tongue of the Chandler formation.

Coal was seen at isolated localities downstream from Ninuluk Bluffs as far as the mouth of Prince Creek. Some of the tributaries of the Colville have also exposed coal beds. One sample from a bed in the Chandler formation, exposed on Fossil Creek, was analyzed by the Bureau of Mines laboratory in Pittsburgh (pl. 32, column 4).

Analysis E-73999 (47 ADt 251)

	Coal (as received)	Coal (moisture free)	Coal (moisture and ash free)
Moisture	2. 6		
Volatile matter	40. 9	42. 0	43. 2
Fixed carbon	53. 6	55. 0	56. 8
Ash	2. 9	3. 0	
	100. 0	100. 0	100. 0

The coal bed is 5 feet thick. Underlying the coal is 13 feet of sandstone and siltstone with another 1 foot coal bed under the sandstone. This coal had one of the highest fuel ratios of any of the samples tested, and is in strata dipping 8° S. Other coal beds were measured on Fossil Creek, but most of them were less than 1 foot thick.

CHANDLER RIVER

Coal beds and coal float occur along the Chandler River from just north of the Tuktu escarpment to within about 10 miles of the Colville River. Six samples were collected by Detterman and were analyzed at the Pittsburgh laboratory of the Bureau of Mines.

One sample was collected from the Killik tongue of the Chandler formation on the south flank of Big Bend anticline in a sandstone, siltstone, and silt shale section (pl. 32, column 5). The strata are inclined 15° S. The coal has a few shale partings.

Coal from Big Bend anticline. Analysis E–74002 (48 ADt 275)

	Coal (as received)	Coal (moisture free)	Coal (moisture and ash free)
Moisture	6. 0		
Volatile matter	32. 8	34. 9	41. 1
Fixed carbon	47. 1	50. 1	58. 9
Ash	14. 1	15. 0	
	100. 0	100. 0	100. 0

Another sample was collected from the Tuluvak tongue of the Prince Creek formation at camp D–July 25–48. Four beds totaling 6 feet of coal and separated by several feet of clay and silt shale were measured on the north flank of Fossil Creek anticline in strata dipping 10° N. Shale partings were common in the coal.

Coal from Fossil Creek anticline. Analysis E–74003 (48 ADt 375)

	Coal (as received)	Coal (moisture free)	Coal (moisture and ash free)
Moisture	7. 1		
Volatile matter	31. 6	34. 0	39. 1
Fixed carbon	49. 2	53. 0	60. 9
Ash	12. 1	13. 0	
	100. 0	100. 0	100. 0

Four coal samples were collected from the Kogosukruk tongue of the Prince Creek formation about 15 miles upstream from the mouth of the Chandler River (pl. 36, column 5). The samples are from the Prince Creek syncline in strata dipping 5° or less.

Coal from the Prince Creek syncline

	Coal (as received)	Coal (moisture free)	Coal (moisture and ash free)
Analysis E-74004 (48 ADt 433)			
Moisture	5. 0		
Volatile matter	25. 2	26. 5	43. 0
Fixed carbon	33. 4	35. 2	57. 0
Ash	36. 4	38. 3	
	100. 0	100. 0	100. 0
Analysis E-74005 (48 ADt 434)			
Moisture	7. 6		
Volatile matter	32. 6	35. 3	39. 1
Fixed carbon	50. 7	54. 9	60. 9
Ash	9. 1	9. 8	
	100. 0	100. 0	100. 0
Analysis E-74006 (48 ADt 439)			
Moisture	6. 3		
Volatile matter	29. 3	31. 2	41. 2
Fixed carbon	41. 8	44. 7	58. 8
Ash	22. 6	24. 1	
	100. 0	100. 0	100. 0
Analysis E-74007 (48 ADt 443)			
Moisture	7. 4		
Volatile matter	30. 3	32. 7	43. 7
Fixed carbon	39. 0	42. 1	56. 3
Ash	23. 3	25. 2	
	100. 0	100. 0	100. 0

Shale and bone partings are common to all the coal beds. Offsetting the poor quality of the coal, however, is its abundance and the ease with which it could be mined. The four samples represent 24.5 feet of coal that could be strip mined. The beds dip 5° or less, and the maximum amount of overburden on the lowest bed in the center of the syncline would not exceed 150 feet. The average amount of overburden to be removed would be about 30–40 feet. The lateral extent of the coal is unknown but is believed to exceed 10 miles.

KANAYUT RIVER

One sample of coal from the Killik tongue of the Chandler formation was collected by R. M. Chapman on the Kanayut River. The bed was 3 feet thick in a sandstone and siltstone section. The bed dips 39° S. This sample has the highest fixed carbon ratio of all the samples analysed. It was analysed by Roy F. Abernethy, chemist at the Pittsburgh laboratory of the Bureau of Mines, as follows:

Analysis E-73995 (45 AFs 225)

	Coal (as received)	Coal (moisture free)	Coal (moisture and ash free)
Moisture	2. 5		
Volatile matter	31. 4	32. 2	33. 3
Fixed carbon	62. 8	64. 4	66. 7
Ash	3. 3	3. 4	
	100. 0	100. 0	100. 0

ANAKTUVUK RIVER

One coal sample from the Anaktuvuk River was collected by R. E. Fellows, from the Tuluvak tongue of the Prince Creek formation, at Schrader Bluff. Several beds 3 feet thick were measured, as well as several thinner beds. The beds dip 50° to 60° S. This coal is considered to be typical of all coal beds sampled and both the proximate and ultimate analysis were made by H. M. Cooper, chemist at the Pittsburgh Laboratory of the Bureau of Mines.

Analysis C-54647 (45 AFs 85)

	Coal (as received)	Coal (moisture free)	Coal (moisture and ash free)
Proximate analysis			
Moisture	5. 2		
Volatile matter	28. 3	29. 8	39. 6
Fixed carbon	43. 1	45. 5	60. 4
Ash	23. 4	24. 7	
	100. 0	100. 0	100. 0
Ultimate analysis			
Hydrogen	4. 2	3. 8	5. 1
Carbon	54. 1	57. 1	75. 7
Nitrogen	1. 4	1. 5	2. 0
Oxygen	16. 2	12. 2	16. 3
Sulphur	. 7	. 7	. 9
Ash	23. 4	24. 7	
	100. 0	100. 0	100. 0

Yields of carbonization products by Fisher low-temperature carbonization assay at 500° C [coal as received]

Carbonized residue	percent	76. 7
Tar	do	5. 7
Water	do	11. 7
Light oil	do	. 37
Hydrogen sulfide	do	. 21
Gas, by difference	do	5. 3
Tar	gallons per ton	13. 6
Light oil	do	1. 17
Gas, H_2S free	Cubic feet per ton	1, 980
Gas	B.T.U. per pound of coal	580

BENTONITE

Beds of nearly pure bentonite are present locally in the Colville group and in the Niakogan tongue of the Chandler formation, and the Ninuluk formation of the Nanushuk group; it is also commonly a detrital constituent in rocks of the Colville group. The bentonite conceivably could be used in drilling mud for any future drilling operations. Beds from 2 to 5 feet thick are present in the Tuluvak tongue at three localities: on the south bank of the Colville River about 9 miles upstream from Umiat, near camp D–July 25–48, on the Chandler River, and at Schrader Bluff on the Anaktuvuk River. Beds less than 2 feet thick occur in the Barrow Trail member of the Schrader Bluff formation at the same localities.

SOURCE OF PLACE NAMES

The Chandler River region is a remote part of northern Alaska, and few place names were available for geographic features essential to the discussion of the geology of the region. The region is uninhabited except for a few maintenance personnel at Umiat. The Nunamiut Eskimos have had hunting and fishing camps in the region and have traveled across it on the way to the coast for trading, but they do not normally apply geographic place names similar to the pattern used in United States. They use names for something that happened or was seen at a particular spot; where possible these names were retained and are now used for an entire stream or other feature rather than a particular spot. Some of the geographic names used in this paper were proposed by workers who visited parts of the region before the time of the present investigation.

Schrader (1904) was the first person to write a report on the part of the region that he visited in 1901. He proposed the following geographic terms: Anaktuvuk River, Killik River, Nanushuk River, Ninuluk Creek, Tuluga River, and Willow Creek (now named Kanayut River). The Colville River was first traversed by Schrader but had been named in 1837 by Dease and Simpson of the Hudson Bay Company.

Smith and Mertie (1930) traversed the Killik River and part of the Colville River in 1926. Their report included a map on which the following geographic names were used for the first time: Chandler River (this river is now named the Okokmilaga River and the river that drains Chandler Lake is now named the Chandler River) and Prince Creek.

New names were proposed for the Chandler River region by Gryc, Patton, and Payne (1951) when they established a nomenclature for part of the Cretaceous sequence in northern Alaska. The names were: Hatbox Mesa, Niakogon Buttes, Okpikruak River, Schrader Bluff, Torok Creek, Tuluvak Bluffs, and Tuktu Bluff.

Some additional names used by personnel of the Geological Survey in unpublished reports to the U.S. Navy during the exploration of Naval Petroleum Reserve No. 4, initiated in 1944, were first published by Payne and others (1951). New names for the Chandler River region were: Ayiyak Mesa, Ayiyak River, Fossil Creek, Itkillik River, Kayak Mountain, Kiruktagiak River, Kutchik River, May Creek, Okokmilaga River, Outpost Mountain, Rooftop Ridge, Siksikpuk River, Starfish Bluff, Table Top Mountain, and Twin Bluffs.

W. W. Patton, Jr. has proposed a number of new names for geographic features in the southern part of the region. These new names include: Autumn Creek, Canoe Creek, Cobblestone Creek, Desolation Creek, Ivory Creek, and Okok Creek.

Some additional names for geographic features were needed for the discussion and the mapping of the geology in this paper; consequently the following names were proposed: Banded Mountain, Big Bend, Coal Creek, East Fork Tuluga River, Gunsight Mountain, Gunsight Pass, Heart Lake, Mammoth Creek, Ninuluk Bluff, Outpost Creek, Quandary Creek, Racetrack Basin, Shale Wall Bluff, South Fork Ninuluk Creek, Terrace Creek, Trouble Creek, Tuktu Escarpment, Tundra Creek, West Fork Tuluga River, and Wolverine Creek.

A description of the geographic features named during the recent investigation of Naval Petroleum Reserve No. 4 has been filed with the Board on Geographic Names and may be obtained from the Board.

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