Geology of the Umiat-Maybe Creek Region Alaska

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

PART 3, AREAL GEOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 303-H

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

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By WILLIAM P. BROSGÉ *and* CHARLES L. WHITTINGTON

With Heavy-Mineral Studies of the Umiat-Maybe Creek Region
By ROBERT H. MORRIS

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By William P. Brosgé and Charles L. Whittington

ABSTRACT

The Umiat-Maybe Creek region is an area of 3,000 square miles within Naval Petroleum Reserve No. 4 that is bounded on the east and south by the Colville River and on the west by the Ikpikpuk River. Petroleum investigations in this region were conducted cooperatively by the U.S. Department of the Navy and the U.S. Geological Survey from 1944 to 1953. Geological data are from the work of 20 geological parties, drilling of 20 wells, and many seismic traverses.

Exposed rocks consist of the Nanushuk Group (Lower and Upper Cretaceous) and the Colville Group (Upper Cretaceous). They are overlain by unconsolidated deposits of the Gubik Formation (Pleistocene) and loess, terrace gravels, and alluvium (Pleistocene and Recent). In some wells, a Lower Cretaceous shale, herein referred to the Torok Formation, was penetrated below the Nanushuk Group.

The stratigraphy records the northward advance of nonmarine sediments as the Cretaceous geosyncline was filled.

The Nanushuk Group consists of the marine Grandstand and Ninuluk formations and the intertonguing nonmarine Chandler Formation. The Grandstand Formation (Albian), at the base of the group is composed of clean marine sandstone and shale and thins northeastward toward Umiat. It intertongues with and is overlain by coal-bearing nonmarine sandstone and shale of the Killik Tongue of the Chandler Formation. Fossiliferous marine sandstone beds of the Ninuluk Formation (Cenomanian) rest on the Killik Tongue and interfinger with coal-bearing nonmarine beds of the Niakogon Tongue of the Chandler Formation. The combined thickness of Ninuluk and Niakogon decreases northward and eastward.

The Colville Group rests unconformably on the Nanushuk Group and is distinguished from it by the abundance of bentonite and tuff. It comprises three formations. The Seabee Formation, a widespread fossiliferous bentonitic marine black shale of Turonian age, rests on the Ninuluk Formation with local erosional unconformity. The Seabee thickens eastward which is opposite to the direction of thickening of the Nanushuk Group and indicates a shift in the basin of deposition. The nonmarine Prince Creek Formation, distinguished by coal and conglomerate, rests conformably on the Seabee and intertongues with the fossiliferous marine Schrader Bluff Formation. The lowest tongue of the Prince Creek Formation is the Tuluvak Tongue. It is overlain by and apparently intertongues with shale of the Rogers Creek Member of the Schrader Bluff Formation, succeeded by sandstone and shale of the Barrow Trail Member (Santonian and Campanian) and soft shale and clay of the Sentinel Hill Member (Campanian). The Sentinel Hill Member intertongues with poorly consolidated coal-bearing sandstone of the Kogosukruk Tongue of the Prince Creek Formation.

The Colville Group is restricted approximately to the structurally low area east of the Ikpikpuk River. Near-shore sands in the Seabee Formation along the upper Ikpikpuk indicate that the present western limit of outcrop may be near the edge of the basin of deposition. Facies changes of some sandstones in the Seabee Formation and Tuluvak Tongue at Titaluk anticline indicate that some present structural highs were topographic highs during deposition.

The Gubik Formation of Pleistocene age rests on a gently northward-sloping erosion surface cut on the Cretaceous rocks in the Arctic Coastal Plain. It consists of as much as 150 feet of unconsolidated yellow sand and a basal bed of gravel. To the north, a wedge of marine clay lies between the gravel and the bedrock, whereas, to the south, the sand interfingers with or is overlain by fresh-water silt and loess.

South of the Arctic Coastal Plain a northward-sloping terrace surface 200 feet above Colville River level lies on the approximate extension of the pre-Gubik erosion surface. A bed of gravel as much as 67 feet thick covers this terrace. A layer of brown loess rests on the gravel. The gravel may be correlative with the upper sands in the Gubik Formation and the loess is probably correlative with the silts.

Regional warping and local folding occurred during late Cretaceous time, and folding of the Cretaceous rocks took place during the Tertiary. Folding was from the south and its intensity decreased northward. The folds strike from east-northeast to southeast and the axial planes dip steeply south. A persistent regional north dip and an east plunge produce a total structural relief of 10,000 feet across the area.

Magnetic and gravity anomalies within the basement rock are roughly parallel to surface structural trends. However, according to seismic data the lowest Mesozoic beds and the surface of the basement dip continuously southward under the Arctic Coastal Plain without reflecting either surface structure or basement trends. The depth to basement is 20,000 feet at the crest of Umiat anticline, based on computations from magnetic data, and is 20,000 feet at Ocean Point, based on interpretation of seismic data.

Most of the anticlines in the region have closure where the dominant east plunge is locally reversed. All except Weasel Creek and Fossil Creek anticlines have been tested by drilling.

Twenty test wells have been drilled in the region. Eleven wells at Umiat outline a productive area of 5,000 to 7,000 acres with estimated oil reserves of 30 to 100 million barrels. An estimated 7 to 15 percent of the reserves are in sandstones of the Ninuluk Formation north of the axial fault. Most of

the reserves are in two sandstones of the Grandstand Formation on the south flank of the anticline; the lower of these two sandstones also produced gas near the crest of the anticline. Drilling at Umiat was not successful until fresh-water mud was abandoned, and wells were drilled with cable tools and brine, or with rotary drill and oil-base mud.

Tests of the Grandstand Formation on other structural features were unsuccessful. The Grandstand sandstone west of Umiat is much less permeable than the reservoir rocks at Umiat. In addition, only one well drilled with the methods proved successful at Umiat penetrated the full thickness of the Grandstand Formation at a favorable structural location. However, sandstones in the Seabee Formation at Square Lake are estimated to have recoverable gas reserves of 33 to 58 billion cubic feet, and the Grandstand Formation had gas shows at Wolf Creek.

INTRODUCTION

LOCATION AND SIZE OF AREA

The Umiat-Maybe Creek region lies within Naval Petroleum Reserve No. 4 on the Arctic Slope of northern Alaska (fig. 92). The region comprises almost 3,000 square miles in a roughly rectangular block bounded on the east and south by the Colville River and on the west by the Ikpikpuk River. It is about 80 miles long from east to west and about 35 miles wide, extending northward from the Colville River valley into the southern part of the Arctic Coastal Plain. Along the eastern edge a dogleg extends northward along the lower Colville River to Ocean Point, about 25 miles south of the Arctic coast.

PURPOSE AND SCOPE

The U.S. Geological Survey made reconnaissance surveys along the major rivers of Naval Petroleum Reserve No. 4 in the four field seasons that followed the establishment of the Reserve in 1923. When petroleum prospecting was begun by the U.S. Navy in 1944, the Geological Survey was requested to help complete the exploration of the Reserve and of the adjacent areas. Field investigations made in cooperation with

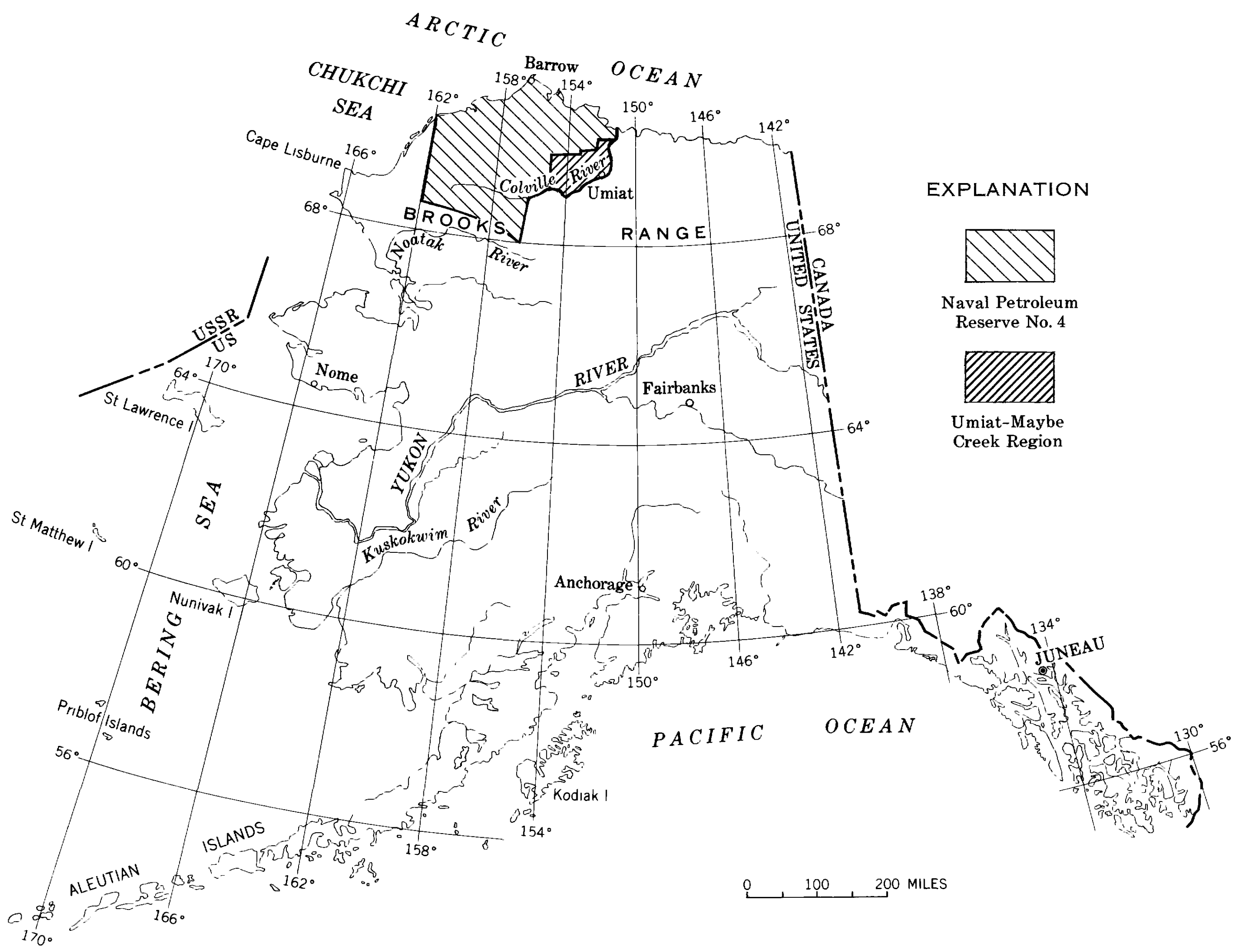

FIGURE 92.—Naval Petroleum Reserve No. 4 and Umiat-Maybe Creek region.

the Office of Naval Petroleum and Oil Shale Reserves were begun in 1945 and continued through 1953 with the aim of completing the reconnaissance mapping and of outlining in more detail those structural features that might be favorable for the accumulation of oil.

Upon the confirmation of reports of oil seeps at Umiat, mapping there was begun independently by the Navy and by the Geological Survey in 1944. In 1945 four Navy parties investigated the area north and west of Umiat, and the first Umiat test well was spudded in. In 1946 the first Geological Survey parties to work cooperatively with the Navy within the Reserve began work in the Umiat-Maybe Creek region and both reconnaissance and detailed structural mapping within that region were continued intermittently by the Geological Survey from 1946 to 1953. During the same period 20 test wells were drilled within the region (table 1), and the rocks penetrated were described and correlated by Geological Survey personnel. In all, 5 Navy field parties and 15 Geological Survey parties have worked in the Umiat-Maybe Creek region during the recent investigations, some for full field seasons of areal mapping, some more briefly on special problems or on problems incidental to work in adjacent areas. The areas covered by the fieldwork of the various parties is shown as part of plate 52. The results of each party's work were submitted to the Navy, and the reports have been placed on open file by the Geological Survey. The present report has been compiled from unpublished reports, maps, and notes of all the parties; the data have been revised to fit the most recent interpretation of the stratigraphy and gaps in the field mapping filled in by photointerpretation. This report also includes stratigraphic information from the test wells and structural information from seismic surveys made by the United Geophysical Co. under contract to the Navy. As the subsurface information is discussed in detail in U.S. Geological Survey Professional Papers 304 and 305, the conclusions of the subsurface workers have been used here to augment the surface information without further discussion. The heavy minerals of sandstones sampled in wells and outcrops were studied by Robert H. Morris. His discussion of the occurrence and stratigraphic significance of the heavy-mineral suites of the region is included as a separate section in this report.

EARLY WORK

Before intensive exploration began in 1944, only three mapping parties had traversed the Umiat-Maybe Creek region. The first exploration and report on the region was by Ens. (later Rear Admiral) W. L. Howard, a member of a naval expedition to the Kobuk River under command of Lt. G. M. Stoney, U.S. Navy. In April 1886, Howard, together with Carpenter's Mate Price and three Eskimos, sledded from Stoney's camp near Shungnak on the Kobuk northward across the Brooks Range to the headwaters of the Etivluk River. There they joined a group of Eskimos on their spring trip to Point Barrow. After following the caribou herds down the Etivluk and Colville valleys to the mouth of the Kurupa River, Howard and part of the Eskimo group crossed Knifeblade Ridge to the rendezvous village of Kigalik, at the head of the Ikpikpuk River, where about 150 Eskimos awaited spring breakup. On June 8 Howard left Kigalik by boat and traveled down the Ikpikpuk River to the Arctic coast. His map of the Ikpikpuk and upper Colville Rivers and his account of the trip are published in Stoney's report (1900, p. 66–77).

The earliest geological and topographic survey in the region was made by the U.S. Geological Survey. The discovery of gold in the Koyukuk valley had led to reports of a pass through the Brooks Range between the Koyukuk and the Arctic drainage basins. In 1901 a topographic party in the charge of W. J. Peters, accompanied by F. C. Schrader, geologist, ascended the John River from Bettles, portaged through Anaktuvuk Pass, and descended the Anaktuvuk and lower Colville Rivers to the Arctic Ocean. The river courses and the surrounding topography were mapped (200-foot contour interval) and the major rock series were mapped and described. Schrader (1902) mapped the Cretaceous rocks along the lower Anaktuvuk River, named them the Anaktoovuk and Nanushuk Series, and projected them westward along strike into the Umiat-Maybe Creek region. The less consolidated Cretaceous rocks along the lower Colville below the mouth of the Anaktuvuk River were mapped as the Colville Series, and the unconsolidated sands that unconformably overlie them were named the Goobic Sands. Schrader (1904) assigned his Gubik [sic] Sand to the Pleistocene and his Colville Series to the Tertiary, partly on the basis of fossils that are now believed to have come from the Gubik.

The year after the Petroleum Reserve was established, a second Geological Survey expedition visited the area. In the spring of 1924 geologists P. S. Smith and J. B. Mertie, Jr., and topographers Gerald FitzGerald and R. K. Lynt traversed across the crest of the Brooks Range from the head of the Alatna River to the Killik River. From the mouth of the Killik, Smith and Lynt worked their way up the Colville River in hope of finding a portage into the Meade River, and Mertie and FitzGerald worked their way downstream toward a portage into the Ikpikpuk River. The Ikpikpuk portage was made in July by way of Prince Creek and Maybe Creek. Smith's group, after traveling a short distance up the Awuna River, portaged northward into what proved to be a tributary of Kigalik River, rather than of the Meade, and early in August they caught up with the rest of the party on the Ikpikpuk. All the rocks found in the Umiat-Maybe Creek region were mapped as Upper Cretaceous. As no Tertiary rocks were found on strike with Schrader's presumed Tertiary Colville Series, his age designation was revised. Most of the rocks previously mapped as the Colville Series were included in the Upper Cretaceous, and the Tertiary rocks were restricted to the small area at Ocean Point from which Schrader's Tertiary fossils had been collected. The Gubik Sand was not mapped separately (Smith and Mertie, 1930).

RECENT WORK

The detailed structural mapping in Naval Petroleum Reserve No. 4 was begun at Umiat because of the oil seeps there. Seeps along the coast had been known when the Reserve was first set aside and were investigated immediately thereafter, but the Umiat seeps were not visited until 1943. In the summer of that year an airborne party consisting of Norman Ebbley, Jr., of the U.S. Bureau of Mines, Henry Joesting, of the Territorial Department of Mines, and Captain Henry Thomas, Corps of Engineers, U.S. Army, examined the seeps at Umiat Mountain in the course of an investigation of all the reported seeps both on the coast and inland (Ebbley, 1944). In the spring of 1944 Lt. W. T. Foran, USNR, noted the anticlinal reversal at the Umiat seeps during an areal reconnaissance of the Reserve. That summer he, together with Lt. (jg.) Glen Woodward and a party of Navy enlisted men, mapped the Umiat anticline in detail from Umiat Mountain westward for 22 miles to the head of the Kikiakrorak River, using locally prominent and persistent beds as key mapping horizons. The party was supplied by plane; fieldwork and the transportation of supplies within the area was by foot. As a result of the structural mapping, a drilling site was chosen for Umiat test well 1 near the anticline axis on upper Seabee Creek. During the same summer R. R. Coats and George Gryc, of the Geological Survey, traversed the Colville River by boat from the mouth of Prince Creek to the mouth of the Anaktuvuk River and bridged the gap between the earlier traverses of Mertie and Schrader. They measured and correlated riverbank exposures of the Upper Cretaceous rocks from the Seabee Formation through the lower part of the Kogosukruk Tongue of the Prince Creek Formation and collected and analyzed samples of the numerous bentonite beds in the section.

In 1945 the Geological Survey's surface work was confined to the rivers south of the Reserve, where the Cretaceous stratigraphic section and the concept of intertonguing marine and nonmarine facies within the Cretaceous geosyncline were established. After descending the Killik River, L. A. Warner and C. E. Kirschner mapped exposures along the Colville River from the mouth of the Killik to Prince Creek, R. E. Fellows, R. M. Chapman, and C. T. Bressler mapped the Colville bluffs for about 10 miles downstream from the mouth of the Anaktuvuk. A special airborne magnetometer survey covered all the Reserve north of the Colville River, as well as adjacent areas to the east. A base camp was set up at Umiat by the Navy, and Umiat test well 1 was spudded in by Naval Construction Battalion Detachment 1058. The surrounding area was mapped by four Navy parties of two officers and four enlisted men each: These were:

Party 1, in the Kogosukruk-Kikiakrorak Rivers area north of Umiat: Lt. (jg.) J. A. Rogers, USNR, and Lt. (jg.) A. P. McConnell, USNR.

Party 2, in the Square Lake area northwest of Umiat: Lt. M. V. Paine and Lt. (jg.) G. S. Wayman, Jr.

Party 3, in the Maybe Creek, upper Ikpikpuk River, and Colville River area west of Umiat: Lt. W. H. Phillippi and Lt. H. C. Cortes, Jr.

Party 4, in the Ninuluk and Prince Creek areas west and southwest of Umiat: Lt. W. L. Kreidler, USNR, and Lt. (jg.) S. C. Brown, USNR.

These and Lieutenant Foran's party of 1944 were the first to attempt detailed mapping in the areas away from the major streams. Supplies for the parties were cached in advance by plane, and the parties were flown to and from the areas of their summer's work. The moves from camp to camp during the season's work were by foot and by small boat. Since many of the small streams proved unnavigable, especially in late summer, the parties in the Square Lake area and along Prince Creek and the Kikiakrorak River moved mostly by backpacking. Movement of supplies and equipment occupied much of the working time. Because the Navy parties lacked base maps, all their traverses were surveyed with planetable or transit and were tied to Foran's assumed datum at Umiat.

Data from all the Navy parties have been incorporated in this report. The network of elevations they established has been used in this report after adjusting it to a more recent datum at Umiat; the descriptions and elevations of the Colville River terrace gravels along Prince Creek and the detailed structural contours on the lower part of the Kogosukruk Tongue on the Kogosukruk River have not been duplicated by later work and have been used with only a datum correction. The gas seep south of the Colville River on Aupuk anticline was discovered by party 4.

In 1946 the Navy gave up direct participation in the geologic field exploration. From then on the surface exploratory work was done by the Geological Survey and the subsurface exploration by private contractors. The test drilling and the overland transport in support of drilling were done by Arctic Contractors and the geophysical exploration, by United Geophysical Co., Inc.

The cooperative investigations by the Geological Survey that began in 1946 in the Umiat-Maybe Creek region were accomplished by boat travel on the larger streams; in the interstream areas transportation was by weasel, a light amphibious tracked cargo-carrying vehicle about the size of a small automobile. The weasels were furnished by the Navy and were serviced (and in the earlier years driven as well) by mechanics employed by Arctic Contractors. They were used both to move camp and for the daily work; thus the mobility of the field parties was increased. As with the previous Navy parties, food and heating and cooking fuel were cached in advance by ski plane; drums of gasoline for the weasels were dropped in advance by parachute. The boat parties were flown to their initial field stations. The weasel parties in the Umiat-Maybe Creek region drove their vehicles from Umiat to the field and returned in them at the end of the season's work.

A detailed history of the surface and subsurface exploration is given by Reed (1958). The geophysical and geological field parties that worked in the Umiat-Maybe Creek region after 1945 are listed below in chronologic order.

Seismic and gravimetric surveys by United Geophysical Co.

1946, party 46. Two short seismic lines (1–46 and 2–46) across the apex of Umiat anticline.

1947, party 46. Gravimetric survey as far south as the latitude of Umiat, with observations at 27½-mile intervals.

1950, party 144. Seismic line 5–50 northward for 60 miles from Umiat to Fish Creek. Lines 6–50 and 7–50 on Gubik anticline; lines 8–50, 9–50, and 10–50 on Sentinel Hill anticline; lines 11–50, 12–50, 13–50, and 14–50 on Titaluk anticline and northward into the Arctic Coastal Plain.

1951, party 144. Seismic lines 14–51 through 25–51 on Square Lake anticline; lines 26–51 through 32–51 along the trend of Sentinel Hill anticline from Square Lake to the Colville valley.

Geological surveys

1946, R. M. Chapman and R. F. Thurrell, Jr. Boat traverse along the Kurupa and Oolomnagavik Rivers and along the Colville River from the mouth of the Kurupa to Prince Creek.

R. G. Ray and W. A. Fischer; accompanied by Ben Hurlbut and Walter Moore, recorders; Douglas Bertek, cook; and Clarence Knutson and John Watson, weasel driver-mechanics. Areal mapping on Wolf Creek, Titaluk, and Weasel Creek anticlines from Wolf Creek to the upper Ikpikpuk River.

Karl Stefansson and C. L. Whittington; accompanied by Jim Moore, Jack McCarney, cooks; and Jack Irwin, weasel driver-mechanic. Areal mapping on Umiat anticline.

1947, R. L. Detterman, D. E. Matthewson, and John Townley, accompanied by Charles Siegle, cook. Boat traverse along Ninuluk Creek and the Colville River to Prince Creek. Weasel traverse down Tommy Creek and lower Prince Creek.

Karl Stefansson, R. F. Thurrell, Jr., and D. H. Zumberge, accompanied by Elder Lebert, cook, and "Red" Jenkins, mechanic. Boat and weasel traverse of Kogosukruk and lower Kikiakrorak Rivers; boat traverse of Colville River from Umiat to Ocean Point; and areal mapping on Wolf Creek anticline near the head of Wolf Creek.

E. J. Webber and R. K. Sorem. Boat traverse of Ikpikpuk River from Maybe Creek to Price River.

C. L. Whittington and M. L. Troyer. Areal mapping on Knifeblade anticline and the Kigalik River area from September Creek west to the Awuna River.

1949, W. P. Brosgé and A. N. Kover; accompanied by P. F. Armbrust and J. H. Downs, assistants; S. E. Dwornik, cook, and William Wiggam, mechanic. Areal mapping Titaluk anticline from the head of Maybe Creek to the Ikpikpuk River.

George Gryc and W. A. Fischer. Boat traverse of Colville River from Umiat to the Anaktuvuk River.

1950, G. D. Eberlein, R. M. Chapman and C. D. Reynolds. Areal mapping between the Kurupa and Etivluk Rivers and on Aupuk anticline at the Colville River.

1951, C. L. Whittington. Detailed mapping of the area around the Knifeblade test wells.

1953, R. L. Detterman and R. S. Bickel. Boat traverse of lower Killik River and Colville River near Killik Bend. Areal mapping on Fossil Creek anticline at the head of Prince Creek.

The surficial deposits have also been investigated. In 1947 Black (1957, 1964), of the Geological Survey, sampled the Gubik Formation on the Colville River and Prince Creek in connection with his studies in the Arctic Coastal Plain. In 1951, 1952, and 1953, field parties of Boston University Physical Research Laboratories made intensive studies of the surficial deposits, geomorphology, and ecology of selected sites in and adjacent to the Reserve. These studies included the Umiat area and localities along the lower Colville River.

In 1953 the Navy terminated its exploration of the Reserve, and cooperative fieldwork by the Geological Survey in this area was ended. The results of the geologic exploration up to 1951 were summarized by Payne and others (1951) in Oil and Gas Investigations Map 126, which in addition to a map of the major rock units, includes brief descriptions of the stratigraphy and facies relationships, of the surface and subsurface structure, and of the paleontology and petrology of the rocks.

ACKNOWLEDGMENTS

The fieldwork and the preparation of this report were under the supervision of G. O. Gates, R. L. Miller, and George Gryc.

Florence Robinson Weber and Florence Rucker Collins described and interpreted the stratigraphic data from test wells, and H. R. Bergquist and Helen Tappan identified and correlated the Cretaceous microfauna of both the wells and the outcrops. Their work provided the subsurface stratigraphic information for this report, and their help was given freely throughout its preparation. The Tertiary(?) and Quaternary ostracodes were identified by F. M. Swain and I. G. Sohn. The megafossils of the Nanushuk Group were identified by R. W. Imlay; those of the Colville Group, by George Gryc, D. L. Jones, and W. A. Cobban; and those of the Gubik Formation, by F. S. MacNeil.

Charles Matthews and Ralph Fellows of Boston University Physical Research Laboratories gave new information on the surficial deposits, and the laboratories kindly made available photographs and soil samples from the lower Colville River area.

A special acknowledgment is due T. G. Payne and P. D. Krynine, who early applied to the Cretaceous stratigraphy the concept of intertonguing marine and nonmarine facies that transgress time horizons.

MAPPING METHODS

Aerial photographs have been used for the geologic mapping both in the field and in the office. Except in the first years of the recent work, data have been plotted directly on the photographs, and the contacts and beds have been mapped on them in the field. In compilation of the series of photogeologic maps of 1950 and 1951 and in the preparation of this report, field mapping throughout the area was extended by projecting formation contacts along, or parallel to, traces of bedding visible on the vertical aerial photographs. These bedding traces rarely represent outcrops. Most are small topographic terraces or merely conspicuous bands of vegetation. In areas with too few exposures to have been profitably mapped in the field, formations have been identified on the photographs by their characteristic topographic expression and surface texture. The surficial deposits—alluvium, the Gubik Formation, and the high terrace gravels of the Colville River—have been mapped almost entirely by this method.

The field studies, as well as the photointerpretation, have been hindered by the scarcity of fresh exposures. In the interstream areas solifluction and frost heaving are the dominant agents of erosion, and most outcrops are only weathered rubble in the soil. Shale is rarely exposed, but sandstone makes conspicuous bedding traces that are commonly marked by a low growth of alders; these sandstone beds can readily be mapped even when completely hidden by soil. Except for exposures in streambanks, lithologic descriptions and measurements of the thickness of beds are mostly based on samples of float and on topographic breaks rather than on direct observation of the rocks in place.

The structure was in part mapped from aerial photographs. Where field measurements are lacking, dips and strikes have been estimated from the photographs. Some structural features—Umiat anticline, Titaluk anticline and Wolf Creek anticline—were contoured almost entirely from measured altitudes of key beds mapped in the field and from well data. Others —Fossil Creek anticline and Weasel Creek anticline— were contoured from both field data and known or estimated elevations of key horizons that have been traced out on photographs.

The structure, like the areal geology, was mapped originally on the vertical aerial photographs at 1:20,000 scale and then transferred to the base maps. As the base maps used were compiled from Tri-Metrogon photographs with little ground control, planimetry on these maps is distorted. In the area north of Maybe Creek, the planimetry has been redrawn from the photographs so as to fit the triangulation net established during the 1949 survey of Titaluk anticline. Also, because of the scarcity of geodetic control, it is probable that the geographic coordinates on these maps are not in true relation to the planimetry and that coordinate positions given in this report will not be true for the later revisions of the map.

Elevations have been measured by vertical-angle traverses in most parts of the area. The datum for the original survey by Lieutenant Foran at Umiat was based on an assumed elevation. The surveys by the Navy parties of 1945 were tied to this datum; three of the parties tied in to cairns set by Lieutenant Foran, and the Maybe Creek party tied in to a cairn set by the Prince Creek party.

The Geological Survey's vertical-angle traverses west of Umiat are tied to Umiat through the Navy traverses. The 1946 traverse of the Maybe Creek area was tied to a cairn set by the Navy's Square Lake party. The surveys on Wolf Creek in 1947 and in the Maybe Creek area in 1949 were tied to cairns set by the 1946 party, and the traverses south of Maybe Creek were tied to a cairn set by the 1949 party. Elevations of other parties are tied to the Umiat datum through airplane altimeter readings based on Umiat and through established elevations of major streams.

The datum has been changed twice since Lieutenant Foran's original survey at Umiat. The elevation he obtained for Umiat Mountain with his 1944 assumed datum was 1,173 feet. In 1946, when the topographic map of Umiat (special, 1948 ed.) was made by the Geological Survey, a new datum was assumed, based on the barometric records of the Navy meterological detachment at Umiat. The elevation obtained for Umiat Mountain with this datum was only 915 feet. In compiling this report, all surveys made in connection with the geological work have been adjusted to the Umiat (special) datum, and all bedrock structure contours are based on the adjusted elevations from those surveys.

A more precise topographic survey, made after the geological data were compiled, shows that the old surveys were in error. The Ikpikpuk River and Umiat quadrangles of the new Alaska Topographic Series (1956 ed.) are controlled by triangulation tied to sea-level datum. Elevations on these new maps show the Umiat (special) assumed datum was 72 feet too high; the elevation of Umiat Mountain is only 843 feet. Spot elevations of random stations common to the old and new surveys show that error accumulated in the old geologic traverses as they were extended westward from Umiat and partly compensated for the original datum error. Although elevations at Umiat are 72 feet higher than those of the new survey, elevations from geologic traverses in the Maybe Creek-Knifeblade area are within 20± feet of those of the new survey. However, elevations of the Colville River up to Killik Bend and Aupuk Creek are consistently about 70 feet too high throughout. These Colville River elevations were based not on the long traverses but on direct airplane altimeter readings of difference in elevation from that at Umiat. Elevations on the Kogosukruk River are about 100 feet too high. Thus, there is an overall, but inconsistent, error on the order of about 100 feet in the elevations used in this report.

The older set of elevations has been kept in use in spite of the known error, which is spread over a great distance. The old elevations are consistent within the local areas of structural closure, and the effect of the errors on total structural relief is only about 2 percent. The only significant quantitative effect of the error is on the computed gradient of the Colville River downstream from Umiat to known sea level and on the related gradient of the pre-Gubik Formation erosion surface in the lower Colville Valley. Because of this, elevations of the pre-Gubik surface given in figures 114 and 115 have been adjusted to the new datum of the 1956-edition maps.

GEOGRAPHY

PHYSIOGRAPHY

The Umiat-Maybe Creek region lies principally in the Northern Foothills section of the Arctic Foothills province as defined by Payne and others (1951, sheet 1), but roughly the northern quarter is in the Arctic Coastal Plain province. The highest elevation in the region is 1,557 feet at Knifeblade Ridge, low elevations occur on the principal rivers at the northern edge of the map area, about 100 feet on the Ikpikpuk and 50 feet on the Colville. The region is drained by the Colville and Ikpikpuk Rivers and their tributaries, as shown in plate 52. Topography of the Umiat area is depicted in plate 56; that of the Umiat-Maybe Creek region and adjacent areas is depicted with 100-foot contours at 1:250,000 scale on the Umiat, Ikpikpuk River, and Harrison Bay maps of the Geological Survey's Alaska Topographic Series.

In general, the Umiat-Maybe Creek region is a gently rolling hill country, but its topography ranges from nearly flat and featureless areas in the coastal plain along the northern margin of the region to very steep slopes on strike ridges formed by resistant sandstone beds. The principal strike ridges are those on the flanks of the Umiat-Square Lake anticline, formed by sandstone beds of the Barrow Trail Member of the Schrader Bluff Formation; Kimikpak Ridge, formed by the Ninuluk Formation on Weasel Creek anticline; and Knifeblade Ridge, formed by the Grandstand Formation of the Knifeblade anticline. North of Maybe Creek the country consists of a gently rolling upland protected by nearly flat-lying sandstones into which tributaries of Maybe Creek and the Ikpikpuk River have carved relatively narrow, steep-walled valleys. The southeastern part of the Umiat-Maybe Creek region is dominated by the flat topography formed by high-level gravel terraces. Lateral stream migration seems to be the cause of noteworthy examples of steep to precipitous topography, one of which is the Colville Bluffs, extending from Umiat to Ocean Point almost without a break. These bluffs are about 50 feet high at Ocean Point, 100 feet high at Sentinel Hill, and more than 200 feet high opposite the mouth of the Anaktuvuk River.

ACCESSIBILITY

Air travel is the principal means of reaching the Umiat-Maybe Creek region; overland travel by various means is feasible, but for the most part is more expensive and certainly far more time consuming.

Because of its 5,000-foot gravel airstrip, Umiat is the principal center for air travel. In 1961 a commercial airline undertook operation of communications and maintenance of the airstrip. During the summer floatplanes can land on the Colville River; during the winter ski-equipped aircraft can use the airstrip; and in late spring when the snow has melted, skiplanes can land on nearby Umiat Lake.

Generally there is enough snow that ski-equipped single-motor aircraft can land almost any place during the later part of the winter. Landings on snow-covered tundra can usually be made without much difficulty until the middle of May, and ski landings on frozen lakes are possible until at least the end of the first week in June. Single-motored wheel-equipped planes can land on gravel bars along the Colville River and probably at places on the Ikpikpuk throughout the snow-free season, starting early in June. The rivers are suitable for floatplane landings from about the same time, but the Ikpikpuk is probably suitable only for the smallest planes along most of its course, and none of the smaller streams are usable. Floatplanes can use the lakes along the Colville and Ikpikpuk Rivers after about June 15 and those in the Arctic Coastal Plain perhaps 1 to 2 weeks later.

Overland travel into or within the Umiat-Maybe Creek region could be conducted by dogsled or tractor train in the winter, by tracked vehicles such as the weasel throughout the year, and by foot in the summer.

The Colville River is navigable in the summer, but the other streams are too small to be of much use. Poling boats, 20 to 30 feet long and equipped with large outboard motors, are commonly used in central Alaska and could undoubtedly be used on the Colville, except possibly in the stretch from Killik Bend to Umiat during a season of unusually low water. Small boats have been used on the Ikpikpuk River, Maybe Creek, and Prince Creek as well as extensively on the Colville.

CLIMATE

The Umiat-Maybe Creek region has a cold climate with greater extremes of temperature than those of coastal stations such as Barrow. Precipitation is low, perhaps 10 to 15 inches a year; but because of the generally low temperatures, there is no impression of aridity. On the contrary, the general impression is that water is everywhere, particularly in early June when the snow is not completely melted and the top of the ground is only starting to thaw.

Much of the precipitation occurs as snow from September to April. Rain is frequent during the summer, but it is usually little more than a mist. Thunderstorms are infrequent.

Temperatures are generally below freezing from the middle of September to the first of May. Freezing weather and snow may occur in any month but seldom in the period June through August. Most of the snow melts during May, but drifts in protected localities may persist until the middle of July. Ice on the streams and rivers usually breaks up during the last week in May; ice on lakes persists until the second or third week in June. Freezeup begins about the middle of September, and by the end of October even the largest streams are frozen over.

Permafrost.—The ground in the Umiat-Maybe Creek area is permanently frozen to a depth of several hundred feet. Data on the extent of permafrost in some of the wells in Umiat-Maybe Creek region have been reported by M. C. Brewer (in Collins, 1958a, p. 131–132, 142, 170–171, 197; in Robinson, 1959a, p. 396, 397, 416).

SETTLEMENT AND POPULATION

There are no permanent settlements in the Umiat-Maybe Creek region. The semipermanent camp at Umiat is occupied only by the airline's staff and by headquarters of summer field parties.

STRATIGRAPHY

The exposed consolidated rocks of the Umiat-Maybe Creek region are sedimentary strata of Cretaceous age (fig. 93). Lying below the Cretaceous rocks and above the basement probably are lower Mesozoic sedimentary rocks and possibly upper Paleozoic sedimentary rocks. The Cretaceous rocks are extensively mantled by relatively thin unconsolidated deposits of Quaternary age.

The distribution of the outcropping stratigraphic units is shown on the geologic map, plate 52. Correlated columnar sections of Lower Cretaceous rocks are shown on plate 53 and the correlation of exposed sections of Lower Cretaceous rocks with those in the wells is shown in figure 94. Correlated columnar sections of Upper Cretaceous rocks are shown on plate 54. The sections are described in detail under "Stratigraphic sections" on pages 609–632.

PRE-CRETACEOUS ROCKS

A basement complex of metamorphic and igneous rocks no doubt underlies the Umiat-Maybe Creek

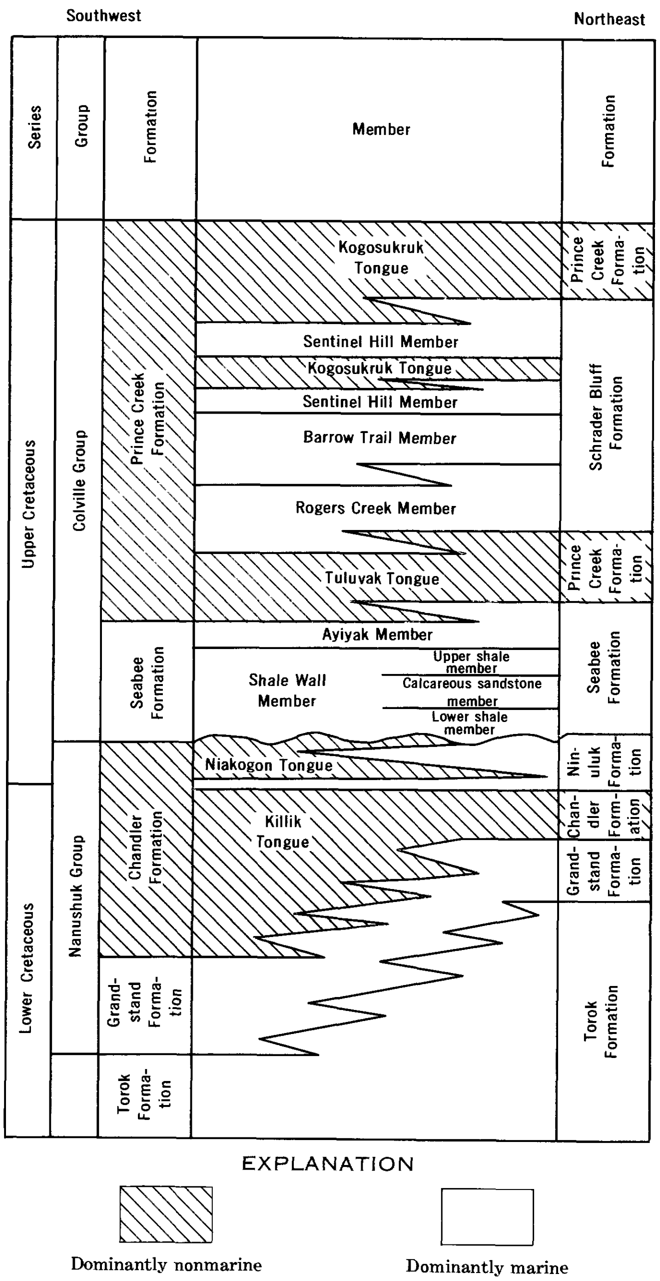

FIGURE 93.—Nomenclature of outcropping Cretaceous rocks.

region at great depth. In the northernmost part of the Arctic Coastal Plain, the top of the basement is drawn at the top of a zone of steep and erratic dips shown by seismic data (Payne and others, 1951, fig. 10). Steeply dipping argillite, dolomite, and chert of unknown age in the top part of this zone have been drilled at Simpson and Barrow (Robinson, 1959b, p. 530–531, 548; Collins, 1961, p. 573). In the Topagoruk River area, steeply dipping rocks were locally mappable (Woolson and others, 1962), and Topagoruk test well 1 penetrated 463 feet of steeply dipping Middle, or possibly Lower, Devonian conglomerate and shale (Collins, 1958b, p. 271) corresponding to the upper part of the seismic zone of steep dips. The steeply dipping Devonian rocks are not metamorphosed; hence, whether or not they should be considered part of the basement is questionable. However, the basement complex, whatever it may be, probably does not include rocks younger than Devonian.

Unmetamorphosed sedimentary rocks of Devonian to Permian age may underlie the Umiat-Maybe Creek region. In the central Brooks Range the Upper Devonian Kanayut Conglomerate is several thousand feet thick and is lithologically similar to the Devonian rocks in Topagoruk test well 1. It is succeeded by the Kayak Shale and the limestones of the Lisburne Group, both locally of Mississippian age (Bowsher and Dutro, 1957), and the shaly Siksikpuk Formation of Permian age (Patton, 1957). Unconformably overlying the Devonian rocks in the Topagoruk well are 270 feet of red beds similar to the Siksikpuk Formation and 390 feet of Permian sandstone (Collins, 1958b, p. 270–271). The Lisburne Group is absent. Farther north at Barrow and Simpson, rocks of known Paleozoic age are absent. It has been postulated that from late Paleozoic to Early Cretaceous time the present northern coast of Alaska was part of a low-lying platform or shield area and that progressively younger rocks overlapped onto this shield from the geosynclinal areas to the south (Payne and others, 1951, sheets 1 and 3). On this basis the upper Paleozoic rocks underlying the Umiat-Maybe Creek region should be thicker and encompass a greater span of geologic time than do those farther north at Topagoruk. Because they are known both to the north and to the south, it is probable that Permian rocks underlie the Umiat-Maybe Creek region at depth. Upper Paleozoic rocks older than Permian may also be present.

Triassic and Jurassic shales are probably present at depth in the Umiat-Maybe Creek region. Rocks of these ages are known to crop out to the south in the foothills (Payne and others, 1951, sheet 1) and have been penetrated in wells in the Barrow (Collins, 1961, p. 572–573), Simpson (Robinson, 1959b, p. 528–530) and Topagoruk (Collins, 1958b, p. 269–270) areas, and possibly in the Oumalik area (Bergquist, 1956, p. 66). Seismic surveys show that these rocks thicken continuously southward from about 1,000 feet in the Barrow and Simpson areas to about 2,800 feet in the Topagoruk area (Woolson and others, 1962), but whether this thickening continues south of lat 70°30′ N. is not known.

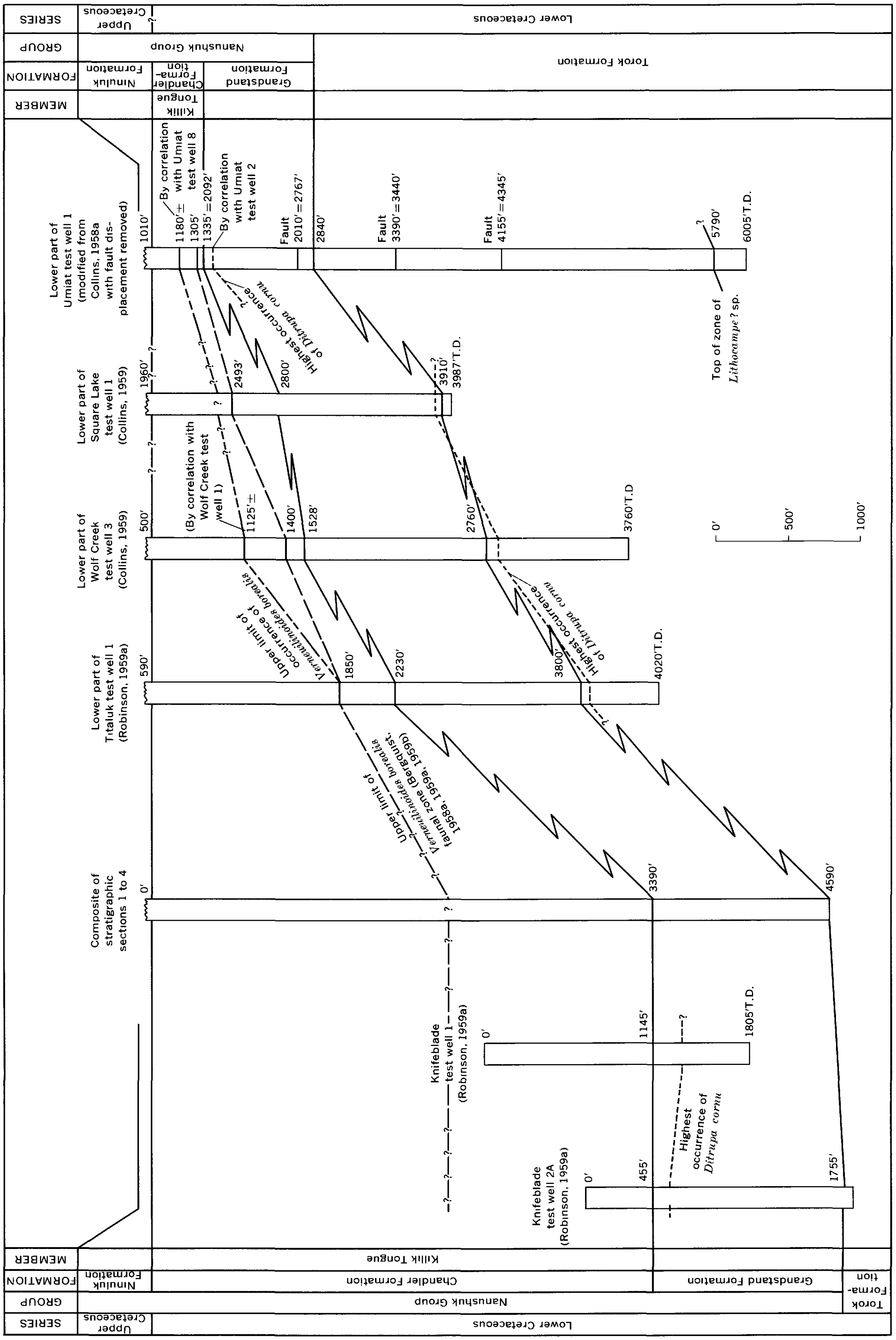

FIGURE 94.—Correlation of Lower Cretaceous rocks. Datum is base of Ninuluk Formation. Well data from Robinson (1959a) and Collins (1958a, 1959). Correlations revised by Whittington.

CRETACEOUS SYSTEM

The Torok Formation (late Early Cretaceous in age), Nanushuk Group (late Early Cretaceous to early Late Cretaceous in age), and the Colville Group (Late Cretaceous in age) make up the outcropping indurated rocks of the Umiat-Maybe Creek region. In the subsurface, rocks equivalent to the Torok Formation have been described as the Oumalik and Topagoruk Formations (Robinson and others, 1956).

Most, if not all, of the Torok Formation and of the equivalent Oumalik and Topagoruk Formations and most of the Nanushuk Group represent the Albian Stage of the Lower Cretaceous. In the Umiat-Maybe Creek region, the upper part of the Torok Formation (upper part of the Topagoruk Formation in the subsurface) is apparently the offshore-marine equivalent of near-shore rocks in the lower part of the Nanushuk Group. The upper part of the Nanushuk Group represents the Cenomanian Stage of the Upper Cretaceous, and the succeeding stages—the Turonian, Coniacian, Santonian, and Campanian—are at least in part represented in the Colville Group.

Rocks of Berriasian and Valanginian ages may be present beneath the Torok, although the succeeding Hauterivian, Barremian and Aptian Stages of the Lower Cretaceous are not present in northern Alaska (Imlay, 1961, p. 5). Rocks of Berriasian and Valanginian ages crop out south of the mapped area and are referred to the Okpikruak Formation (Gryc and others, 1951, p. 159–160). Because of the wide distribution of rocks of these ages in the foothills and the probable occurrence of such rocks in Oumalik test well 1, they are likely to be present beneath the Umiat-Maybe Creek region. They seem to be absent at Topagoruk, Barrow, and Simpson.

TOROK FORMATION

NAME AND TYPE SECTION

As originally described by Gryc, Patton, and Payne (1951, p. 160), the Torok Formation included a predominantly shaly sequence, 6,000 feet thick, that crops out immediately south of Tuktu Bluff and a 10,500-foot-thick sequence containing thick graywacke sandstone and conglomerate in the vicinity of Castle Mountain. Patton (1956, p. 222) redefined the Torok Formation as the sequence of shale, siltstone, and minor sandstone, approximately 6,000 feet thick, that underlies the Nanushuk Group on Torok Creek and on the Chandler River between Torok Creek and the Kiruktagiak River. The thicker sequence of coarser grained rocks at Castle Mountain was assigned to the Fortress Mountain Formation. The Torok and Fortress Mountain Formations are approximately the same age, but no exact correlation between the two seems possible. In the type area the Torok is overlain by the Tuktu Formation. The base of the Torok is not exposed in the type area, but the formation probably rests on either the Fortress Mountain Formation or the Okpikruak Formation (Patton, 1956).

In most of the wells in the Arctic Coastal Plain province and Northern Foothills section, strata equivalent to the Torok Formation are divided into the Oumalik and Topagoruk Formations (Robinson and others, 1956). In the Oumalik area the Oumalik Formation rests on strata at least as old as the Okpikruak Formation and is overlain by the Topagoruk Formation. The Topagoruk is overlain by the Grandstand Formation and is considered to be equivalent in age to the upper part of the Torok Formation, to all of the Tuktu Formation, and to part of the Grandstand Formation. The contact between the Oumalik and Topagoruk Formations is considered to be gradational in the Oumalik area, although farther north in the Topagoruk area it is described (Robinson and others, 1956, p. 230) as an uncomformity that can be traced in the seismic records. Both the Oumalik and Topagoruk Formations are primarily shale but contain subordinate amounts of siltstone and sandstone. Lithologic differences between the two are subtle, and differentiation is based primarily on microfossils. The *Verneuilinoides borealis* fauna, also present in the lower part of the Nanushuk Group, is best developed in the upper part of the Topagoruk. As depth increases it gradually disappears, to be succeeded in the Oumalik Formation by a different fauna, meager but characteristic. Both faunas are present, in the same stratigraphic positions, in outcrops of the Torok Formation (Robinson and others, 1956, p. 226; Bergquist, 1958a, p. 199).

The reports by Collins and Robinson on the subsurface geology of the Umiat-Maybe Creek region also refer the shale below the Grandstand Formation to the Oumalik and Topagoruk Formations. In this report, however, the shale underlying the lowest sandstone unit of the Nanushuk Group in the Umiat-Maybe Creek region is referred to the Torok Formation.

There is little evidence, other than faunal, for separating this shale unit into two formations in this region. Only in Umiat test wells 1 and 2 did drilling go deep enough to reveal the fauna characteristic of the Oumalik Formation; all other wells in the region bottomed in the Topagoruk Formation or younger beds, according to Collins (1958a, p. 75; 1959, p. 448) and Robinson (1959a, p. 381). In Umiat test well 1 the Oumalik and Topagoruk Formations are similar enough to make their contact difficult to recognize (Collins, 1958a, p. 76); and in Umiat test well 2, descriptions of color, texture, composition, and dip of the 400 feet of Oumalik Formation logged are virtually the same as descriptions of the overlying 400 feet of Topagoruk Formation. The steeper dip of the Oumalik Formation at a depth of 4,995 feet in Umiat test well 2 may well be due to deformation connected with a fault of more than 1,000 feet displacement at a depth of 5,100 feet.

The possibility that the overlying sandstone unit in this region may correlate with the Tuktu Formation as well as with the Grandstand makes it uncertain that the shale here extends as far above the typical Torok as does the Topagoruk. Consequently, although the shale can be mapped at only one locality in this region, we prefer the less restrictive terminology of the other outcrop areas, in which the undivided shale is termed Torok and the top contact of the Torok is at the base of the sandstone sequence and coincides with the base of the Nanushuk Group.

DISTRIBUTION, THICKNESS, AND LITHOLOGY

The Torok Formation is inferred to be present at the surface on the Knifeblade anticline in an area about 500 yards wide extending westward from the cross fault for about 3 miles (pls. 52 and 55). In this area the rock is believed to be largely shale, for bedding traces as well as outcrops are absent. Comparison of the log of Knifeblade test well 2A with section 3 (pl. 53 indicates that the lower 50 feet of the well section is in the Torok. The rock in this interval consists of shale, siltstone, and very fine grained sandstone. The sandstone (actually loose sand) may represent contamination from beds higher in the hole. Robinson (1959a, p. 378, 380, 397, 412) included these beds in the Nanushuk Group but considered it likely that the hole was near the base of the Nanushuk Group or below it at total depth.

The Torok Formation is represented throughout the Umiat-Maybe Creek region by the subsurface units that were referred to the Oumalik and Topagoruk Formations by Robinson and Collins. Their descriptions of these units in the wells, the only data on the character of the Torok in this region, are summarized below.

The most nearly complete sections of the Torok are in Umiat test wells 1 and 2 (Collins 1958a). Both wells went through a complete section of the unit of shale that is within the *Verneuilinoides borealis* faunal zone (the Topagoruk Formation). This unit is about 2,500 feet thick in Umiat test well 1 and about 3,000 feet thick in test well 2, allowing for repetition of beds by the faults recognized in these wells. Both wells also penetrated about 400 feet of the underlying *Lithocampe*-bearing shale (the Oumalik Formation). About 1,000 feet of shale in the *Verneuilinoides borealis* faunal zone was penetrated by Wolf Creek test well 3 and about 520 feet by Titaluk test well 1. The other wells penetrated no more than the upper 228 feet of shale.

In the four wells mentioned, the Torok contains from 64 to 95 percent shale, most of which is medium dark gray and much of which is silty. Medium-gray to light-gray siltstone and medium-light-gray, generally very fine grained, silty argillaceous sandstone make up the rest of the formation. The sandstone is generally a minor constituent; but in Wolf Creek test well 3, sandstone, fine grained and very fine grained, makes up about 28 percent. Because much of the sandstone at Wolf Creek is concentrated in the upper 500 feet of the formation, deposition of the upper part of the formation in the Wolf Creek area was probably about concurrent with deposition of the thick sandstones in the lower part of the Nanushuk Group in the area of the Knifeblade wells.

PALEONTOLOGY AND AGE

Megafossils have been found in the Torok Formation in Titaluk test well 1, Wolf Creek test well 3, and Umiat test wells 1, 2, and 9. The occurrences are listed by Collins (1958a, p. 91, 106, 108, 160; 1959, p. 467–469), Robinson (1959a, p. 391–392), Bergquist (1958a, p. 201; 1959a, p. 418; 1959b, p. 482), and Imlay (1961, p. 37). Worm tubes of the genus *Ditrupa* are reported from all these holes except Umiat test well 1. Crinoid ossicles occur in Umiat 1 and 2, and crinoid fragments identified as *Balanocrinus* sp. occur in the Titaluk well. *Inoceramus sp.* [juvenile] cf. *I. anglicus* Woods occurs in Umiat 2 at a depth of 2,784 feet and in the Wolf Creek well at 3,755 feet; and, in samples prepared for microfossil separation, *Inoceramus* prisms were identified from one place in the Wolf Creek well and three places in the Titaluk well. *Gastroplites* sp. is reported from depths of 2,148 and 2,634 feet in Umiat 2 and unidentified ammonites from 1,171 feet in Umiat 9 and 3,095 feet in Wolf Creek 3. No megafossils were found in Umiat 1 at depths from 5,650 to 6,005 feet or in Umiat 2 at 4,700 to 5,100 feet, the beds assigned by Collins (1958a) to the Oumalik Formation.

Subsurface microfossil occurrences in the Torok Formation (Topagoruk and Oumalik Formations of the wells) in the Umiat-Maybe Creek region have been summarized by Bergquist (1958a, 1959a, 1959b). About 90 percent of the total thickness of the Torok penetrated in the wells was within the *Verneuilinoides borealis* zone, which also characterizes the overlying Grandstand Formation. Only Umiat test wells 1 and 2 penetrated beds older than this faunal zone. In these two wells a few occurrences of *Lithocampe?* sp. suggest that the beds in which they occur are the same age as the Oumalik Formation in Oumalik test well 1 and the middle to lower part of the Torok in the area south of the Colville River (Robinson and others, 1956, p. 226). At Umiat the *Verneuilinoides borealis* zone aparently extends through the upper 2,500 feet to 3,000 feet of the Torok.

Imlay (1961) dated the Torok, Oumalik, and Topagoruk Formations as Albian in age. Consideration of various lines of evidence led him (p. 7–9) to conclude that the Oumalik and the lower two-thirds of the typical Torok are early Albian. A close reading of his discussion, however, suggests the remote possibilities that the lower part of the beds dated early Albian could be of Aptian age or that the upper part could be middle Albian. The upper third of the typical Torok and that part of the Topagoruk equivalent to the Torok and Tuktu Formations are dated with considerable certainty as middle Albian (Imlay, 1961, p. 9-11). In some areas the upper part of the Topagoruk may be late Albian (p. 11-12, pl. 22).

NANUSHUK GROUP

Schrader (1902, p. 247–248; 1904, p. 79–80) introduced the term Nanushuk Series to include a group of rocks overlying his Anaktuvuk Series and underlying his flat-lying Colville Series of the Arctic Coastal Plain. The strata mapped by him as the Nanushuk Series are mostly those mapped as the Colville Group by recent workers. The principal source of information for Schrader's lithologic description, the locality now known as Schrader Bluff, is a long cutbank exposing parts of the Seabee, Prince Creek, and Schrader Bluff Formations of the Colville Group (Whittington, 1956, p. 249).

Smith and Mertie (1930, p. 208–210) included the Nanushuk and Colville Series of Schrader in their Upper Cretaceous Series and revised Schrader's mapping on the Anaktuvuk River so that the Upper Cretaceous Series included the upper part of the Torok Formation and all of the Nanushuk Group of present usage.

Gryc, Patton, and Payne (1951, p. 162–164) applied the name Nanushuk Group to a sequence of rocks which had been included in the lower part of the Upper Cretaceous Series of Smith and Mertie. The group was divided into the marine Umiat Formation with two named members and the nonmarine Chandler Formation with two named tongues. The two formations intertongue, but northward nonmarine rocks tend to tongue out and be replaced by marine rocks.

Detterman (1956a) revised the formational nomenclature of the Nanushuk Group. The marine rocks of the group were placed in the Tuktu, Grandstand, and Ninuluk Formations, which are characterized by marine sandstones bearing fossils of late Early to early Late Cretaceous age. The name Chandler Formation was retained for the nonmarine rocks, which were divided into the Lower and Upper Cretaceous Killik Tongue and the Upper Cretaceous Niakogon Tongue. South of the Colville River the basal unit of the group is the Tuktu Formation. This unit is succeeded by the Chandler and Grandstand Formations, which intertongue in many places and are overlain in most places by the Ninuluk Formation and the Niakogon Tongue of the Chandler Formation. The Tuktu Formation becomes more shaly northward (Detterman and others, 1963, p. 238) and has not been recognized in the Umiat-Maybe Creek region, where the lowest unit of the Nanushuk Group has been designated Grandstand Formation by Collins (1958a, 1959) and Robinson (1959a).

GRANDSTAND FORMATION

NAME AND TYPE SECTION

The name Grandstand Formation was proposed by Detterman (1956a, p. 235–237) for a 1,700-foot section of predominantly marine rocks where the Anaktuvuk River breaches the Grandstand anticline. The type section rests on the Tuktu Formation and contains several interfingering units of the Killik Tongue of the overlying Chandler Formation. About half of the upper 500 feet is nonmarine. White quartz sand distinguishes the sandstone of the Grandstand from that of the underlying Tuktu.

The Grandstand Formation of the Umiat-Maybe Creek region does not correspond very well to either of the previously defined basal Nanushuk Group marine formations—the Tuktu and Grandstand Formations of Detterman (1956a, p. 233–237). Comparison of the Nanushuk Group section at Knifeblade Ridge with sections of the Nanushuk Group in the Killik-Etivluk Rivers region (Chapman and others, 1964) to the south (fig. 95) suggests that the Grandstand at Knifeblade Ridge is stratigraphically the same formation as the Tuktu mapped in its northernmost outcrops south of the Colville River. On the other hand, northeastward convergence of the Grandstand with the base of the next higher faunal zone in the Umiat-Maybe Creek region suggests that the Grandstand in the northern and eastern parts of the region is considerably younger than the type Tuktu of the Tuktu escarpment. Because the basal sandstone formation of the Nanushuk Group in the Umiat-Maybe Creek region has already been assigned to the Grand-

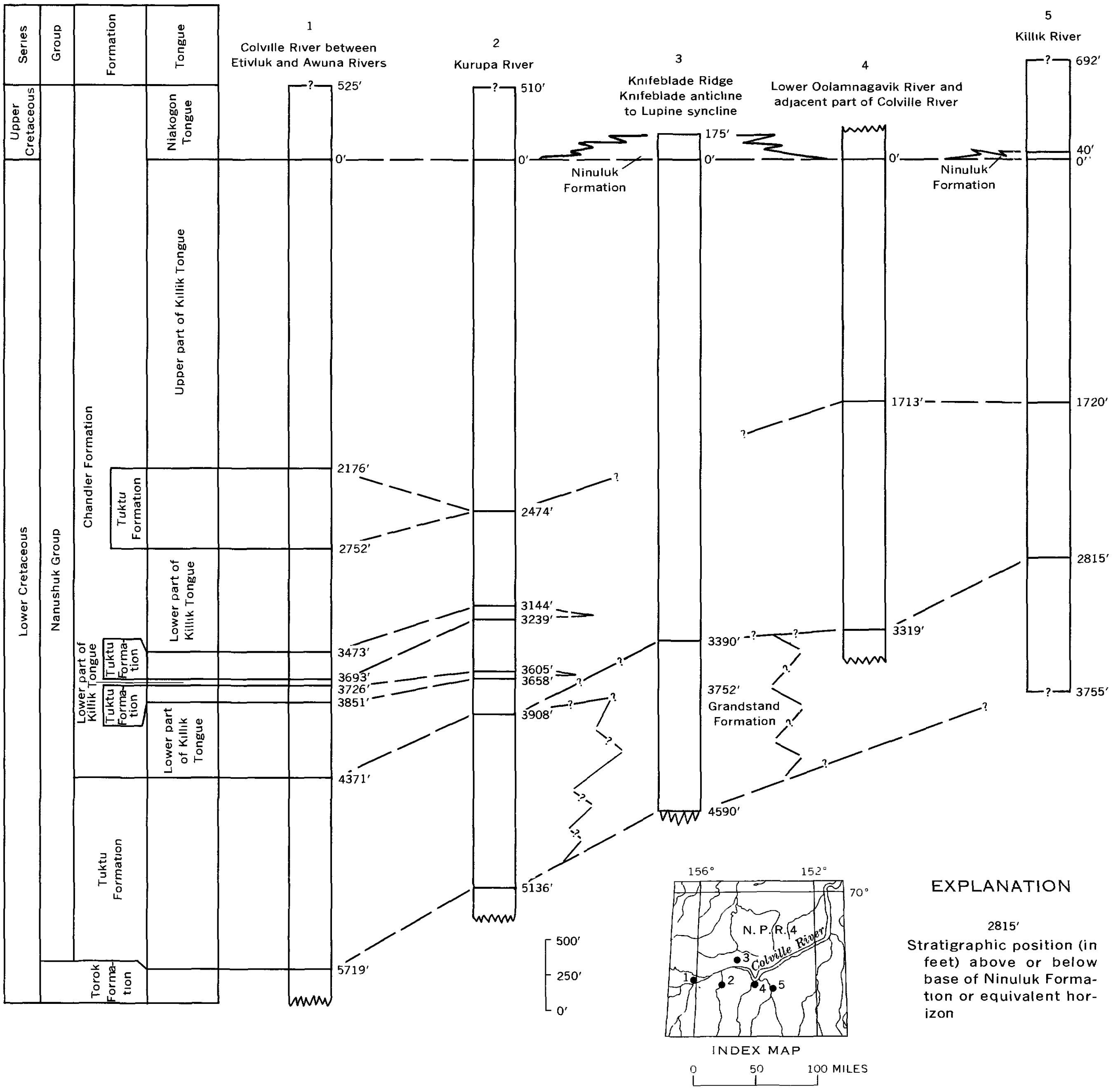

FIGURE 95.—Formations in the Nanushuk Group near Knifeblade Ridge and south of the Colville River. Sections 1, 2, 4, and 5 are from Chapman and others (1964).

stand Formation (Collins, 1958a, p. 75; 1959, p. 424-427, 448; Robinson, 1959a, p. 380), that designation is continued in this report.

DISTRIBUTION

The Grandstand Formation crops out on the Knifeblade anticline and in the bank of the Colville River at Fossil Creek anticline, but it is not otherwise exposed in the Umiat-Maybe Creek region. It occurs in the subsurface in most of the area but is probably absent along the lower Colville River and farther east. It is not present in the well at Fish Creek about 70 miles north of Umiat (Robinson and Collins, 1959, p. 503).

In descriptions of the Grandstand Formation in the subsurface by Collins (1958a, 1959) and Robinson (1959a), the top of the Grandstand was picked at the top of the *Verneulinoides borealis* microfaunal zone or at the top of the abundant fauna of that zone. In order to use the Grandstand Formation as a mapping unit on the Knifeblade anticline, the writers found it desirable to pick a lower horizon for the top of the formation than that used by Robinson (1959a, p. 397). This horizon, 325 to 365 feet lower, is the top of the uppermost thick sandstone. On the same basis a new top for the formation was picked in the other wells in the area, 380 feet lower at Titaluk, 128 to 135 feet lower at Wolf Creek, 325 feet lower at Square Lake, and 7 to 40 feet lower at Umiat. The limits of the Grandstand Formation as used by Collins (1958a, 1959) and Robinson (1959a) in the various wells of the area compare with the revised limits adopted by the writers as follows:

Limits of the Grandstand Formation, in feet

[Asterisk indicates Grandstand Formation incomplete]

Test well	Subsurface reports	This report
Knifeblade 1	*820–1, 805	*1, 145–1, 805
2	*105–373	(1)
2A	90–1, 805(?)	455–1, 755
Titaluk 1	1, 850–3, 500	2, 230–3, 500
Wolf Creek 1	*1, 350–1, 500	*1, 485–1, 500
2	*1, 545–1, 618	(1)
3	1, 400–2, 760	1, 528–2, 760
Square Lake 1	2, 475–3, 987(?)	2, 800–3, 910
Umiat 1	*1, 309–2, 010	*1, 335–2, 010
	2, 085–2, 840	2, 092–2, 840
2	365–1, 060	390–1, 060
3	*225–572	*248–572
4	*320–840	*353–840
5	335–1, 060	365–1, 060
6	*630–825	*655–825
7	*795–1, 384	*820–1, 384
8	*840–1, 327	*865–1, 327
9	425–1, 090	465–1, 090
10	*1, 025–1, 573	*1, 055–1, 573
11	2, 420–3, 075	2, 435–3, 075

[1] Not penetrated.

LITHOLOGY AND THICKNESS

The Grandstand Formation has yielded almost all the oil produced in this region and is known mostly from the wells described by Collins (1958a, 1959) and Robinson (1959a). In the Colville River bank at Fossil Creek anticline, where the formation is estimated to be 1,000 to 1,500 feet thick, it is exposed as buff to gray, very fine grained to fine-grained sandstone separated by long covered intervals. The sparse rubble outcrops near Knifeblade Ridge are described in stratigraphic sections 2, 3 and 4. The detailed descriptions of the formation in the wells are summarized below.

The formation as defined in this report contains 40 to 55 percent sandstone and generally less than 10 percent siltstone; the rest is shale and claystone, containing minor amounts of coal and bentonite, and scarce limestone.

The shale and claystone are generally medium to dark gray, slightly to very silty, and locally interlaminated or gradational with siltstone. The siltstone is light to medium gray and locally grades into sandstone. Thin coal beds occur throughout the formation in the Knifeblade and Titaluk wells; coaly streaks and partings are scarce at Wolf Creek and Umiat, and coal seems to be absent at Square Lake. Thin bentonite beds occur near the top and bottom of the formation at Wolf Creek and throughout the formation at Umiat. Thin limestone beds occur near the middle and bottom of the formation in the Titaluk well.

The sandstone is almost entirely light gray to medium light gray, although there are some medium-gray and dark-gray beds at Umiat and in the upper half of the formation in the Knifeblade wells. According to petrographic descriptions by P. D. Krynine of 32 selected samples from the Umiat wells, the sandstones are mostly low-rank graywackes and quartzose graywackes containing some protoquartzites. Almost all the graywackes described have less than 15 percent detrital matrix and are therefore subgraywackes of Pettijohn's (1957, p. 291) classification. Throughout the region quartz is the dominant constituent. Chert, rock fragments, and minor amounts of pyrite and mica make up most of the remainder. Feldspar, from a trace to 9 percent, occurs in all 32 Umiat samples. Clastic grains of coal and carbonaceous material occur in many of the sandstones; these coal grains are common in the Knifeblade and Titaluk wells, scarce in the Umiat and Wolf Creek wells, and apparently absent at Square Lake. The matrix of the sandstone in the Umiat, Square Lake, and Wolf Creek wells is commonly argillaceous. According to F. R. Collins and F. M. Robinson (written commun., 1955) the sandstone at Umiat is, as a whole, cleaner than that in the Wolf Creek and Square Lake wells and contains less interstitial clay and mica. Most of the sandstone in these wells is noncalcareous. In the Titaluk well, on the other hand, about two-thirds of the sandstone is calcareous; and in the Knifeblade wells very little argillaceous sandstone is reported except in the upper 200 feet.

The grain size of the sandstone ranges from very fine to coarse and decreases eastward. The average grain size (median and, coincidentally, modal) and the range of grain sizes for the sandstone in the wells is:

Well	Average grain size	Range of grain size from very fine to—
Knifeblade 2A	Fine	Coarse.
Titaluk 1	do	Medium.
Wolf Creek 3 [1]	do	Do. [1]
Square Lake 1	Very fine	Fine.
Umiat [2]	do	Medium.

[1] Only 1 or 2 ft of medium-grained sandstone.
[2] Average of wells, 1, 2, 5, 9, 11.

In the wells west of Umiat, grain size also decreases downward. In these wells the Grandstand has a fairly constant thickness (1,110 to 1,270 ft) and may be divided into three zones: the upper is about 300 to 400 feet thick; the middle, about 500 to 600 feet thick; and the lower, 220 feet thick at Square Lake to 415 feet thick at Knifeblade. In the Titaluk well almost all the sandstone is fine to medium grained, and the proportion of fine-grained sandstone increases steadily downward from slightly more than one-half of the total sandstone in the upper zone to about three-quarters of the total in the lower zone. At Wolf Creek and Square Lake almost all the sandstone is very fine to fine grained. The very fine grained sandstone increases steadily downward at Wolf Creek from about one-third of the sandstone in the upper zone to slightly more than one-half of the sandstone in the lower zone, and at Square Lake from about one-third of the sandstone in the upper zone to all of the sandstone in the lower zone. In the Knifeblade wells also, the upper zone is the coarsest; more than one-half the sandstone is medium to coarse grained. However, the finest sandstone at Knifeblade is in the middle zone, in which almost all the sandstone is very fine grained, whereas the sandstone of the lower zone is mostly fine grained but includes some medium-sized grains.

In the thinner section of the Grandstand at Umiat (625 to 748 ft thick) an upper sandstone zone about 100 feet thick and a lower sandstone zone about 300 feet thick are separated by a zone consisting largely of shale. Overall, the sandstones of both zones are about half very fine grained and half fine grained and contain a minor amount of medium-grained sandstone, but the proportions of very fine grained and fine-grained sandstone vary widely between closely spaced wells.

Thin layers of rounded chert pebbles occur in very fine grained to fine-grained sandstone about 70 feet above the base of the formation at Square Lake and about 170 and 740 feet above the base at Wolf Creek. Some graded bedding, which is generally inverse, grading upward from finer to coarser, has been reported.

Permeability and porosity of the sandstones are greater at Umiat than in the other areas tested. Of 225 samples from Umiat, only 66 percent had permeability less than 10 millidarcies, and 19 percent had permeability greater than 50 millidarcies. Of 111 samples from the other wells, 84 to 94 percent of the samples from each well had permeability less than 10 millidarcies and only 7 percent or less had permeability greater than 50 millidarcies. Of 182 samples from Umiat, only 14 percent had effective porosity less than 8 percent, and 29 percent had effective porosity greater than 15 percent. Of 123 samples from the other areas, 10 to 50 percent of the samples from each well had effective porosity less than 8 percent, and only 2 to 10 percent had porosity greater than 15 percent.

PALEONTOLOGY AND CORRELATION

The Grandstand Formation lies entirely within the *Verneuilinoides borealis* microfaunal zone of Bergquist (1958a, 1959a, 1959b) (pl. 53). As originally desinated by Robinson and Collins, the top of the Grandstand in the wells coincides approximately with the top occurrence of abundant species or specimens of this zone, but in many of the wells it is below the uppermost limit of the zone. According to Bergquist (in Robinson, 1959a, p. 418, 419), the faunal zone extends up through all the overlying Chandler Formation penetrated in the Knifeblade wells; tongues of the zone occur in the Chandler Formation above the Grandstand in the three Wolf Creek wells (1959b, p. 480–481), and *Verneuilinoides borealis* itself occurs more than 100 feet above the top of the Grandstand in Umiat test well 8 (1958a, p. 203). The writers have moved the upper contact of the Grandstand to a lithologic boundary even lower in the section and thus accentuated the difference between the top of the formation and the top of the *Verneuilinoides borealis* zone.

Worm tubes of *Ditrupa cornu* Imlay, commonly associated with the *Verneuilinoides borealis* zone, occur up to within 75 feet of the top of the formation in the Umiat wells and to within about 200 feet of the top in the Knifeblade wells. In the other wells, however, the highest occurrence of *Ditrupa* is within 100 feet above or below the base of the formation (pl. 53).

At three closely spaced localities on the Colville River on the south flank of Fossil Creek anticline (USGS Mesozoic locs. 20435, 20477, and 25137 (Imlay, 1961)), the probable upper part of the formation contains *Ditrupa cornu*, *Tancredia* sp., *Arctica*? sp., *Panope*? sp., *Thracia stelcki* McLearn, and *Entolium utukokense* Imlay. The only megafossils identified from the wells are from Square Lake and Umiat, except for *Ditrupa cornu* and fragments of *Inoceramus* sp., which occur in all the wells but Titaluk. *Pleuromya* sp. and *Entolium* sp. occur in sandstone in the wells; *Lingula* sp., *Yoldia kissoumi* McLearn, *Corbula*? sp., *Cymbophora* sp., and *Psilomya*? sp. occur in shale and siltstone. According to Imlay the identified species range through the middle Albian into the upper Albian and occur in the Tuktu as well as the Grandstand Formation.

The correlation of the Grandstand in the Umiat-Maybe Creek region with adjacent areas is uncertain. The formation in the Titaluk and Wolf Creek wells and at least the upper part of the formation at Knifeblade Ridge seem to be the Grandstand according to all criteria. The rocks at Square Lake are probably equivalent to the Grandstand, but the rocks at Umiat and the lower part of the section at Knifeblade Ridge may be equivalents of the Tuktu Formation.

The typical Grandstand is regarded as a time-transgressive near-shore marine sandstone that is transitional between the underlying entirely marine Torok and Tuktu Formations and the overlying and partly equivalent coal-bearing Killik Tongue of the Chandler Formation. Inasmuch as definitive megafossils are rare in this region and all these rocks except the lower part of the Torok and possibly the highest part of the Killik lie within the same microfaunal zone, the exact time relations cannot yet be established. The convergence of the Grandstand with the next higher faunal horizon at the base of the Upper Cretaceous rocks (pl. 53 and fig. 94) suggests that the sandstone unit becomes younger to the north and east, but this convergence might also be due either to regional thinning of the overlying Killik Tongue or to an undetected regional unconformity that is suggested by the abrupt faunal change at the base of the Upper Cretaceous (Imlay, 1961, p. 11–12).

Lithology and stratigraphic position of the Grandstand Formation in this region suggest correlations with both the Tuktu and the Grandstand Formations of the area south of the Colville. Because of similar thickness of the overlying Killik Tongue of the Chandler Formation as shown in figure 95, the Tuktu Formation of the lower Kurupa-Oolamnagavik area seems to be equivalent to the Grandstand of Knifeblade Ridge, or at least to the finer grained lower two-thirds of it. The Grandstand at Umiat and Square Lake also resembles the Tuktu in being fine to very fine grained and virtually free of coal. However, the sandstone in the Knifeblade, Titaluk, and Wolf Creek wells contains coal layers as well as detrital coal that must have come from a nearby source; and the sandstone in all the wells differs from the Tuktu by being almost entirely light gray and very quartzose.

Within the region, the sections of Grandstand at Titaluk, Wolf Creek, and Square Lake correlate fairly well. They are similar in thickness; each comprises a similar sequence of three sandy zones of increasing coarseness upward; and they are also similar in their relation to the local highest occurrences of *Ditrupa* and the *Verneuilinoides borealis* fauna. They are probably synchronous, and they show a progressive northeastward decrease in average grain size and in content of coal beds and coaly detritus. The section of the Grandstand at Knifeblade Ridge is similar to these in thickness and contains the coarsest sandstones and much bedded and detrital coal, whereas the section at Umiat is similar to that at Square Lake in fineness of sand and in general lack of coaly material. Inasmuch as the Knifeblade and Umiat sections are respectively the farthest southwest and the farthest east in the series, they fit the pattern of northeastward decrease in grain size and in amount of coaly rocks shown by the others. The section at Umiat is, however, much thinner than any of the others; and at both Umiat and Knifeblade Ridge the Grandstand is much lower with respect to the highest occurrences of *Ditrupa.*

CHANDLER FORMATION

The nonmarine Chandler Formation was named from the Chandler River where that river crosses the northern foothills. In that area the formation, including some minor marine units, is 4,700 feet thick (Gryc and others, 1951, p. 164).

Two major tongues of the Chandler Formation have been named: the Killik Tongue, discussed immediately below, and the Niakogon Tongue, which in this region has not been differentiated from the Ninuluk Formation, and is discussed with that formation.

KILLIK TONGUE

Name and Type Section

Originally the lower part of the Chandler Formation was named the Hatbox Tongue (Gryc and others, 1951, p. 164). Detterman (1956a, p. 237–239) abandoned that name and renamed the unit the Killik Tongue from the area of much better exposures near the Killik River. The tongue is about 2,800 feet thick in the type locality along the east bank of the Killik River 13 to 16 miles southeast of its confluence with the Colville River. Where possible the tongue is divided into two parts which show some differences in lithology. The lower part, about 1,100 feet thick in the type locality, contains many thick beds of sandstone along with siltstone, silty shale, and numerous thick coal beds. At the type locality the upper part is about 1,700 feet thick; it is characterized by a few massive conglomerate beds but has considerably less sandstone than the lower part, and only thin beds of coal are present.

Distribution

The Killik Tongue of the Chandler Formation is present throughout the Umiat-Maybe Creek region as a subsurface unit, but it is extensively exposed only in the southwestern part of the area on the Knifeblade and Aupuk anticlines. In addition to this extensive area, the tongue comes to the surface at four other localities: (1) on the north flank of Weasel Creek anticline in an area of complex faults, (2) on the west side of the Colville valley just north of Killik Bend, (3) on the west side of the Colville valley at Fossil Creek anticline, and (4) in a small area along Bearpaw Creek on the Umiat anticline. The second locality is the northernmost part of an extensive exposure, the rest of which is just south of the Umiat-Maybe Creek region (Chapman and others, 1964).

Lithology and Thickness

In the southwestern area exposures are generally poor except along the Colville River, where parts of the tongue are well exposed in cutbanks, providing the data presented in section 1 (see strat. sections and pl. 53). Sections 2 and 4 illustrate the scantiness of the data that can be gathered away from the major streams. Knifeblade test well 1, however, provides an excellent section of the lower 1,145 feet of the tongue. The rocks are mostly gradational from shale to siltstone and contain relatively minor amounts of sandstone, coal, and bentonite.

The sandstone is generally fine to very fine grained and silty and argillaceous, but at a few localities there are occurrences of medium- to coarse-grained clean sandstone, as illustrated by unit 2 of section 2 and units 34 and 42 of section 4. These clean sandstones cannot be traced laterally for any distance, and it is doubtful that they are much more than a quarter of a mile wide in an east-west direction. They probably represent stream-channel fillings. Unit 2 of section 2 and unit 42 of section 4 are at practically the same level above the base of the Killik Tongue and may represent what was a continuous sand body prior to folding and erosion.

Coal beds are present, but little information as to their extent and continuity can be gathered. Most of the beds seen in outcrop were 2 feet thick or less; however, in unit 35 of section 4 a 10-foot section of coal and bentonite contains one coal bed at least 3 feet thick.

Cuttings from the Knifeblade wells indicate a considerable number of coal beds, most of which are probably only 1 or 2 feet thick, but 5- and 6-foot beds are indicated near the top of Knifeblade test well 2A, 10- and 5-foot beds near the top of Knifeblade test well 1, and three 5- and 6-foot beds deeper in this well. Because of the difference in specific gravity between coal and other rocks, it is uncertain whether samples of cuttings are an accurate indication of the thickness of coal beds.

Northeastward the Killik Tongue progressively thins. The tongue is 3,400 feet thick at Knifeblade, but it is about 1,600 feet thick at Titaluk and about 1,000 feet at Wolf Creek. The lithology in these places is much the same as in the southwestern area, and there are numerous indications of coal. Farther eastward at Square Lake, where it is 800 to 900 feet thick, at the Colville River on Fossil Creek anticline, where it is about 1,000 feet thick, and at Umiat, where it is about 300 feet thick, the Killik Tongue contains very little coal, probably no beds more than a few inches thick.

At Umiat about the upper 125 feet of the 300-foot Killik Tongue comes to the surface along Bearpaw Creek. Parts of this section are covered, and only about 50 feet is actually exposed, the lowest exposure consists of 30 feet of fine-grained rather friable salt-and-pepper sandstone. Outcrops and bedding traces of the sandstone occur 0.3 to 0.6 mile north of Umiat test well 4. A covered interval of about 40 feet intervenes between this sandstone and a higher 20-foot sandstone which crops out and forms bedding traces 0.1 to 0.4 mile east to northeast of Umiat test well 4. Only the upper 3 feet of this unit, a massive fine-grained calcareous sandstone, is well exposed. Float indicates that the lower half contains interbeds of shale and bentonite.

Paleontology and Correlation

Although the Killik Tongue is almost entirely nonmarine and is generally barren of fossils, it intertongues with the underlying marine rocks and contains a minor proportion of thin marine tongues throughout. In the lower half to lower quarter of the Killik, these thin marine tongues contain a few specimens of pelecypods, *Arctica?* sp., *Thracia* sp., and *Entolium* sp. (Imlay, 1961), and Foraminifera of the *Verneuilinoides borealis* zone (pl. 53; Bergquist, 1958a, 1959a, 1959b). Inasmuch as this faunal zone is also typical of the underlying marine rocks, no faunal boundary can be drawn at the base of the Killik Tongue except in terms of abundance.

Scarce marine beds in the upper part of the Killik on the surface locally contain *Thracia stelcki* McLearn (USGS Mesozoic loc. 12413, Imlay, 1961) and in the wells locally contain *Inoceramus* sp., fish teeth and vertebra, and a few nondiagnostic Foraminifera. Fossils of the *Gaudryina irenensis-Trochammina rutherfordi* faunal zone in ditch samples from the upper 500 feet of the Killik in Titaluk test well 1 (Bergquist, 1959a, p. 417) and a specimen of *Verneuilinoides fischeri* in the core 25 feet below the top of the Killik in Umiat test well 8 (Bergquist, 1958a) are regarded as contamination from the overlying Ninuluk Formation. Imlay (1961) has assigned an Albian (Early Cretaceous) age to the Killik.

The thinning of the Killik Tongue toward the north and east may be due to one of three causes: (1) decrease in rate of deposition, (2) facies change from nonmarine to marine conditions, or (3) an unrecognized unconformity at the base of the overlying Ninuluk Formation. Evidence that would permit rating the relative effectiveness of these factors is lacking. The upward shift of the underlying Grandstand Formation with respect to the parallel tops of the occurrence of *Verneuilinoides borealis* and *Ditrupa* from Knifeblade Ridge to Square Lake suggests (pl. 53) that the Grandstand becomes progressively younger toward the northeast and that the Grandstand at Square Lake is the age equivalent of some part of the Killik Tongue in the southwestern part of the area. However, convergence of the same two faunal zone tops from Square Lake to Umiat also suggests an eastward decrease in rate of deposition.

NINULUK FORMATION AND NIAKOGON TONGUE OF THE CHANDLER FORMATION, UNDIFFERENTIATED

The Ninuluk Formation is the youngest marine formation of the Nanushuk Group. It consists largely of siltstone and shale and contains abundant sandstone and conglomeratic sandstone. It is generally fossiliferous, and the basal beds contain a distinctive fauna that includes *Inoceramus dunveganensis* McLearn. South of the Colville River the Ninuluk lies conformably on both the marine Grandstand Formation and the nonmarine Killik Tongue of the Chandler Formation and intertongues with the nonmarine Niakogon Tongue of the Chandler Formation. In the Umiat-Maybe Creek region it rests on the Killik Tongue and is overlain unconformably by the Seabee Formation. The type section, described by Detterman (1956a, p. 241–244) is at Ninuluk Bluffs on the right bank of the Colville River (69°08′ N., 153°18′ W.). There the formation is 657 feet thick and is intertongued in its middle part with 261 feet of nonmarine rocks of the Niakogon Tongue.

The Niakogon is the upper tongue of the nonmarine Chandler Formation and is in most places separated from the Killik Tongue by an intervening tongue of the Ninuluk Formation. It is distinguished from the Ninuluk by the abundance of coal and bentonite. It was originally named by Gryc, Patton, and Payne (1951, p. 164) for the exposures at Niakogon Buttes near the Chandler River, but Detterman (1956a, p. 240–241) has redefined the tongue from a new type locality on the Killik River 10 miles above its mouth (68°58′ N., 153°33′ W.). The tongue there is about 650 feet thick and overlies 40 feet of the marine Ninuluk Formation.

Although the Ninuluk Formation and the Niakogon Tongue of the Chandler Formation are separately defined and mapped in the area south of the Colville River, they are mapped as a single unit in the Umiat-Maybe Creek region. For convenience, the undifferentiated Ninuluk Formation and Niakogon Tongue of the Chandler Formation will be referred to informally in this report as the Ninuluk-Niakogon unit. Except in the area south of Maybe Creek, no more than 300 feet of the two units is exposed; and, because of poor outcrops, the surface section is known at only a few localities. Coal zones and fossiliferous marine rocks are closely interbedded in most places and have not been traced out in sufficient detail in the field to permit mapping of the individual marine and nonmarine tongues. Moreover, the Ninuluk Formation and the Niakogon Tongue of the Chandler Formation together make a usable map unit in this area. Typically, they both contain abundant sandstone and are thus easily distinguished from the overlying Seabee Formation which, in most places, is largely shale. Because they intertongue, the Ninuluk Formation and the Niakogon Tongue are regarded as time equivalents. The *Inoceramus dunveganensis* fauna, so far as is known, occurs only in the lowest beds of the Ninuluk Formation and, where present, identifies the basal contact of that formation. As these lowest beds everywhere lie below the lowest beds of the Niakogon Tongue, they also serve as the base of both units when mapped together as an undifferentiated unit.

DISTRIBUTION

In the western part of the Umiat-Maybe Creek region, the Ninuluk-Niakogon unit is exposed in a continuous belt from the Colville River northward to the Arctic Coastal Plain. It crops out in the synclines as well as on the anticlines. In the east half of the region, where the structural features are generally lower and the overlying Seabee Formation is thicker, the Ninuluk-Niakogon unit is exposed only on the highest parts of the anticlines and in the deep trench of the Colville River. Over most of its area of outcrop, the unit forms uplands. Together with older formations of the Nanushuk Group, it forms most of the high divide between the Colville River and the headwaters of the Ikpikpuk River. Where exposed over broad areas of gentle dips in these uplands, the sandstone and conglomerate beds of the unit form bold ledges; and, even in areas of fairly steep dips, they form traces in the topography and vegetation that are easily visible on aerial photographs (fig. 96). However, the bedding traces become obscure and discontinuous where they extend into areas of subdued topography and unconsolidated Quaternary deposits in the

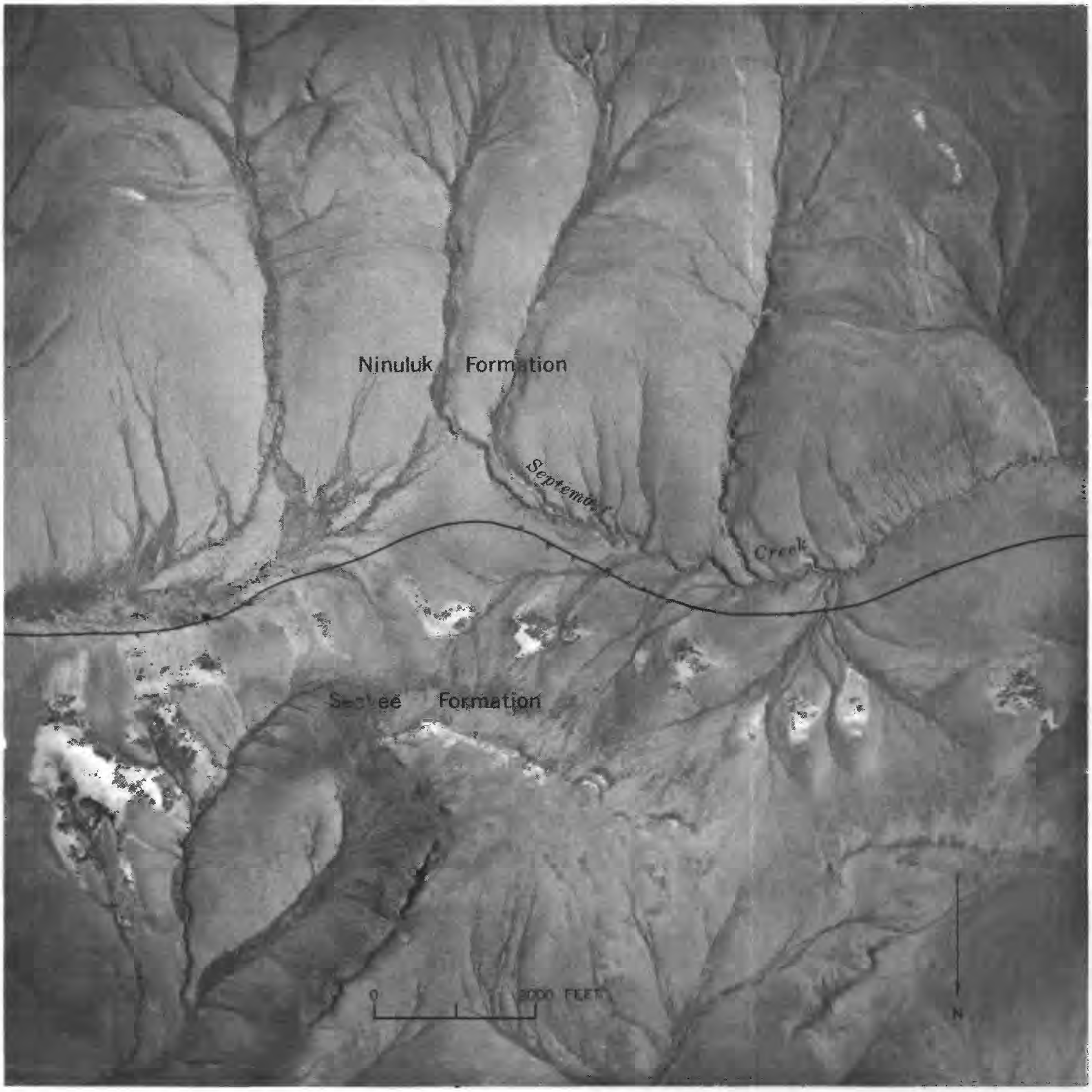

FIGURE 96.—Ninuluk and Seabee Formations at the head of September Creek. Contact is approximately at the creek. White patches in the lower half of the photograph are weathered bentonitic shale of the lower part of the Seabee. Vertical aerial photograph (BAR-69-181) from 10,000-foot altitude by U.S. Navy.

Colville valley, the Ikpikpuk valley, and the Arctic Coastal Plain.

The southernmost outcrops of the Ninuluk-Niakogon units in the Umiat-Maybe Creek region are on the north flank of Killik Bend anticline within Killik Bend. Detterman and Bickel in 1953 identified the base of the Ninuluk Formation in the bluffs of the Colville by the *Inoceramus dunveganensis* fauna (loc. 20, fig. 98). These basal beds can be traced southwestward in the steep bluffs for about 3 miles and there disappear on the west side of Killik Bend, where the ridge spurs are partly covered by terrace gravels.

The basal fossiliferous beds of the Ninuluk Formation also crop out near the axis of Weasel Creek anticline on Weasel Creek and in the fault zone on Maybe Creek. Inasmuch as the beds on Maybe Creek are fairly low on the flank of Weasel Creek anticline, pre-Ninuluk beds are probably exposed along the anticline axis there. Outcrops and bedding traces near the axis are few and obscure, so the inferred base of the Ninuluk Formation has been mapped without any evidence other than the estimated thickness.

Older rocks of the Nanushuk Group are exposed on Knifeblade anticline. In the section of the Nanushuk Group measured by Whittington on the north flank of the anticline between Knifeblade Ridge and September Creek, the *Inoceramus dunveganensis* fauna was not found at the base of the Ninuluk, but the Ninuluk Formation was distinguished from the underlying rocks on the basis of lithology. The contact with the underlying Killik Tongue can easily be traced on aerial photographs to the axial fault zone of the anticline. South of the fault zone, in an area of poor exposures and little field control, the location of the contact has been inferred from the estimated thickness of the Ninuluk-Niakogon unit. The location chosen for the contact is based on the interpretation from aerial photographs that several hundred feet of uppermost Ninuluk beds on the south flank of Knifeblade anticline pinch out beneath the shales of the overlying Seabee Formation near long 154° W. If this interpretation is incorrect, the inferred contact is too low and the Killik Tongue is exposed farther east along the axis than is now shown. The contact with the overlying Seabee Formation was mapped in the field by Whittington at September Creek. Elsewhere in the area south of Maybe Creek it was mapped from aerial photographs with the help of Ray and Fischer's field notes.

North of Lupine syncline and west of the Ikpikpuk River, the Ninuluk-Niakogon unit is little known, but its location has been inferred by photointerpretation. On aerial photographs beds of sandstone in the lower part of the Ninuluk-Niakogon unit may be traced northward from Knifeblade anticline across Lupine syncline and the Kigalik River into the hills west of the Ikpikpuk. The contact with the overlying Seabee Formation, however, is covered. North of the Kigalik River outcrops are sparse and bedding traces are discontinuous except in the cutbanks of the Ikpikpuk. E. J. Webber (written commun., 1948) reported the Ninuluk Formation in cutbanks all along the Ikpikpuk River from its head to the north edge of the mapped area. Isolated outcrops of the Ninuluk Formation occur as far north as lat 69°27′ N. in the hills just west of the mapped area. However, microfossils found in soil samples taken by Whittington indicate that the Seabee Formation also is present on the hilltops just west of the Ikpikpuk. For lack of outcrops the boundary between the Ninuluk-Niakogon unit and the Seabee Formation west of the Ikpikpuk must be inferred.

East of the Ikpikpuk River the Ninuluk Formation crops out extensively from Maybe Creek to the Arctic Coastal Plain. On Titaluk anticline a doubly plunging structural high lies just east of the Ikpikpuk, and sandstones of the upper part of the Ninuluk-Niakogon unit form most of the upland surface. Two of these sandstones are mapped individually; they are shown on the geologic map as sandstone 1 and 2. The contact of the Ninuluk-Niakogon unit with the Seabee Formation coincides with the base of a higher sandstone bed (sandstone 3). This sandstone bed has been mapped only along and south of the anticline axis. Because the Arctic Coastal Plain lies only 2 to 4 miles north of the axis and outcrops and bedding traces are poor along its margin, in most of the area north of the axis the location of the contact with the Seabee Formation can only be inferred.

Although the Gubik Formation (Pleistocene) covers much of the Arctic Coastal Plain, the aerial photographs show that in the area between the Ikpikpuk River and Wolf Creek older and more steeply dipping beds are present beneath the Gubik Formation in streamcuts and are also exposed above the level of the Gubik on the highest parts of the hills. No fieldwork has been done to identify these pre-Gubik beds except along the Ikpikpuk River, where the Ninuluk Formation is exposed below the Gubik in the cutbanks. Because the beds in the cutbanks dip 3° or less, their stratigraphic position gives a clue to the stratigraphic position of the higher beds exposed on the hilltops. The cutbank exposures cannot be correlated precisely, but where the Ikpikpuk crosses Billy syncline the beds at water level appear to be only about 150 feet below the top of the Ninuluk-Niakogon unit and the Seabee Formation must therefore be present on the higher ground above the cutbanks. At Wolf Creek anticline, the beds at water level are about 400 feet below the top of the Ninuluk-Niakogon unit. The topographic relief is probably less than 400 feet; along the anticline, therefore, the Ninuluk-Niakogon unit probably crops out in the hills as well as on the river. The seismic evidence bears this out; a single seismic line from Titaluk anticline north to Wolf Creek anticline about 8 miles east of the Ikpikpuk shows that the upper seismic horizons are as high in elevation at Wolf Creek anticline as they are at the outcrops of the Ninuluk-Niakogon unit on the Titaluk anticline. Thus, both the Ninuluk-Niakogon unit and the Seabee Formation probably are exposed in the Arctic Coastal Plain west of Wolf Creek. As the contact between them cannot be mapped, they have not been differentiated.

Near the eastern end of Wolf Creek anticline, the Ninuluk-Niakogon unit does crop out where each of the two forks of upper Wolf Creek cuts across the anticline axis. On the western fork of the creek, Wolf Creek test wells 1 and 3 were drilled just south of the anticline axis within the area of Ninuluk-Niakogon outcrop; Wolf Creek test well 2 was drilled about 1½ miles to the north within the Seabee Formation and penetrated the contact with the Ninuluk-Niakogon at a depth of 130 feet. Correlation of the well logs shows that well 1 started 80 feet below the contact and that well 3 started 30 feet below the contact. This correlation places the contact approximately at the top of a sandstone bed that is close above wells 1 and 3 in the valley wall and has been traced around the axis on aerial photographs. On the eastern fork of Wolf Creek, sandstones and coaly shales that contain a megafauna and microfauna typical of the Ninuluk Formation crop out at the axis. These beds can be correlated with the Ninuluk-Niakogon unit at the wells by their relation to a thick sandstone bed (sandstone unit A on geologic map, pl. 52) 225 feet above the base of the Seabee Formation that crops out above all three wells on the west fork and can be traced from there to the east fork. At the south edge of the Ninuluk-Niakogon unit the beds dip steeply and have apparently been faulted up against the shales of the Seabee Formation.

The Ninuluk-Niakogon unit is also exposed in two separate areas on Fossil Creek anticline. One of these is on the doubly plunging high at the west end of the anticline where the basal sandstones bearing *Inoceramus dunveganensis* crop out at the axis (R. L. Detterman and R. S. Bickel, written commun.) and are overlain by about 150 feet of shale that supports a conspicuous bedding trace and has been assigned to the Ninuluk-Niakogon unit. A long covered interval above this shale is taken to represent the Seabee Formation. The next exposures of the Ninuluk-Niakogon unit on the anticline are in the bluffs of the Colville River. The fossiliferous basal beds are exposed about 6 miles southwest of the axis. About 4 miles northeast of the axis the complete thickness of the Ninuluk-Niakogon unit, overlain by the Seabee Formation, is exposed in a single cutbank. Detterman and Bickel collected *Inoceramus dunveganensis* from beds at the base of the Ninuluk Formation at both localities. The Ninuluk cannot be traced inland from the cutbanks because of the cover of high-terrace gravel, and small areas on the divide between the Colville River and Prince Creek that are apparently not gravel covered have been left unmapped because they lack outcrops and the location of contacts cannot be inferred.

In the area long the Colville between the outcrops of the Ninuluk-Niakogn unit on the southwest flank of Fossil Creek anticline and those at Killik Bend, the only outcrops in the river bluffs themselves are those of the Ninuluk Formation in cutbanks just north of Ninuluk Creek syncline (lat 69°09′ N., long 153°23′ W.). However, the Seabee Formation is known to occur on the hilltops above the river at Ninuluk Creek syncline and may also be present in some of the bluffs. Where outcrops are lacking in the bluffs, therefore, the Ninuluk-Niakogon unit and Seabee Formation is undifferentiated on the map.

At Umiat the Ninuluk Formation is exposed in two areas on the anticline axis between Umiat Mountain and the east fork of Seabee Creek. It crops out mostly in the lower walls of the streamcuts, and in part of the area it is covered by alluvium of the Colville River. In the original mapping at Umiat each of the outcropping sandstone beds of the Ninuluk Formation was mapped, but these beds were included in the Seabee Formation. Since then the Ninuluk has been identified in almost all the wells. It occurs immediately beneath the alluvium in Umiat test wells 2, 4, and 5. The older Killik Tongue of the Chandler Formation occurs at the top of Umiat test well 3; the other wells begin in younger formations of the Colville Group and penetrate the Ninuluk at depth. The contacts of the Ninuluk have been picked in these wells and have been projected to the surface section. They are mapped from the original mapping of the individual sandstone beds supplemented by aerial photographs.

THICKNESS

The full section and thickness of the Ninuluk-Niakogon unit is known from the Umiat, Square Lake, Wolf Creek, and Titaluk test wells and from the surface exposures at Knifeblade, Weasel Creek, Fossil Creek, and Umiat anticlines. The approximate thickness of the Ninuluk-Niakogon unit is known at the head of Prince Creek and at Killik Bend.

The combined thickness of the undifferentiated Ninuluk Formation and the Niakogon Tongue of the Chandler Formation is shown on figure 98. Thicknesses south of the Colville River are those of Detterman, Bickel, and Gryc (1963). The thickness ranges from a maximum of 920 feet just south of Weasel Creek anticline to a minimum of about 95 feet in the Umiat wells. The unit may be only 75 feet thick in the Square Lake well, but the lower contact there is indefinite and fossil evidence suggests that the top of the unit may be 75 feet above the top shown in the well log. The isopachous lines trend southeastward, showing the unit thinning eastward to a minimum along a line running south through Umiat. Another line of local minimum thickness trends westward along Prince Creek and Maybe Creek. These changes in the thickness of the Ninuluk-Niakogon unit are similar in trend to those of the underlying rocks of the Nanushuk Group, but are generally inverse to the changes in thickness of the overlying Seabee Formation (fig. 100). Whereas the Ninuluk-Niakogon unit and the other rock units of the Nanushuk Group thin to the northeast, the Seabee Formation thickens in that direction.

LITHOLOGY IN THE UMIAT AREA

On the Umiat anticline the Ninuluk-Niakogon unit consists mainly of a 90-foot sandstone unit. Strictly interpreted, the unit should include the shaly beds for perhaps 10 feet above and 30 to 50 feet below the sandstone, but because of uncertainties as to their proper location and as a matter of convenience, the contacts shown on the map and sections (pl. 56) have been placed, as nearly as possible, on the top and bottom of the sandstone. In three of the Umiat wells microfossils serve to identify this sandstone (and associated shale) with the Ninuluk Formation. In other occurrences in wells and outcrops, identification is based on lithologic character and, in most instances, on stratigraphic position.

As described by Collins (1958a) from test wells 1, 6, 7, 8, and 9, the sandstone is medium light gray, fine to very fine grained, silty to argillaceous, and is composed of quartz and dark rock fragments. In incomplete exposures near Bearpaw Creek, the upper 8 feet is fine-grained calcareous thin-bedded to massive sandstone; the lower part includes massive medium-grained salt-and-pepper sandstone. The amount of interbedded clay shale and siltstone ranges from minor partings to about two-thirds of the interval.

LITHOLOGY IN THE MAYBE CREEK AREA

The Ninuluk-Niakogon unit in the Maybe Creek area is shown in sections 5, 7, 8, 9, and 11 on plate 54, and described under "Stratigraphic sections." Sandstone generally constitutes 25 to 35 percent of the unit but makes up 50 percent in the very thin section (200 ft.) at Fossil Creek anticline on the Colville River. The rest is largely gray shale and gray to green siltstone containing scattered ironstone nodules. Limestone beds and lenses are scarce. Coal, representing the Niakogon Tongue, occurs in all sections, and ranges in total thickness from 2 feet at Fossil Creek anticline to 27 feet at Titaluk test well 1. It ranges in grade from lignite to a soft coal having dull to subvitreous luster and shaly to blocky fracture. It is widely disseminated as thin lenses and partings in the shales and also occurs in thick beds in the upper part of the section. The thickest single bed is a 4½-foot bed in the coal zone cored about 275 feet below the top of the Ninuluk-Niakogon unit in Titaluk test well 1. Coal from this zone contains amber both in the well and in nearby outcrops on Kay Creek. Bentonite in beds as thick as 10 feet generally occurs with the coal in the upper part of the section.

The sandstone of the Ninuluk-Niakogon unit is light gray and salt-and-pepper to tan, red, and green, and is composed largely of quartz and chert grains. Rock fragments and reworked coal grains occur in some of the sandstone logged in the wells. The heavy minerals of the sandstone are marked, according to R. H. Morris (p. 602), by the lowest stratigraphic occurrence of glaucophane in the Maybe Creek area. The sand is generally cemented by calcite, siderite, or limonite, but friable sand occurs 230 to 320 feet below the top of the unit in the Wolf Creek wells and unconsolidated sand occurs about 300 to 400 feet below the top of the unit on the Ikpikpuk. In most sections the most massive sandstone units are 30 to 75 feet thick and are near the top of the unit. The sand is mostly fine to medium grained, and in each section the fine-grained sand is the most abundant. Coarse-grained sand occurs only in the Fossil Creek anticline section and locally at Weasel Creek, where fine-grained sandstone grades laterally into coarse. However, much of the fine-grained sand is locally conglomeratic, the amount of conglomeratic material ranging from scattered isolated pebbles to lenses of compact conglomerate containing only interstitial sand matrix. In each section the sand near the base of the unit is all fine grained, and the amount of medium- and coarse-grained sand increases upward.

Environment of Deposition in the Maybe Creek Area

Most of the sandstone beds are fossiliferous. Those in the outcrops contain marine pelecypods; those in the wells contain marine microfossils and *Inoceramus* prisms. Except at Weasel Creek, where pelecypods are not found in the upper 400 feet, the marine megafossils occur in the lower part and to within 150 feet of the top of the unit. In addition to the marine fossils, one collection on the Ikpikpuk River from a sandstone bed about 400 feet below the top of the unit includes the fresh-water pelecypod *Elliptio sulfuriensis* McLearn (R. W. Imlay, written commn. 1955).

Distinguishing any but very thin nonmarine beds of the Niakogon Tongue of the Chandler Formation is difficult even in the measured sections and wells. The coal beds are certainly nonmarine deposits, and the unfossiliferous sandstones that are interbedded with the coal and that locally contain plant fossils may also be nonmarine. In some places, however, coal, plants, and marine fossils occur side by side. The uppermost fossiliferous sandstone at Weasel Creek contains plants as well as marine fossils, and the lignite bed on the Ikpikpuk lies directly on marine fossiliferous sandstone. *Elliptio sulfuriensis* suggests that one sandstone bed is a fresh-water deposit, but the same 20-foot thick unit also contains marine pelecypods. In the wells, where microfossil samples from the complete section are available, shales and sandstones both above and below the coals, and even some that are interbedded with the coals, contain arenaceous marine Foraminifera. These are tolerant arenaceous forms but are nevertheless marine. They occur to the top of the formation, even in the thin zone that is barren of *Inoceramus* prisms.

Of *Elliptio sulfuriensis*, Ralph W. Imlay said (written commun., 1955): "Its presence indicates the presence of fresh-water beds in the Ninuluk. The occurrence of *Mytilus* in several lots indicates littoral deposits. Apparently most of the Ninuluk Formation on the outcrop was deposited only slightly below low tide and some of it was littoral or even continental." In such an environment slight changes in relative sea level could bring about rapid shifts from fresh- or brackish-water swamp and delta deposits to marine beach and bar deposits.

At times during the deposition of the Ninuluk the present anticlines may have been high enough above wave base to affect the distribution and texture of the sandstones. At Weasel Creek a slightly conglomeratic sandstone (unit 9, strat. section 9) is green to tan and fine to medium grained on the south flank of the anticline and becomes tan and coarse grained near the axis. At Titaluk anticline, sandstone 1, the lower of two sandstones in the Ninuluk-Niakogon unit that have been mapped in detail, is localized along the axis. Figures 97*A* and *B* show its thickness and lithology. This sandstone occurs at a depth of 145 to 210 feet in Titaluk test well 1 as well as in the outcrop. It is about 60 feet thick and consists of two parts separated by a thin shale. Both parts consists of gray to yellow and salt-and-pepper fine- to medium-grained sandstone that weathers gray to rusty brown, and both parts contain lenses of chert-, quartz-, and quartzite-pebble conglomerate. Much of the sandstone in the outcrop is without cement and is friable and porous, and in some places the lower part weathers to loose sand. Effective porosities of five samples average 17½ percent, but in the unweathered samples from the well, and locally in the outcrop, the sands are cemented by calcite and probably siderite. The entire interval occupied by sandstone 1 contains microfossils in the well, and at one outcrop the upper part includes at its top a 7-foot bed of red fine-grained very calcareous platy sandstone that carries *Panope?* sp. Sandstone 1 crops out only near the apex of Titaluk anticline and is well exposed there. Both the upper and the lower parts of the sandstone appear to be lenticular. The trace of the lower unit disappears along the creek north of the axis and along Kay Creek to the south. A 10-foot-thick sandstone, which is probably the lower unit of sandstone 1, is present on the Ikpikpuk River; its eastern limit is not known. It is absent over an area of about 1½ square miles immediately at the high point of the anticline but is present all around that area. Thickness of this unit ranges from 7 feet on the southern margin and 13 feet on the northern margin to a maximum of 35 feet in a belt that lies ½ to 1 mile south of and parallel to the anticline axis. The upper unit of sandstone 1 is limited to a much smaller area at the head of Kay Creek but is present at the crest of the anticline where the lower part is absent. It is thickest in a belt about half a mile south of and parallel to the anticline axis. Over most of the area it consists of both fine- and medium-grained sandstones but at the axis is entirely medium grained. The distribution, porosity, and fossil content of these sandstones indicate they were marine bar deposits on a submerged linear high approximately coincident with the area of closed contours on the Titaluk anticline (pl. 52).

The next higher sandstone at Titaluk, mapped as sandstone 2, seems not to have been affected by the structure. Figure 97*C* shows its thickness and lithology.

Sandstone 2 is the uppermost unit of the Ninuluk Niakogon unit and is found through an interval of about 60 feet. It consists of three zones of sandstone of which the upper two are exposed at only one locality in the area of greatest thickness. Both upper zones are yellow to gray medium-grained sandstone, the upper one is massive and noncalcareous, the lower one, platy and calcareous. The lowest zone of sandstone is gray to yellow, fine grained, and locally weathers rusty brown. Near its southern extremity sandstone 2 contains plant leaves. It crops out all along the west side of Kay Creek but extends no more than 1½ miles up the eastern tributaries. It is absent in Titaluk test well 1, where equivalent beds are shale, siltstone, and coal containing only traces of sandstone. South of Kay Creek two thin bedding traces separated by a 40-foot covered interval occupy the position of sandstone 2. Elsewhere the unit ranges in thickness

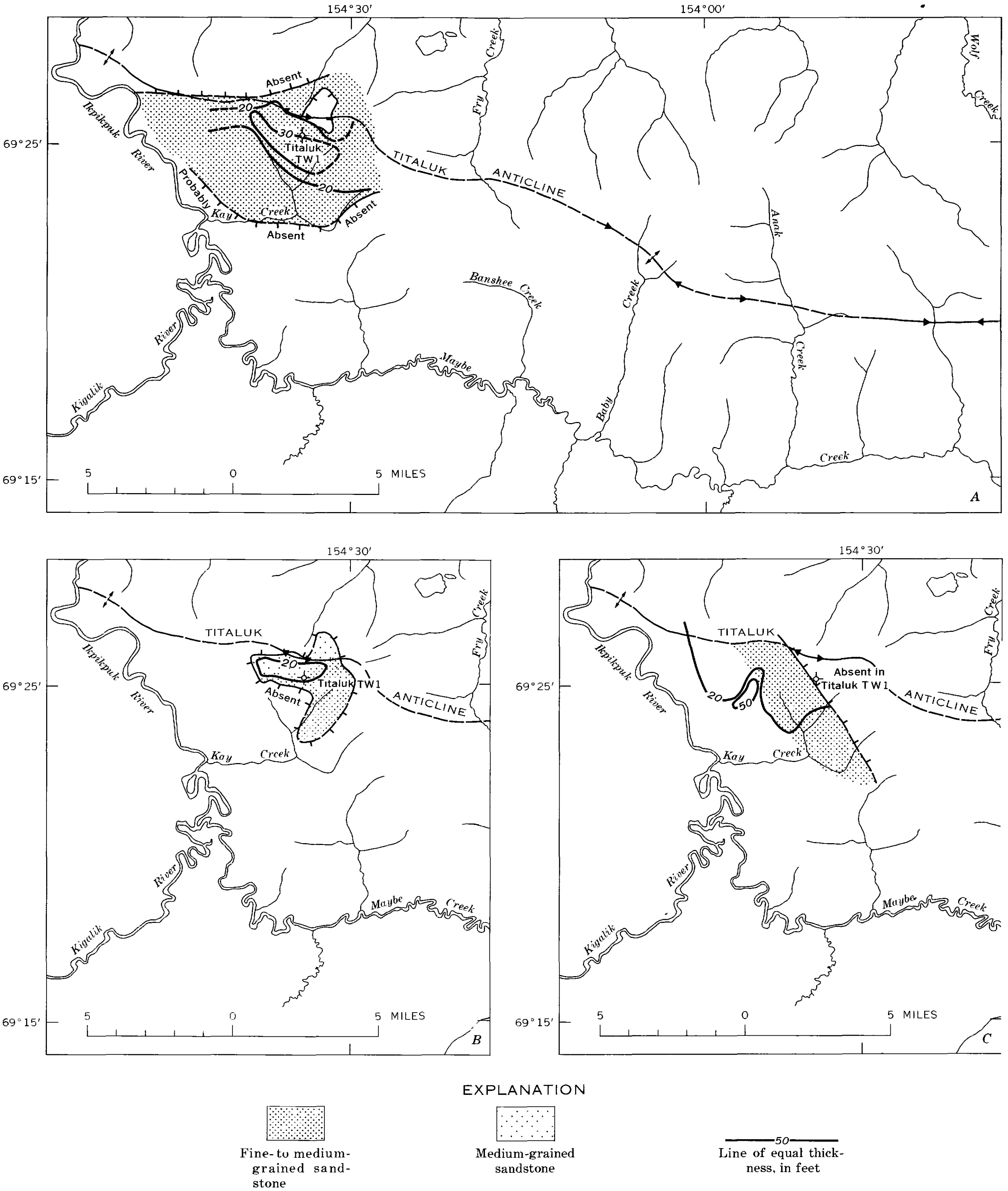

FIGURE 97.—Grain size and thickness of sandstones 1 and 2 of the Ninuluk Formation and the Niakogon Tongue of the Chandler Formation, undifferentiated, in the Maybe Creek area. Grain size data are incomplete. *A*, Lower unit of sandstone 1 about 160 feet below the top of the Ninuluk-Niakogon unit. *B*, Upper unit of sandstone 1 about 130 feet below the top of the Ninuluk-Niakogon unit. *C*, Sandstone 2 at the top of the Ninuluk-Niakogon unit.

from 6 to 57 feet. The greatest thickness is about 1 mile west of Kay Creek and 2 miles south of the anticline axis. The isopachous lines and the eastern limit of the sandstone trend northwestward parallel to the Ikpikpuk River and across the trend of the anticline, and the unit thins and shales out toward the high point of the anticline, indicating that the structure did not control the deposition of this sandstone as it did sandstone 1. Plant material shows the sands were deposited near shore. The northwest trend of deposition is parallel to that of sandstone 4, a near-shore sand in the lower part of the overlying Seabee Formation (fig. 106) and probably shows the major trend of the shoreline.

CORRELATION

Direct bed-for-bed correlation between surface sections of the Ninuluk-Niakogon unit can be made only between Weasel Creek and Knifeblade Ridge, where the topmost sandstone beds have been traced on aerial photographs. The *Inoceramus dunveganensis* beds at the base of the sections at Weasel Creek, Killik Bend, and two localities on Fossil Creek anticline can also be broadly correlated by their fauna. Except for these, no horizons within the Ninuluk-Niakogon unit have been correlated between localities.

The location of the basal contact of the marine Ninuluk Formation in the wells is based on different types of evidence than the location in the outcrops. Although the base of the Ninuluk in both the wells and the outcrops is chosen where the sandy partly marine, fossiliferous section gives way downward to a less sandy section in which coal is very abundant, the *Inoceramus dunveganensis* fauna which marks the base of the marine section in the outcrops cannot be identified in the well cuttings. The contact in the wells is determined instead from microfossils. In the wells, as well as in the outcrops, the Ninuluk is characterized, according to Bergquist (1958a, p. 199; 1959b, p. 479), by a microfaunal assemblage dominated by *Gaudryina irenensis* Stelck and Wall and *Trochammina ribstonensis* subsp. *rutherfordi* Stelck and Wall. The underlying Killik Tongue of the Chandler Formation contains the same microfossils but very few in number. Thus in the wells the basal contact is picked at the base of the abundant *Gaudryina-Trochammina* fauna, whereas in the outcrops it is picked at the base of the *Inoceramus dunveganensis* fauna wherever found.

An unconformity at the top of the Ninuluk-Niakogon may account for the changes in its thickness. However, evidence of the unconformity in the Umiat-Maybe Creek region is so slight that it is more likely that the changes in thickness are largely due to original variations in deposition. An angular unconformity between the Ninuluk-Niakogon unit and the overlying Seabee Formation is exposed at several places south of the Colville. The exposure farthest north and nearest to the Umiat-Maybe Creek region is on the south bank of the Colville just north of Ninuluk Creek syncline (Detterman and others, 1963). There the discordance is greater than 30°. In the Umiat-Maybe Creek region, however, no angular discordance has been noted in the outcrops, and the only indications of local relief at the contact are at Weasel Creek. At Weasel Creek anticline the uppermost sandstone bed of the Ninuluk-Niakogon unit has been identified both on the north flank in Lupine syncline and on the south flank in Ninuluk Creek syncline. A zone of white-weathering bentonitic shale in the basal part of the Seabee has also been identified on aerial photographs in both synclines. The bentonitic shale is only 40 feet above the sandstone in Lupine syncline but is 215 feet above the sandstone in Ninuluk Creek syncline on upper Weasel Creek. The additional 175 feet of section there has been arbitrarily assigned to the Ninuluk-Niakogon unit. It is a covered interval, probably occupied by shale, and has not been studied in the field. Whichever formation it is assigned to, however, its absence on the north flank of the anticline indicates a hiatus there between the deposition of the uppermost sandstone bed of the Ninuluk-Niakogon unit and the overlying bentonitic shale beds of the Seabee Formation. In addition to the probable truncation of this shale zone, photointerpretation indicates that the uppermost sandstone bed itself is cut out west of Weasel Creek. This bed cannot be traced across the ridge west of Weasel Creek, even though the sandstone beds below it and the bentonitic beds above it make conspicuous and continuous traces. The same, or a correlative, sandstone bed is present at a creek 6 miles west of Weasel Creek. This topmost sandstone bed is thus apparently absent over an area of about 20 square miles extending west of Weasel Creek and south to Knifeblade Ridge.

Photointerpretation also indicates that an additional 300 to 500 feet of beds may occur above this sandstone and below the base of the Seabee Formation on the south flank of Knifeblade anticline. These beds seem to pinch out by progressive overlap northeastward on the anticline near long 154°00′ W. This interpretation has been used in the mapping, but the evidence is not good enough to eliminate the possibility that these beds are truncated by unmapped faults. The pebble conglomerate bed logged as the base of the Seabee in Square Lake test well 1 may indicate an unconformity. However, recent discovery of *Artica* sp. in a core 61 feet above the conglomerate suggests that the top of the Ninuluk may actually be 75 feet above the conglomerate bed, inasmuch as these specimens of *Arctica* resemble those found in the Ninuluk more than those in the Seabee.

The only indication of unconformity in the Umiat-Maybe Creek region, other than these, is the northeastward thinning of the whole Ninuluk-Niakogon unit. To a small extent the opposing thickening of the overlying Seabee Formation tends to compensate for this thinning, as though the Seabee had filled in and leveled off a surface of relief on the Ninuluk-Niakogon unit. The reduction in relief, however, would have been slight. In this area the variation in thickness of the Seabee is as much as 1,085 feet and of the Ninuluk-Niakogon, as much as 845 feet, but variation of their combined thicknesses is 755 feet, almost as much as the original variation of the Ninuluk-Niakogon unit. As the Grandstand Formation thins about 900 feet and the Chandler Formation about 4,000 feet in the same northeastward direction and through the same area as the Ninuluk-Niakogon unit thins, it is likely that most of the Ninuluk-Niakogon thinning in this area results from a regional arching that was continuous throughout the deposition of the Nanushuk Group, rather than from an unconformity at the top of the group. However, the opposed thickening of the Seabee Formation may well indicate a shift of the sedimentary basin between the deposition of the Nanushuk and the Colville Groups and so would indicate regional uplift or warping in the area. Significantly, the only local evidence for unconformity in the Maybe Creek area is at about the same latitude and on the same structural trend as the northernmost evidence found by Detterman on the other side of the Colville. Probably the intensity of the indicated uplift died out northward of this latitude.

PALEONTOLOGY AND AGE

The marine Ninuluk Formation and the nonmarine Niakogon Tongue of the Chandler Formation interfinger and are equivalent in age. In both wells and outcrops the Ninuluk has a distinctive microfauna, including *Gaudryina irenensis* Stelck and Wall and *Trochammina ribstonensis* subsp. *rutherfordi* Stelck and Wall (originally designated *Gaudryina canadensis–Trochammina rutherfordi* faunal zone by Bergquist (1958a, p. 199) and Tappan (1960, p. 284); this fauna also appears in the coal-bearing rocks that are assignable to the Niakogon. The lower part of the Ninuluk contains *Inoceramus dunveganensis* McLearn, and both *Arctica?* sp. and *Panope?* sp. occur throughout the formation. No megafossils are known from the Niakogon except the fresh-water clam *Elliptio sulfuriensis*. Localities at which megafossils and microfossils have been collected from outcrops of the Ninuluk-Niakogon unit in the Umiat-Maybe Creek region are shown in figure 98, and the stratigraphic positions of the collections are shown in figure 99. Table 2 lists the fauna. D. L. Jones and R. W. Imlay identified the pelecypods, except for the collection from USGS locality 12413, which was identified by W. R. Smith and reported by Smith and Mertie (1930, p. 231). H. R. Bergquist identified the microfossils.

R. W. Imlay assigned most of the Inocerami from the Ninuluk Formation in the Umiat-Maybe Creek region to the species *Inoceramus athabaskensis* McLearn. However, D. L. Jones has shown that *I. athabaskensis* is a junior synonym of *I. dunveganensis* McLearn, and he has identified specimens from USGS Mesozoic localities 20418, 20419, 24630, 25155, and M1264 as *I. dunveganensis* (Jones and Gryc, 1960, p. 156, 157, 159, 160, and D. L. Jones, oral commun., 1961). Inocerami from two localities (24631 and 25150), identified by Imlay as *Inoceramus* cf. *I. athabaskensis* and *Inoceramus* cf. *I. dunveganensis*, have not been reexamined but would probably be included with the others as *I. dunveganensis*.

According to Jones and Gryc (1960, p. 152) *Inoceramus dunveganensis* is found in rocks of late Albian to late Cenomanian age. They conclude that the Ninuluk Formation is probably nearly equivalent to the Belle Fourche Shale of the western interior of the United States and the Dunvegan Formation of British Columbia, both considered to be of late Cretaceous age.

Earlier, Imlay and Reeside (1954, p. 238, 243) also correlated with the Cenomanian the basal Ninuluk beds that contain *Inoceramus dunveganensis*. *I. dunveganensis* occurs in the Dunvegan Formation of northeastern British Columbia and northwestern Alberta along with fragments of the ammonite *Dunveganoceras*, accepted as being of Cenomanian age. In the Athabaska River valley, *I. athabaskensis* occurs in the lower part of the LaBiche Formation together with "*Acanthoceras*" sp. (McLearn and Kindle, 1950, p. 99). This ammonite, of a genus near *Acanthoceras*, was reported by McLearn to be of "early Turonian–Upper Cenomanian (lowest Upper Cretaceous) age" (Wickenden, 1949, p. 10).

COLVILLE GROUP

The uppermost rocks of the Colville Group were originally defined by Schrader (1902, p. 248) as the Colville "Series" from their exposures along the Colville River below the mouth of the Anaktuvuk. On the basis of a fossil collection that apparently came

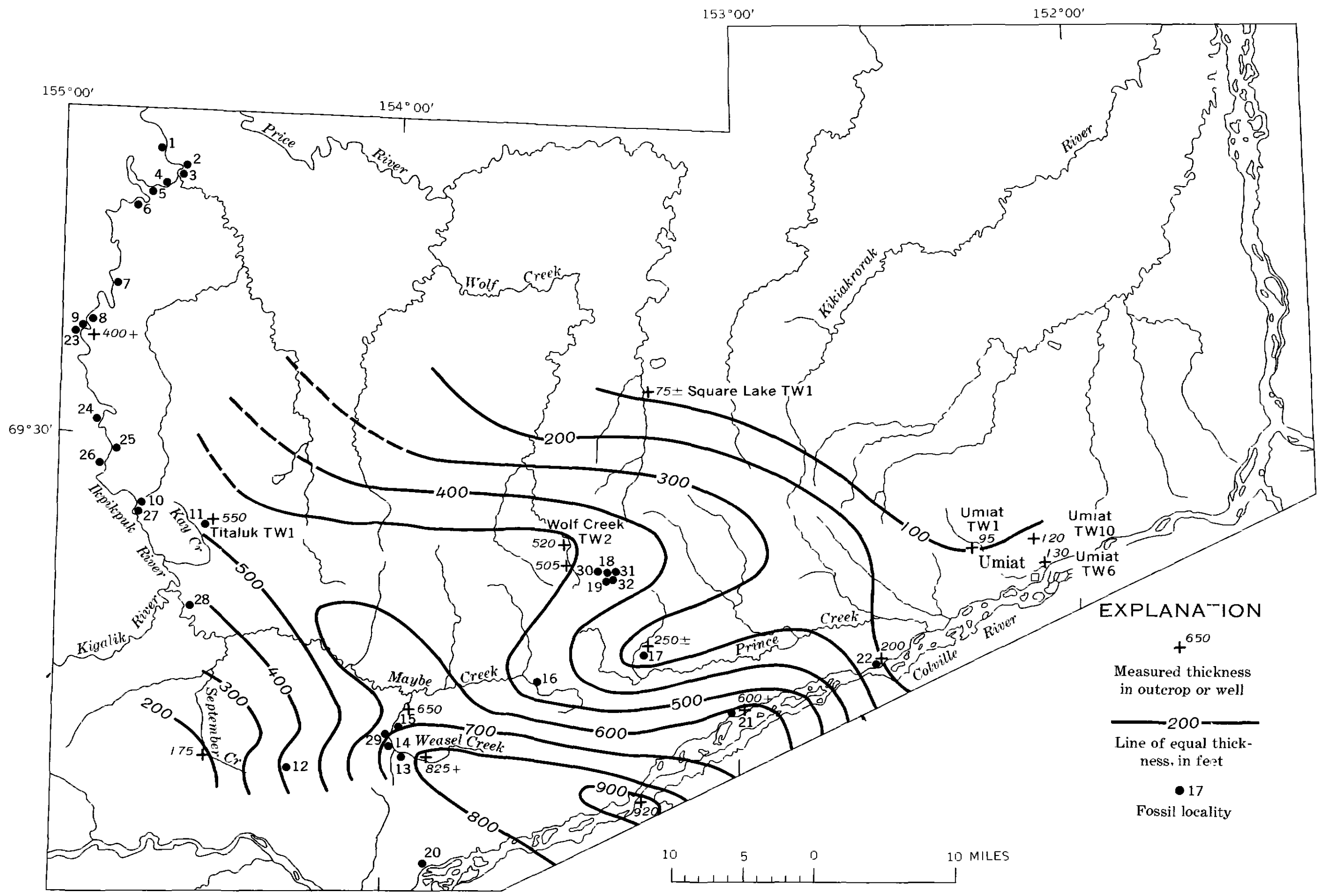

FIGURE 98.—Thickness and fossil localities of the Ninuluk Formation and the Niakogon Tongue of the Chandler Formation, undifferentiated (see fig. 99).

from the overlying Gubik Formation, Schrader mistakenly identified the age of the Colville "Series" as Tertiary. This age assignment was changed to Late Cretaceous by Smith and Mertie (1930, p. 232), who traversed the Ikpikpuk River and discovered only Upper Cretaceous rocks on line of strike with those of the Colville "Series." In 1951, in light of detailed studies in the Colville basin, Gryc, Patton, and Payne (1951, p. 164) redefined the Colville "Series" as the Colville Group and extended the group so that it includes not only the rocks of the original "series" but also the 3,000-odd feet of Upper Cretaceous rocks that lie between them and the underlying Nanushuk Group along the Colville River between Prince Creek and the Anaktuvuk.

The Colville Group can be distinguished from the Nanushuk Group because the Colville contains an abundance of volcanic detritus and associated fresh feldspar and brown biotite, poorly consolidated sediments in its upper part, and distinctive mollusks and microfaunas. In addition, the Seabee Formation, an easily identified basal unit of dark-gray bentonitic fossiliferous shale, is found wherever the Colville Group has been mapped.

The Colville Group is about 5,550 feet thick in the Umiat area. It comprises three formations—the Seabee and the Schrader Bluff, both marine, and the Prince Creek, nonmarine. The facies classification is that of Payne (Payne and others, 1951, sheet 1, fig. 5), who grouped the various gradations between fresh-water deposits and marine deposits below wave base under the two extremes, nonmarine and marine. Payne's nonmarine facies includes continental channel and flood-plain deposits of the inland facies and barred-basin, marsh, and lagoon deposits of the coastal facies. His marine facies include beach, bar, and nearshore deposits of the inshore facies and deeper water deposits of the offshore facies. The rocks of the Prince Creek Formation are probably partly of the nonmarine coastal facies and partly of the marine inshore facies but are classed as nonmarine because of the predominance of the coastal facies.

The end-member concept of two formations, one entirely marine and the other entirely nonmarine, has not been followed strictly in the mapping, for the amount of fieldwork and the number of outcrops do

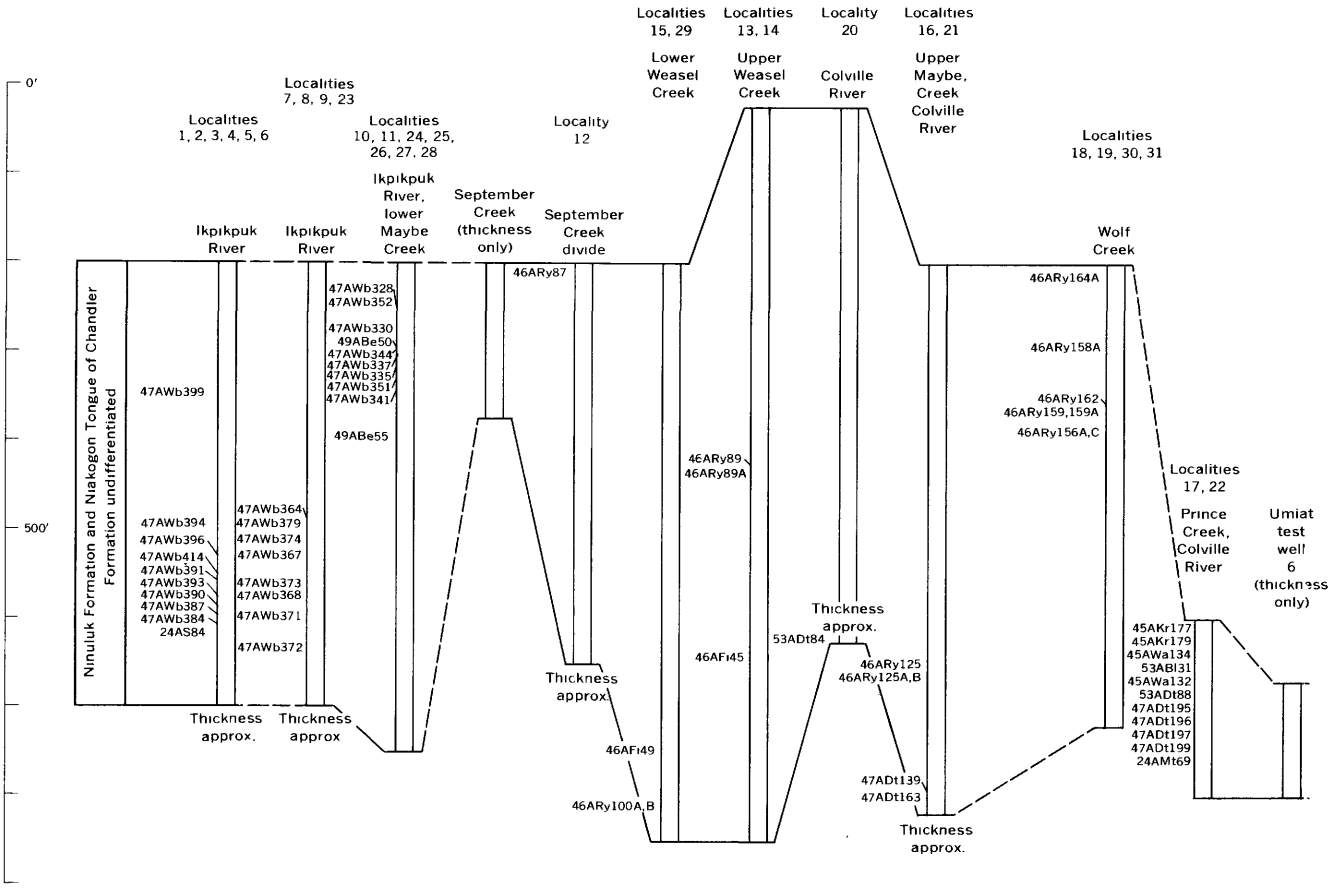

FIGURE 99.—Stratigraphic position of fossils collected from the Ninuluk Formation and the Niakogon Tongue of the Chandler Formation, undifferentiated. Fossil identifications are given in table 1.

not permit continuous tracing of facies boundaries or of minor tongues. The formations have been mapped in the field on the basis of gross lithology. The formation boundaries have been extended between the areas mapped in the field by following bedding traces on aerial photographs. These traces tend to follow somewhat constant horizons rather than to vary with the changing stratigraphic position of the marine-nonmarine boundaries, so units that are defined as rock units are locally mapped as time-rock units.

SEABEE FORMATION

NAME AND TYPE SECTION

The Seabee was originally defined as a member of the Schrader Bluff Formation (Gryc and others, 1951, p. 166), and was later redefined as the Seabee Formation to include all the dominantly marine strata of the Colville Group that underlie the Tuluvak Tongue of the Prince Creek Formation (Whittington, 1956, p. 246–247). The Seabee Formation was named for Seabee Creek. The type locality is in Umiat test well 11 between depths of 545 and 2,040 feet. More recently, the type locality has been described in greater detail by Collins (1958a, p. 183–187, pl. 12).

Detterman (1956b) named and described the Ayiyak Member of the Seabee Formation in the area south of the Colville River. The member was named for the Ayiyak River, and the type section is on the east fork of the Tuluga River about 10 miles east of the confluence of the Chandler and Ayiyak Rivers. At its type locality, the member constitutes the upper 360 feet of the Seabee Formation and differs from typical Seabee lithology, being composed of greenish-gray siltstone and silty shale and of about 10 to 20 percent light-tan to light-chocolate-brown sandstone. The member becomes more shaly toward the base and contains limestone lenses and beds in the lower part.

That part of the Seabee Formation below the Ayiyak Member has recently been named the Shale Wall Member (Detterman and others, 1963).

DISTRIBUTION

The Seabee Formation is known from outcrops and wells in an area extending from the Arctic coast to about 50 miles south of the latitude of Umiat. Its western boundary in the Arctic Coastal Plain and in the Arctic Foothills north of the Colville River is

TABLE 1.—*Fossils collected from the Ninuluk Formation*

[Arranged in approximate stratigraphic order. Abundance of species indicated by number of specimens in each sample: F, 1 to 6; R, 6 to 12; C, 13 to 25; A, more than 25. Other symbols used: ?, identification queried because of poor preservation; X, present; +, guide fossil present. Fossils identified by H. R. Bergquist, R. W. Imlay, D. L. Jones, and W. R. Smith]

			Microfossils															Megafossils																	
Locality (fig. 98)	Field sample (fig. 99)	U.S.G.S. Mesozoic loc.	*Bathysiphon brosgei* Tappan	*Saccammina lathrami* Tappan	*Haplophragmoides bonanzaensis* Stelck and Wall	*Haplophragmoides topagorukensis* Tappan	*Verneuilinoides fischeri* Tappan	*Gaudryina irenensis* Stelck and Wall	*Trochammina ribstonensis* Wickenden	*T. ribstonensis* subspecies *rutherfordi* Stelck and Wall	*Milliammina* sp.	*Bulimina* sp.	*Praebulimina* sp.	*Cenosphaera* sp.	*Zonodiscus* sp. B	*Zonodiscus*? sp. C	*Spongodiscus* sp.	*Inoceramus dunveganensis* McLearn	*Inoceramus* cf. *I. dunveganensis* McLearn	*Inoceramus* cf. *I. athabaskensis* McLearn	*Inoceramus* sp.	*Elliptio sulfuriensis* McLearn	*Anomia* sp.	*Mytilus* sp.	*Volsella* cf. *V. silentiensis* (McLearn)	*Volsella* sp.	*Thracia*? sp.	*Psilomya*? sp.	*Arctica*? *dowlingi* (McLearn)	*Arctica*? sp.	*Tancredia*? sp.	*Tellina* sp.	*Panope*? *dunveganensis* (Warren)	*Panope*? sp.	*Corbula*? sp.
12	46ARy87	20414																			X				X				X						
19	164A	20422																						X											
28	47AWb328			F						C																									
24	352			F	C			C		A							F																		
31	46ARy158A		F							C																									
28	47AWb330									F																									
11	49ABe50	25372																																X	
26	47AWb344									A																									
27	335						F?																												
	337						F?			F																									
25	351									R																									
10	341				A			A		A																									
1	399	25381																														X		
32	46ARy162		F	C	F			F		A						F	C																		
18	159, 159A	20421	F							C																		X						
30	156A, C		F	F	C			C		A				F																				
10	49ABe55	25373																					X		X				X						
13	46ARy89	20416																											X						
13	89A	20415																											X						
2	47AWb394				F			F		C																									
23	364			F	C			C		A																									
7	379	25376																			X												X		
8	374	25375																			X														
2	396									A																									
23	367					F				F																									
2	47AWb391				C			C		A																									
2	414	25382																											X						
8	373			F	F		F?	F		F		F																							
23	368			F	F			F		A																									
3	393	25380																																	X
4	390	25379																						X										X	
5	387	35378		C	A			A		A																		X						
6	384	25377																											X						
2	24AS84	12482																			X														
9	47AWb371	25374																				X							X						
22	45AKr177							C		A					A																				
	179			F						R																									
	45AWa134								F?																										
20	53ADt84	24630																+																	
8	47AWb372				F	R		F		F																									
14	46AFi45	20423																												X					
16	46ARy125	20419																+																	
22	47ADt195			F									F								X														
16	46ARy125A, B		C	F	F	F		F																											
22	47ADt196	25152																										X			X				
	53ADt88	24631																		+								X	X				X		
	45AWa132	20469																								X				X					
	47ADt197			F				F					C								X														
17	53ABl31	M1264																+																	
22	24AMt69	12413																									X					X			
	47ADt199	25153																															X		
29	46AFi49		F							F	F?																								
21	47ADt139	25150																	+																
21	163	25155																+												X					
15	46ARy100A,B	20417																+						X											
		20418																+																	

approximately along the Chipp and Ikpikpuk Rivers. In the Arctic Coastal Plain east of these rivers, it occurs in wells in the Simpson area (Robinson, 1959b) and at Fish Creek (Robinson and Collins, 1959); only older rocks occur in all wells to the west. In the Arctic Foothills south of the Colville the Seabee is known from the Oolamnagavik River on the west (Chapman and others, 1964) to the Nanushuk River on the east (Detterman and others, 1963).

In the Umiat area the Seabee Formation crops out only on the crest of the anticline at Umiat. In the Maybe Creek area it crops out extensively in Ninuluk

Creek syncline and on all structural features from Lupine syncline north to Wolf Creek anticline. Because of the east plunge of these structural features, the Seabee Formation is exposed on both the western parts of the synclines and the eastern parts of the breached anticlines and may be followed continuously from Maybe Creek northward to the Arctic Coastal Plain.

The Ayiyak Member, a sandy upper unit described by Detterman (1956b) from outcrops south of the Colville River, has been mapped as a separate unit in this region only at Umiat (pl. 56). However, a sandstone bed (sandstone 5) believed to be the basal bed of the member has been mapped locally in the lower Maybe Creek-September Creek area (pl. 52).

The Shale Wall Member has not been mapped in this region. The rocks approximately equivalent to this member at Umiat (pl. 56) have been divided into three informal local members: the lower shale, calcareous sandstone, and upper shale. On lower Maybe Creek the Seabee below sandstone 5 is approximately equivalent to the Shale Wall Member.

In parts of the Umiat-Maybe Creek region the Seabee Formation has been mapped by interpretation of aerial photographs. Bare clay-covered knobs produced by weathering of bentonitic shales are characteristic of the formation south of Maybe Creek. North of Maybe Creek the shales form smooth grass-covered slopes and are exposed only on streambanks, but sandstone beds are locally prominent and scattered vegetation bands outline the trace of bedding in the shales. Where the gentle topography of the shales borders the Arctic Coastal Plain, the hills are so subdued and expressionless that formations cannot be identified or traced without field data. As no fieldwork has been done there, the Seabee has not been differentiated from the Ninuluk-Niakogon unit or the Prince Creek Formation in the interstream areas on the Arctic Coastal Plain margin. Elsewhere field data control mapping, and photointerpretation has been used largely to extend contacts located in the field.

In 1946 Ray and Fischer mapped the outcrops of the base of the Seabee Formation on Weasel Creek on the north limb of Ninuluk Creek syncline. In 1953 R. L. Detterman and R. S. Bickel (written commun., 1953) tentatively located the base of the Seabee on the south limb of the syncline from poor exposures in the hills near the Colville River (lat 69°06′ N., long 153° 53′ W.). The approximate base of the Seabee Formation can be traced around Ninuluk Creek syncline between these localities in the hills west of the Colville but is lost where it enters the Colville valley. Exposures in the west wall of the valley are poor, and high-level terrace gravels of the Colville River cover the adjacent hills. The few outcrops that have been found are those of Ninuluk Formation (R. L. Detterman, E. J. Webber, and D. E. Matthewson, written commun., 1948). However, the Seabee Formation is probably also present in the valley wall from Ninuluk Creek syncline northward to the south flank of Fossil Creek anticline, for it crops out extensively just across the river in both Outpost Mountain and Ninuluk Creek synclines (Detterman and others, 1963). Most of the west wall of the valley has therefore been mapped as the Ninuluk Formation, Niakogon Tongue of the Chandler Formation, and the Seabee Formation, undifferentiated.

On the south limb of Lupine syncline, Ray and Fischer mapped the Seabee Formation from Weasel Creek eastward to the fault zone near the head of Maybe Creek, and Whittington and Troyer mapped it to the west along September Creek. From September Creek westward to the axis of Lupine syncline, well-defined bedding traces and a zone of bentonite knobs near the base of the formation have been mapped from the aerial photographs. North of the syncline axis, in the lower Maybe Creek valley, tundra hides the bedrock, and there the location of the base of the Seabee Formation is inferred.

North of Maybe Creek the Titaluk anticline and Banshee syncline were mapped by Ray and Fischer in 1946 and Brosgé and Kover in 1949. Maybe Creek and the Ikpikpuk River were traversed by Phillippi and Cortes in 1945 and Webber in 1947. The upper and lower contacts of the Seabee Formation have been traced in the field over most of this area, and prominent sandstone beds in the western part have been mapped individually (beds 4, 5, and 6 on pl. 52). Nevertheless, the location of the base of the Seabee Formation is indefinite along the lower 8 miles of Maybe Creek valley. The Ninuluk-Niakogon unit crops out there at stream level; the next higher outcrops are those of sandstone 5, in the upper half of the Seabee Formation. The location of the contact therefore is based on photointerpretation and on estimates of the stratigraphic interval between the contact and sandstone 5. Similarly, along the margin of the Arctic Coastal Plain west of Watermelon Lake, only a few bedding traces are visible, and there the location of the base of the Seabee Formation is also inferred.

Wolf Creek anticline is breached down to the Seabee shale for most of its length. Near the east end of the anticline, Ray and Fisher mapped the top of the Seabee Formation in the field; the base of the formation is mapped from their field notes and from well data. The top of the Seabee Formation there is at

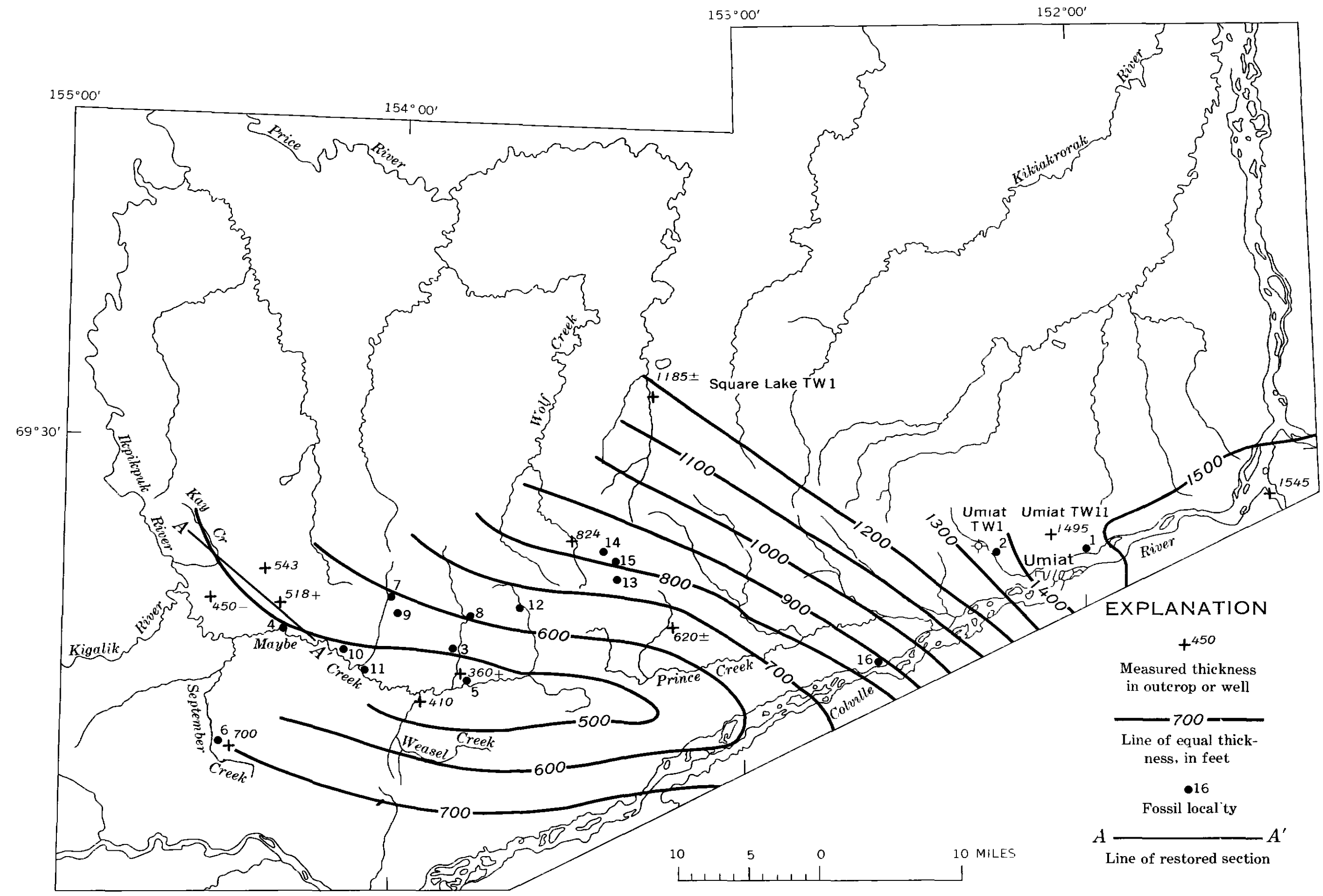

FIGURE 100.—Thickness and fossil localities of the Seabee Formation (see fig. 101).

the base of a prominent ledge of sandstone which has been traced westward to the Arctic Coastal Plain on aerial photographs; the sandstone has also been traced southeastward around the nose of Wolf Creek anticline to the north flank of Fossil Creek anticline. In 1953 R. L. Detterman and R. S. Bickel (written commun., 1953) mapped this sandstone on the north flank of Fossil Creek anticline at the head of Prince Creek. The base of the Seabee Formation on Fossil Creek anticline is less definite than the top contacts but its location has been inferred from the location of known rocks of the underlying Ninuluk-Niakogon unit, and the horizon thus established has been traced southward across the Fossil Creek axis on photographs. The presence of the Seabee Formation along Prince Creek is inferred from thickness and dips.

LITHOLOGY IN THE UMIAT AREA

At Umiat, the Seabee Formation is about 1,500 feet thick. Characteristically, it is a shale containing minor amounts of sandstone. The overall lithology is best portrayed by the log of Umiat test well 11 between depths of 545 and 2,040 feet, the type locality of the formation. Outcrops are not extensive, but there is a fair correspondence in lithology between them and the well sections described by Collins (1958a).

The upper 300 feet of the Seabee Formation on the Umiat anticline has been mapped as the Ayiyak Member (pl. 56), the base being taken as the base of a 125-foot sandstone-siltstone unit at a depth of 845 feet in Umiat Test well 11. This mapping unit probably represents only part of the Ayiyak Member as defined south of the Colville River (Whittington, 1956, p. 248), which is probably about 500 to 550 feet thick in the Umiat area. In Umiat test well 11, the character of the shale changes between 1,060 and 1,090 feet, the shale below this interval being darker, harder, and less bentonitic. This lithologic change probably represents the base of the typical Ayiyak Member, but because it is a contact of two shale units, it is useless for mapping purposes on the Umiat anticline.

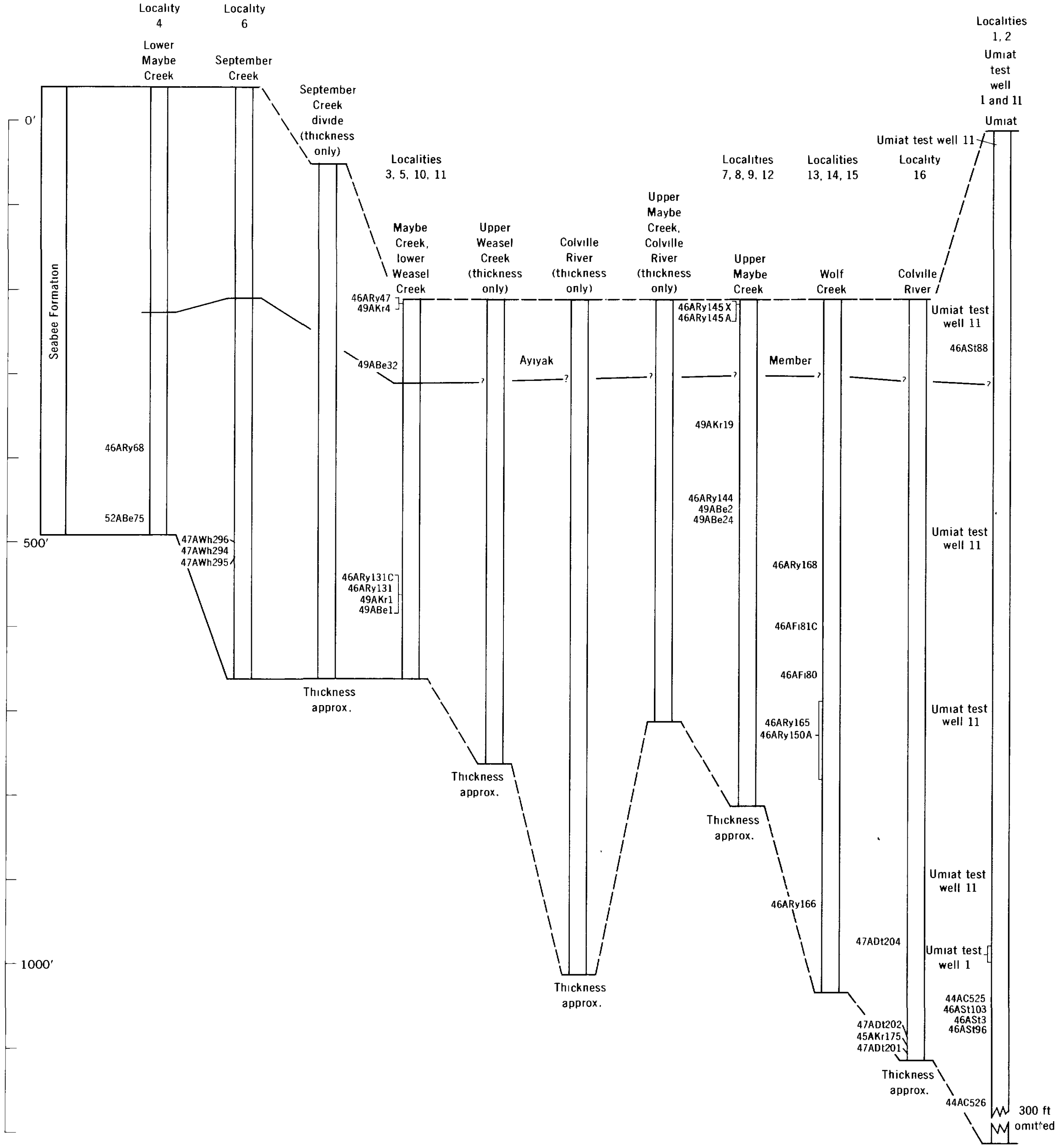

FIGURE 101.—Stratigraphic position of fossils collected from the Seabee Formation. Fossil identifications are given in table 2.

For mapping purposes the Seabee Formation on the Umiat anticline is divided into three informal members and the Ayiyak Member as in the adjacent tabulation.

Member	*Depth in Umiat test well 1 (feet)*	*Depth in Umiat test well 11 (feet)*
Ayiyak Member	--------	545–845
Upper shale member	0–80	845–1,315
Calcareous sandstone member	80–250	1,315–1,495
Lower shale member	250–915	1,495–2,040

Lower Shale Member

Subsurface data for the lower shale member is more complete than for any of the other units. The member is 665 feet thick in Umiat test well 1 and 555 feet thick in Umiat test well 11. The lower 189 feet was drilled in Umiat test well 6, and the lower 340 feet, in Umiat test well 7. In Umiat test wells 8 and 10, five different sections in the base of the member from 50 to 200 feet thick were drilled, but only four of these were sampled. The well sections show that the member is largely shale and silty shale and contains, in places, considerable sandstone and siltstone. The sandstone and siltstone are sporadic in occurrence and cannot be traced from well to well. The lower 189 feet in Umiat test well 6 is silty shale, but the rocks in the same interval in Umiat test well 7, one-quarter of a mile away, contain considerable sandstone. A 55-foot sandstone unit about 200 feet above the base in Umiat test well 11 cannot be found in Umiat test well 1 and is poorly represented in Umiat test well 7, where the notable sandstone beds are about 100 and 275 feet above the base.

The only data available from outcrops for the lower half of the lower shale member are for a sandstone unit in the lower 100 feet (sandstone F, pl. 56), which forms a bedding trace in the area from 0.6 mile north to 1.5 miles east of Umiat test well 9.

Outcrops and the logs of Umiat test wells 1 and 11 indicate that the upper half of the lower shale member is almost entirely shale. The best exposure is in vertical cliffs at Umiat Mountain, where 175 feet of fossiliferous shale immediately underlies the calcareous sandstone member (figs. 102 and 103). At this place the shale is underlain by a 15-foot sandstone, the lowest rock exposed in the bluff. Several small outcrops are present along Seabee Creek 1.0 mile to 1.3 miles southeast of Umiat test well 1. The shale is extensively exposed in a saddle flanked by the calcareous sandstone member on the ridge crest 1.3 miles east of Umiat test well 1; about 2 miles east of this same well, about 135 feet of steeply dipping shale is exposed immediately south of the calcareous sandstone member. Gray soil that is barren of vegetation except in frost cracks is characteristic of the shale in the upper part of the lower member and is present at several localities in the Umiat area. A conspicuous area of barren soil occurs just east of the summit of the hill known locally as Red Mountain 3 miles southeast of Umiat test well 1. Smaller areas of barren soil are present in a few places just south of the linear ridge trend of the calcareous sandstone member for about a mile west of Bearpaw Creek.

The shale in the upper part of the lower shale member is dark gray and very fissile. Many individual laminae, 0.2 to 0.5 mm thick, may be picked out, and these are notably pliable or flexible. Thin bentonite seams are present in the shale at most places, and the appearance of light-colored bentonite seams, a fraction of an inch thick, alternating with dark shale in units, a few inches thick, is characteristic of the Seabee Formation. Silty layers and calcareous layers are present in the shale in places and calcareous concretions are common.

The fissility seen in the outcrops is not apparent in the cored sections of this shale in the wells; it is apparently due to weathering and may be connected with a relatively high content of pyroclastic debris. The thin bentonite seams seen on outcrop were not described from the well sections, apparently because they are too thin before swelling to be noticeable.

Calcareous Sandstone Member

The calcareous sandstone member is 170 to 180 feet thick in Umiat test wells 1 and 11, and 165 feet of it is exposed in the upper part of the bluff at Umiat Mountain. The east and northeast slopes of Umiat Mountain are a dip slope on the member; and from the top of Umiat Mountain the member crops out in an arc, convex to the northeast, that extends to Bearpaw Creek 1 mile north of Colville valley. From Bearpaw Creek steeply dipping beds of the member trend westward in a linear ridge to a point about half a mile north of Umiat test well 1. On the small creek about 0.7 mile west of Umiat test well 1, one of the sandstone beds forms the crest of the anticline. On the south flank of the anticline, the southwest-dipping sandstone beds of the member form southerly dip slopes on the ridge on which Umiat test well 1 is located, on the next ridge to the east, and on the southwest side of the next hill to the east.

The calcareous sandstone member is predominantly sandstone interbedded with dark shale and light-colored bentonite. Sandstone in most outcrops of the member is notably calcareous and very hard. Much of the sandstone at Umiat Mountain is not as hard or as calcareous, and much of the sandstone in the wells is not at all calcareous. Apparently the hard sandstone beds form only a small part of the member, but they are most commonly seen as rubble and small outcrops because they are very resistant to disintegration.

Upper Shale Member

The upper shale member is 470 feet thick in Umiat test well 11. Its calculated thickness south of Umiat test well 1 is about 400 feet.

In Umiat test well 11 the upper shale member is very largely shale, but there are a number of thin

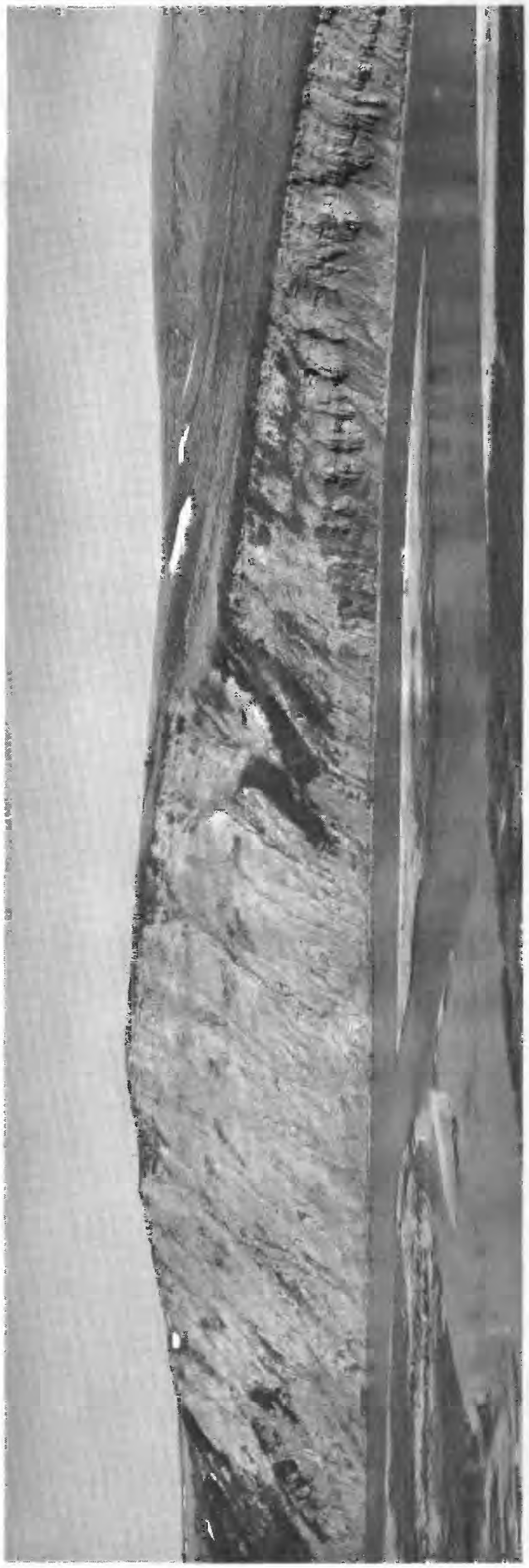

FIGURE 102.—Bluff at Umiat Mountain exposing parts of calcareous sandstone and lower shale members of the Seabee Formation. Break in top of bluff in center is probably caused by west-dipping thrust fault which apparently trends north from the break along the steep slope marked by the snow drifts. Low-angle aerial photograph (COL–OV–47–97) by U.S. Navy.

FIGURE 103.—Seabee Formation exposed in east half of bluff at Umiat Mountain. Lower part of calcareous sandstone member overlies upper part of lower shale member.

sandstone beds from 250 to 340 feet above the base. At this place in the section and slightly lower there is also some siltstone. Shale in the upper part of the member is medium gray, slightly silty, and slightly bentonitic. In the lower 250 feet the shale is a little darker, harder, and less bentonitic, but bentonite beds occur in at least two places. The shale in the lower part is virtually identical in lithology with the upper 220 feet of the lower shale member in this same well.

There are very few outcrops of the upper shale member. Along the streams about half a mile northwest of Umiat test well 1 are a few small outcrops of dark shale containing light-colored bentonite stringers similar to shale outcrops in the lower shale member. Stratigraphically these outcrops are not far above the calcareous sandstone member. The only other outcrop is a 40-foot section of vertically dipping greenish-gray shale about 1 mile northeast of Umiat test well 1; this is probably in the upper part of the member.

The shothole at SP–12 (pl. 56) was drilled to a depth of 185 feet through shale that is mainly fissile and nonsilty. The shothole is in part of the upper shale member, but whether it falls above or below the thin sandstones in the member is uncertain. No sandstone or siltstone was present in cuttings from the hole, but the presence of *Pseudoclavulina hastata* (Cushman) (pl. 58) indicates that it is from the upper part, in the faunal zone typical of the Ayiyak Member. The dip at this place may be fairly steep, and the true thickness of the section drilled may be considerably less than 185 feet.

Ayiyak Member

The Ayiyak Member in Umiat test well 11 is 300 feet thick and is about half shale similar to that in the upper part of the upper shale member. The lower 125 feet is mostly sandstone and siltstone and includes one sandstone bed 55 feet thick.

In the vicinity of Umiat test well 1, several bedding traces occur from 400 to 600 feet above the calcareous sandstone member. The lowest of these traces has been mapped as the basal bed of the Ayiyak Member and the uppermost as the basal bed of the Tuluvak Tongue of the Prince Creek Formation. These traces occur on both flanks of the anticline near Umiat test well 1, and cross the anticlinal axis about 2 miles west of the well. Rubble and small outcrops indicate that these traces are made by beds of sandstone, much of it calcareous. Southwestward these sandstone beds become conglomeratic, and in the area 1¼ miles southwest of Umiat test well 1 practically all the rubble on the traces is pebble conglomerate.

LITHOLOGY IN THE MAYBE CREEK AREA

Sections 5 to 11, shown on plate 54 and described under "Stratigraphic sections," give the lithology in detail. Most of the Seabee Formation in the Maybe Creek area is dark-gray noncalcareous shale, silty shale, and thin-bedded siltstone. Yellow bentonite in beds about a quarter of an inch thick and occasionally as much as 2 feet thick is commonly interbedded with these fine-grained clastics (fig. 104). Thin partings and lenses of coal as much as half an inch thick also occur locally. The shales rarely weather to the typical paper-shale fissility; in most outcrops they weather to gray chips and to mud. Fresh exposures of these rocks are found only in streamcuts; elsewhere the weathered material is found in the soil. On steep slopes the weathered material produces characteristic white mudflows and bare white knobs (fig. 96); on gentle slopes it is covered by vegetation. Consequently, large parts of each of the measured outcrop sections of the Seabee Formation are covered.

Limestone lenses and concretions are abundant in the shale in the valleys of Wolf Creek and Maybe

FIGURE 104.—Shale of Seabee Formation on September Creek 7½ miles south of Maybe Creek. Interbedded with the dark shale are thin bentonite seams and thicker lenticular limestone beds. Calcareous concretions occur sporadically in the shale. Height of exposure is about 30 feet.

Creek and their tributaries, as well as at Umiat. The limestone is gray to dark gray, very finely crystalline, and slightly argillaceous to slightly silicified; it weathers ochre to dark brown. It occurs in two forms. The first type is most common in the upper 100 feet of the formation and consists of nodules and lenticular beds, as much as 1 foot thick, of soft gray yellow-weathering argillaceous limestone in which cone-in-cone structure is abundant and in some places makes up the entire bed. Along Maybe Creek a few nodules of this rock contain isolated black chert pebbles and granules. No fossils have been found in this nodular and lenticular limestone, although clams do occur in the accompanying very limy sandstones. A second type is found in the lower part of the formation, where the limestone occurs as oblate concretions of dark-gray hard dense limestone as large as 1 foot thick and 4 feet in diameter. The weathered surfaces of some of these concretions show fine laminae along which the bedding planes of the shale apparently continue through the limestone, but the rock breaks with conchoidal fracture and bedding is not apparent in the fresh interior of the concretions. In these concretions *Inoceramus labiatus* (Schlotheim) and ammonites of the genera *Scaphites*, *Watinoceras*, and *Borissiakoceras* are common and well preserved. Other concretions similar to these fossiliferous concretions in shape and lithology are broken by a reticulate boxwork of coarse, calcite-filled joints, but these are generally barren of fossils.

Sandstone, although a minor constituent, is found in most measured sections of the Seabee Formation and is abundant locally. In the area from the head of Wolf Creek through the upper parts of Prince Creek and Maybe Creek to September Creek, sandstone constitutes less than 8 percent of the thickness of the formation; but at Square Lake test well 1 it constitutes about 17 percent, and at the head of Ikpikpuk River, more than 25 percent. The sandstone is generally gray, fine grained, and calcareous.

Some of the prominent sandstone beds in the lower part of the Seabee Formation have been mapped as key horizons on Wolf Creek and Titaluk anticlines (sandstone A and sandstone 4, pl. 52). On Wolf Creek anticline the prominent sandstone bed consists of fine-grained calcareous sandstone about 28 feet thick and is about 225 feet above the base of the formation (sandstone A, pl. 52; section 11, pl. 54). This bed crops out near each of the three Wolf Creek wells and serves as a stratigraphic tie between them.

The Ayiyak Member has been identified in only a few of the outcrops in the Maybe Creek area. It is probably represented by the fossiliferous gray siltstone and very fine grained sandstone that occur with the cone-in-cone and chert-pebble-bearing limestones in the upper 100 feet of the formation near the head of Maybe Creek (section 10, pl. 54; units 23 to 27, strat. section 10). Also near the head of Maybe Creek at locality 12 (fig. 100) about 30 feet below the top of the formation, these sandstones and siltstones contain the foraminifer *Pseudoclavulina hastata* (Cushman), which is characteristic of the Ayiyak Member of other areas. Two fine-grained unfossiliferous calcareous sandstones which occur in the upper 250 feet of the formation on lower Maybe Creek have also been included in the Ayiyak Member. They are mapped separately as sandstones 6 and 5 (section 6, pl. 54; units 7 and 10, strat. section 6). Sandstone 6 is correlative in position with the *Pseudoclavulina* beds of upper Maybe Creek. As it is also very similar in lithology to sandstone 5, both sandstones are included in the Ayiyak Member. A sandstone bed on September Creek, about 5 miles south of Maybe Creek, that is about 225 feet below the top of the formation (section 5, pl. 54; unit 5, strat. section 5) is correlated with sandstone 5.

The relation of the 250-foot-thick zone of sandstone and shale at the top of the formation in the Lower Maybe Creek-September Creek area to the thinner zone of *Pseudoclavulina*-bearing siltstone and sandstone in the upper Maybe Creek area is shown on plate 54. The individual thick beds of sandstone found in the lower Maybe Creek area pinch out eastward. The only lithologic zone that can be traced through to the upper Maybe Creek area is a zone of prominent white knobs ("bentonite boils") that crops out continuously near the base of the formation from September Creek eastward to Weasel Creek.

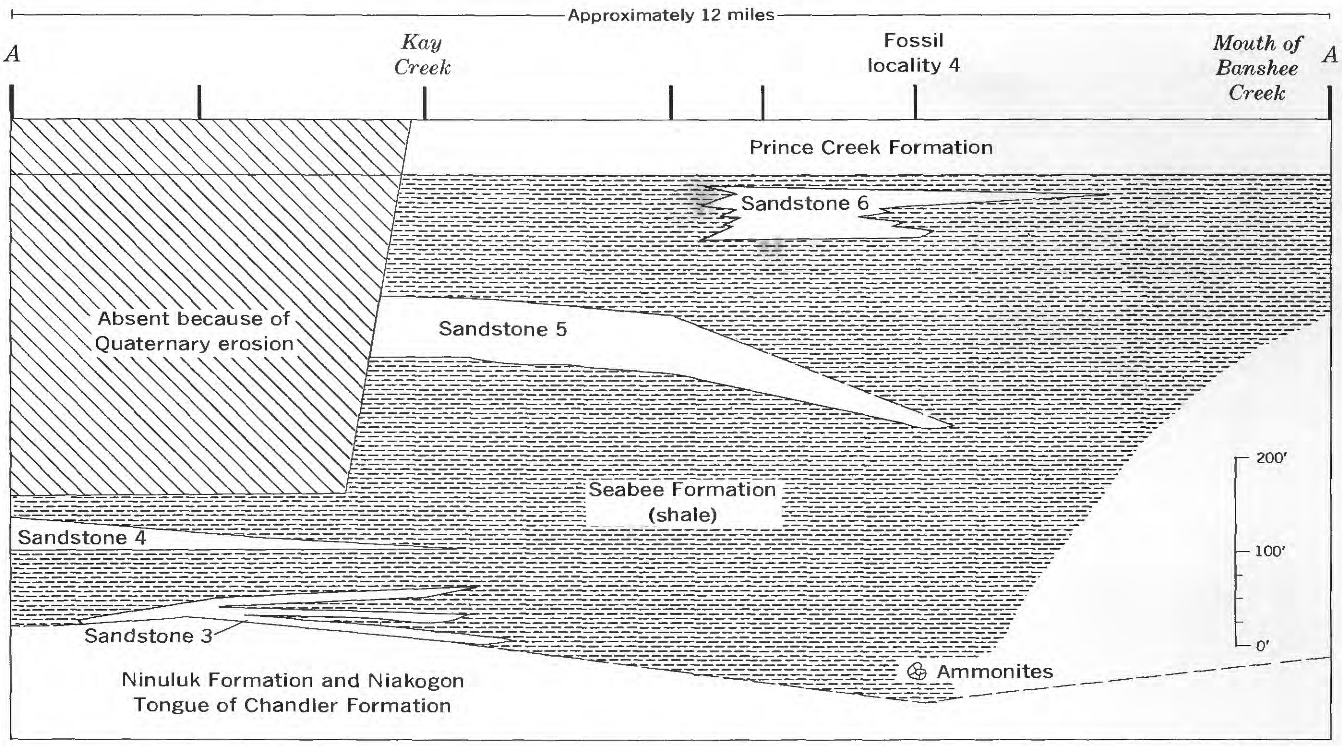

FIGURE 105.—Restored section of the Seabee Formation on Maybe Creek along line *A–A′* of figure 100. Sandstone 4 and the base of the Prince Creek Formation are arbitrarily made horizontal. Vertical bars indicate localities at which formation was measured. Vertical exaggeration × 50.

On the basis of the single occurrence of *Pseudoclavulina*, the clastic section at the top of the Seabee in the Maybe Creek area is correlated with the Ayiyak Member. The member has not been separately mapped, except insofar as the mapping of sandstone 5 marks its bottom contact, because its basal beds are not persistent enough or well enough exposed to warrant mapping by photointerpretation and because the bottom contact as such was not traced out in the field.

In Square Lake test well 1 (pl. 54) the upper part of the Seabee Formation, at a depth of 700 to 1,140 feet, probably represents the Ayiyak Member, although no fossils diagnostic of that member were found in the well. This unit consists largely of medium-gray bentonitic shale that is less dark and more bentonitic than the shale in the lower part of the formation and includes a 40-foot unit, at a depth of 1,040 to 1,080 feet, that is largely sandstone (Collins, 1959, p. 426, 430–431).

On the eastern part of Titaluk anticline near the head of Maybe Creek, sandstone is scarce in the Seabee Formation; but on the western part near Titaluk test well 1, four sandstone beds occur. These sandstone beds make up most of the exposed part of the formation there and range from the bottom to the top of the formation. They pinch out laterally and their outcrops are limited to the area west of Banshee Creek and Fry Creek. These beds are shown on the geologic map and sections (pl. 52) as sandstones 3, 4, 5, and 6. The base of sandstone 3, where present, is mapped as the base of the Seabee Formation, and the base of sandstone 5 is the base of the Ayiyak Member. The en echelon stratigraphic arrangement of the sandstone beds is shown in figure 105, a restored section along a line running northwest from the mouth of Banshee Creek and showing in detail the stratigraphic variations in the area encompassed by sections 6 and 7 of plate 54. The distribution of the sandstone beds suggests that they were deposited near shore by an eastward-retreating sea. The facies and thickness changes of the individual sandstone beds agree with this and indicate a shoreline roughly parallel to the Ikpikpuk River (fig. 106).

Sandstone 3 is present along a narrow belt trending eastward from the lower part of the Kay Creek to the Fry Creek divide. Just northwest of the bend in Kay Creek, this sandstone is 15 feet thick and consists of chert pebbles in a matrix of coarse-grained iron-stained sandstone and gray medium-grained calcareous sandstone. It thins northward to 9 feet and disappears within three-quarters of a mile. A small outlier of sandstone on the ridgetop about 1 mile

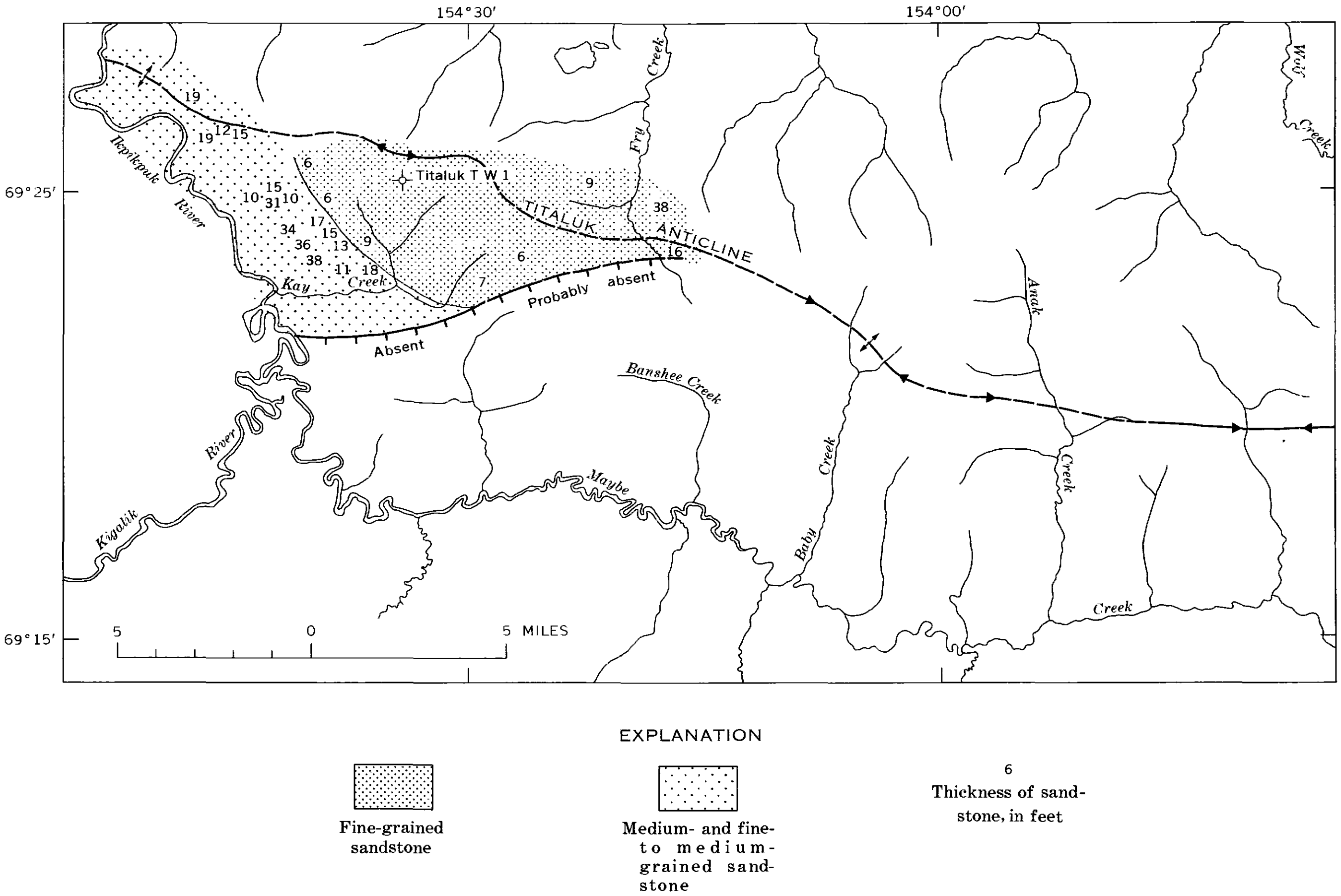

FIGURE 106.—Grain size and thickness of sandstone 4 about 90 feet above the base of the Seabee Formation in the Maybe Creek area. Near the boundary between the areas of fine-grained sandstone and medium-grained and fine- to medium-grained sandstones, rocks of both sandstone units are locally conglomeratic.

northwest of Titaluk test well 1 is also believed to be sandstone 3, but in the well itself only shale and calcareous concretions are reported at the horizon (about 30 feet below the top of the well) at which sandstone 3 should appear. South and east of Kay Creek three thin sandstone beds interbedded with shale have been included in this unit. The sandstone there is gray green, medium grained, and very calcareous, and contains ironstone and clay galls.

Sandstone 4 is about 90 feet above the base of the Seabee Formation. It extends east beyond Fry Creek but is absent south of Kay Creek (fig. 106). In a narrow belt adjacent to and parallel to the Ikpikpuk River, the sandstone is medium grained, light gray to yellowish gray, and, locally, noncalcareous and crossbedded. In all the outcrops east of this belt the sandstone is fine grained, gray to gray green, and entirely calcareous. Ironstone is common in the fine-grained rocks and is also found with abundant limonite in the northern outcrop of the medium-grained rocks. Pebbles occur with both fine- and medium-grained sand in the area just west of Kay Creek but not east of the creek.

Sandstone 5 is about 300 feet above the base of the Seabee Formation. It is more widespread and more uniform in facies than the other sandstone beds of the Seabee, and is the only sandstone in the Maybe Creek area that consistently produces outcrops of sound rock in place rather than of weathered rubble. Its thickness ranges from 33 to 119 feet but is generally 40 to 60 feet. The rock is dark gray, fine to medium grained, very calcareous, dense, and massive. It weathers buff to yellow along smooth broadly curved, conchoidal surfaces. Locally, it contains coaly wood fragments. The uppermost 5 to 10 feet consists of gray fine-grained calcareous sandstone that is softer, friable, thin bedded, and, in some places, crossbedded.

Sandstone 5 crops out south of Kay Creek and was at first correlated with the outcrops of sandstone 4 on hilltops north of Kay Creek and regarded as a more marine facies of sandstone 4. However, the projected dips show that sandstone 5 is about 200 feet above sandstone 4. Sandstone 5 is much thicker, darker, and more massive than sandstone 4 and also contains much less quartz and more fresh biotite and plagioclase than sandstone 4. The following list compares the composition of the clastic material in three thin sections of sandstone 4 and four thin sections of sandstone 5. Calcite cement constitutes 30 to 60 percent of the total rock in six of these thin sections and 85 percent in one thin section of sandstone 5.

Clastic material	*Sandstone 4 (percent)*	*Sandstone 5 (percent)*
Quartz	34–50	14–33
Chert and weathered rock fragments	37–50	30–49
Plagioclase	2–8	23–33
Biotite	0–3	5–10
	100	100

Plate 57 shows the heavy mineral composition of five other samples of sandstone 4 (49ABe54, 49AKr26, 49AKr36, 49AKr38, and 49AKr39) and two other samples of sandstone 5 (49ABe41 and 49ABe47).

Sandstone 6 is present only in a small area along Maybe Creek just west of the mouth of Banshee Creek. Its western part crops out above outcrops of sandstone 5, but sandstone 6 extends farther east than that sandstone. Sandstone 6 is about 20 feet below the top of the Seabee Formation and ranges in thickness from 14 to 50 feet. The upper 14 feet of this sandstone is persistent and is gray, yellow weathering, fine grained, thin bedded, and calcareous. The mineral composition is about the same as that of sandstone 5.

CORRELATION OF SANDSTONES IN THE IKPIKPUK AREA

Sandstones 3 and 4 might well be included in the Ninuluk Formation. They are, however, designated as being within the Seabee Formation partly on the basis of fossils and partly on the basis of heavy minerals. At locality 4 (fig. 100 and fig. 105), the typical Seabee fossils, *Inoceramus labiatus* and *Scaphites* sp., occur in the shale 265 feet stratigraphically below the trace of sandstone 5 (section 6, pl. 54; strat. section 6, unit 10). Sandstones 3 and 4 pinch out north of this locality and, therefore, do not occur in the section directly above the fossils. As no fossils are found in the Seabee Formation to the north, where these sandstones do occur, there is no direct fossil control of sandstones 3 and 4. However, sandstone 3 occurs within the range of 240 to 300 feet below sandstone 5 and thus occupies the same position relative to sandstone 5 as does the fossil zone on Maybe Creek. The projected horizon of sandstone 3 also occurs in Titaluk test well 1 at a depth of about 30 to 40 feet. From this depth downward in the well, the rocks include diagnostic microfossils of the Ninuluk Formation as well as thick beds of coal and sandstone. No samples from the upper 40 feet of the well were received in the Geological Survey laboratory, but the well geologist reported hard buff shale and calcareous concretions in that interval. Thus, in the well, the Ninuluk Formation lies just below the horizon of sandstone 3, and rocks above that horizon, although of undetermined microfossil content, are like the Seabee Formation in lithology.

Abundant fresh biotite typifies the Seabee Formation in the test wells, according to the petrographic studies by Robert Morris (p. 602 and pl. 57). Most of the heavy-mineral samples from sandstone 4 have abundant biotite. Only one heavy-mineral sample of sandstone 3 was collected (49AKr27), and this specimen lacks biotite. This sample is from the same locality (lat 69°24′ N., long 154°27′ W.) as the only nonbiotitic occurrence of sandstone 4 (heavy-mineral sample 49 AKr26 and thin section 49AKr28) and so it may not be typical.

THICKNESS

The Seabee Formation ranges in thickness from 410 feet on Weasel Creek to 1,495 feet at Umiat. Figure 100 shows the distribution of thickness by isopachous lines. The thinner part, from 410 to 700 feet, is in an east-trending trough along Maybe Creek. From there the formation thickens eastward toward Umiat and northeastward toward Square Lake. South of Maybe Creek the Seabee thickens slightly, but information for this area is scant, as it marks the southern limit of outcrop of the formation in this region.

In general, the Seabee Formation is thick where the Ninuluk-Niakogon unit is thin and is thin where the Ninuluk-Niakogon is thick; isopachous lines for the two units are parallel, trending southeastward in the area between Maybe Creek and Umiat and then southward from Umiat. Both formations, however, are relatively thin along Maybe Creek. The eastward thickening of the Seabee Formation from Maybe Creek toward Square Lake and Umiat is partly accounted for by the thickening of the Ayiyak Member; this member, however, includes less than 400 feet of the 1,100-foot increase in thickness, and therefore most of the change in thickness of the Seabee Formation must be due to the addition and thickening of units in the lower part of the formation.

PALEONTOLOGY, AGE, AND CORRELATION

Fossil occurrences in the Seabee Formation in the Umiat-Maybe Creek region are shown in figure 101;

fossils are listed in table 2. Megafossils were identified by Jones and Gryc (1960) and Cobban and Gryc (1961). H. R. Bergquist and Helen Tappan identified the microfossils. The microfossils from the Seabee of the Umiat, Wolf Creek, and Square Lake wells has been summarized by Bergquist (1958a, 1959b).

The characteristic fossils of the Seabee Formation are *Inoceramus labiatus* (Schlotheim), *I.* aff. *I. cuvierii* Sowerby, *Scaphites delicatulus* Warren, *Otoscaphites seabeensis* Cobban and Gryc, *Watinoceras reesidei* Warren, and *Borissiakoceras ashurkoffae* Cobban and Gryc. These fossils occur mostly in calcareous beds and concretions in shales of the Shale Wall Member or equivalents and are common in outcrops at Umiat and along Maybe Creek and September Creek. In the Maybe Creek area they occur in the interval from about 150 feet below the top of the formation almost to the base. At Umiat, where the formation is about 1,500 feet thick, they are found about 450 feet above the base of the formation in the outcrops and from 610 to 1,030 feet above the base of the formation in Umiat test well 11. South of the Colville River *Inoceramus* aff. *I. cuvierii* ranges into the Ayiyak Member, but it has not been found in this member in the Umiat-Maybe Creek region.

A different fauna occurs sparingly in some of the sandstone beds of the Seabee Formation in the Umiat-Maybe Creek region. This fauna includes pelecypods of the genera *Yoldia*, *Arctica*, and *Protocardia* and probably ranges into the Schrader Bluff Formation. Of three occurrences, two (USGS Mesozoic locs. 26536 and 26537) are in sandstone beds of the Ayiyak Member in the Maybe Creek area, and the third (USGS Mesozoic loc. 19436) is in a sandstone bed of the lower shale member at Umiat Mountain. In 1963 two additional pelecypods (not shown in fig. 101) were discovered in the core from 1,824-foot depth in Square Lake test well 1. These pelecypods, found 61 feet above the logged base of the Seabee but about 65 feet below the lowest occurrence of Seabee microfossils, are "*Arctica* sp., similar to a species from the Ninuluk Formation" according to D. L. Jones (written commun., 1963). Their presence suggests that the logged base of the Seabee at Square Lake may be about 75 feet too low. In addition, although no collections were made, a few poorly preserved pelecypods have been seen in the calcareous sandstone member at Umiat Mountain.

Microfossils are common in places in the Seabee Formation, but much of the well sections and many of the outcrop samples are barren. *Haplophragmoides rota* Nauss, *Textularia* sp., *Saccammina lathrami* Tappan, and *Trochammina whittingtoni* Tappan account for more than half the specimens. All four species range through the Colville Group, but *Textularia* sp. and *Trochammina whittingtoni* are more abundant in the Seabee Formation than in any other unit. *Praebulimina seabeensis* Tappan is restricted to the Seabee. *Pseudoclavulina hastata* (Cushman) is a guide for the Ayiyak Member; it has been found in the Umiat-Maybe Creek region only in the upper 200 feet of the Seabee Formation in Umiat test well 11, in Umiat shothole 12, and in one outcrop sample from near the top of the formation on upper Maybe Creek.

Jones and Gryc (1960, p. 153) inferred that the age of the member of the Seabee Formation now termed the Shale Wall Member is early Turonian and that of the Ayiyak Member, late Turonian. However, there is no stratigraphic evidence for postulating a hiatus in the Seabee Formation to account for the possible absence of rocks of middle Turonian age.

Jones and Gryc (1960) correlated the Shale Wall Member with the upper part of the Greenhorn Limestone and possibly with the lower part of the Carlile Shale of the Western Interior, and they correlated the Ayiyak Member with the upper part of the Carlile. Cobban and Gryc (1961) also correlated rocks now known as the Shale Wall Member of the Seabee Formation with the upper part of the Greenhorn Limestone. They reported two ammonite faunas from the Shale Wall Member. The younger fauna consists of the ammonities mentioned above as characteristic of the Shale Wall and is considered to correlate with the *Inoceramus labiatus* zone of the western interior of the United States and to be definitely lower Turonian. The older fauna has not been found in the Umiat-Maybe Creek region. Its age is uncertain, but tentatively it also is assigned to the lower Turonian.

Tappan (1960, p. 289) correlated beds that locally contain *Hedbergella loetterlei* (Nauss) and *Heterohelix globulosa* (Ehrenberg) with the Favel Formation of Manitoba and the upper part of the Lloydminster Formation of Alberta.

In the northeastern Alaska the upper member of the Ignek Formation may include in its basal part beds as old as the Turonian (Keller and others, 1961, p. 207) and thus may also be partly equivalent to the Seabee Formation.

SCHRADER BLUFF FORMATION

NAME AND TYPE SECTION

The Schrader Bluff Formation was originally defined as encompassing all marine rocks of the Colville Group (Gryc and others, 1951, p. 164), but it was later

TABLE 2.—*Fossils collected from the Seabee Formation*

[Arranged in approximate stratigraphic order. Abundance of species indicated by number of specimens in each sample; F, 1 to 6; R, 6 to 12; C, 13 to 25; A, more than 25. Other symbols used: ?, identification queried because of poor preservation; ×, present; +, guide fossil present. Fossils identified by H. R. Bergquist, W. A. Cobban, George Gryc, D. L. Jones, and Helen Tappan Loeblich]

Locality (fig. 100)	Field sample (fig. 101)	U.S.G.S. Mesozoic locality	Microfossils														Megafossils																
			Saccammina lathrami Tappan	*Haplophragmoides rota* Nauss	*Haplophragmoides bonanzaensis* Stelck and Wall	*Textularia rollaensis* Stelck and Wall	*Verneuilinoides fischeri* Tappan	*Gaudryina* sp.	*Pseudoclavulina hastata* (Cushman)	*Trochammina ribstonensis* Wickenden	*Trochammina whittingtoni* Tappan	*Milliammina* sp.	*Praebulimina seabeensis* Tappan	*Cenosphaera* sp.	*Zonodiscus*? Sp. C	*Spongodiscus* sp.	*Yoldia* sp.	*Inoceramus labiatus* (Schlotheim)	*Inoceramus* cf. *I. labiatus* (Schlotheim)	*Inoceramus* aff. *I. cuvieri* Sowerby	*Inoceramus* sp.	*Arctica* cf. *A. ovata* (Meek and Hayden)	*Protocardia* cf. *P. borealis* Whiteaves	*Protocardia*? sp.	*Scaphites delicatulus* Warren	*Scaphites* sp.	*Otoscaphites seabeensis* Cobban and Gryc	*Proplacenticeras* sp.	*Watinoceras reesidei* Warren	*Watinoceras* sp.	*Borissiakoceras ashurkoffae* Cobban and Gryc	*Borissiakoceras* sp.	Fish scales and vertebra
Umiat test well 11	545–745 ft								F																								
3	46ARy47	26530																			×												
11	49AKr4	26536															×						×										
12	46ARy145X			C					F																								
	46ARy145A														C																		
2	46ASt88		R	A		F?	R				R																						
10	49ABe32	26537																						×									
7	49AKr19	26559																									+				+		
4	46ARy68	20413																+		+													
8	46ARy144														F																		
	49ABe2	26561																+		+							+				+		
9	49ABe24	26562									F							+							+		+				+		
4	52ABe75	26572																+								+							
Umiat test well 11	1015 ft																	+															
6	47AWh296	26553																+								+						+	×
	47AWh294			F?																													
	47AWh295		F	C			R?	R		F	F																						
13	46ARy168		C	C			F							F	F																		
5	46ARy131C									F?																							
	46ARy131	20420																	+		×				+		+	×	+		+		
	49AKr1	26558																+															
	49ABe1	26560																+		+					+		+				+		
14	46AFi81C		R	C		A	F			C																							
	46AFi80			A		R?	R			F			F																				
Umiat test well 11	1,230–1,235 ft																															+	
13	46ARy165									R?				C		F					×												
15	46ARy150A		F?	A		F	R?	F?				F?																					
Umiat test well 11	1,427 ft																															+	
13	46ARy166		F	A			C?			F?																							
16	47ADt204				F?																×												
Umiat test well 1	379–387 ft																		+													+	
	387–397 ft																															+	
	397–407 ft																															+	
1	44AC525	19435																+															
2	46ASt103	20431																								+				+		+	×
1	46ASt3	20424																+			×												
2	46ASt96	20430																			×									+		+	
16	47ADt202		F								F?																						
	45AKr175						F	C?		A																							
	47ADt201		F				F?			F																							
1	44AC526	19436																				×	×										

restricted upward to the predominantly marine sections of the Colville Group overlying the Tuluvak Tongue of the Prince Creek Formation. The type section is at Schrader Bluff on the east bank of the Anaktuvuk River just south of its junction with the Tuluga River. As redefined, the upper 1,900 feet of the 2,700-foot exposure in Schrader Bluff is the type section of the Schrader Bluff Formation (Whittington, 1965, p. 249). In its outcrop area, the Schrader Bluff is divided into three members—the Rogers Creek, Barrow Trail, and Sentinel Hill.

DISTRIBUTION

The Schrader Bluff Formation is the major outcropping stratigraphic unit in the northeastern half of the Umiat-Maybe Creek region. Its southwestern limit lies along the south flank of the Prince Creek syncline. South of the Arctic Coastal Plain the western limit of the formation is about long 154° W. To the north in the Arctic Coastal Plain the western limit of the formation in the subsurface probably trends generally north-northwest toward Cape Simpson.

ROGERS CREEK MEMBER

NAME AND TYPE SECTION

The Rogers Creek Member is described as follows by Whittington (1956, p. 250):

The Rogers Creek member is the lowest named member of the Schrader Bluff formation. In the Umiat area it is very poorly exposed, but it is expressed as areas of subdued topography enclosed by the cuestas formed by the overlying Barrow Trail member. The subdued topography and scarcity of exposures suggest that the member is largely shale. It is named from the upper part of Rogers Creek, about 10 miles S. 80° W. of Umiat Mountain, where the subdued topography is typically developed (fig. 5).

The thickness of the Rogers Creek member in the vicinity of Umiat has been calculated as about 700 feet. It is 585–595 feet thick in the type section, designated as Gubik test well No. 1 from 295 to 890 feet and Gubik test well No. 2 from 555 to 1,140 feet (fig. 5).

A detailed description of the type sections in the Gubik wells is given by Robinson (1958, p. 214–215, 232–233). In these wells about two-thirds of the member is shale, which is interbedded with tuff, siltstone, sandstone, and bentonite.

Distribution and Lithology

The Rogers Creek Member crops out in two linear belts, along the Umiat-Square Lake anticline and along the south flank of the Prince Creek syncline. On the Umiat-Square Lake anticline older stratigraphic units crop out on both the Umiat and Square Lake highs, causing the belt of Rogers Creek to split in two at these places. In the Wolf Creek area the two belts join to form an extensive area of nearly flat-lying rocks of the Rogers Creek Member, which extends westward nearly to long 154° W.

The Rogers Creek outcrop belts are characterized by subdued topography having few and relatively faint bedding traces from which it may be inferred that the member is largely shale. The contact with the underlying Tuluvak Tongue of the Prince Creek Formation is not as well defined as its upper contact because of a gradual transition from the thick sandstone beds of the lower part of the Tuluvak Tongue through a shaly section containing much coal into a shaly section containing little or no coal. The member as mapped actually interfingers to a larger extent with the Tuluvak Tongue here than it does in the type area to the southeast. The contact is placed where coal becomes scarce and microfossils become common and is projected between points of control. The contact with the overlying Barrow Trail Member is easily approximated because of the conspicuous sandstone beds that characterize the Barrow Trail.

The best exposures of the Rogers Creek Member are on Prince Creek and its tributaries (strat. sections 12, 13 in the southern belt. In this area the member as mapped contains considerable coal and some wood-bearing conglomerate. The lower part is shale, bentonite, and limestone. Much of the shale contains common to abundant microfossils, and megafossils were found in a few places.

At Umiat, coal appears to be absent from most of the member. The member crops out at only one place in the Umiat area, but shotholes 14, 15, 33 and 34 furnish additional data. The outcrop (section 14, pl. 54; units 216 to 218, strat. section 14) exposes about 60 feet of interbedded claystone, siltstone, sandstone, and bentonite. Samples from the shotholes show that the member is largely shale containing conspicuous amounts of tuff and bentonite and minor amounts of siltstone and sandstone.

Thickness

Calculated thickness of the Rogers Creek Member is about 700 feet on the south flank of Umiat anticline and about 700 to 900 feet on the north flank. It is 825 feet thick near Prince Creek (Tommy Creek, section 12, pl. 54) and 720 feet thick at Wolf Creek (section 11, pl. 54).

BARROW TRAIL MEMBER

Name and Type Section

Whittington (1956, p. 250–251) described the Barrow Trail Member:

> The middle member of the Schrader Bluff formation is named from the Barrow Trail, an old tractor trail which, in the area from 13 to 28 miles west of Umiat Mountain, follows the cuesta formed by the sandstones of this member. The type locality is the bluffs along the north side of the Colville River, 3 to 5 miles northeast of Umiat Mountain, where the gently north-dipping rocks of the member are well exposed.
>
> In the vicinity of Umiat the member is 575 feet thick.
>
> * * * * *
>
> More than half the member at the type locality is fine- to very fine-grained, light gray to olive-gray, thick-bedded sandstone, in part bentonitic to tuffaceous. Interbedded with the sandstone are clay shale, siltstone, bentonite, and tuff. Marine fossils were found at five horizons from 40 feet to 525 feet above the base. A minor nonmarine tongue of the Prince Creek formation is represented in this type section by a 2-foot coal bed about 170 feet above the base.

The type section of the Barrow Trail Member is described in detail as units 148 to 214 of stratigraphic section 14. (See also section 14, pl. 54.)

Distribution and Lithology

The Barrow Trail crops out in the Prince Creek syncline and on the north flank of the Umiat-Square Lake anticline. The belt on the north flank of Prince Creek syncline forms a prominent ridge system that extends westward from Umiat to the vicinity of Wolf Creek and provides a favorable route for tracked vehicles. On the north flank of the Umiat-Square Lake anticline a short distance north of Umiat, the Barrow Trail Member makes a prominent ridge, but to the northwest this escarpment is broken at several places by north-flowing streams and becomes much lower and less prominent. This northern belt extends nearly to Square Lake and then disappears under the deposits of the Arctic Coastal Plain. Eastward the belts of outcrop cross the Colville River but are largely masked by terrace deposits there.

The Barrow Trail Member is largely sandstone and siltstone and separates the Rogers Creek and Sentinel Hill Members, which are largely shale. In the subsurface the Barrow Trail Member is recognized in the Gubik wells (Robinson, 1958, p. 209), but to the north it is not distinguishable as a separate unit in the Simpson and Fish Creek wells (Robinson, 1959b, p. 524; Robinson and Collins, 1959).

Thin-section studies show that the sandstones of the Barrow Trail Member range from those composed almost entirely of volcanic debris to those in which volcanic detritus cannot be identified. At one extreme these sandstones are vitric-crystal volcanic-ash arenites, at the other, subgraywackes.

In the pyroclastic arenites, angular crystal fragments make up about one-third to one-fifth of the rock, and the remainder of the grains and matrix are composed of glass, somewhat devitrified. Plagioclase is the principal constituent of the crystal phase which contains about ½ to ⅓ as much quartz and a considerable amount of biotite. Shard structure that is abundantly and excellently preserved in the vitric phase is evidence that much of the sediment as deposited consisted of sand-sized grains. Between crossed nicols the vitric phase is largely dark, but there are numerous scattered small slightly birefringent patches, and it is probable that much of the matrix has been altered. Some shards, however, appear to be completely isotropic. Carbonate is absent.

In the subgraywackes, subangular to subrounded quartz and chert grains are the principal constituents. Slate and phyllite grains are next in abundance, occurring in amounts as large as about 20 percent. Feldspar makes up only 5 to 10 percent of the grains, and biotite is scarce. Carbonate is present in small amounts in one slide.

Most of the sandstone of the Barrow Trail is intermediate to the extremes described above. Under a hand lens or binocular microscope much of the sandstone has a white aphanitic matrix, which in some specimens is the dominant constituent of the rock. The peculiar appearance of this soft white matrix, the common biotite, and the associated bentonite first suggested that these sandstones were tuffaceous; thin-section study confirmed it.

West of Umiat, near Prince Creek and Wolf Creek (sections 11, 12, and 13, pl. 54), the Barrow Trail Member contains less sandstone and more shale, and thin tongues of coal are more common than in the type section.

Thickness

In the bluffs east of Umiat the member is 575 feet thick. On lower Prince Creek (section 13, pl. 54) it is about 800 feet thick.

SENTINEL HILL MEMBER

Name and Type Section

The Sentinel Hill Member is a nonresistant unit of bentonitic to tuffaceous predominantly marine shale and claystone. It was named from Sentinel Hill core test 1. (See Gryc and others 1951, p. 166.) In this well, fossiliferous marine rocks of the Sentinel Hill Member are interbedded with nonmarine rocks of the Kogosukruk Tongue of the Prince Creek Formation between depths of 469 and 1,180 feet (total depth). A thick tongue of entirely nonmarine rocks (lower part of the Kogosukruk Tongue) at depths of 840 to 949 feet divides the member into an upper and a lower part. The total thickness of the Sentinel Hill Member at the well is unknown, as the contact of the lower part with the underlying Barrow Trail Member was not penetrated (Robinson in Robinson and Collins, 1959, p. 486–498).

The complete section of both the upper and lower parts of the Sentinel Hill Member is exposed only in bluffs on the west bank of the Colville River near the mouth of the Chandler River. This section, measured by Stefansson and Thurrell in 1947 and Stefansson and Whittington in 1946, has been designated the surface type section (Whittington, 1956, p. 251). In this section the base of the lower part of the Sentinel Hill Member rests conformably on the Barrow Trail Member and dips northward into the Kutchik syncline, reaching the level of the Colville River about 8 miles above its confluence with the Chandler River. The top of the lower part of the member coincides with the tops of the bluffs northward across both Kutchik syncline and Gubik anticline. On the north flank of Gubik anticline, opposite the mouth of the Chandler River, the top of the lower part of the member dips beneath river level and is succeeded by the interfingered lower part of the Kogosukruk Tongue. The upper part of the Sentinel Hill Member rests on this lower nonmarine tongue and crops out at river level three-fourths of a mile downstream. Three-fourths of a mile farther downstream it is succeeded by the upper part of the Kogosukruk Tongue.

Distribution

In 1947 Detterman and his party mapped the base of the Sentinel Hill Member. In addition, Stefansson and Thurrell mapped the approximate base of the lower part of the Kogosukruk Tongue of the Prince Creek Formation as a key horizon for structure-contouring the Gubik anticline. Mapping of both these horizons has been extended by tracing them on aerial photographs.

The upper part of the Sentinel Hill Member has been identified only at the surface type section and in the Sentinel Hill well, both on the Colville River. Field data show that the upper part may also be present on the Kogosukruk River, but it has not been traced across the area between the rivers. For convenience, therefore, the upper part of the Sentinel Hill Member is included with both parts of the Kogosukruk Tongue as an undifferentiated unit on the map, and the lower part of the Sentinel Hill Member has been mapped separately.

The lower part of the Sentinel Hill Member crops out in two areas north and west of the Colville River. The largest of these areas centers around Dogbone syncline between the Colville and Kikiakrorak Rivers and includes the type section. The smaller is along the axis of Prince Creek syncline.

In the Kikiakrorak-Colville area the lower part of the Sentinel Hill Member forms a narrow lowland that extends westward between sandstone cuestas of the Barrow Trail Member and the Kogosukruk Tongue of the Prince Creek Formation from the Colville bluffs to the head of the Kogosukruk River. West of the head of the Kogosukruk River, the outcrop belt strikes northward toward the axis of Dogbone syncline and is partly covered by surficial deposits. No fieldwork has been done in this area, and very few bedding traces are apparent on aerial photographs. The contact with the underlying Barrow Trail Member is vague, and therefore the Barrow Trail and Sentinel Hill Members have not been differentiated in the Arctic Foothills between the Kikiakrorak and Kogosukruk Rivers.

In the Prince Creek syncline the Sentinel Hill Member is reliably mapped on the south bank of the Colville (Detterman and others, 1963), but north of the Colville the member has been identified in the field only in the section measured by Detterman on the lowest tributary of Prince Creek. The Sentinel Hill Member there is similar in lithology to the underlying Barrow Trail Member and was not divided from it in the 1947 mapping, but the characteristic foraminifer *Eoeponidella strombodes* Tappan identified in collections from the upper part of the measured section suggests the member's presence there. The approximate base of the Sentinel Hill Member may be picked in the measured section (section 13, pl. 54), but the location of the contact beyond the line of section can only be inferred because outcrops and bedding traces are lacking.

Elsewhere in the Prince Creek area the presence of the Sentinel Hill Member is inferred from the thickness of rocks preserved in the syncline. If a thickness of 600 feet is assumed for the Barrow Trail Member about 4 miles southwest of Umiat test well 1, the base of the Sentinel Hill Member lies along the line where the dip slope of the Barrow Trail cuesta gives way to the high-level Colville River terraces. The topographic situation there is similar to that of the Sentinel Hill Member north of Umiat where Sentinel Hill shales underlie a lowland behind the Barrow Trail cuesta. The geometrically located contact has been extended westward around the axis of Prince Creek syncline by following a series of discontinuous bedding traces on the aerial photographs. The line so traced is stratigraphically above all known or apparent outcrops of the Barrow Trail Member and encloses an area of smooth covered slopes, swampy stream courses, and drainage heads characteristic of areas underlain by shale in this region.

South of the Umiat area the Sentinel Hill Member has been mapped (Detterman and others, 1963) along both flanks of the Prince Creek syncline and in three small areas on the Chandler and Anaktuvuk Rivers, the southernmost of which is about 28 miles south of the latitude of Umiat. North of the Umiat area the Sentinel Hill Member is found only in Fish Creek test well 1 (Collins in Robinson and Collins, 1959, p. 502). It is lacking in wells in the Arctic Coastal Plain west of there. The regional northward strike and eastward dip of shallow seismic horizons (Woolson and others, 1962) in the Arctic Coastal Plain indicate that the member is absent west of the longitude of the Kikiakrorak River. The Sentinel Hill Member is probably preserved downdip in the relatively unexplored Arctic Coastal Plain east of the Colville.

Thickness and Lithology

LOWER PART

The lower part of the Sentinel Hill Member is 389 feet thick at the type section (section 14, pl. 54) and is almost entirely clay, shale, bentonite, and tuff. Clay in the lower half is gray; that in the upper half weathers red to yellow. At the top of the section is a zone of tuff and bentonite 25 feet thick overlain conformably by sandstone of the Kogosukruk Tongue of the Prince Creek Formation. At the base is shale. Thin beds of tuff occur 12 feet above the base; and 32 feet of interbedded tuff, ash, bentonite, and clay occurs

42 feet above the base. Thin beds of bentonite are common throughout, and some in the lower half are a foot or more thick. Foraminifera, both arenaceous and calcareous, are abundant throughout the section from the uppermost tuff to within 30 feet of the base.

The lower part of the Sentinel Hill Member that is present in Sentinel Hill core test 1 extends from the depth of 949 feet to the bottom of the hole at 1,180 feet (pl. 54). The thickness of rocks penetrated (231 ft) is probably not more than half the full thickness of the lower part of the member here. The rocks penetrated are shale in the lower half and sandstone and shale in the upper half. The lowest sandstones in the upper half are thin bedded, very fine grained, and bentonitic and are interbedded with shale. They give way near the top to fine- and medium-grained calcareous, somewhat carbonaceous sandstone that is 35 feet thick. Banded shale that is 15 feet thick and in part silty lies between this sandstone and the basal sandstone of the Kogosukruk Tongue. Marine microfossils occur throughout.

In the section measured by R. L. Detterman on lower Prince Creek, rocks of the uppermost 308 feet have been assigned to the Sentinel Hill Member (units 1 to 8, strat. section 13). As in the other sections, they are largely shale, much of which is silty to sandy. Bentonite is scarce, and only one thin bed of very fine grained and slightly conglomeratic sandstone has been described. Except in the sandstone units, marine mircofossils are found in almost every exposed unit of the section. The Sentinel Hill Member was not distinguished in the Prince Creek section until *Eoeponidella strombodes* Tappan was identified in samples by H. R. Bergquist. On the Colville River this microfossil is common in the Sentinel Hill Member; accordingly, most of the rocks that contain it at Prince Creek are also included in the member. This species has been found at Prince Creek in three zones: 70 to 130 feet, 232 to 308 feet, and 342 to 356 feet below the top of the measured section. Between the lower two of these zones is a unit that includes 20 feet of green to red crossbedded fossiliferous sandstone. The base of the Sentinel Hill Member has been drawn above this sandstone in order to assign all the resistant beds to the Barrow Trail Member. The upper contact of the Sentinel Hill Member was not observed in the field at Prince Creek. The highest exposed unit is yellow-brown crossbedded silty shale that contains both marine microfossils and plant fragments. The plant fragments indicate that coaly nonmarine rocks of the lower part of the Kogosukruk Tongue may be only a short distance stratigraphically above this bed and that almost the full thickness of the member is exposed.

UPPER PART

In the type section the upper part of the Sentinel Hill Member is 316 feet thick. It consists of gray to brown bentonitic shale and claystone and four thin sandstone units, the lowest of which contains black chert pebbles (units 67 to 84, strat. section 14). Foraminifera, including *Eoeponidella strombodes*, are abundant in the shale and claystone 50 and 130 feet above the base, and megafossils occur in the sandstone at the top and in the sandstone 100 feet above the base. The two middle sandstone beds are unfossiliferous. About 70 feet below the top of the section are beds of bony coal totaling 3 feet in thickness. Plant spores are present in samples collected from the shale directly beneath the coal zone.

In Sentinel Hill core test 1 (pl. 54) the upper part of the member is 371 feet thick. Although it consists largely of noncalcareous shale, both sandstone and coal are more abundant here than they are in the type section. The sandstone beds aggregate 87 feet in thickness. Most are fine- to very fine-grained and less than 5 feet thick, but at the center of the section is a 69-foot unit of fine- to medium-grained sandstone that grades upward from hard calcareous bentonitic sandstone to soft noncalcareous carbonaceous sandstone. This sandstone unit is correlated with the two middle sandstone units in the type section. Coal and lignite beds from 1 to 5 inches thick are present in the upper 30 feet of the core test section, the lowest 40 feet, and just above the thick carbonaceous sandstone at the middle. In addition, thin coaly streaks are found in some of the shale as well as in the carbonaceous sandstone. The coal near the middle of the core test section is at the stratigraphic position of the single zone of coal beds found in the type section. The upper and lower coal beds are not found in the type section.

The coal-bearing beds and the thick coaly nonfossiliferous coarser grained sandstone at the middle of the section may each be considered part of the Kogosukruk Tongue of the Prince Creek Formation. However, marine microfossils and pelecypods occur in the upper and lower coal-bearing intervals and are lacking only in the thick carbonaceous sandstone at the middle of the section. The interbedded nonmarine units have been included in the upper part of the Sentinel Hill Member to differentiate this largely marine unit from the largely nonmarine units above and below.

The upper part of the Sentinel Hill Member may also crop out on the upper Kogosukruk River and

Henry Creek. The base of the Kogosukruk Tongue is the highest mapped horizon but it serves as a datum for correlation of the younger beds. At Texas Hill (fig. 111 and loc. 5, fig. 107) Stefansson collected *Mytilus* sp. from sandstone (47ASt17 USGS Mesozoic loc. 26489) and Foraminifera from shale (47ASt14, 47ASt12) in a coal-bearing sequence in the upper 150 feet of the lower part of the Kogosukruk Tongue. Fossiliferous sandstone and shale at approximately the horizon of the *Mytilus*-bearing sandstone about 50 feet below the projected top of the lower part of the Kogosukruk Tongue also crop out on Henry Creek about 5 miles above its mouth (47ASt23 USGS Mesozoic loc. 26490, loc. 6, fig. 107). Fossiliferous beds, about 50 feet higher stratigraphically, crop out on Henry Creek about 3 miles above its mouth (47ASt24 USGS Mesozoic loc. 26491, loc. 4, fig. 107). At each of these localities the fossiliferous beds are near the horizon at which the upper part of the Sentinel Hill Member should appear, and at each locality they are close to, or interbedded with, coal beds. The stratigraphic sequence above them is only partly known, and there may be a thick unit of entirely marine rocks in addition to these tongues. Coal, however, occurs in almost all outcrops described by Stefansson and Thurrell in this area, so it seems likely that nonmarine rocks interfinger with the marine rocks throughout.

Shoreline Trend

The measured sections of the Sentinel Hill Member are too few and too incomplete to give more than a clue as to the trend of the shoreline. A general northward thickening of the Sentinel Hill is indicated by the northward increase in the thickness of the upper part of the member from 315 feet at the type section to 371 feet in Sentinel Hill core test 1. The absence of coal from the lower part of the member and its presence in the upper part indicate an environment that became more nonmarine as time progressed.

The relative abundance of the coal in the upper part of the Sentinel Hill Member at different localities may indicate the trend of the shoreline. At the type section, coal in the upper part of the member is scarce. To the north at the Sentinel Hill well, the coal at the top of the section represents nonmarine beds that are included in the Sentinel Hill Member only because marine tongues extend stratigraphically higher there than at the type locality, but the coal in the bottom of the well section seems to represent nonmarine tongues not found at the type locality. Coal is apparently even more abundant to the west near Texas Hill on the Kogosukruk River. Therefore, the upper part of the Sentinel Hill Member within the Colville-Kogosukruk Rivers area seems to become slightly more nonmarine north of the type locality and much more nonmarine west of the type locality, indicating a shoreline trend at least locally northward or northeastward.

Paleontology and Correlation

In the Umiat-Maybe Creek region, the Schrader Bluff Formation encompasses a somewhat fossiliferous succession of predominantly marine strata about 2,000 to 2,500 feet thick. The middle third of this succession, the Barrow Trail Member, includes most of the sandstone of the formation, and most of the megafossils came from these sandstone beds. In contrast, the shaly Rogers Creek and Sentinel Hill Members yield most of the microfossils found in the formation. Megafossils from the Barrow Trail Member indicate that this part of the formation is middle Santonian to early Campanian in age. Microfossils indicate that most of, if not all, the formation is post-Turonian in age but not younger than Maestrichtian.

Fossil occurrences in the Schrader Bluff Formation in the Umiat-Maybe Creek region are shown in figures 107, 108, and 109. Fossil identifications are shown in tables 5 and 6. Microfossils were identified by H. R. Bergquist and Helen Tappan. Megafossils were identified by George Gryc except for parts of the collections from USGS Mesozoic localities 19641 to 19644 and the *Inoceramus* from locality 19434. Collections from localities 19641 to 19644 were made by W. L. Kreidler of the U.S. Navy, and specimens in these four collections that are referred to the genera *Periplomya*, *Trigonocallista*, *Lunatia*, and *Oligoptycha* were identified by J. S. Templeton of the U.S. Navy. *Inoceramus patootensis* de Loriol from locality 19434 was identified by D. L. Jones.

Among the megafossils the genera *Protocardia*, *Tellina*, *Panope* and *Gyrodes* are most common, each being represented in 7 to 10 of the 20 collections from the Schrader Bluff Formation in the Umiat-Maybe Creek region. According to George Gryc (written commun., 1959), these common pelecypods in the Umiat-Maybe Creek collections range through the entire Upper Cretaceous, as far as known.

The single collection of *Inoceramus* (*Sphenoceramus*) *patootensis* de Loriol (loc. 19434) is diagnostic. Together with *I. (S.) steenstrupi* de Loriol, this *Inoceramus* is common in the Barrow Trail Member outside the Umiat-Maybe Creek region, and the member has been assigned a late Santonian and early Campanian age on the basis of these fossils (Jones and Gryc, 1960, p. 153). George Gryc also stated (written commun., 1959) that *Protocardia cf. P. borealis* is

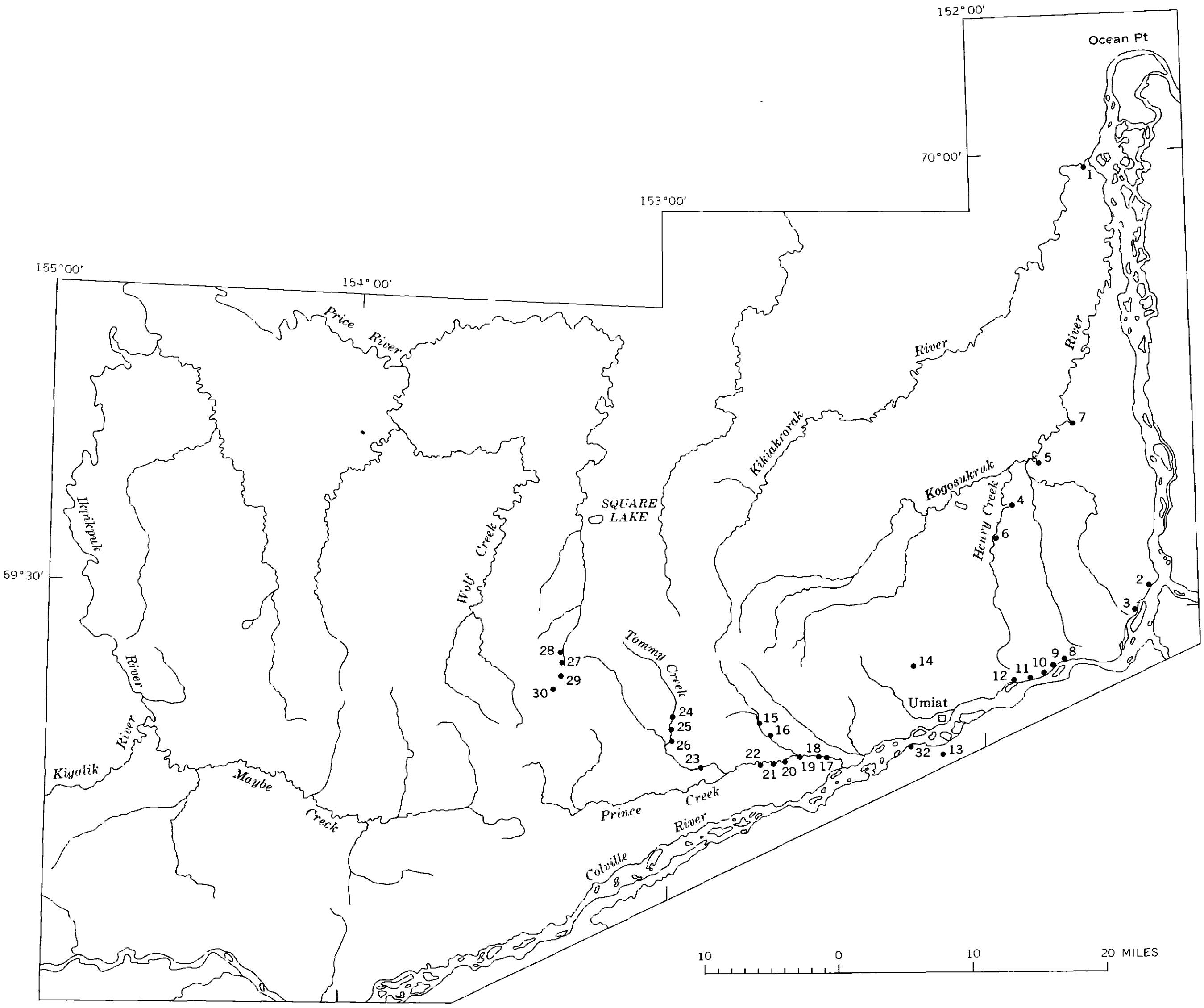

FIGURE 107.—Fossil localities in outcrops of the Schrader Bluff and Prince Creek Formations (see figs. 108, 109).

abundant in the Schrader Bluff Formation and occurs with *Inoceramus patootensis* de Loriol and *I. steenstrupi* de Loriol. Although *I. patootensis* is reported from only one collection from the Umiat-Maybe Creek region, it may be represented in several other collections by fragmental material. Stefansson recorded an uncollected *Inoceramus* at locality 20425 and *Inoceramus* fragments at localities 20428 and 20429; Whittington found *Inoceramus* fragments at about the horizons of localities 19437 and 20429.

Overall, the faunas of the Barrow Trail and Sentinel Hill Members are about the same. *Nucula* and *Legumen* are reported only from the Barrow Trail Member, and *Mytilus* and *Leptosolen*, only from the Sentinel Hill Member; but these differences are probably only accidental. George Gryc (oral commun., 1959) has identified *Mytilus* in the Barrow Trail Member at Umiat and at one or more localities south of the Colville. *Ostrea* was found in 1948 in about the lowest part of the Barrow Trail. Pelecypod fragments are common in outcrops of the few sandstone beds of the Sentinel Hill Member and are abundant in shale and sandstone throughout the upper part of the member in the Sentinel Hill well (Robinson in Robinson and Collins, 1959, p. 489, 493–496).

Microfauna

Foraminifera are generally more abundant in the Schrader Bluff Formation than they are in the Seabee, but most species occur in both formations. *Neobulimina canadensis* has been selected as one of the zonal markers for the Schrader Bluff (Tappan, 1960, p. 285). Two species of *Eoeponidella* especially charac-

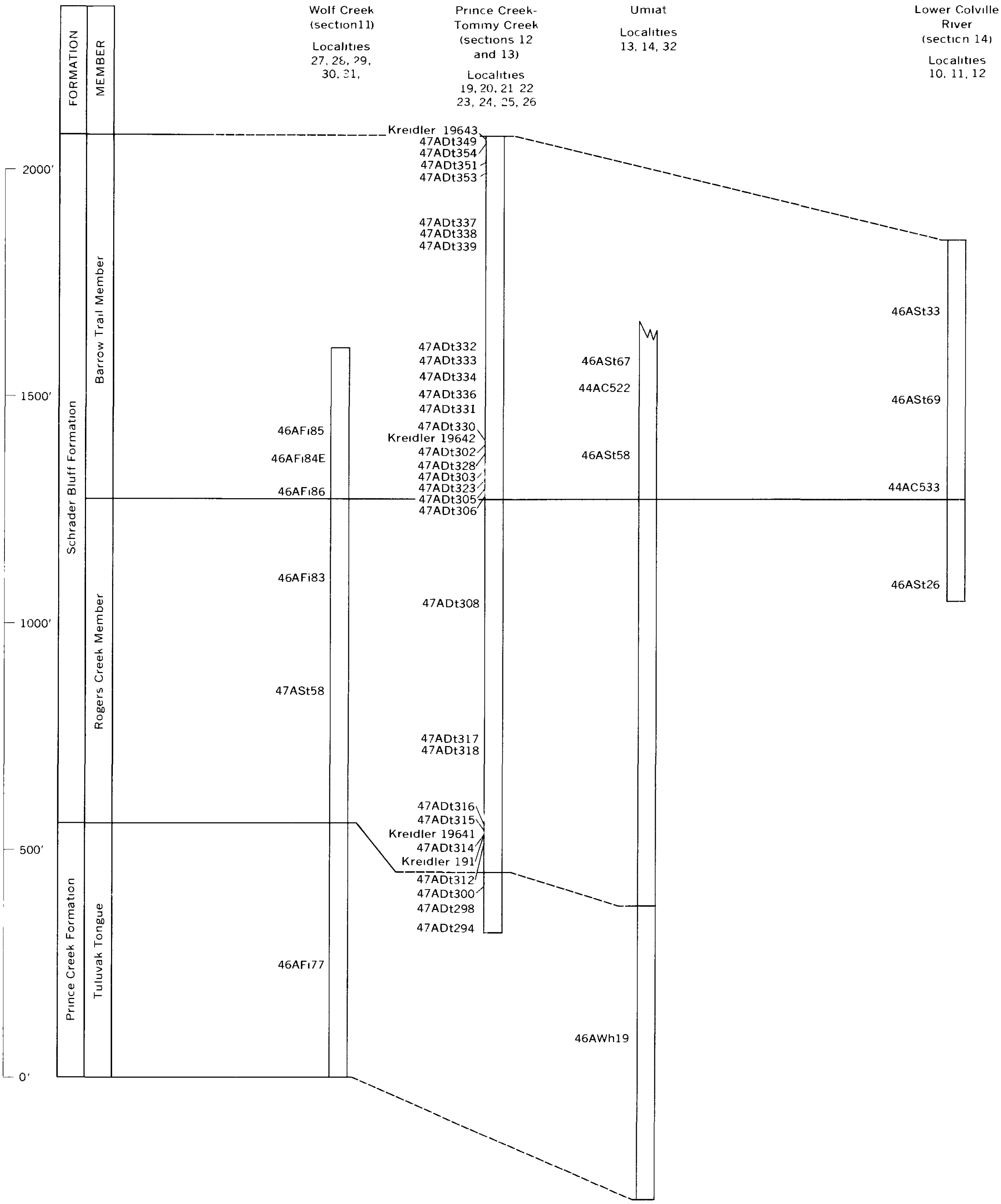

FIGURE 108.—Stratigraphic position of fossils collected from the Tuluvak Tongue of the Prince Creek Formation and the Rogers Creek and Barrow Trail Members of the Schrader Bluff Formation. Fossil identifications are given in table 3 and stratigraphy is shown on plate 54.

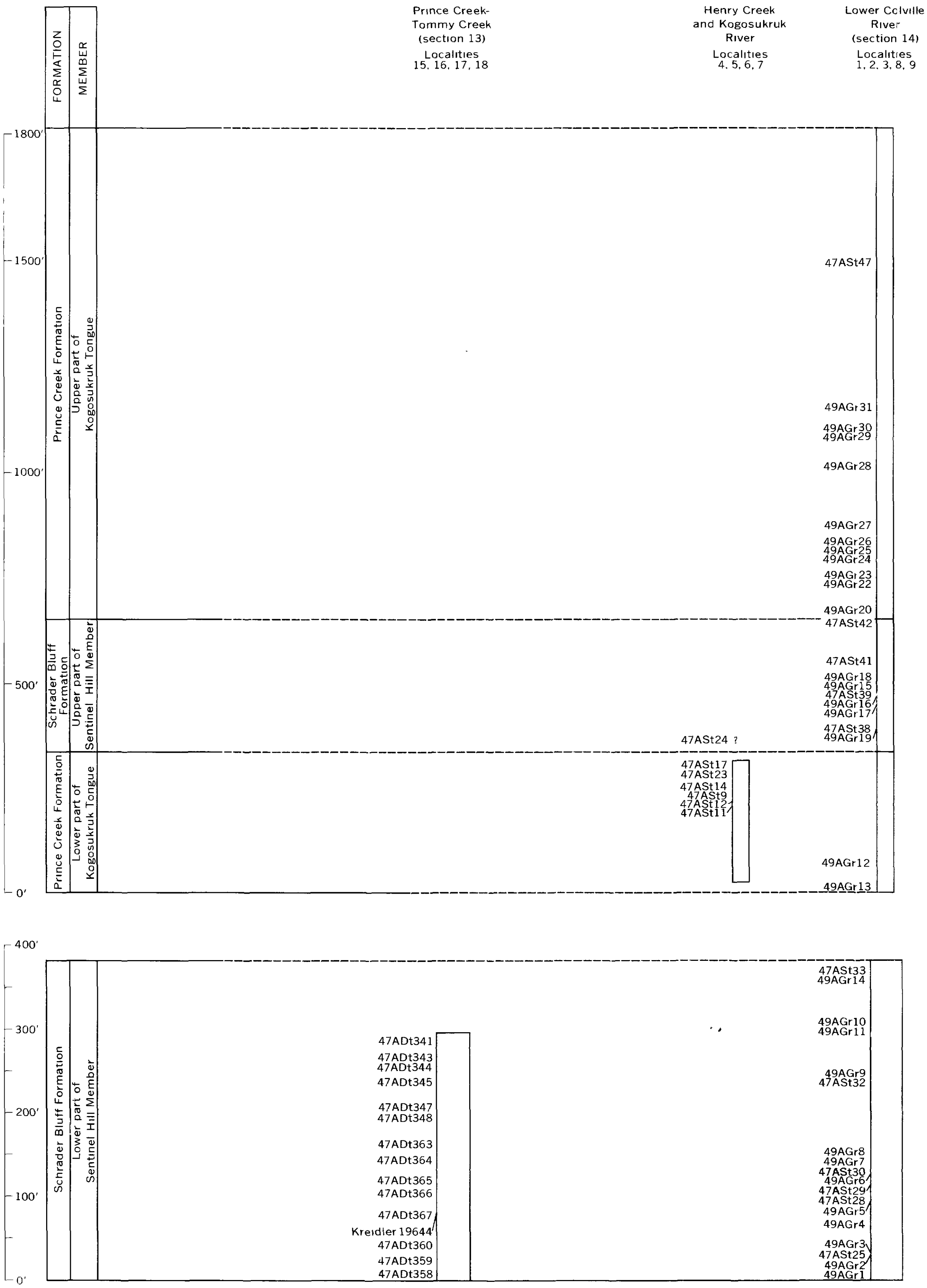

FIGURE 109.—Stratigraphic position of fossils collected from the Sentinel Hill Member of the Schrader Bluff Formation and the Kogosukruk Tongue of the Prince Creek Formation. Fossil identifications are given in table 4 and stratigraphy is shown on plate 54.

terize the Sentinel Hill Member, but *Eoeponidella* also occurs in a few places in the upper part of the Barrow Trail.

Radiolaria are much more common in the Schrader Bluff Formation than they are in the Seabee, and the number of species present is considerably larger. In the Umiat-Maybe Creek region the most notable occurrences are in the lower part of the Sentinel Hill Member in outcrops along the Colville River and in Umiat shothole 20. The radiolarian fauna from the Rogers Creek and Barrow Trail Members is more restricted in number of species.

Tappan (1960, p. 289) assigned the Foraminifera of the Schrader Bluff Formation to the *Trochammina ribstonensis–Neobulimina canadensis* zone of Senonian age. Most of the diagnostic species range throughout the Schrader Bluff Formation.

PRINCE CREEK FORMATION

The Prince Creek Formation comprises the predominantly nonmarine parts of the Colville Group, and in the outcrop area it consists of two major tongues. The Tuluvak Tongue lies upon the marine Seabee Formation and is overlain by the marine Schrader Bluff Formation. The Kogosukruk Tongue is intertongued with the uppermost member of the Schrader Bluff Formation and is the highest unit in the Colville Group; no younger Cretaceous rocks are known in the area.

The Prince Creek Formation was named by Gryc, Patton, and Payne (1951, p. 166) from the type locality at Prince Creek. The formation is not well exposed on Prince Creek itself and only the Tuluvak Tongue is present there. However, the Tuluvak Tongue crops out conspicuously just north of Prince Creek, and the Prince Creek area is one in which the nonmarine environment has been relatively persistent, because minor undifferentiated nonmarine tongues are common even in the marine Schrader Bluff Formation there.

The Prince Creek Formation can be distinguished from the marine formations of the Colville Group because the Prince Creek contains a greater abundance of medium- to coarse-grained sandstone and conglomerate, lacks invertebrate fossils, and contains an abundance of coal and plant remains. It can be distinguished from the nonmarine formations of the Nanushuk Group because it contains an abundance not only of bentonite but also of tuff: Both the Tuluvak and Kogosukruk Tongues have conglomerate beds near their base that persist over wide areas, and both tongues overlie marine units that consist mostly of nonresistant shale (the Seabee Formation and the Sentinel Hill Member of the Schrader Bluff Formation) so that the basal contact of each tongue is easily traceable by its topographic expression as well as by the lithologic break.

Although the basal contacts of the nonmarine tongues are clearly defined both topographically and lithologically and may be traced consistently by either criterion, the upper contacts are not. The top of the Tuluvak Tongue apparently grades into the overlying Rogers Creek Member of the Schrader Bluff Formation in the Prince Creek area; the upper part of the Kogosukruk Tongue is interbedded with the Sentinel Hill Member of the Schrader Bluff in the lower Colville area. The nonresistant Rogers Creek Member can be distinguished topographically from the Tuluvak Tongue, but the upper part of the Sentinel Hill Member has not been differentiated from the Kogosukruk Tongue in the mapping.

TULUVAK TONGUE

Name and Type Section

The Tuluvak Tongue was named by Gryc, Patton, and Payne (1951, p. 166) from Tuluvak Bluffs on the Chandler River at lat 69°13′ N., long 151°25′ W., where coal and conglomerate occur in abundance. Because these exposures at Tuluvak Bluffs are incomplete, Detterman (in Detterman and others, 1963) designated Schrader Bluff on the Anaktuvuk River as a reference locality. There, conglomerate is scarcer than usual, but the tongue is exposed in its full thickness. It consists of medium- to fine-grained sandstone, shale, bentonite, and a few beds of coal. It lies conformably upon the Ayiyak Member of the Seabee Formation and is overlain conformably by the Rogers Creek Member of the Schrader Bluff Formation.

Distribution

In the eastern part of the Umiat-Maybe Creek region the Tuluvak Tongue crops out only at the crest of the anticline at Umiat. In the western part of the area it crops out around all the structural features north of Maybe Creek.

In Banshee, Lupine, and Billy synclines the rocks lie almost flat; there, the Tuluvak Tongue is the highest unit preserved. Its basal conglomerate forms a clear, continuous marker; the resistant sandstones of the tongue cap the hills over broad areas in the synclines and also lie across the plunging nose of the Titaluk anticline at the head of Maybe Creek. South of Maybe Creek small outliers of the tongue are found on hilltops along the Lupine syncline axis as far west as the head of September Creek. Over most of this area, the lower contact of the tongue has

TABLE 3.—*Fossils collected from outcrops of the Tuluvak Tongue of the Prince Creek*

[Arranged in approximate stratigraphic order. Abundance of species indicated by number of specimens in each sample: F, 1 to 6; R, 6 to 12; C, 13 to 25; A, more than 25. Megafossils identified by George

Locality (fig. 107)	Field sample No. (fig. 108)	Megafossil collections U.S.G.S. Mesozoic locality No.	Microfossils: Barren	*Saccammina lathrami* Tappan	*Glomospira* sp.	*Ammodiscus cretaceus* (Reuss)	*Reophax* sp.	*Haplophragmoides rota* Nauss	*Spiroplectammina mordensis* Wickenden	*Textularia rollaensis* Stelck and Wall	*Verneuilinoides fischeri* Tappan	*Dorothia smokeyensis?* Wall	*Trochammina ribstonensis* Wickenden	*Trochammina whittingtoni* Tappan	*Trochammina* sp.	*Quinqueloculina sphaera* Nauss	*Miliammina bisobscura* Stelck and Wall	*Marginulina* sp.	*Vaginulina schraderensis* Tappan	*Neobulimina canadensis* Cushman and Wickenden	*Praebulimina carseyae* (Plummer)	*Eoeponidella linki* Wickenden	*Eoeponidella strombodes* Tappan	*Gavelinella ammonoides* (Reuss)
Barrow Trail Member of Schrader Bluff Formation																								
19	Kreidler 19643	19643																						
	47ADt 349							R			F		F											
	354	26507																						
	351							R	F	F?	F?		F?								F		F	F
	353		■																					
20	337							F																
	338			F				C								F					F	F	F	
	339			F				R												F				
10	46ASt 33	20425																						
21	47ADt 332				F	R		C					C	F										
	333					A				R?			A											
13	46ASt 67	20428																						
21	47ADt 334																							
11	46ASt 69	20429																						
32	44AC 522	19434																						
21	47ADt 336	26506																						
22	331		■																					
27	46AFi 85		■																					
22	47ADt 330	26505																						
	Kreidler 19642	19642																						
24	47ADt 302		■																					
22	328		■																					
27	46AFi 84E							F		C			R				F							
24	47ADt 303		■																					
22	323		■																					
24	305										F				R									
	306		■																					
28	46AFi 86		■																					
32	46ASt 58	20427																						
	44AC 533	19437																						

Formation and the Rogers Creek and Barrow Trail Members of the Schrader Bluff Formation

Other symbols used: ×, present; ?, identification queried because of poor preservation; ■, barren. Microfossils identified by H. R. Bergquist and Helen Tappan Lœblich. Gryc, D. L. Jones, and J. S. Templeton]

Microfossils—Continued									Megafossils																									
Gavelinella tumida Brotzen	*Anomalinoides pinguis* (Jennings)	*Anomalinoides talaria* (Nauss)	*Cenosphaera* sp.	*Spongurus (Spongurantha)* sp. B	*Zonodiscus* sp. C	*Spongodiscus* cf. *S. renillaeformis* Campbell and Clark	*Archicorys* sp. A	*Dictyomitra multicostata* Zittell	*Nucula* sp.	*Yoldia* sp.	*Glycymeris* cf. *G. borealis* Whiteaves	*Gervillia?*	*Inoceramus (Sphenoceramus) patootensis* deLoriol	*Inoceramus* sp.	*Pecten* sp.	*Volsella* cf. *V. meeki* (Evans and Shumard)	*Volsella* sp.	*Pholadomya* sp.	*Periplomya* sp.	*Arctica* cf. *A. ovata* (Meek and Hayden)	*Arctica* sp.	*Tancredia* cf. *T. americana* Meek and Hayden	*Corbula?* sp.	*Cardium?* sp.	*Protocardia* cf. *P. borealis* Whiteaves	*Protocardia* sp.	*Trigonocallista* sp.	*Tellina* sp.	*Legumen* sp.	*Panope* sp.	*Gyrodes* sp.	*Lunatia* sp.	*Desmoscaphites?* sp.	Shark tooth
Barrow Trail Member of Schrader Bluff Formation—Continued																																		
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TABLE 3.—*Fossils collected from outcrops of the Tuluvak Tongue of the Prince Creek*

Locality (fig. 107)	Field sample No. (fig. 108)	Megafossil collections U.S.G.S. Mesozoic locality No.	Microfossils																					
			Barren	*Saccamina lathrami* Tappan	*Glomospira* sp.	*Ammodiscus cretaceus* (Reuss)	*Reophax* sp.	*Haplophragmoides rota* Nauss	*Spiroplectammina mordensis* Wickenden	*Textularia rollaensis* Stelck and Wall	*Verneuilinoides fischeri* Tappan	*Dorothia smokyensis?* Wall	*Trochammina ribstonensis* Wickenden	*Trochammina whittingtoni* Tappan	*Trochammina* sp.	*Quinqueloculina sphaera* Nauss	*Miliammina bisobscura* Stelck and Wall	*Marginulina* sp.	*Vaginulina schraderensis* Tappan	*Neobulimina canadensis* Cushman and Wickenden	*Praebulimina carseyae* (Plummer)	*Eoeponidella linki* Wickenden	*Eoeponidella strombodes* Tappan	*Gavelinella ammonoides* (Reuss)
Rogers Creek Member of Schrader Bluff Formation																								
29	46AFi 83			C				C		F	F		A											
12	46ASt 26			R				C			A	F?		A										
25	47ADt 308										R	R?	R											
31	47ASt 58			R				C		C	C		A											
23	47ADt 317		■																					
	318							F?																
	316					F?					C		A											
	315			R		F?		F			R		R					×						F
	Kreidler 19641	19641																						
	47ADt 314	26528																						
	Kreidler 191																							
	47ADt 312										F								F	R		F?		F
Tuluvak Tongue of Prince Creek Formation																								
26	47ADt 300		■																					
	298												F?											
	294											F?												
30	46AFi 77		■																					
14	46AWh 19			F				F																

Formation and the Rogers Creek and Barrow Trail Members of the Schrader Bluff Formation—Continued

Microfossils—Continued									Megafossils																									
Gavelinella tumida Brotzen	*Anomalinoides pinguis* (Jennings)	*Anomalinoides talaria* (Nauss)	*Cenosphaera* sp.	*Spongurus* (*Spongurantha*) sp. B	*Zonodiscus* sp. C	*Spongodiscus* cf. *S. renillaeformis* Campbell and Clark	*Archicorys* sp. A	*Dictyomitra multicostata* Zittell	*Nucula* sp.	*Yoldia* sp.	*Glycymeris* cf. *G. borealis* Whiteaves	*Gervillia?*	*Inoceramus* (*Sphenoceramus*) *patootensis* de Loriol	*Inoceramus* sp.	*Pecten* sp.	*Volsella* cf. *V. meeki* (Evans and Shumard)	*Volsella* sp.	*Pholadomya* sp.	*Periplomya* sp.	*Arctica* cf. *A. ovata* (Meek and Hayden)	*Arctica* sp.	*Tancredia* cf. *T. americana* Meek and Hayden	*Corbula?* sp.	*Cardium?* sp.	*Protocardia* cf. *P. borealis* Whiteaves	*Protocardia* sp.	*Trigonocallista* sp.	*Tellina* sp.	*Legumen* sp.	*Panope* sp.	*Gyrodes* sp.	*Lunatia* sp.	*Desmoscaphites?* sp.	Shark tooth
Rogers Creek Member of Schrader Bluff Formation—Continued																																		
		C	F																															
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							F																											
F	F?					F																												
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Tuluvak Tongue of Prince Creek Formation—Continued																																		

TABLE 4.—*Fossils collected from outcrops of the Sentinel Hill Member of the*

[Arranged in approximate stratigraphic order. Abundance of species indicated by number of specimens in each sample: F, 1 to 6; R, 6 to 12; C, 13 to 25; A, more than 25. Megafossils identified by George

Locality (fig. 107)	Field sample No. (fig. 109)	Megafossil collections U.S.G.S. Mesozoic locality No.	Microfossils																				
			Barren	*Bathysiphon* sp.	*Saccammina lathrami* Tappan	*Glomospira* sp.	*Ammodiscus cretaceus* (Reuss)	*Reophax* sp.	*Haplophragmoides rota* Neuss	*Spiroplectammina mordensis* Wickenden	*Textularia rollaensis* Stelck and Wall	*Verneuilinoides fischeri* Tappan	*Dorothia smokyensis?* Wall	*Trochammina diagonis?* Carsey	*Trochammina ribstonensis* Wickenden	*Trochammina whittingtoni* Tappan	*Trochammina* sp.	*Quinqueloculina sphaera* Nauss	*Miliammina bisobscura* Stelck and Wall	*Lenticulina gryci* Tappan	*Marginulina* sp.	*Dentalina basiplanata* Cushman	*Vaginulina schraderensis* Tappan
Upper part of Kogosukruk Tongue of Prince Creek Formation																							
1	47ASt47	26492																					
2	49AGr31		■																				
	30		■																				
	29		■																				
	28		■																				
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	24		■																				
	23		■																				
	22		■																				
	20								F?														
Upper part of Sentinel Hill Member of Schrader Bluff Formation																							
2	47ASt42	26494																					
	41		■																				
3	49AGr18																						
	15																						
	47ASt39						R		A														
	49AGr16								F?														
	17		■																				
	47ASt38				C		F		C							A							
	49AGr19		■																				
4	47ASt24?	26491																					
Lower part of Kogosukruk Tongue of Prince Creek Formation																							
5	47ASt17	26489																					
6	23	26490																					
5	14								F														
7	9		■																				
5	12				F																		
7	11		■																				
8	49AGr12		■																				
	13		■																				

Schrader Bluff Formation and the Kogosukruk Tongue of the Prince Creek Formation

Other symbols used: X, present; ?, identification queried because of poor preservation; ■, barren. Microfossils identified by H. R. Bergquist and Helen Tappan Loeblich. Gryc, D. L. Jones, and J. S. Templeton]

Microfossils—Continued																				Megafossils																		
Neobulimina canadensis Cushman and Wickenden	*Praebulimina carseyae* (Plummer)	*Nonionella taylorensis* Hofker	*Eoeponidella linki* Wickenden	*Eoeponidella strombodes* Tappan	*Gavelinella ammonoides* (Reuss)	*Gavelinella tumida* Brotzen	*Anomalinoides pinguis* (Jennings)	*Anomalinoides talaria* (Nauss)	*Gaudryina* sp.	*Cenosphaera (Cenosphaera)* sp. A	*Cenosphaera (Phormosphaera)* sp. B	*Spongurus (Spongurantha)* sp. A	*Spongurus (Spongurantha)* sp. B	*Zonodiscus?* sp. C	*Spongodiscus* cf. *S. renillaeformis* Campbell and Clark	*Spongodiscus* sp. B	*Stylospongia (Stylotrochiscus)* sp. A	*Archicorys* sp. A	*Dictyomitra multicostata* Zittel	*Yoldia* sp.	*Yoldia?* sp.	*Inoceramus* sp.	*Pecten* sp.	*Mytilus* cf. *M. subarcuatus* (Meek)	*Mytilus* sp.	*Volsella* sp.	*Pholadomya* sp.	*Tancredia* sp.	*Protocardia* cf. *P. borealis* Whiteaves	*Tellina* sp.	*Leptosolen* sp.	*Panope* sp.	*Gyrodes* sp.	*Lunatia* sp.	*Oligoptycha* sp.	*Haminea* sp.	Gastropods, unidentified	Fish vertebra
Upper part of Kogosukruk Tongue of Prince Creek Formation—Continued																																						
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Upper part of Sentinel Hill Member of Schrader Bluff Formation—Continued																																						
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Lower part of Kogosukruk Tongue of Prince Creek Formation—Continued																																						
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TABLE 4.—*Fossils collected from outcrops of the Sentinel Hill Member of the*

Locality (fig. 107)	Field sample No. (fig. 109)	Megafossil collections U.S.G.S. Mesozoic locality No.	Microfossils																				
			Barren	*Bathysiphon* sp.	*Saccammina lathrami* Tappan	*Glomospira* sp.	*Ammodiscus cretaceus* (Reuss)	*Reophax* sp.	*Haplophragmoides rota* Nauss	*Spiroplectammina mordensis* Wickenden	*Textularia rollaensis* Stelck and Wall	*Verneuilinoides fischeri* Tappan	*Dorothia smokyensis?* Wall	*Trochammina diagonis?* Carsey	*Trochammina ribstonensis* Wickenden	*Trochammina whittingtoni* Tappan	*Trochammina* sp.	*Quinqueloculina sphaera* Nauss	*Miliammina bisobscura* Stelck and Wall	*Lenticulina gryci* Tappan	*Marginulina* sp.	*Dentalina basiplanata* Cushman	*Vaginulina schraderensis* Tappan
Lower part of Sentinel Hill Member of Schrader Bluff Formation																							
8	47ASt33								R						F								
	49AGr14				F				R														F
	10		■																				
	11		■																				
15	47ADt341																				×		F?
16	343				F				F?			F											
	344								R														
8	49AGr9		■																				
	47ASt32	Fragments in microfossil collection.			R	F			A			R	R		C								F
16	47ADt345																						
	347				F	F?			R														
	348			×	F		F		C						R			F				×	F?
17	363								F?			F	F	R									
	364								A				C	C?	F								
9	49AGr8	Fragments in microfossil collection.																					
17	47ADt365								F				F	R?									
9	49AGr7								F			F?	R										
	47ASt30				R				F?				F		A	F			F				F
	49AGr6								F				F										
	47ASt29			F	A		F	R		C			A		R	A							
17	47ADt366						F																
9	47ASt28				R		R				R	R	C		A	A							
	49AGr5				F				F														
17	47ADt367								C				R				F						
9	49AGr4								F?														
18	Kreidler 19644	19644																					
9	49AGr3								F														
	47ASt25				F		F		A			F	R										
	49AGr2								F				F										
18	47ADt360								R			F?			F			F		×			
	359				F				C				F			C							F
9	49AGr1				F				F							F							
18	47ADt358				F				R			F	F								F		

Schrader Bluff Formation and the Kogosukruk Tongue of the Prince Creek Formation—Continued

Microfossils—Continued																				Megafossils																		
Neobulimina canadensis Cushman and Wickenden	*Praebulimina carseyae* (Plummer)	*Nonionella taylorensis* Hofker	*Eoeponidella linki* Wickenden	*Eoeponidella strombodes* Tappan	*Gavelinella ammonoides* (Reuss)	*Gavelinella tumida* Brotzen	*Anomalinoides pinguis* (Jennings)	*Anomalinoides talaria* (Nauss)	*Gaudryina* sp.	*Cenosphaera (Cenosphaera)* sp. A	*Cenosphaera (Phormosphaera)* sp. B	*Spongurus (Spongurantha)* sp. A	*Spongurus (Spongurantha)* sp. B	*Zonodiscus?* sp. C	*Spongodiscus* cf. *S. renillaeformis* Campbell and Clark	*Spongodiscus* sp. B	*Stylospongia (Stylotrochiscus)* sp. A	*Archicorys* sp. A	*Dictyomitra multicostata* Zittel	*Yoldia* sp.	*Yoldia?* sp.	*Inoceramus* sp.	*Pecten* sp.	*Mytilus* cf. *M. subarcuatus* (Meek)	*Mytilus* sp.	*Volsella* sp.	*Pholadomya* sp.	*Tancredia* sp.	*Protocardia* cf. *P. borealis* Whiteaves	*Tellina* sp.	*Leptosolen* sp.	*Panope* sp.	*Gyrodes* sp.	*Lunatia* sp.	*Oligoptycha* sp.	*Haminea* sp.	Gastropods, unidentified	Fish vertebra
Lower part of Sentinel Hill Member of Schrader Bluff Formation—Continued																																						
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been mapped in the field by Whittington and Troyer at September Creek, by Ray and Fischer in the Maybe Creek-Wolf Creek area, by Brosgé and Kover in the Maybe Creek-Ikpikpuk area, and by Detterman and Bickel in the area east of Puddin Lake at the head of Prince Creek. The outliers of the tongue just south of Maybe Creek have been mapped from aerial photographs and from the field notes of Ray and Fischer. Aerial photographs have also been used to extend the field mapping around the western end of the outcrops in Billy syncline and around the eastern end of the outcrops just west of Puddin Lake.

North of Wolf Creek the Tuluvak Tongue forms the lowest escarpment in the series of steplike escarpments that rise to a summit at the axis of Prince Creek syncline. There, as to the south, the basal conglomerate forms a prominent ledge, and aerial photographs have been used to extend Ray and Fischer's mapping of the bottom contact westward to the place where it disappears in the Arctic Coastal Plain. Their mapped contact has also been traced eastward on aerial photographs to join Detterman and Bickel's mapping just east of Puddin Lake. From Puddin Lake to Prince Creek the outcrops are covered by high-level terrace gravels, and the location of the Tuluvak Tongue on Prince Creek itself has been inferred from the location of the outcrops of the Schrader Bluff Formation downstream. North of Prince Creek syncline, the base of the tongue does not crop out; but it does occur 700 feet below the surface in Square Lake test well 1 on Square Lake anticline. The upper part of the tongue does crop out and forms low hills at the foot of the Prince Creek synclinal escarpment close to the edge of the Arctic Coastal Plain. Bedding traces there are partly hidden, and the tongue has been mapped from its topographic expression and by projection of its thickness along surface and subsurface dips.

The upper contact of the Tuluvak Tongue has not been mapped separately in the field because the Tuluvak and the overlying Rogers Creek Member were mapped in the field as a single unit in most of the region. The contact of the Tuluvak with the Rogers Creek in the western part of the area is located by field observation in the measured sections at Tommy Creek and Wolf Creek. Elsewhere in the western area it has been mapped either by tracing beds from these control points or on the basis of approximate thickness and topographic character of the formations. Therefore, except in the type area of the Rogers Creek Member at Umiat, the contact between the Tuluvak Tongue and the Rogers Creek Member has been mapped as inferred.

Thickness and Lithology in the Umiat Area

Umiat test well 11 penetrated the Tuluvak Tongue between depths of 22 and 545 feet (Collins, 1958a, p. 179). According to the well log by Collins, the section consists of about one-third sandstone, mostly fine- to very fine-grained, one-half shale and siltstone, and about one-sixth coal and associated bentonite.

In the vicinity of Umiat test well 11 the Tuluvak Tongue is at least 625 feet thick, but only about 525 feet was drilled in the well. Nearby, shothole 13 (pl. 56) provides additional section and contains a 2-foot coal bed about 100 feet stratigraphically higher than the first bedrock found in the well.

Otherwise the section is very poorly known, mostly because of lack of outcrops. Interbedded coal and bentonite were found cropping out in three localities: 1¾ miles southeast of Umiat test well 1, where there are four coal beds with associated ironstone and bentonite in a total section of about 10 to 15 feet; about 1 mile northeast of Umiat test well 1, where the section is 15 feet of poorly exposed coal and bentonite; and along a stream about 2¾ miles northeast of Umiat test well 1, where coal and bentonite are exposed at places through a total section of about 20 to 40 feet.

Thickness and Lithology in the Maybe Creek Area

The section described by Ray and Fischer at Wolf Creek (section 11, pl. 54; units 18 to 28, strat. section 11) is the only complete section of the Tuluvak Tongue in the Maybe Creek area. The total thickness of the Tuluvak Tongue in this section, as computed directly from a series of planetable elevations of the top and bottom contacts, is 560 feet, and this thickness has been used in plotting the section. The sum of the computed thicknesses of the individual beds that compose the section is about 100 feet greater but is based on less reliable barometer elevations. The 100-foot discrepancy has been distributed over the long covered intervals in the described section, and the thickness of individual exposed beds has been given as they were determined from the computations.

The beds at the bottom of the tongue form a prominent ledge and are persistent throughout the Wolf Creek area; 30 feet of medium-grained hematitic sandstone is succeeded by 30 feet of bentonitic shale and coal and then by 40 feet of granule-pebble conglomerate. Above this ledge the escarpment of Prince Creek syncline rises steeply; but, except for a bed of bentonite, only the ledge-forming beds of conglomerate and sandstone in the upper part of the tongue are exposed. Coal occurs as float just above the basal sandstone and just below the conglomerate that lies at the top of the tongue; plant fossils occur in fine-grained sandstone 80 feet below the top. Because the overlying Rogers Creek Member of the Schrader Bluff Formation also contains some coal and conglomerate, the location of the top of the Tuluvak Tongue at Wolf Creek is arbitrary. The contact with the Rogers Creek has been placed at the horizon where outcrops of conglomerate and coal give way to 400 feet of green and tan fine-grained sandstone, siltstone, and microfossiliferous shale. This horizon is about the same distance stratigraphically below the base of the Barrow Trail Member of the Schrader Bluff as is the top of the Tuluvak Tongue at Umiat.

In the section measured by Detterman at Tommy Creek the lowest 133 feet of rocks has been assigned tentatively to the Tuluvak Tongue (section 12, pl. 54; units 31 to 36, strat. section 12). As at Wolf Creek, the location of the contact of the Tuluvak Tongue with the overlying Rogers Creek Member is based on a change in facies at approximately the same stratigraphic horizon as the contact at Umiat. At Tommy Creek, however, the facies change is marked more by a change in abundance of fossils than by a change in lithology, as the Rogers Creek Member there contains many nonmarine tongues. The rocks assigned to the Tuluvak Tongue at Tommy Creek include bentonitic shale, bentonite, fine- to medium-grained sandstone, some of which is unconsolidated, and granule conglomerate that contains wood fragments. Both megafossils and microfossils are common in the lower part of the Rogers Creek section measured on Prince Creek immediately to the east (section 13, pl. 54; units 39 to 41, strat. section 13). In contrast, the three collections for microfossils from the rocks assigned to the Tuluvak Tongue on Tommy Creek yielded only two individuals.

At Square Lake (pl. 54) 675 feet of rocks of the Tuluvak Tongue was penetrated in the upper part of test well 1. Subsurface contours on shallow seismic horizons (pl. 52) tie the section in the well to the outcrops of the base of the Barrow Trail Member and of the inferred base of the Rogers Creek Member. The computed thickness from the base of the Tuluvak Tongue in the well to the inferred top of the tongue in the outcrop is 1,100 to 1,200 feet. The 400 or 500 feet of rocks in this interval that are present at the surface are mostly covered; Paine and Wayman, who traversed these rocks along Keith Creek, interpreted them to be resistant shale that forms well-defined ridges, but some sandstone is probably included. Part of the rocks in this covered interval may belong in the Rogers Creek Member.

As described by Collins (1959, p. 427–430), the 675 feet of the Tuluvak Tongue that was penetrated by the well consists of about 40 percent sandstone. The rest is shale, bentonite, and coal. Conglomerate is lacking. The sandstone is light gray, fine to medium grained, and mostly noncalcareous. In the lower half of the section most of the sandstone is bentonitic, but the sandstone in the upper half is rarely so. On the other hand, beds of bentonite as well as beds of coal are more abundant in the upper half than they are in the lower half of the section. Fossils are absent except in a zone from 178 to 150 feet above the base, where microfossils are rare.

The rocks of the incomplete section of Tuluvak Tongue in Lupine syncline near the head of Maybe Creek are computed to be about 700 feet thick (section 10, pl. 54; units 1 to 22, strat. section 10). With one exception outcrops of the Tuluvak Tongue along Maybe Creek consist of the lower 425 feet of this section. Of this lower 425 feet more than one-third is sandstone, conglomerate, and tuff. The basal sandstone is 15 to 60 feet thick and consists of gray-green to red fine-grained locally conglomeratic sandstone that is locally overlain by gray fine- to coarse-grained sandstone. Most of the other sandstone is medium to coarse grained and grades laterally to conglomerate. Tuff that weathers yellow to orange occurs in three beds within the interval from 215 to 360 feet above the base of the tongue. Coal and carbonized or silicified plant material is common throughout; one coal bed, about 130 feet above the base, is locally as much as 12 feet thick.

The thickness and stratigraphic assignment of the rocks in the upper 275 feet of the Maybe Creek section are doubtful. These rocks occur at only one locality on Maybe Creek. They make up a long covered interval capped by a single outcrop of conglomerate on the hilltop just east of the bend in Maybe Creek (lat 69°17′ N., long 153°35′ W. The computed thickness of this covered interval (250 ft) may easily be in error by 50 feet. Moreover, the covered interval may represent shale of the Rogers Creek Member rather than of the Tuluvak Tongue. The rocks in this interval have been mapped as the Tuluvak Tongue because there is no evidence that they do include marine beds and because they may easily be below the horizon of the top of the Tuluvak Tongue established at Wolf Creek; within the limits of error of the measurements, the total thickness of the Tuluvak Tongue at Wolf Creek might be 660 rather than 560 feet and, the thickness of the Tuluvak Tongue preserved at Maybe Creek, might be 650 rather than 700 feet.

Sandstones on Maybe Creek

Almost flat-lying rocks of the lower 200 feet of the Tuluvak Tongue crop out extensively along the north side of Maybe Creek. These rocks are described in sections 6, 7, and 10 (strat. sections and pl. 54). Because each unit in the Maybe Creek area varies in lithology and thickness, the composite sections show only averages. The variations of individual sandstone beds are described in detail below and are shown in figure 110, which shows the grain size and thickness of sandstones 7, 8, and 9. Sandstones 10, 11, 12, and 13 are not included in these maps because they occur only locally, but all the sandstones are shown on plate 52. The isopachous lines and the patterns that indicate areas of rocks of similar grain size are generalized. In the areas marked "Absent" in figure 110 the sandstone is presumed to be absent either because of minor unconformity, nondeposition, or shaling-out of the sand. The boundaries of these areas of absence connect points at which the traces of each bed disappear. The bedding traces may disappear from causes unrelated to original deposition, but at a few of these points the sandstone can be seen in outcrop to grade from coarse to fine toward the end of the bedding trace.

The changes in lithology and distribution of sandstones 7 and 8 show that during the deposition of the Tuluvak Tongue the shoreline was built northward. In the Maybe Creek area the first deposits were near-shore sands that locally graded into the Seabee Formation below and into shale northward. They consisted largely of fine grains of resistant quartz and chert. Successively younger sandstone beds were deposited farther north. In them, gravel and plant material were increasingly abundant; rounded fragments of argillaceous rock formed as much as one-third of the detritus; and tuff was deposited, probably in local basins.

The present structurally low area along Banshee syncline and in the saddle of Titaluk anticline seems to have been relatively low topographically during the deposition of the Tuluvak Tongue as well. It is the locus of fine sands and of greatest thickness of the shale units between the sands. The structurally high area between Baby Creek and the head of Maybe Creek contains most of the red sandstone and most of the plant material.

The contact of sandstone 7 and the underlying Seabee Formation appears to be conformable and in some places gradational. Sandstone 7 is the finest grained and most calcareous in the Tuluvak Tongue; near the mouth of Baby Creek, it lies on similar gray calcareous fossiliferous siltstone and fine-grained sandstone of the Seabee Formation. Black chert pebbles, such as are widespread in sandstone 7, also occur sporadically in the siltstone and the limestone in the upper part of the Seabee Formation. Plant material and coal, though common in the rest of the Tuluvak Tongue, are found in sandstone 7 at only one locality near the head of Banshee Creek.

Sandstone 7 is mostly fine-grained to very fine grained calcareous sandstone. Where coarser grained sandstone is present, it is in beds that overlie the fine-grained sandstone. The fine-grained sandstone is gray green to yellowish green except in the area between Anak and Banshee Creeks, where much of the sandstone is hematitic red to brown. The coarser sandstone is gray to yellowish gray. Whenever red and gray sandstone occur together, the red lies below the gray. The fine sand grains are angular to subangular, and the coarser sand grains are angular to subrounded. The average composition of nine thin sections of sandstone 7 is: 50 percent calcite, 23 percent quartz, 16 percent chert, 5 percent chlorite, 3 percent feldspar, and 3 percent mica (mostly biotite). The total percentage of quartz, chert, and feldspar decreases northward from about 50 percent near Maybe Creek to about 25 percent near the Titaluk anticline axis and the proportion of calcite increases correspondingly.

A covered interval, probably shale, separates sandstone 8 from sandstone 7. The thickness of this interval ranges from 18 to 55 feet, and in general is about 30 feet; it is greatest in a northeast-trending belt that crosses the Titaluk anticline axis at Baby Creek. Coal float from the interval is found at seven localities, which are all in a north-trending belt between Anak and Banshee Creeks coincident with an area of red sandstone in sandstone 7.

Sandstone 8 (fig. 110) is from 5 to 27 feet thick; lithologically it is divided into two distinct types—conglomeratic sandstone and fine- to medium-grained sandstone. The conglomeratic sandstone consists of granules and pebbles of chert and quartz in a matrix of well-sorted medium- to coarse-grained gray, gray-brown, or salt-and-pepper sandstone. The matrix is cemented by calcite in some localities and by silica in others. The fine- to medium-grained sandstone is calcareous and ferruginous; it weathers to a combination of gray and red or to red. Fossil leaves, wood, and coal are common in the fine-grained sandstone, whereas in the conglomerates they are found at only one locality nearby on Baby Creek. The average percentage composition of two thin sections of the fine-grained rock and two thin sections of the conglomerate matrix is:

	Fine-grained sandstone	*Conglomerate matrix*
Quartz	25	15
Chert	14	17
Rock fragments	13	32
Feldspar	5	3
Mica	5	3
Siderite	10	--
Cement	27	30

The rock fragments are siltstone and shale and are more rounded than the quartz and chert grains. They were not noted in the fine-grained rocks of sandstone 7.

At two localities sandstone 8 can be seen to grade laterally into very fine grained rock. At the southern edge of the outlier beyond Banshee Creek, the rock grades southward within 500 feet from conglomerate through coarse-grained sandstone to medium-grained sandstone; then the bedding trace disappears. In the northeastern part of the area of fine-grained rocks, coal-bearing sandstone grades laterally into coal-bearing shale.

The interval between sandstones 8 and 9 ranges in thickness from 35 feet in the south to 90 feet in the north, the average being about 50 feet. The maximum thickness is in a southwest-trending area that crosses the Titaluk anticline axis at the head of Baby Creek. The additional thickness of the shale at the head of Baby Creek may be due to upward migration in time of sandstone 9 through the section. Between the head of Baby Creek and the areas farther south along Baby Creek where the shale is only 40 to 50 feet thick, the bedding trace of sandstone 9 is formed by several thin beds of sandstone that span an interval of 60 feet and are separated by shale beds. The lower of these sandstone beds is at the horizon of the sandstone to the south, and the upper, at the horizon of the sandstone to the north.

Coal float is common in the upper part of this interval. In three places the coal crops out: on Banshee Creek a 6½-foot bed of coal lies below sandstone 9; west of the head of Baby Creek, 11 feet of coal and bentonite lies below the sandstone; north of the anticline axis between Anak Creek and the head of Maybe Creek, 8 to 12 feet of interbedded coal and bentonite lies below the sandstone and above exposures of bentonitic shale.

Sandstone 9 ranges in grade from fine-grained sandstone to pebble conglomerate (fig. 110). At one locality the fine-grained rock can be seen to grade laterally into this conglomerate. The fine-grained sandstone is gray to gray green and calcareous. The average composition of four thin sections of medium-grained rock is 45 percent calcite, 25 percent chert, 15 percent rock fragments, 10 percent quartz, 4 percent feldspar, and 1 percent biotite. The quartz and chert are angular; the rock fragments are subrounded and include some calcite grains.

The conglomeratic sandstone along Baby Creek is mostly gray to salt-and-pepper, coarse to medium grained, and partly calcareous; locally, there are minor amounts of red fine-grained sandstone. Granules and pebbles are abundant in the south, scarce in the north. The conglomeratic sandstone at the head of Maybe Creek is gray to brown, coarse to medium grained, and noncalcareous and contains abundant granules, pebbles, and even some cobbles. Ironstone is common and much of the conglomerate is in a matrix of soft, earthy limonite. Locally, the limonitic conglomerate grades upward to clean coarse-grained sandstone.

Paleontology and Age

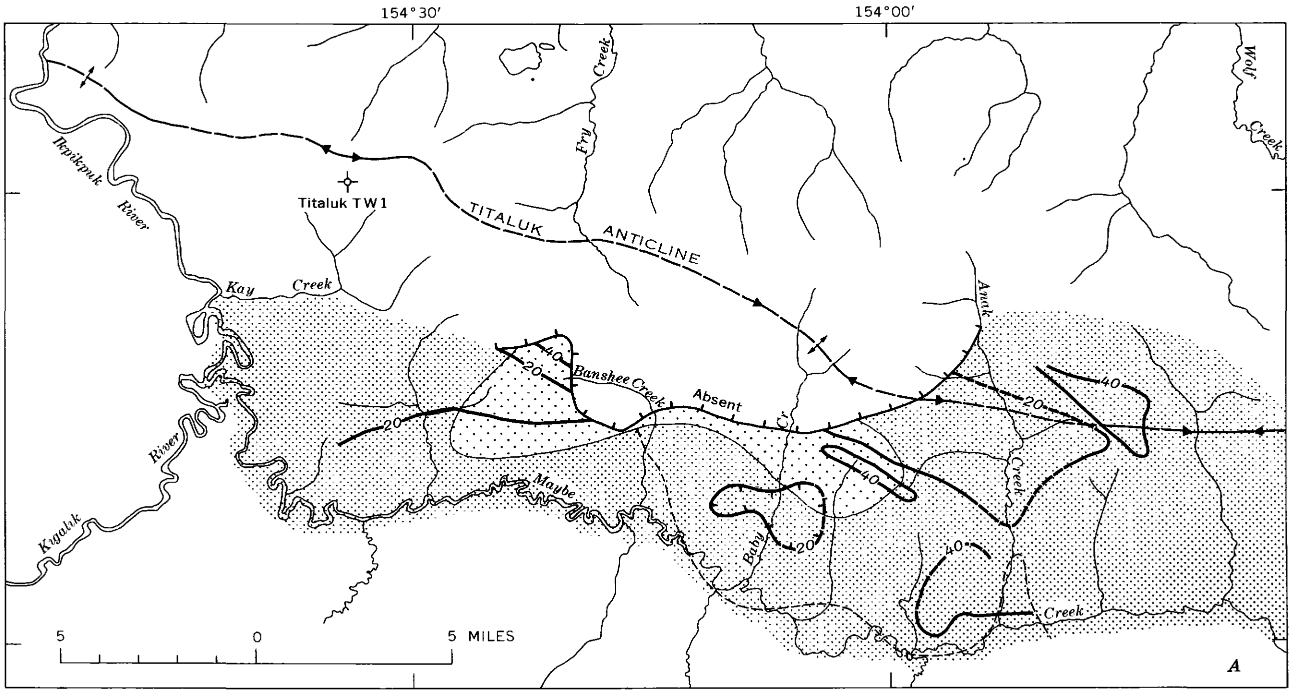
No megafossils have been collected from the Tuluvak Tongue in the Umiat-Maybe Creek region. A few microfossils have been collected from the outcrops on Tommy Creek and at Umiat (fig. 108 and table 5) and from the Square Lake test well 1 and Umiat test well 11. These are mostly long-ranging species that occur in both the Seabee and the Schrader Bluff Formations.

An approximate age can be assigned to the Tuluvak Tongue on the basis of the ages of the underlying Seabee Formation and the overlying Schrader Bluff Formation. Jones and Gryc (1960, p. 153) correlated the upper part of the Seabee Formation with the upper Turonian and have correlated the Barrow Trail Member of the Schrader Bluff Formation with the upper Santonian and lower Campanian. The Rogers Creek Member, which rests on the Tuluvak Tongue, has yielded no diagnostic megafossils and has a microfauna similar to that of the Barrow Trail Member; however, Jones and Gryc (1960, p. 153) and Tappan (1960, fig. 6) indicated that the Rogers Creek may be either Coniacian or lower Santonian. Thus, the Tuluvak Tongue in the Umiat-Maybe Creek region is probably younger than the Turonian and older than the upper Santonian; it might easily be equivalent only to the Coniacian.

KOGOSUKRUK TONGUE

Name and Type Section

Gryc, Patton, and Payne (1951, p. 166–167) named the Kogosukruk Tongue "from the Kogosukruk River,



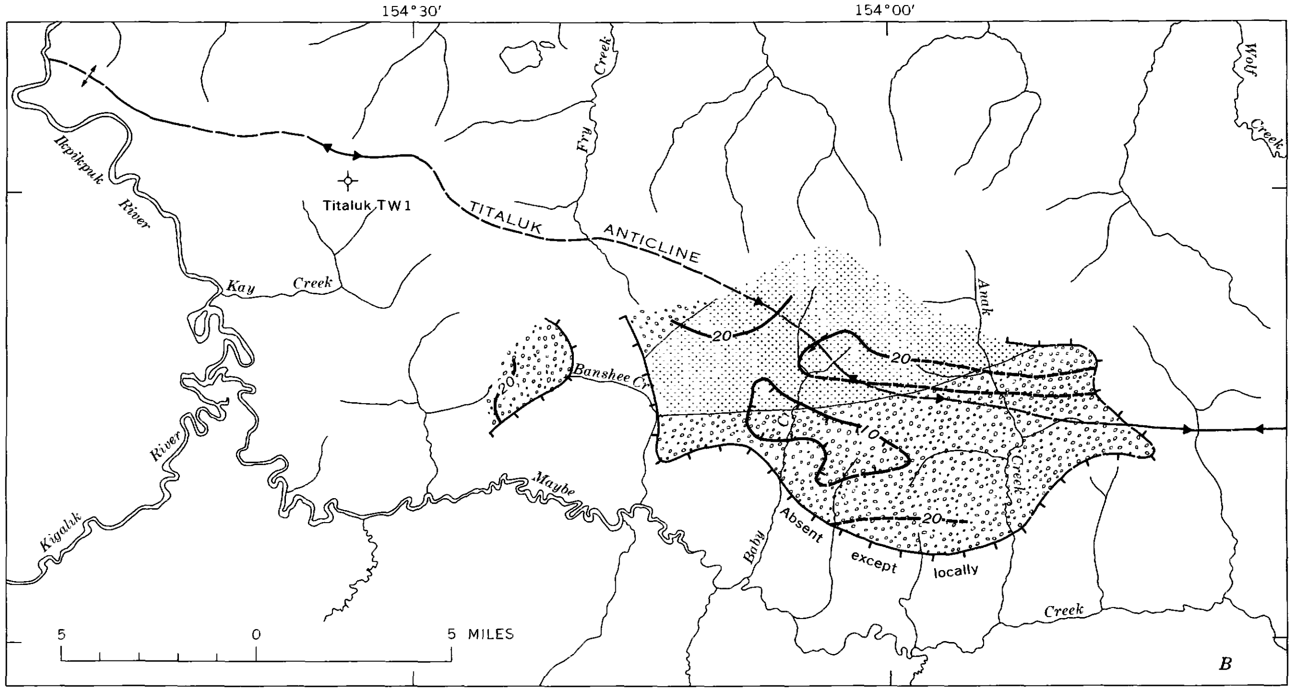
EXPLANATION TO *A*

Mostly fine-grained sandstone	Mostly coarse- and medium-grained sandstone	Northern limit of conglomeratic sandstone	Line of equal thickness, in feet

EXPLANATION TO *C*

Fine- to medium-grained sandstone	Medium-grained sandstone	Medium- to coarse-grained conglomeratic sandstone Fine- to coarse-grained along southeast Maybe Creek	Line of equal thickness, in feet

FIGURE 110.—Grain size and thickness of sandstones 7, 8, and 9 of the Tuluvak Tongue of the Prince Creek Formation in the Maybe Creek area. *A*, Sandstone 7 at the base of the Tuluvak. *B*, Sandstone 8 about 70 feet above the base of the Tuluvak. *C*, Sandstone 9 about 140 feet above the base of the Tuluvak; within the belt of conglomeratic sandstone mapped along southeastern Maybe Creek, conglomerate is sparse except in the basal beds of the unit.



EXPLANATION TO *B*

Fine- to medium-grained sandstone	Medium- to coarse-grained conglomeratic sandstone	20 Line of equal thickness, in feet

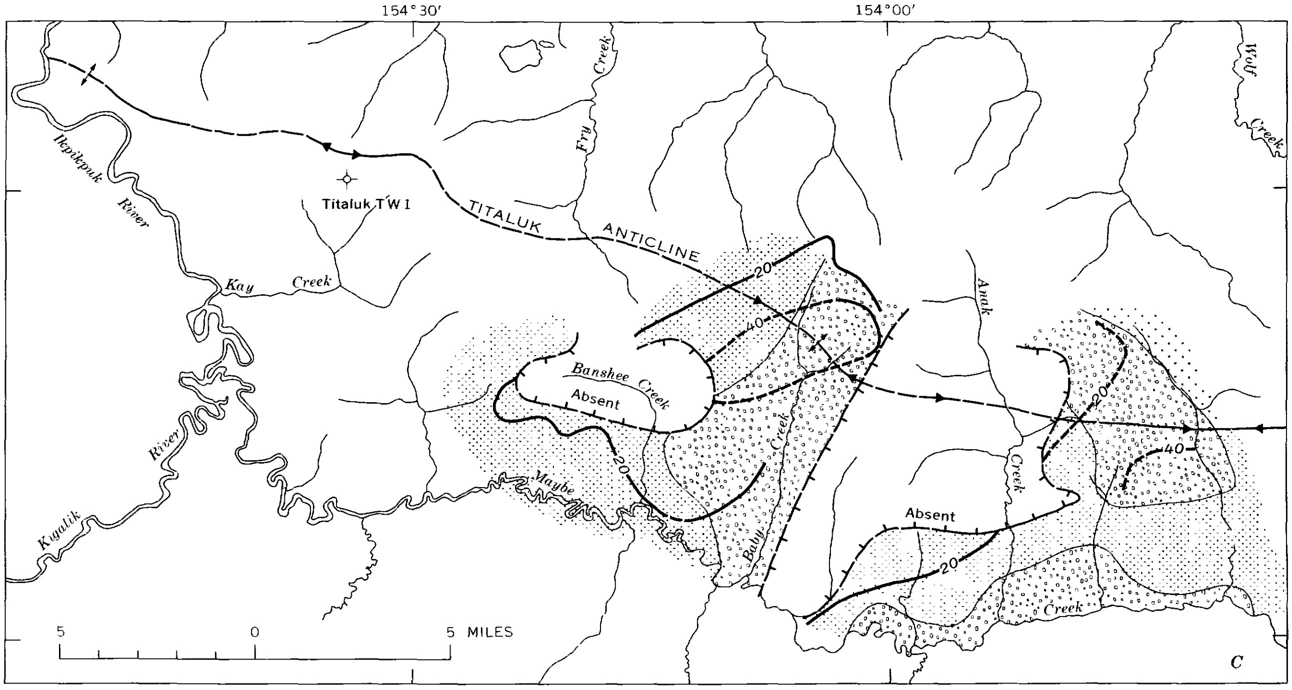


FIGURE 110—Continued

along which it is well exposed." They also cited the good exposures of rocks of this tongue along the Colville River from near the mouth of the Anaktuvuk River to Ocean Point, in which the aggregate thickness of the Kogosukruk Tongue and the Sentinel Hill Member of the Schrader Bluff Formation had been measured as 2,340 feet.

The sections of the Kogosukruk Tongue exposed along the Kogosukruk and Colville Rivers were measured by Stefansson and Thurrell in 1947. This measurement includes the two units of both the Sentinel Hill Member and the Kogosukruk Tongue. The section (No. 14, pl. 54; units 140 to 1, strat. section 14) they measured in the bluffs consists, in ascending order, of: lower part of Sentinel Hill Member, 366 feet (complete thickness 389 ft); lower part of Kogosukruk Tongue, 336 feet; upper part of Sentinel Hill Member, 316 feet; and upper part of Kogosukruk Tongue, originally 1,322 feet, now revised to 1,160 feet. These are the only fairly complete measured sections of the tongue, and of these only the Colville River section is well enough exposed to permit reliable correlation of beds. Therefore, the exposures in the bluffs on the west bank of the Colville River from near the mouth of the Anaktuvuk River to Ocean Point are here designated the type section (section 14, pl. 54 and strat. sections).

Rocks in the Colville bluffs dip predominantly to the north. The base of the Kogosukruk Tongue is near the top of the bluffs about 8 miles above the mouth of the Chandler River but is at river level on the north flank of the Gubik anticline almost opposite the mouth of the Chandler. About three fourths of a mile downstream the base of an interbedded marine tongue is at river level, and about three fourths of a mile farther downstream the top of this tongue is at river level. From there to Ocean Point the younger rocks of Kogosukruk Tongue are almost continuously exposed in the bluff. Ocean Point is the limit of the measured section. The rocks there lie flat and the outcrops end just downstream. Rocks at higher horizons may, however, be present beneath the tundra downstream and to the east.

The Kogosukruk Tongue consists of poorly consolidated, varicolored clay, silt, shale, sandstone, tuff, and bentonite. It is distinguished from the adjacent marine rocks by abundant coal and sandstone and by scarcity of fossils.

The intercalated marine tongue on the north flank of Gubik anticline, although not separately mapped, has been distinguished from the enclosing nonmarine rocks in the section measured in the bluffs; this tongue was designated the upper part of the Sentinel Hill Member of the Schrader Bluff Formation by Whittington (1956, p. 251). It divides the Kogosukruk Tongue into an upper and lower part. Both parts are present in the section, and the lower part has also been identified in the Sentinel Hill core test.

The contacts between the lower and upper parts of the Sentinel Hill and Kogosukruk are apparently conformable, with interfingering of marine and nonmarine beds.

The upper limit of the Kogosukruk Tongue is not known. It probably grades northward into marine beds. In the outcrop area it is unconformably overlain by the Gubik Formation. The surface of this unconformity in the mapped area is approximately the present topographic surface of the Arctic Coastal Plain and of adjacent low valley bottoms in the foothills.

Distribution

The Kogosukruk Tongue has been mapped in only four areas, all in the vicinity of Umiat and the lower Colville River. The largest area is between the Kikiakrorak and Colville Rivers north of Umiat and includes the type locality. Detterman, Bickel, and Gryc (1963) mapped the lowest part of the tongue in three small areas on the Prince Creek syncline south of the Colville. The southernmost of these areas is about 12 miles south of the latitude of Umiat.

The Kogosukruk Tongue has not been mapped in the Arctic Coastal Plain north of the Kikiakrorak River. Its distribution may be inferred from subsurface evidence. Seismograph surveys north of the area mapped in this report (Woolson and others, 1962) show that in the area between the Ikpikpuk and Colville Rivers and north of lat 69°45′ N. the shallow Cretaceous rocks strike generally north and dip eastward about 50 feet per mile. The Kogosukruk Tongue is probably not preserved west of long 152°30′ W. Wells in the Arctic Coastal Plain west of this meridian begin in rocks of the older Colville or Nanushuk Group. At Fish Creek test well 1, about 15 miles east of this meridian, the Kokosukruk Tongue is lacking, but the well penetrated 600 feet of marine shale of the Schrader Bluff Formation, and the upper part of this thick marine unit may be equivalent to the nonmarine beds of the lower part of the Kogosukruk Tongue exposed farther south on the Colville. The regional eastward dip continues east of the Colville, and the Kogosukruk Tongue may well be present there in the Arctic Coastal Plain. The region east of the Colville has been only partly explored, however; and Cretaceous rocks there are hidden by a mantle of Tertiary and Quaternary deposits.

The basal sandstone and conglomerate beds of the Kogosukruk Tongue strike westward from the Colville River bluffs and form the northernmost of two prominent cuestas on the north flank of the Umiat anticline. This cuesta rises 100 to 200 feet above a narrow lowland formed on the shale of the lower part of the Sentinel Hill Member. Northward-flowing tributaries of the Kogosukruk River have trenched through the cuesta, and sharp crooks in their courses where they leave the shale lowland mark its location. At the Kogosukruk River the cuesta curves northward toward the axis of Dogbone syncline and forms a high bluff on the east bank of the Kogosukruk. A sandstone bed about 100 feet above the base of the tongue dips very gently northward in this bluff and reaches river level 5 miles donwstream; there the cuesta disappears. West of the Kogosukruk River is a broad lowland area from which the sandstone bed has apparently been stripped. This lowland merges northward with the Arctic Coastal Plain and is mantled with sands of the Gubik Formation.

The bottom contact of the Kogosukruk Tongue can be located accurately where it crosses the Kogosukruk River, but it can only be projected across the lowland west of the river. Stefansson and Thurrell and the Navy party under Lt. (jg.) J. A. Rogers have measured stratigraphic sections in the Kogosukruk River bluffs near the base of the cuesta. The lowest bed described is siltstone estimated to be about 30 feet above the base of the Kogosukruk Tongue. On aerial photographs the line of outcrop of this siltstone appears to cross the Kogosukruk River near the bend in the cuesta. The Kogosukruk–Sentinel Hill contact has been drawn across the river near this point. Field traverses west of the Kogosukruk River have not crossed the contact, however.

Lithology

The detailed description by Stefansson and Thurrell of the exposures in the Colville Bluffs is given in units 1 to 66 and 85 to 114 of section 14. They (written commun., 1948) described the general lithology:

> The color of the bluffs is banded yellow, buff, light gray, yellow-red, pink. The section, on the whole, is poorly consolidated. It consists largely of clay, silt, and shale. Coal (bony) and tuff are very common. The entire section is very bentonitic. Sandstone members are not numerous. They occur as either thin (up to five feet thick) beds, usually fairly well consolidated, slabby, fine to medium grained, silty, gray in color; or as thicker beds, loosely consolidated, light gray, fine to medium grained, and friable. The thicker beds are usually bentonitic and some are cross-bedded. The sandstone members have high porosities * * *. Porosities greater than 20 percent are common, and some sandstone members show porosities greater than 30 percent. These high porosities are probably due largely to the poor consolidation of the sediments. Conglomeratic beds do not occur, with one notable exception. This is the 15-foot conglomeratic sand on which the structure contour map of the Gubik anticline * * * was drawn. Ironstone lenses and nodules are common, especially in the sandstone members.

LOWER PART

The lower part of the Kogosukruk Tongue in the type section on the Colville River (336 ft thick) consists of a sandy and conglomeratic unit 207 feet thick overlain by bentonitic shale and coal unit 129 feet thick (fig. 111). The sandy and conglomeratic unit includes zones of shale and zones of interbedded coal and bentonite as much as 13 feet thick. The lowest coal zone, about 2 feet thick, occurs within 25 feet of the base. Several of the sandstone beds are carbonaceous and most are fine grained. Sixty-five feet above the base is a zone of conglomeratic sandstone that includes the massive cuesta-forming conglomerate (fig. 112); the massive beds contain plant and tree fragments.

The basal bed of the lower part of the Kogosukruk Tongue is light gray fine-grained sandstone that rests conformably on stratified tuff and bentonite. The tuff has yielded marine microfossils of species that are common in the Sentinel Hill Member, but samples from the lowest 65 feet of the Kogosukruk Tongue are barren.

The top of the lower part of the Kogosukruk Tongue has been drawn at the top of a one-half foot coal bed that is 40 to 50 feet below the lowest horizon of abundant microfossils in the overlying part of the Sentinel Hill Member.

The lower part of the Kogosukruk Tongue has also been recognized in the bluffs of the Kogosukruk River (fig. 111). The basal sandy unit there is similar to that exposed on the Colville, except that at the Kogosukruk River the massive conglomerate is absent, and, in its place near the head of the river are sandstone and, locally, a bed of pebble conglomerate only 6 inches thick. Downstream near Texas Hill these rocks give way to tuff interbedded with sandstone and conglomerate. Correlations between exposures of rocks above the sandy unit on the Kogosukruk River are only approximate. The interbedded shale and coal that overlies the sandy unit at Texas Hill is only 50 feet thick and is overlain by a sandstone and coal section 60 feet thick. Four specimens of *Saccammina lathrami* and *Haplophragmoides rota* (47ASt12, 47ASt14), common in the Sentinel Hill Member of the Schrader Bluff Formation, were found in shale samples; and *Mytilus* sp. (USGS Mesozoic loc. 26489) was found at two horizons in the overlying sandstone (loc. 5, fig. 107). On Henry Creek mollusks occur at horizons close to or just above that of the *Mytilus*-bearing sandstone (USGS Mesozoic locs. 26490 and 26491;

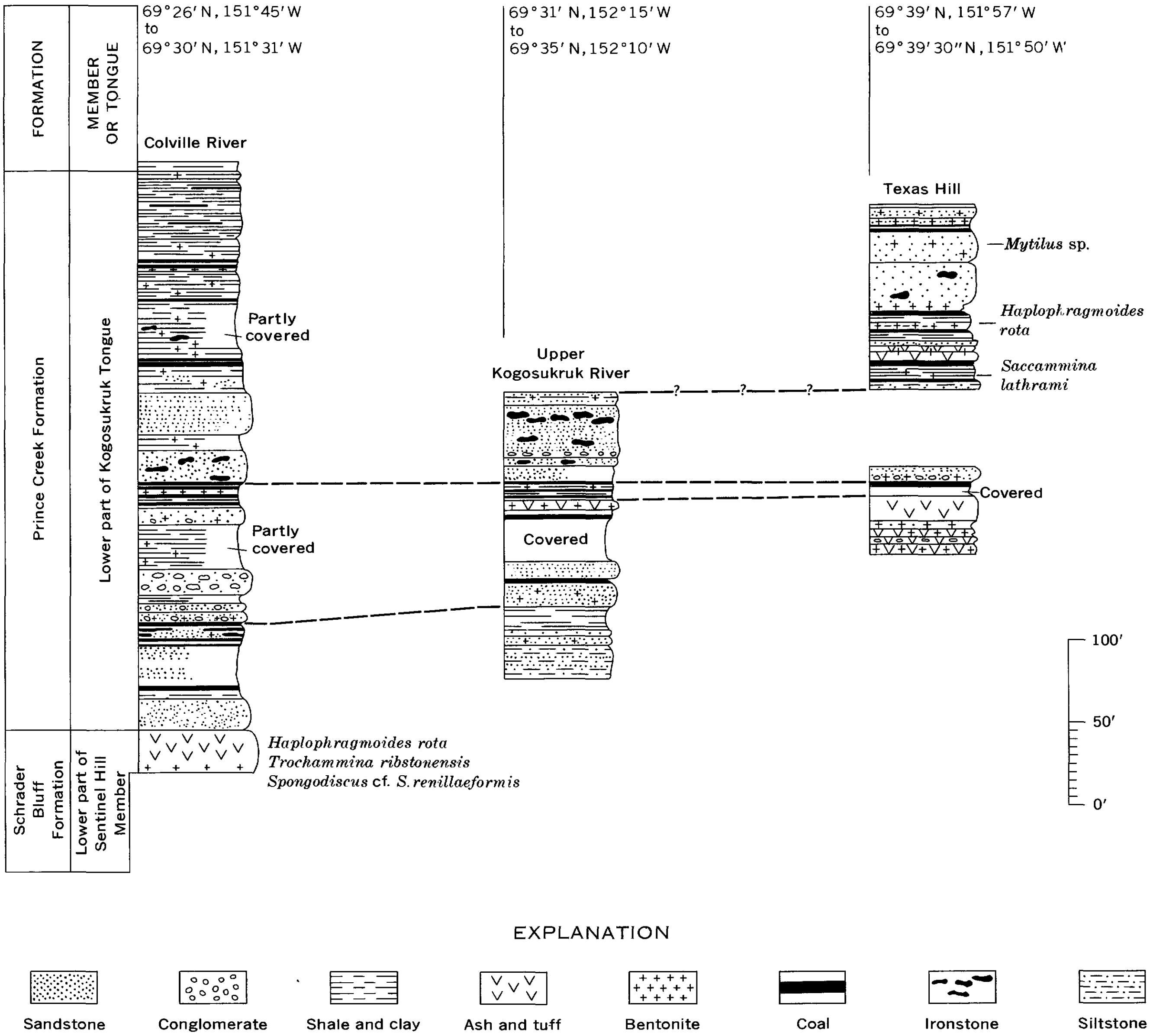


FIGURE 111.—Correlation of the lower part of the Kogosukruk Tongue of the Prince Creek Formation.

locs. 6 and 4, fig. 107). The sequence here is close to the horizon at which the base of the upper part of the Sentinel Hill Member occurs in the Colville bluffs and probably represents intimate interfingering of marine and nonmarine beds; but, because of the abundance of coal, it is included in the Kogosukruk Tongue. In this area the Sentinel Hill Member may be represented only by thin marine tongues, closely interbedded with the nonmarine rocks of the Kogosukruk Tongue, for almost all described exposures on the Kogosukruk River and its tributaries contain coal beds.

In Sentinel Hill core test 1 the lower part of the Kogosukruk Tongue is only 109 feet thick (840 to 949 ft below the top of the hole). It consists entirely of bentonite, shale, and coal except for a 1-foot bed of conglomeratic sandstone 40 feet below the top. Fossils are lacking in the Kogosukruk Tongue but are abundant in both the underlying and overlying parts of the Sentinel Hill Member. Interbedded with the fossiliferous rocks in the overlying part of the Sentinel Hill Member are thin beds and streaks of coal. They are most abundant near the contacts with Kogosukruk Tongue and are actually minor tongues of the nonmarine unit but are included in the Sentinel Hill Member for convenience.

UPPER PART

The upper part of the Kogosukruk Tongue in the Colville bluffs section (1,160 ft, incomplete) contains

FIGURE 112.—Basal conglomerate of Kogosukruk Tongue of Prince Creek Formation capping bluff on south flank of Gubik anticline. View west up Colville River. Umiat Mountain in left distance. Aerial photograph (COL–OV–14–1) by U.S. Navy.

fine-grained shoreline and near-shore sandstone beds throughout. The sandstone beds are interbedded with coal and shale in the lower half and with coal and siltstone in the upper half. Generally, individual coal beds pinch out within ¼ to ½ mile, but coal-bearing zones are more persistent. Most of the sandstone beds are gray to neutral but the upper ones (at 113, 302, and 357 ft below the top of the measured section) are green. The lower two of these green sandstone beds contain conglomeratic layers.

Stefansson and Thurrell noted that several of the sandstone beds change laterally in thickness and grain size within the exposures in the bluffs. Most of them become finer northward, but one thin sandstone bed 525 feet below the top of the section becomes finer to the south. The green conglomeratic sandstone 302 feet below the top of the section becomes silty and crossbedded northward. The thick silty sandstone 916 to 961 feet below the top of the section changes northward to interstratified sandstone and siltstone, and the unit of interbedded clay and sandy siltstone from 18 to 69 feet below it becomes less sandy and more clayey northward. Most striking is the northward pinchout of a silty sandstone 50 feet thick and 488 feet below the top of the section. This silty sandstone was described by Stefansson and Thurrell from exposures at station 71 (see index map, pl. 54) about 3½ miles south of Sentinel Hill core test 1 (unit 37, strat. section 14). It can be traced northward in the bluffs and lies about 100 feet vertically above the well. Within the next mile northward, the silty sandstone disappears, and its place in the section is occupied at station 227 by silt, clay, and bony coal (unit 37(?), strat. section 14). A fine- to medium-grained sandstone 15 feet thick rests on the silt-clay-coal sequence and on the silty sandstone near the well; it is probably the same as the fine- to medium-grained sandstone (unit 36(?), strat. section 14) 2 feet above the silty sandstone at station 71 south of the well.

The green and green-gray sandstone beds at the top of the section near Ocean Point are probably marine, for marine fossils (USGS Mesozoic loc. 26492) occur at a horizon near the base of these green sandstone beds at the mouth of the Kikiakrorak River (loc. 1, fig. 107). The marine character of these beds may be due more to their northerly geographic position than to their high stratigraphic position, for they are the northernmost outcrops and, except for the 28-foot section (units 28 to 32, strat. section 14) at station 79 (index map, pl. 54), all the rocks below them are described from outcrops 25 miles or more to the south. They are regarded therefore as evidence that the sand units become increasingly marine to the north.

Northward Thinning

A northward decrease of nonmarine rocks is shown by the changes in thickness of the major marine and nonmarine units as well as by the changes in individual sandstone beds. Sentinel Hill core test 1 penetrates complete sections of the upper part of the Sentinel Hill Member and the lower part of the Kogosukruk Tongue 7 to 10 miles north of their outcrops. The upper part of the marine Sentinel Hill Member is 371 feet thick in the well but only 316 feet at the outcrop. The lower part of the nonmarine Kogosukruk Tongue is only 109 feet thick in the well but is 336 feet thick in the outcrop to the south. Apparently the northward thinning of this part of the Kogosukruk Tongue results from loss of sand at the base, for while the upper shale and coal unit is only 30 feet thinner in the well than in the outcrop, the lower sandstone unit is missing entirely. The basal sandstone may not pinch out northward, but may grade into the fossiliferous marine sandstone just below the Kogosukruk Tongue in the well.

Paleontology and Correlation

Thick marine fossiliferous zones have been excluded from the Kogosukruk Tongue and herein considered part of the Sentinel Hill Member of the Schrader Bluff Formation. Thin marine fossiliferous zones have been included in the Kogasukruk Tongue for convenience in mapping and description.

All but one of the five fossiliferous collections from the Kogosukruk Tongue are from the upper unit of the lower part (figs. 107, 109; table 6). The collections include *Panope* sp., *Mytilus* sp., unidentified snails, and the arenaceous Foraminifera *Haplophragmoides rota* and *Saccammina lathrami*. A single collection from about 300 feet below the top of the measured section of the upper part of the tongue contains *Panope* sp., *Gyrodes* sp., and unidentified gastropods.

The Kogosukruk Tongue is at least partly equivalent in age to the Sentinel Hill Member, which intertongues with the lower part and with the base of the upper part and which is probably of Campanian or younger age.

QUATERNARY DEPOSITS

GUBIK FORMATION

NAME AND TYPE SECTION

The unconsolidated sediments that mantle Upper Cretaceous rocks on the bluffs of the Colville River from the mouth of the Anaktuvuk River to Ocean Point were first described by Schrader (1902, p. 249–

250). He later (1904, p. 93) referred to these deposits as the Gubik Sand after the Eskimo name for the Colville River and described them as an unstratified deposit of fine sand and silt containing sparse gravel at the base, about 10 to 15 feet thick, which rest unconformably on the rocks of his Colville Series. In the field he tentatively called these sediments loess, but he later concluded that the Gubik was a delta deposit.

On the basis of well data and further field studies in the Arctic Coastal Plain, Gryc, Patton, and Payne (1951, p. 167) redefined these surficial deposits as the Gubik Formation, retaining Schrader's type locality but classifying the formation as a largely marine deposit with a microfauna similar to Recent faunas. They described the formation as loosely consolidated crossbedded gravel, sand, silt, and clay as much as 150 feet thick.

Black (1964, p. 62) summarized the data on the Gubik Formation and pointed out that in practice the term Gubik "has been broadened in scope to encompass all unconsolidated surficial materials overlying the Cretaceous or Tertiary rocks in the coastal plain." In part, this has come about because little fieldwork has been done to make possible a finer subdivision of the surficial deposits. Most of the Gubik has been mapped by photointerpretation in which the broadest definition of the formation is the most easily applied. In part, it has come about because the Gubik Formation in its type area includes clastics of a wide variety of size grades from clay to gravel, probably deposited in various environments, both marine and nonmarine. Although the marine microfauna of the Gubik referred to by Gryc, Patton, and Payne (1951, p. 167) has been found in the wells of the northern part of the Arctic Coastal Plain, it has not been found in the type area south of Ocean Point. In the type area marine fossils are limited to the lowest beds, and the upper part of the formation probably includes freshwater deposits.

DISTRIBUTION

The formation is well exposed along many of the small streams in the Arctic Coastal Plain, but because the object of fieldwork was the delineation of bedrock structures, the traverses in the Arctic Coastal Plain have been along streams that expose Cretaceous rocks rather than those that expose the Gubik. Most field data on the Gubik are therefore limited to incidental observations of the lower part of the formation at the tops of bedrock exposures in the streamcuts and do not include observations in the mantled interstream areas where the higher parts of the formation would be preserved. Therefore, neither the full thickness of the formation is known nor is the height to which it overlaps upon the hills beyond the valley floors.

The characteristic appearance of the Gubik Formation in areas where it is known from field observation is the criterion used in the photomapping. The Gubik underlies a generally flat plain having a slight northward slope. It forms smooth rounded surfaces that lack the fine, closely spaced drainage lines common on bedrock slopes and that appear lighter in tone than the areas of bedrocks. In the eastern half of the area, bedding planes in the Gubik are not apparent on the photographs except for the surface at the base of the formation, where, in streamcuts, the slumped, rounded Gubik lies above steep banks of Cretaceous rocks. West of Wolf Creek, bedding is apparent in some exposures. Beds dip gently northward, and the Gubik Formation locally forms little cuestas having south-facing scarps.

The area of outcrop of the Gubik Formation coincides with the lake country of the Arctic Coastal Plain, which reaches an elevation of 300 to 400 feet. On the southern margin of the Arctic Coastal Plain the front of the Arctic Foothills rises abruptly to an elevation of about 500 feet along a fairly straight line that runs east-west at about lat 69°35′ N. in the western part of the area and at about lat 69°40′ N. in the eastern part. The front line of the hills is broken by reentrants of the coastal plain level along the stream valleys; these are broad high-level flats along the larger streams and narrow or isolated terraces above the smaller ones. The hilly promontories of the foothills reaching out into the Arctic Coastal Plain between these reentrant flats give the Arctic Foothills border the appearance of a drowned shoreline. The contact of the Gubik Formation with the Cretaceous rocks has been drawn where the smooth flat Arctic Coastal Plain surface butts against the hill slopes. The foothill promontories themselves show bedrock traces at their tops, but in many places the traces are not visible downslope. In places where the break in slope between plain and hill is not sharp, the line of contact of the Gubik with the bedrock is vague. This is true where the foothill slopes consist of easily eroded shale, as in the area west of Wolf Creek where shale of the Seabee Formation borders the Arctic Coastal Plain. It is also true on gentle dip slopes, as along the west fork of the Kogosukruk River in Dogbone syncline. For this reason the Gubik Formation west of Wolf Creek may be more widespread within the foothills valleys than is shown, and the contact on the promontory immediately west of the Kogosukruk River reentrant may be mapped several miles too far down the dip slope.

Data on the Gubik Formation from the field parties and from shothole samples taken during seismic explorations by United Geophysical Co., Inc., are shown in figure 113.

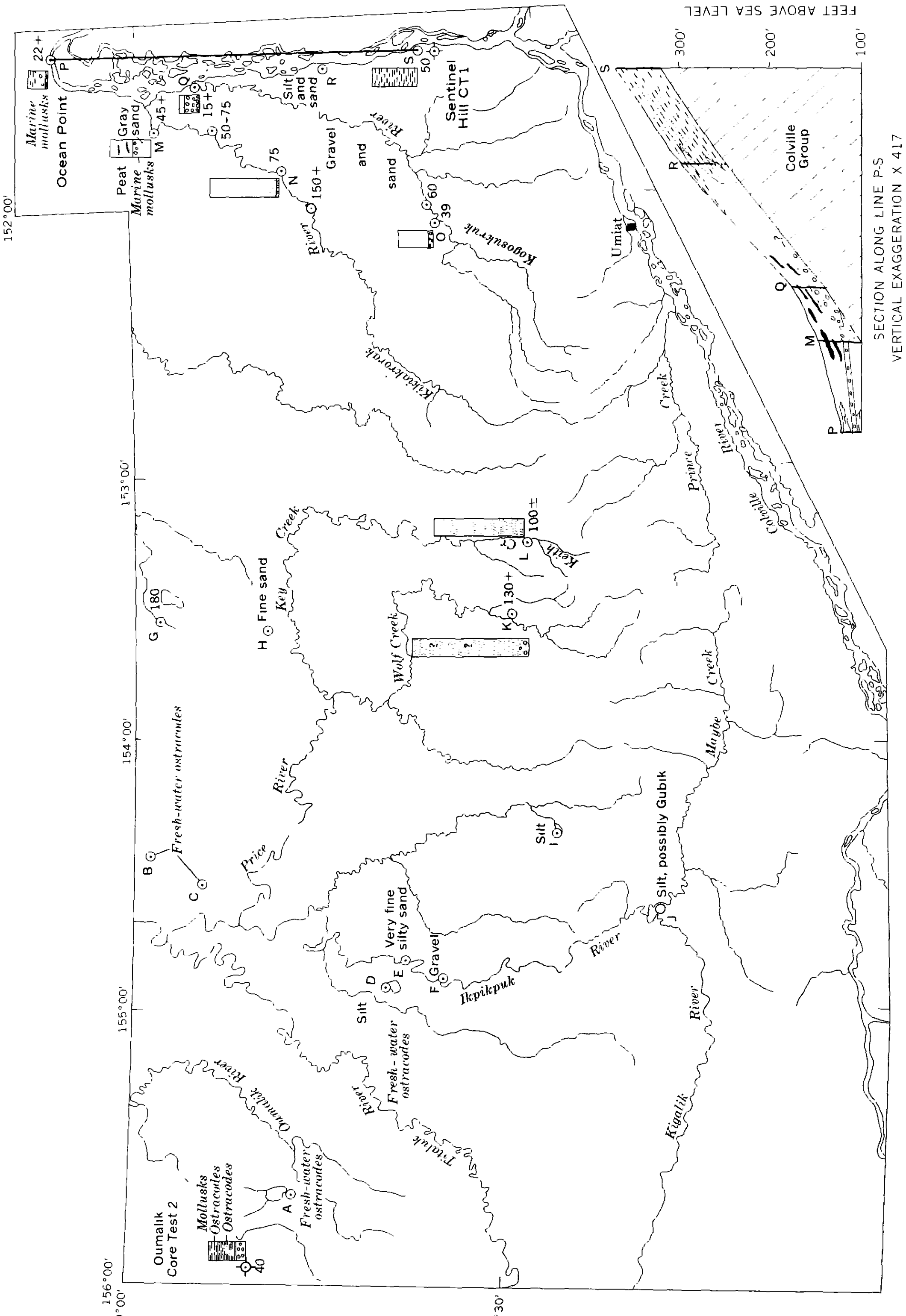


FIGURE 113.—Lithology and thickness of the Gubik Formation from outcrop, well, and seismic-shothole data. Data for localities G, H, and R from Black (1964).

The U.S. Navy party of Rogers and McConnell described the Gubik on the Kogosukruk River near Dogbone Lake and Texas Hill (loc. O, fig. 113). Stefansson and Thurrell described it along most of the length of the Kogosukruk River (locs. O and Q) in the coastal plain, on the lower Kikiakrorak River north of lat 69°46′ N. (locs. M and N), and on the Colville River from Sentinel Hill core test 1 (loc. S) to Ocean Point. Neither party recorded the southern limit of the formation. At Ocean Point (loc. P) Webber described a section of fossiliferous sand containing silt at the top and gravel at the base and overlying 2 feet of plastic clay above the bedrock. On Keith Creek near Square Lake (loc. L) the U.S. Navy party of Paine and Wayman reported yellow porous sand that is apparently confined to the valley floor for 6 miles south of Square Lake but is widespread in the flat Arctic Coastal Plain north of the lake. Paine and Wayman referred this sand to the Cretaceous, but from its lithology and topographic position it is more probably Gubik Formation. On the Ikpikpuk River, Webber assigned gravel at lat 69°36′ N. (loc. F) and sand at 69°39′ N. (loc. E) to the Gubik. About 2½ miles west of the latter locality at a big lake (loc. D) Whittington in 1947 noted Pleistocene silt; Brosgé and Kover found similar silt at Watermelon Lake (loc. I). Webber also noted a high flat terrace of dirty crossbedded silt and sand about 70 feet above water level at the forks at the head of the Ikpikpuk (loc. J) which is mapped as alluvium on plate 52 but may represent the Gubik Formation. Black (1964) sampled the Gubik at several localities in the area, on the Colville River (loc. R) at lat 69°46′ N. and at two lakes near the Price River (locs. G and H).

In addition to the surface data the Gubik is known from shothole samples taken by United Geophysical Co., Inc., during the seismic exploration near the Square Lake and Oumalik wells. Near Square Lake, seismic traverse line 16–51–144 (see pl. 54) runs northward from the Arctic Foothills into the Arctic Coastal Plain along the ridge crest just east of Wolf Creek (loc. K). Single samples taken from near the bottoms of the shotholes have been examined by F. R. Collins. Figure 114 shows the section through the shotholes. Most samples are contaminated and contain fragments of both the Gubik Formation and Colville Group, but the base of the Gubik can be located approximately above the highest occurrences of the Colville Group and below a single sample of unmixed Gubik fragments. The three southernmost samples are of the Colville Group with no Gubik contamination, indicating that they are from beyond the southern limit of the Gubik. The Gubik also occurs in Square Lake test well 1 (Collins, 1959, p. 424). Thirty miles west of the Umiat-Maybe Creek region, Oumalik core test 2 (lat 69°50′ N., long 155°59′ W.) penetrated 40 feet of Gubik deposits above the Cretaceous rocks. In the area between the Oumalik well and the Titaluk River (at and around loc. A, fig. 113), samples of the Gubik from several seismic shotholes of lines 6–47 through

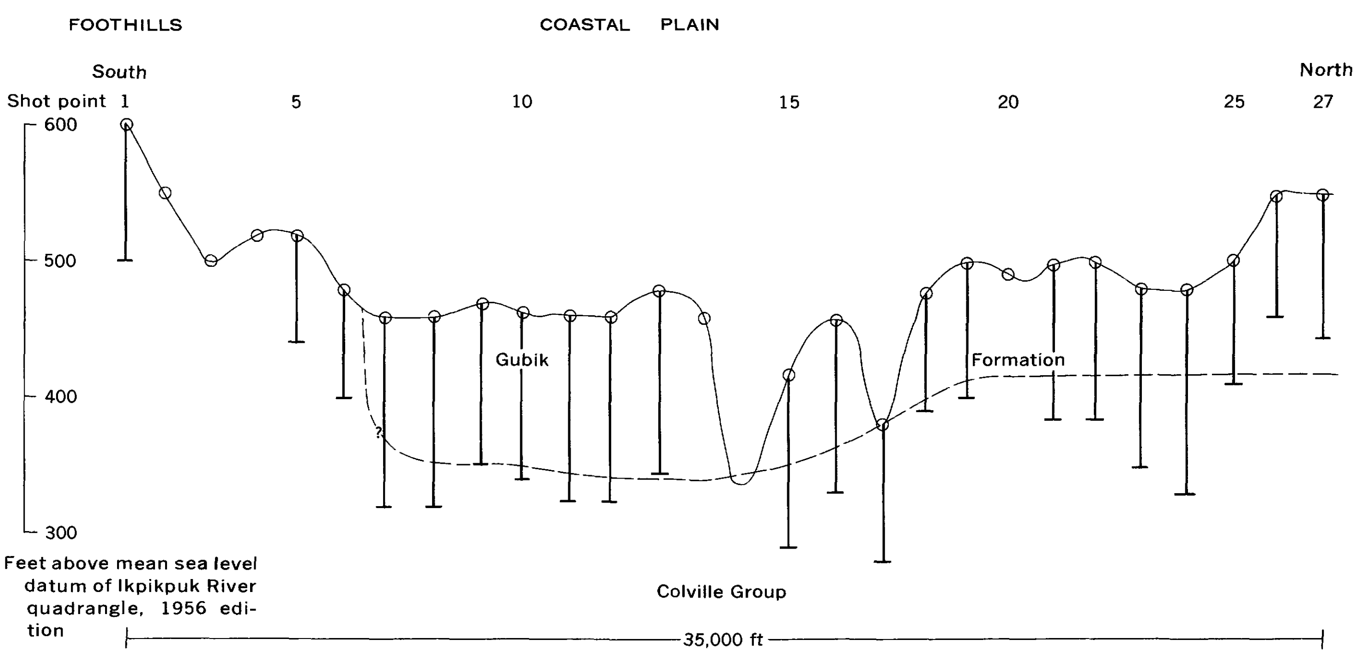


FIGURE 114.—Approximate location of the base of the Gubik Formation near Wolf Creek based on bottom samples from shotholes along seismic traverse line 16–51.

16–47 yielded an abundant fresh-water ostracode fauna. This fauna also occurs at localities B and C in figure 113 (shot point 9, line 11–47 and shot point 7, line 17–47) a few miles east of the mouth of the Titaluk River (F. M. Swain, written commun., 1949).

LITHOLOGY

Black (1957, 1964) tentatively divided the Gubik Formation in the Arctic Coastal Plain province into three lithologic units. From oldest to youngest these are: a basal marine clay in the north and west; a clean, light-colored well-sorted nearshore marine sand that is conglomeratic at the base and includes loesslike material; and a poorly sorted to well-sorted marine fossiliferous deposit in the north. The middle sandy unit lies on the lower clay unit and laps southward onto Cretaceous bedrock. The upper unit also lies on the lower clay unit and grades laterally and vertically into the middle sandy unit.

In the Umiat-Maybe Creek region the Gubik consists largely of the nearshore marine sand of the middle unit. This sand grades southward into fresh-water silt where the unit laps onto the foothills. A layer of gravel at the base of the sand rests unconformably on the bedrock over most of the region. At the northern edge of the region, near Ocean Point (loc. P, fig. 113), a thin wedge of fossiliferous marine clay and fine sand of the lower unit intervenes between the middle unit and the Cretaceous rocks.

Stefansson and Thurrell (written commun., 1948) described the Gubik Formation of this area as:

> a loosely consolidated, extremely crossbedded, yellowish or buff-colored sand, ***. Generally the basal 10 feet is conglomeratic, with angular to subangular pebbles, cobbles and boulders of chert, tuff, sandstone, shale, silt, and ironstone. Some exposures show the basal 1–2 feet to be a grayish sand that usually contains fossils. ***In places a bluish clay underlies the sand. In the upper part of the sand peat beds up to four feet thick are found. The maximum thickness of this sand seen in this area***is about 150 feet***.

The most commonly noted lithologic unit is the fine-grained yellow-red sand. This sand and the underlying gravel are diagnostic lithologic units and have been used by F. R. Collins to identify the Gubik in the shothole samples at Wolf Creek (loc. K, fig. 113; fig. 114). She described the sand unit there (written commun., 1953) as: "very well rounded, usually fine- to medium-grained sand, very clean, unconsolidated, and composed of clear and yellow quartz and orange, yellow, or black chert***." As shown on the map (fig. 113) the yellow sand and gravel comprise almost all the Gubik outcrops described between the Colville and Ikpikpuk Rivers north of the Arctic Foothills. In most of this area the gravel lies beneath the sand and directly on the Cretaceous rocks; at one place on the Kikiakrorak River it includes angular slabs of ash and sandstone apparently reworked from the underlying bedrock. Although in some places the contact with the underlying Cretaceous rocks appears conformable, Stefansson and Thurrell noted several channels at the contact along the Kogosukruk River. At lat 69°38′ N. the basal bed thickens southward from 25 to 60 feet; at lat 69°40′ N. a shallow channel truncates underlying beds; and at lat 69°49′ N. a channel cuts 30 to 40 feet deep in the underlying rock. At Wolf Creek the basal contact of the formation, as shown by the seismic shotholes (fig. 114), has at least 60 feet of relief.

The main body of yellow sand and gravel in the area mapped has yielded fossils at only two localities. In the gravel outcrop on the Ikpikpuk River, Webber noted what he believed to be fresh-water snails. In the shotholes at Wolf Creek three unidentified ostracodes, thin-shelled like the marine ostracodes of the Gubik, were found in the sample from shot point 25 (F. R. Collins, written commun., 1953). Despite the lack of fossil evidence, the wide distribution of the yellow sand and gravel in an area between major rivers, as well as the roundness of the grains and the uniform elevation at which they were deposited, shows that they were probably transported by marine waves and currents, although they may have been reworked by wind.

Along the southern margin of the formation, the yellow sand apparently grades into and is overlain by brown silt that laps onto the Arctic Foothills. The silt rests on the bedrock at one place (loc. S, fig. 113), on the Colville River about 8 miles north of the mouth of the Anaktuvuk River. About 9 miles farther north (loc. R), Black (1964) found silt interbedded with the sand but did not see the base of the section. At the other localities either gravel or gravel and sand appear to underlie the silt. Near the Ikpikpuk River the silt crops out in the interstream area where the base of the formation is not visible (loc. D), but yellow sand and gravel crop out at the base of the formation in the river bluffs 3 to 5 miles away (locs. E and F). At Oumalik core test 2, about 30 miles farther northwest, interbedded clay and sand possibly correlative with the silt are underlain by 10 feet of gravel at the base of the formation. At the head of the Ikpikpuk River (loc. J) in the exposures of alluvial silt that may correlate with the Gubik, Webber noted no evidence of gravel beneath the silt in the high terraces. Possibly there, as at the southernmost exposure on the Colville, the silt rests directly on bedrock.

There is some evidence that in the area west of

Square Lake the silt is more widespread than it is in the area to the east. More outcrops of silt have been noted there, and the sediments above the basal gravel in the Arctic Coastal Plain at the Oumalik wells are largely silt and clay rather than sand as they are in the Arctic Coastal Plain to the east. The bedding of the Gubik Formation observed on aerial photographs west of Wolf Creek may be due to the presence of silt, inasmuch as the known deposits of sand appear structureless on photographs.

As far as is known, the silt along the southern margin of the Gubik outcrop is nonmarine. Black (1964) described it as loesslike in part. No fossils were found in the silt near the Colville River; but throughout the area of seismic traverses around the Oumalik wells where the Gubik, above the basal gravel, consists of clay, sand, and silt, fresh-water ostracodes are abundant in the shothole samples (F. M. Swain, written commun., 1949, 1960) and only two specimens of marine Foraminifera have been found (H. T. Loeblich, written commun., 1949). Fresh-water ostracodes also occur in the silt sampled by Whittington near the Ikpikpuk River (loc. D, fig. 113) (lat 69°40′ N., long 154°58′ W.).

At the northern edge of the mapped area, finer grained clastics of Black's (1957) lower unit intervene between the Cretaceous rocks and the basal gravel of the middle sand unit. From the mouth of the Kikiakrorak River northward to Ocean Point, the gravel is underlain by about 15 to 20 feet of gray fine-grained marine fossiliferous sand which lies uncomformably on the Cretaceous rocks and at one place in the Colville Group truncates a normal fault that has a displacement of 6 feet. At Ocean Point (loc. P, fig. 113) the fossiliferous sand and gravel are underlain by 2 feet of blue clay.

The cross section in figure 113 shows the relation of the marginal silt, the yellow sand and gravel, and the known marine sand and clay as exposed along the Colville River. The marginal silt intertongues northward with the yellow sand, and these, together with their basal gravel, lap northward over the fossiliferous marine sand and clay and interfinger northward with silt that is probably marine. This same relation fits the data for the area that extends westward to the Ikpikpuk River. From this it appears that the Gubik Formation of this area consists of three elements: massive sand and gravel containing peat and plant detritus deposited in beaches and lagoons; silt and sandy silt deposited by streams and possibly by wind in lakes, flood plains, deltas, and barred fresh-water lagoons behind the beach; fossiliferous sand, silt, and clay deposited seaward of the beach. The northward overlap of the beach sand over the marine sand marks a recession of the sea during deposition.

The maximum thickness of the Gubik Formation in this area was measured by Stefansson on the Kikiakrorak River at lat 69°46′ N. The exposure there is 150 feet thick. Just north of the mapped area, Black (1964) reported a thickness of 180 feet. Many thicknesses of 15 to 75 feet have been reported along the Kogosukruk River, but, as they are of incomplete sections, the maximum reported thickness in the area is probably nearer the true thickness. This thickness agrees with the incomplete thickness of 130 feet that was determined from the seismic shotholes at Wolf Creek. The total thickness of the formation probably varies because of facies changes, lensing of beds, and the amount of erosion represented by the unconformity at the base.

In addition to the local relief due to channeling, the unconformity at the base of the Gubik Formation rises generally southward from an elevation (1956 datum) of about 100 feet near Ocean Point to elevations of about 300 feet near Sentinel Hill and about 600 feet on the Nanushuk River at lat 69°14′ N., long 150°53′ W. (Detterman and others, 1963). Elevations have been established for all the reported outcrops of the base of the Gubik Formation in the Umiat-Maybe Creek region as well as for the shothole positions. Figure 115 is based on these elevations. The surface of the unconformity dips northward. In the only area where closely spaced elevations permit detailed shaping of the contours, a valley about 50 feet deep follows the present course of the Kogosukruk River; this valley indicates that the drainage on the pre-Gubik surface had the pattern of the present drainage. Although the general northward slope of the erosion surface is more than twice as steep as the present gradient of the Colville River, the slope of the pre-Gubik valley on that surface is the same as that of the lower Colville and of the Kogosukruk, or about 3 feet per mile; this relation indicates that the Arctic Coastal Plain has not been tilted since the Gubik was deposited.

PALEONTOLOGY AND AGE

Megafossils from the lower marine sand at two localities (D305T, D306T) near Ocean Point have been identified by F. S. MacNeil (1957, p. 110). Fresh-water ostracodes from the silt at one outcrop locality near the Ikpikpuk River were identified by I. G. Sohn. In addition, fresh-water ostracodes from 2 shothole samples near the mouth of the Titaluk River and from 35 shothole samples near the Oumalik wells were identified by F. M. Swain, and marine Foraminifera from two of the Oumalik shotholes were identified by

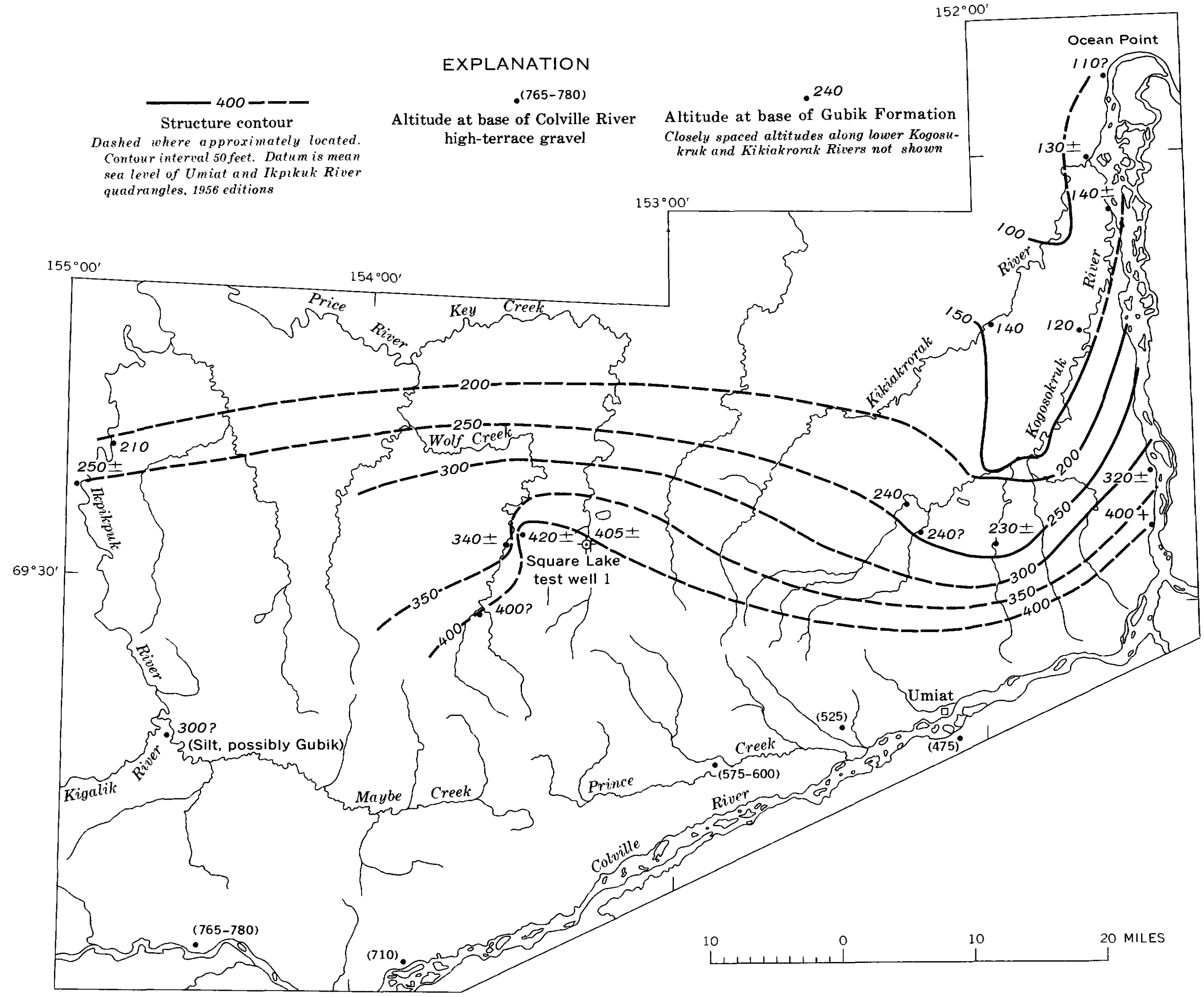


FIGURE 115.—Unconformity at the base of the Gubik Formation.

H. T. Loeblich. The mollusks of the lower marine beds near Ocean Point have been tentatively assigned a late Pliocene or early Pleistocene age by MacNeil. Marine mollusks from higher horizons in the Gubik outside the Umiat-Maybe Creek region are of Pleistocene age (MacNeil, 1957, p. 108), and the fresh-water ostracodes have been assigned a Pliocene or younger, probably Pleistocene, age by I. G. Sohn (written commun., 1955) and a Pleistocene age by Swain (1960). MacNeil (1957, p. 109) suggested that the fossil-bearing rocks, if all are correctly assigned to the Gubik, may have been deposited during several advances and retreats of the sea in Pliocene and Pleistocene time. Black (1957) considered the lowest units to be Pleistocene. The Gubik is herein considered to be Pleistocene, with the reservation that the oldest beds of the formation, as mapped, may prove to be as old as Pliocene.

The identified faunas are listed below; their localities are shown by letter on the map of figure 113.

Locality M

[Colln. 47ASt48, USGS Tertiary loc. D305T. Collected by Stefansson in 1947 from gray sand about 20 ft above the base of the Gubik Formation near the mouth of the Kikiakrorak River]

Gastropoda:
- *Tachyrhynchus erosus major* Dall
- *Neptunea* cf. *N. elatior* (Middendorff)
- *N. leffingwelli* (Dall)

Pelecypoda:
- *Macoma calcarea* (Gmelin)
- *Saxicava arctica* (Linné)

Locality P

[Colln. 47ASt51. USGS Tertiary loc. D306T. Collected by Stefansson in 1947 at Ocean Point on the Colville River from the same horizon as collection 47ASt48]

Gastropoda:
- *Tachyrhynchus erosus major* Dall
- *Natica clausa* (Broderip and Sowerby)
- *Neptunea leffingwelli* (Dall)
- *Buccinum physematum* Dall
- *B.* sp. aff. *B. ochotense* (Middendorff)
- *Colus* (*Aulacofusus*) *spitsbergensis* (Reeve)
- *Plicifusus* sp. aff. *P. kroyeria* (Möller)
- *Antiplanes* cf. *A. perversa* (Gabb)

Pelecypoda:
- *Chlamys hindsii* (Carpenter)
- *Astarte broweri* Meek
- *Cardita* (*Cyclocardia*) cf. *C.* (*C.*) *crebriocostata* (Krause)
- *Serripes groenlandicus* (Bruguière)
- *Spisula* cf. *S. polynyma voyi* (Gabb)
- *Saxicava arctica* (Linné)
- *Cyrtodaria kurriana* (Dunker)

Cirrepedia: *Balanus* sp.
Vermes: Unidentified worm tubes

Locality D

[Colln. 47AWh1. Collected by Whittington in 1947 from 25 ft of silt exposed in the northwest bank of the big lake between Bronx Creek and the Ikpikpuk River at lat 69°40′ N., long 154°58′ W. (I. G. Sohn, written commun., 1955)]

Ostracoda:
- *Ilyocypris*? sp., one broken valve
- *Candona*? sp., two fragments
- Genus indet., young individual

Locality A

[Collected by the United Geophysical Co., Inc., in 1947 in the Oumalik area between lat 69°45′ N. and 69°55′ N. and long 155°20′ W. and 156°00′ W. The species from all samples are summarized here. Ostracoda (F. M. Swain, written commun., 1964) are from 35 shotholes on lines 6–47 through 16–47, party 46. Foraminifera (Helen Tappan, written commun., 1949) are from shot point 12 on line 13–47 and shot point 8 on line 14–47, party 46]

Ostracoda:
- *Candona* sp.
- *C.* cf. *C. candida* (Müller)
- *C.* cf. *C. lactea* (Baird)
- *Cladoceran*?
- *Potamocypris*? *pellucidus* Swain
- *Prionocypris pigra* (Fischer)
- *Cytherissa simplissima* Swain
- *Limnocythere* cf. *L. sancti-patricii* (Brady and Robertson)
- *Candonopsis* cf. *C. kingsleyi* (Brady and Robertson)

Foraminifera: *Elphidium* sp.

Locality B

[Collected by the United Geophysical Co., Inc., in 1947 from shot point 9 on line 11–47, party 43, near the mouth of the Titaluk River at lat 69°59′ N., long 154°24′ W. (F. M. Swain, written commun., 1949)]

Ostracoda: *Ilyocypris* cf. *I bradyi;* Sars

Locality C

[Collected by the United Geophysical Co., Inc., in 1947 from shot point 7, on line 17–47, party 43, near the mouth of the Titaluk River at lat 69°54′ N., long 154°32′ W. (F. M. Swain, written commun., 1964)]

Ostracoda. *Limnocythere* cf. *L. sancti-patricii* (Brady and Robertson)

The measured sections are located by letter in figure 113.

Locality M

[Measured by Stefansson in 1947; lat 69°54′ N., long 151°44′ W.]

	Thickness (feet)
Gubik Formation:	
Sand, yellow-weathering, and peat; contains some layers of gray sand	15
Sand, yellow-weathering, and interbedded gravel; peat	10
Sand, gray, fine-grained, crossbedded, loosely consolidated. Top is conglomeratic and contains gastropods and pelecypods, 47ASt48 (USGS Tertiary loc. D305T	20
Base of Gubik Formation:	
Bony coal, carbonaceous shale, and clay, Colville Group	6

Locality N

[Measured by Stefansson in 1947; lat 69°49′ N., long 151°53′ W.]

Gubik Formation:	
Sandstone, yellow-weathering, loosely consolidated, extremely crossbedded; crossbedding at angles up to 30°. Interbedded, finely layered peat in beds as thick as 4 ft	75
Conglomerate, loose; contains well-rounded fragments to angular slabs as much as 1 ft in diameter consisting in part of sandstone and volcanic ash	½
Erosion surface.	
Colville Group:	
Bentonite and volcanic ash	4

Locality O

[Measured by Rogers and McConnell in 1945; lat 69°38′ N., long 152°0′ W.]

Gubik Formation:	
Sand, yellow, coarse-grained, loose	34
Sand, coarse-grained; and gravel	5
Colville Group:	
Shale, gray, bentonitic	12

Locality P

[Measured by Webber in 1947; lat 70°06′ N., long 151°26′ W.]

Gubik Formation:	
Sand, silt, and gravel, unconsolidated; buff-weathering except for one 6-in. maroon-weathering zone 20 ft above base. Grades upward from mostly gravel at base to interbedded silt and sand. Mostly even bedded; locally crossbedded. Lenses of peat 6 to 8 in. long and twigs ½ in. in diameter and 6 to 7 in. long	20
Sand, at base is unconsolidated; contains some pebbles and cobbles of sandstone, coal, and chert. Contains gastropods and pelecypods. Lower few inches apparently includes lumps of the underlying blue clay. Clay, blue, lower contact gradational. Upper contact indistinct because of mixing with overlying sand	1 to 2
Base of Gubik Formation:	
Rocks of Colville Group.	

Locality Q

[Measured by Stefansson in 1947; lat 69°59′ N., long 151°37′ W.]

	Thickness (feet)
Gubik Formation:	
Sand, yellow-red, yellow-weathering, extremely cross-bedded. Beds of peat.	
Sand as above and gravel consisting predominantly of chert pebbles; some layers contain shale and tuff	15
Base of Gubik Formation:	
Rocks practically horizontal and apparently conformable.	
Colville Group:	
Silt and sandstone	5

HIGH-LEVEL TERRACE DEPOSITS

On both sides of the Colville River above Umiat, a bed of alluvial gravel lies unconformably on the Cretaceous rocks at the top of the river bluffs. This gravel has been recognized by all those who have worked on the bedrock geology of the area but has not been mapped in the field. It consists of pebbles, cobbles, and some boulders of quartz, quartzite, chert, and scarce conglomerate; at one outcrop quartzite is the chief constituent. In addition to the gravel, sand has been noted in the outcrops along Prince Creek. The thickness of the gravel is commonly about 20 feet but ranges from 15 to 67 feet. It occurs about 150 to 250 feet above the level of the Colville River and slopes downstream from Killik Bend to Umiat at the rate of about 5 feet per mile, which is approximately the present river gradient there.

The terrace gravel is apparently overlain by a layer of silt. Except in the broad flats between the Colville River and Prince Creek, the dissected terrace surface is well above the level of the gravel; even in the Prince Creek flats, the topographic surface is slightly higher than the top of the gravel bench. On the south side of the Colville the gravel is known to be overlain by about 30 feet of silt that has been identified as periglacial loess (Detterman and others, 1963). Probably this material also covers the gravel north of the river. In the only observation of the terrace surface there, Bickel noted that the soil above the level of the gravel at Prince Creek is gray to yellow and clayey. On the bluffs above the larger streams, the edge of the gravel bed forms a prominent level bench that is noticeable on aerial photographs. The terrace surface above the bench is generally flat and is characterized by many lakes and by a coarse pattern of short, wide stream channels that ramify at their heads from oval swampy areas that appear to be drained lake beds. Similar topography characterizes the loess mapped by Detterman, Bickel, and Gryc (1963).

DISTRIBUTION

In the Umiat-Maybe Creek region the gravel occurs discontinuously along the north bank of the Colville from a point about 12 miles above Killik Bend to a point about 5 miles above Umiat. At Killik Bend, where the river cuts against rock bluffs that are higher than the terrace level, the belt of gravel is broken. Above Killik Bend the gravel belt is only 2 to 3 miles wide; below Killik Bend the belt is as much as 9 miles wide, extending northward from the Colville River to the head of Maybe Creek and across the valley of Prince Creek. Although limited in extent within the Umiat-Maybe Creek region, the gravel is part of a very widespread deposit. On the south side of the Colville River, the gravel extends downstream at least as far as the mouth of the Anaktuvuk River and is traceable upstream as a great sheet that extends to the head of the Colville River and up the major valleys that enter it from the south (Detterman and others, 1963; Chapman and others, 1964; I. L. Tailleur, B. H. Kent, E. G. Sable, M. D. Mangus and J. T. Dutro, Jr., oral communs.).

The alluvial flat around Puddin Lake at the head of Prince Creek contains lakes like those on the high terrace. The flat seems to be slightly lower than the basal surface of the gravel, but its topography suggests that it may also be covered by silt.

In the area near Umiat covered by plate 56, the average elevation of the base of the gravel is probably about 550 feet (Umiat special datum; about 500 ft relative to mean sea level). Stefansson and Whittington saw the gravel in contact with bedrock only in the bluff on the south side of the Colville at long 152°15′ W., where the elevation of the contact was not determined but is certainly about 550 feet. The approximate contact there has been arbitrarily drawn to parallel the topographic contours—for the most part slightly above the 550-foot contour north of the river and slightly below the same contour south of the river.

AGE AND CORRELATION

The Pleistocene age of the terrace gravel can be inferred from its stratigraphic relation to the Pleistocene Gubik Formation. On the Nanushuk River, about 7 miles above its mouth, the terrace gravel lies conformably on 20 to 25 feet of yellow Gubik sand and gravel and blue clay (Detterman and others, 1963). In the Umiat-Maybe Creek region probably both the terrace gravel of the foothills and sand in the Gubik Formation of the Arctic Coastal Plain are overlain by fresh-water, or possibly windborne, silt. The silt included in the Gubik Formation is probably equivalent to the silt on the terraces, and the terrace gravel probably correlates broadly with some of the upper sands of the Gubik Formation.

LOW-LEVEL TERRACE DEPOSITS

Low-level terrace deposits are mapped on several lake-free surfaces along the Colville and Ikpikpuk Rivers that are above the general level of recognizable flood-plain terraces but below the level of the high terraces of the Colville.

Along the Colville River, the highest active flood plain is the gravel terrace about 25 feet above river level upon which Umiat stands. This terrace was flooded in the spring of 1948. A few lakes and stream channels on its surface retain their original oxbow shape, but most have lost their continuity. Between the level of this flood plain and that of the high-terrace gravels, there are discernible two other surfaces that are probably alluviated. These have been mapped as low terraces of the Colville River. One of the surfaces, which extends up the north side of the Colville about 5 miles from the mouth of Prince Creek, is a lake-free flat about 40 to 100 feet above river level. The other surface, about 100 to 150 feet above river level, is a semicircular area of low relief that borders the river about 20 miles above the mouth of Prince Creek.

In the Maybe Creek-Upper Ikpikpuk valleys, the aerial photographs show at least three sets of terraces at about 20, 50, and 70 feet above present river level. Except for a few remnants at the confluence of Maybe Creek and Kigalik River, the 70-foot terrace is restricted to the valley walls near the mouth of the Kigalik and to the south side of Maybe Creek and lower September Creek. No lakes occur on this terrace, and its drainage is integrated with that of the hill slopes behind it. Deposits on the terrace may correlate with the silt and gravel of the Gubik Formation farther down the Ikpipuk, since both deposits stand about the same distance above the river. The terrace, however, is composed of crossbedded dirty sand and silt and is probably alluvial; it is therefore mapped as a low terrace of the Ikpikpuk.

ALLUVIUM

The deposits mapped as alluvium include all the bars currently worked over by the rivers, as well as the flood plains and the high bars that are flooded only at high water every year or once every few years; on a few rivers they also include some completely abandoned flood plains as much as 50 feet above river level. These deposits have been mapped entirely from aerial photographs, most of them taken during low water in the summer of 1948. The active bars, extending as much as 5 feet above water level, are mostly bare of vegetation and show white on the photographs. The flood plains that are subject only to occasional flooding extend from about 5 to about 25 feet above water level and are overgrown and dark with willows. The abandoned flood-plain terraces at higher levels are also overgrown, and the oxbow lakes on these older flood plains have lost their original form and continuity through thermal sapping of their banks and through filling by alluvium and vegetation. The degree of destruction of the oxbow lakes helps to distinguish between the abandoned flood-plain terraces and the present flood plains. The various flood-plain levels have not been distinguished on the map (pl. 52) but all the flood plains, present and abandoned, have been distinguished from the active bars. Bars are outlined by dotted lines, flood plains by dashed or solid lines.

Unconsolidated deposits underlying the flood plain of the Colville River at Umiat range in thickness from 23 to 35 feet on the basis of apparently reliable logs of seismograph shotholes and certain of the test wells (fig. 116). In shotholes 1 to 6 the unconsolidated deposits consist of 20 to 27 feet of gravel and sand overlain by 2 to 5 feet of silty material or soil which the driller generally described as "frozen muck and ice." In Umiat test well 6 the unconsolidated deposits, described as gravel by the well geologist, are 28 feet thick (Collins, 1958a, p. 138). In Umiat test well 7 these deposits, on the basis of the driller's log, extend to a depth of 39 feet (35 ft below ground level), and Collins (p. 143) concluded that the rock from 39 to 52 feet, described by the driller as "gravel and sandstone," is also largely unconsolidated. On the basis of the data presented in figure 116, the writers consider that bedrock was reached in this hole at 39 feet and that the gravel referred to in the driller's log below this depth consisted of cavings from higher in the hole. Examination of samples of cuttings led Collins (p. 100–101) to conclude that the unconsolidated deposits in Umiat test well 2 were about 70 feet thick, extending from 9 to 80 feet in depth. She noted, however, that the gravels might be much thinner, and the writers are of the opinion that the siliceous sandstone fragments in samples from a depth of 30 to 60 feet represent bedrock rather than disintegrated sandstone pebbles from the gravel. According to the logs of shothole 5 and shothole 6, this well probably encountered bedrock at about 35 feet. Nearby, Umiat test well 5 provides no data on the extent of the surficial materials; the first sample from 65 to 75 feet consists of sandstone, siltstone and shale (Collins, 1958a, p. 132). In shotholes 7 and 38 unconsolidated deposits are 41 and 38 feet thick, respectively; but because these holes are at higher elevations, the elevation of the bedrock surface in these holes is no lower than in the

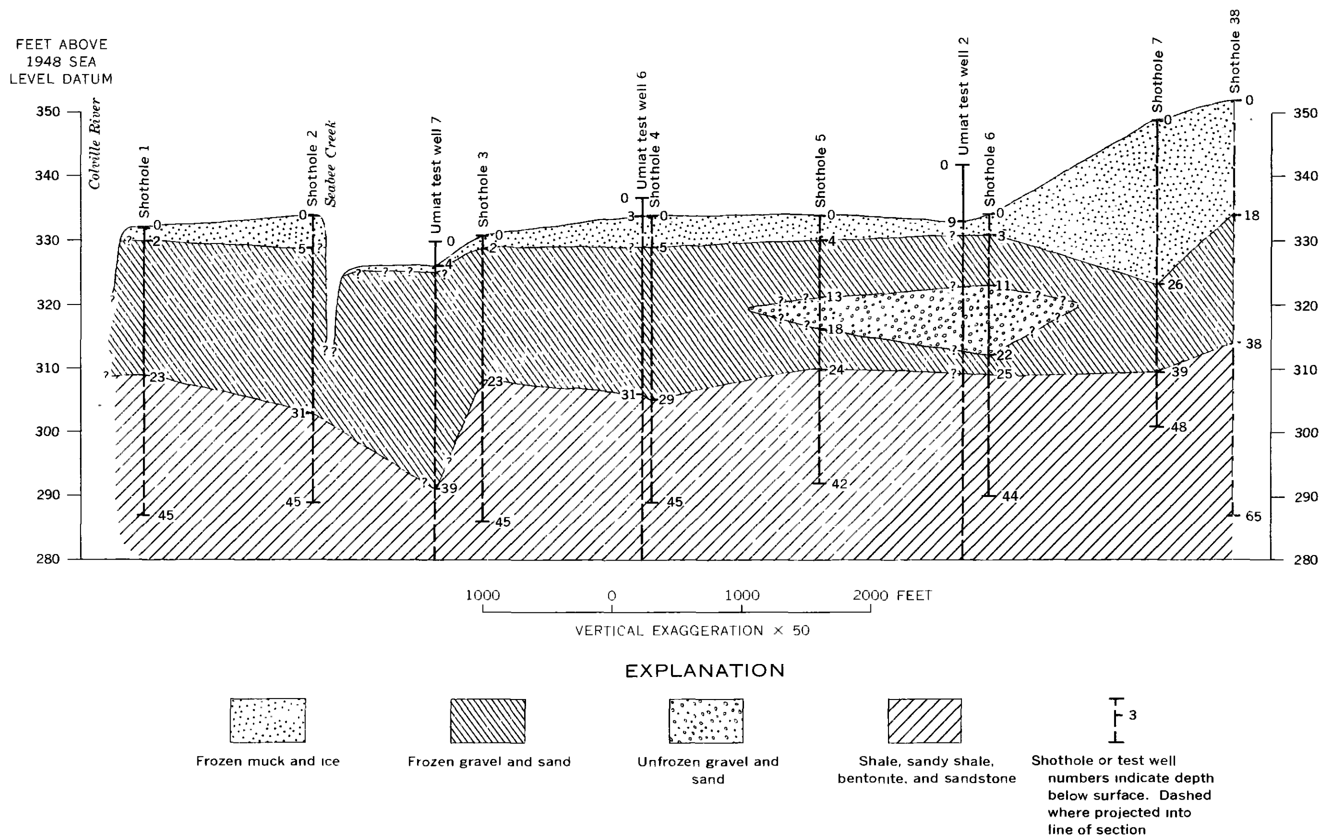


FIGURE 116.—Colville River flood plain at Umiat. Logs of shotholes (line 1-46) by United Geophysical Co., Inc. Shothole elevations decreased 4 feet to adjust them to test-well elevations. All elevations are about 70 feet too high relative to 1956 sea-level datum.

other shotholes. Possibly, the excess surficial material at shothole 7 is solifluction debris from the nearby ridge. In shothole 38, and possibly in shothole 7, the excess section probably represents an alluvial fan deposited by Bearpaw Creek.

In the valley of the Kikiakrorak River are three conspicuous alluvial terraces, about 10, 25, and 40 feet above the river. Oxbow lakes on the two upper terraces have lost their shape and continuity and many have been completely drained, whereas those on the lowest terrace still appear fresh. The upper terraces of the Kikiakrorak River may have their counterparts in the Kogosukruk valley, but there the present flood plain occupies the whole mile-wide valley floor, leaving little room for old terrace remnants.

The 50-foot and 20-foot terraces in the Maybe Creek-upper Ikpikpuk valleys contain many remnant lakes. Few of the lakes on the 50-foot terrace retain the smooth oxbow form, but the 20-foot terrace has fresh oxbow lakes and clearly defined meander scrolls. Locally, smooth slip-off slopes connect the surface of the 20-foot terrace with the present active bars. Both of these terraces extend far up Maybe Creek and down the Ikpikpuk River and have been mapped as alluvium.

The texture and composition of the alluvium varies from river to river. The bars of the Colville, at least as far downstream as the mouth of the Anaktuvuk, consist largely of rounded pebbles and cobbles of chert, quartzite, sandstone, quartz, and limestone. Pebbles and cobbles of Lisburne Group limestone and of Kanayut Conglomerate in the active bars show that the gravels of the Colville River were derived from as far away as the Brooks Range. They could have been recently transported from the mountains or have been reworked from the high-level terrace gravels that were originally carried across the Arctic Foothills as glacial outwash. The bars of Maybe Creek and the Ikpikpuk River, on the other hand, consist of locally derived brown sand and flat pebbles of sandtone and ironstone. In addition to these, the gravel on an Ikpikpuk River bar about 5 miles below the mouth of Maybe Creek includes abundant large irregularly shaped pebbles of gray vesicular, pumicelike material that is probably clinker from a burnt-out coal bed. The flood-plain deposits of the Ikpikpuk are similar to those of its active bars. In a section measured by Webber about 6 miles below the mouth of Maybe Creek, the alluvium consists of three quarters of a foot of soil, largely peat and sand; 13½ feet of very fine grained brown subangular sand containing peat and vegetable matter throughout and thin lenses of reworked coal grains in the lower 4 feet; and a basal 1½ feet of gravel and fine- to medium-grained sand.

Vertebrate remains occur in the alluvium of many streams. Rogers and McConnell reported numerous mammoth tusks, teeth, and bones on the bars of the Kogosukruk and Kikiakrorak Rivers in addition to a tusk embedded in gravel and a large vertebra on alluvial terraces 10 and 25 feet above the Kikiakrorak. Only small chips of ivory have been found on the bars of lower Maybe Creek, but several incomplete tusks, as much as 3 feet long, and one large molar were found in the bed of the Ikpikpuk about 5 miles below the mouth of Maybe Creek. Webber has also noted tusks in the alluvium of the Ikpikpuk about 19 miles below the mouth of Maybe Creek (lat 69°37′ N.). Most of the tusks are not known to have been found in the place of burial; they may have been thawed from the flood-plain deposits or from higher level silt of the Gubik Formation or high terraces of the Colville. Even under water, however, some of the larger tusks were thoroughly split and checked; it is therefore unlikely that, after thawing, they could have been transported very far without having been broken up completely. On the other hand, a spruce log 4 feet long and 5 to 6 inches in diameter, found by Webber on the Ikpikpuk at lat 69°40′ N., and similar logs found at many places along the Kikiakrorak by Rogers and McConnell may well have been reworked from the Gubik Formation after having been beached as driftwood during the last marine invasion.

STRUCTURE

The Umiat-Maybe Creek region is one of low local structural relief and persistent regional northeastward dip. Except near the axial zones of some anticlines, the rocks in the foothills area dip less than 10°, and in most of the coastal plain area dip less than 3°. Nevertheless, because of the persistent regional dip, the total structural relief is about 10,000 feet between the high at Knifeblade Ridge in the southwest and the low at Ocean Point in the northeast. The individual structural features trend generally east to east-southeast and plunge to the east. This plunge is the continuation of a regional plunge eastward from a high near the Meade River and forms one component of the northeastward regional dip.

The structural features are slightly asymmetrical; axial planes of the anticlines dip steeply to the south and in the higher anticlines are associated with axial faults. The three major outcropping fault zones of the area are at Umiat, Weasel Creek, and Knifeblade anticlines and consist of high-angle faults at or just north of the axes of the anticlines. In addition to these major fault zones, small high-angle faults of about 100 feet displacement occur south of the axes of Fossil Creek, Wolf Creek, and Umiat anticlines, and many faults having a displacement of only a few feet occur in the almost flat-lying beds of the Arctic Coastal Plain.

The area is divided by Prince Creek syncline into two areas of different general structural altitude. South of Prince Creek syncline and centered on Maybe Creek is a broad area of relatively small regional northward dip in which the elevations of most anticline axes are accordant. At Prince Creek syncline the beds descend abruptly 1,200 feet, and, except for a small area around the wells on Umiat anticline, the anticlines north of Prince Creek syncline are as low as the synclines to the south.

The general structural pattern of the area is shown by a small-scale structure-contour map (fig. 117) and by four sections (pl. 52). More detailed structure contours of the closed parts of the anticlines, as well as subsurface seismic contours in the Coastal Plain, are shown on plate 52. The sections (pl. 52) were compiled from field, photograph, and well data, supplemented by geophysical information. The detailed contours are based on geologic mapping and elevations by U.S. Geological Survey parties, on well data, and on seismic traverses by United Geophysical Co., Inc. Figure 117 was compiled from the detailed contours and from a scattering of measured and approximated elevations on various stratigraphic horizons—some identified in the field, some from aerial photographs. The contours have been projected from the various locally mapped key horizons to a common datum at the top of the Seabee Formation.

TRANSVERSE TRENDS

Few of the structural features are continuous across the region. All anticline axes terminate or are offset, and their regional east plunge is interrupted by reversals that produce local closed highs. South of Prince Creek syncline many of the reversals and offsets lie along three transverse lines that are structural lows.

The most conspicuous of these transverse lows is a line of reversal that trends N. 65° E. from near meridian 154° W. to the mouth of Prince Creek, approximately parallel to, and about 4 miles north of, the Colville River. The anticlines of the Maybe Creek area plunge eastward into this low; the anticlines in the area south and east of the Colville River plunge abruptly westward into it (Detterman and others,

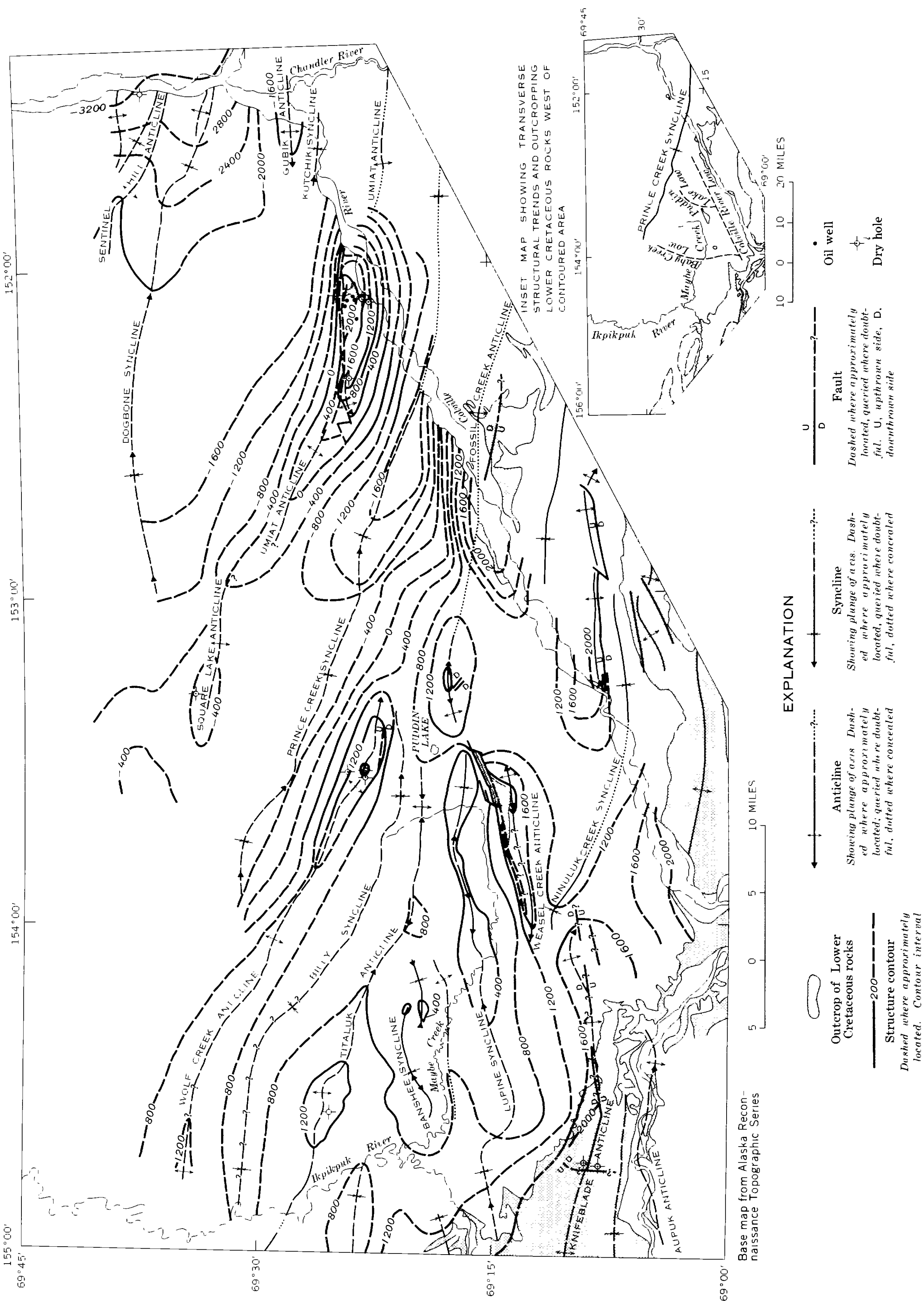


FIGURE 117.—Generalized structure-contour map of the top of the Seabee Formation. Data south of the Colville River are from Detterman and others (1963) and Chapman and others19(64).

1963). This line of reversal lies in an area largely covered by high-terrace gravels of the Colville River, but it appears that only two structural features, Fossil Creek anticline and Ninuluk Creek syncline, are continuous across it; others either end or are offset sharply at the line. The transverse low does not affect the direction of plunge in Prince Creek syncline and in the structural features north of it; indeed, the high at Umiat lies nearly on line with this low.

Two other transverse trends extend almost due north from the Colville River low: one is a line of offset of structural features along the Puddin Lake flats at the head of Prince Creek, the other is a transverse low at Baby Creek. The Baby Creek low extends northward from the reversal between the east-plunging nose of Knifeblade anticline and the west-plunging nose of Weasel Creek anticline, through the low point of Lupine syncline, through a saddle between the two highs on Titaluk anticline, and through a probable saddle on Wolf Creek anticline. As noted in the discussion of sandstone 8 of the Tuluvak Tongue, part of this Baby Creek area was probably low during Tuluvak sedimentation. The Puddin Lake low extends northward through the alluviated flats between the noses of Weasel Creek, Titaluk, and Wolf Creek anticlines and the nose of Fossil Creek anticline. These anticlines end or are offset abruptly at the flats. Wolf Creek and Weasel Creek anticlines plunge toward the flats from the west and Fossil Creek anticline plunges toward the flats from the east, so the Puddin Lake low is a line of reversal as well as of offset. Because the Puddin Lake flats are covered with alluvium, the relation of the structural features is not clear. Fossil Creek anticline may join either Titaluk anticline or Weasel Creek anticline; it may bifurcate and join both; or, as the transverse low is associated with the Weasel Creek anticline fault zone, the eastern and western structural feaures there may be separated by a hidden transverse fault. Neither the Baby Creek nor Puddin Lake trend appears to affect the structure of Prince Creek syncline.

The transverse structural pattern shown by the surface mapping south of Prince Creek syncline is also shown by the total aeromagnetic intensity map of Naval Petroleum Reserve No. 4 prepared by the U.S. Geological Survey (Payne and others, 1951, fig. 8). From Prince Creek syncline northward the linear highs and lows of magnetic intensity trend east to southeast; a major magnetic high lies close to the trend of Umiat anticline and a low occurs approximately along Prince Creek syncline. South of Prince Creek syncline the major feature is a north-trending magnetic low that coincides with the Baby Creek structural low. The least magnetic intensity of the area is at the intersection of this north-south low with the axis of Lupine syncline.

The Maybe Creek area south of Prince Creek syncline is in effect a structural basin having its lowest point where Lupine syncline reverses plunge at the Baby Creek low. This basin is bounded on two sides by a pair of conjugate transverse elements: one, the Colville low, trends N. 65° E.; the other trends N. 50° W. (see inset map, fig. 117). Anticlines plunge eastward into the basin from the high near the Meade River and westward into it from a high near the Chandler River (Detterman and others, 1963). The Lower Cretaceous rocks that crop out extensively on anticlines south and east of the basin plunge out where these anticlines intersect the northeast-trending Colville River low. The Lower Cretaceous rocks that crop out on anticlines south and west of the basin plunge out eastward approximately where these structural features intersect a line that trends N. 50° W. The two conjugate lines intersect at about meridian 154° W., just north of the bend in the Colville River (Killik Bend), and are parallel to the straight line courses of the Colville River above and below the bend.

STRUCTURE AT DEPTH

The structure of the pre-Cretaceous and the oldest Cretaceous rocks in the Umiat-Maybe Creek region is known only from the seismic surveys and gravimetric measurements made by United Geophysical Co., Inc., and from the airborne magnetometer survey by the U.S. Geological Survey (Woolson and others, 1962; Payne and others, 1951, fig. 8, 9, 10). Data from these different geophysical sources give different pictures of the structural features at depth. The seismic work indicates that in the Arctic Coastal Plain both the Jurassic or oldest Cretaceous rocks and the basement surface have a simple monoclinal southward dip—about 100 and 185 feet per mile, respectively—that is little related to the structural feaures and regional dip at the surface. The gravity and magnetic data, on the other hand, indicate that the structure of the basement itself reflects, at least in part, the structural features at the surface.

Because the deep seismic data do not extend south of the Arctic Coastal Plain, however, this discordance need not be inferred beneath the more intensely folded structural features of the Arctic Foothills.

Unlike the maps of the deep seismic horizons, the maps of both gravitational and magnetic intensity show many highs and lows and outline some trends that are parallel to the structural trends at the surface. Anomalies shown on the magnetic intensity map (Payne and others, 1951, fig. 8) are assumed to be controlled by the basement rock. The most conspicuous feature of this map is the magnetic high coincident with Umiat anticline and trending N. 55° W. for over 150 miles from Umiat to the Meade River. Parallel to this high on the south is a magnetic low roughly coincident with Prince Creek syncline. The anomalies south of this low are dominantly northward trending. The anomalies in the Arctic Coastal Plain north of the Umiat high do not coincide with surface structural features but do trend northwestward to westward parallel to them.

None of the observed gravity anomalies (Payne and others, 1951, fig. 9) coincide directly with surface structural features except for a gravity low coincident with part of Prince Creek syncline. The gravity anomalies do, however, have northwestward and northward trends similar to those of the magnetic anomalies and so may be controlled by the same structural features at depth. A marked domelike magnetic high concides with a similarly shaped gravity high in the Arctic Coastal Plain at about lat 69°50′ N., long 152° 40′ W., where no high is shown by any of the seismic contours.

Depths to the basement rocks have been computed from the measured magnetic anomalies for several points in Naval Petroleum Reserve No. 4 (Dana, 1951) and agree with the depths to basement determined by seismic methods in the Arctic Coastal Plain. For the magnetic anomaly at Umiat the computed depth to basement is 20,000 feet. No estimate of the depth to basement has been made by seismic methods as far south as Umiat; but, inasmuch as the estimated depth about 15 miles south of Ocean Point is 21,000 feet, (Payne and others, 1951, fig. 10) the depth at Umiat by extrapolation of the southward gradient of seismic horizons from Ocean Point should be at least 25,000 feet. If the depth measurements obtained by both the seismic and the gravity methods are to the same basement surface, as they appear to be in the Arctic Coastal Plain, then the computed shallower depth to basement at Umiat would indicate that the basement surface arches up over the Umiat high.

AUPUK ANTICLINE

The Aupuk anticline trends westward for about 20 miles along the valley of the Colville River in the southwest corner of the mapped area (pl. 52). The western 6 miles of the 20-mile length lies west of the area of plate 52. At its west end the fold appears to pass into a northwest-trending zone of high-angle reverse faults.

The Aupuk anticline was mapped by Chapman and Thurrell in 1946 and Eberlein and Reynolds in 1950 and is described in a separate report (Chapman and others, 1964), but stratigraphic data from the work on the anticline are presented in section 1 (strat. sections and pl. 53).

KNIFEBLADE ANTICLINE

The Knifeblade anticline, in the southwestern part of the Umiat-Maybe Creek region, is a steep complexly faulted fold which trends about N. 75° W. about 3 to 7 miles north of the Colville River (pls. 52 and 55). It is modified on either end by reverse faults and cut near the west end by a north-trending cross fault. Knifeblade test wells 1 and 2A were drilled on either side of the anticline axis just east of this fault. The anticline can be traced for about 10 miles to the west and 20 miles to the east of the cross fault. The Knifeblade anticline lies on the same line of folding and is probably a continuation of the Kigalik anticline and thrust fault, which can be traced westward for about 75 miles from a point about 17 miles northwest of the cross fault on the Knifeblade anticline.

The presence and location of the cross fault on Knifeblade anticline is clearly indicated by the abrupt eastward termination of vertically dipping sandstone beds of the Grandstand Formation. North of this clearly evident segment the fault presumably continues for some distance, possibly as much as 2 miles. South of the clearly evident segment the fault has been mapped for about 2 miles and may continue farther south. In this area surface expression is much poorer, but as far as is known all bedding traces on both the east and west sides terminate at the fault line, and available evidence indicates that the Killik-Grandstand contact is considerably offset.

East of the cross fault the anticline is modified by a longitudinal reverse fault of considerable displacement. The fault is marked by a topographic break between the resistant rocks of the Grandstand Formation on the south and the less resistant rocks of the Chandler Formation on the north. It is particularly marked for about 1½ miles east of the cross fault by an abrupt change in strike of bedding traces. South of the fault the traces strike a few degrees north of west subparallel to the fault. North of the fault the traces strike N. 30° W. to N. 60° W. at their nearest approach. About 1 mile east of the cross fault, a slight northward convexity of the trace of the longitudinal fault coincides with a topographic high, indicating that the longitudinal fault dips to the south.

Substantial evidence for this fault can be found along the Grandstand-Chandler contact for about 4 miles east of the cross fault. The anticline has been mapped by photointerpretation for about 16 miles farther east along the ridge crest and is broken by longitudinal faults for much of this length. Displacement on these faults seems to be minor, judging from the relative position of well-exposed beds of the Ninuluk Formation on the north flank and the inferred base of the Ninuluk Formation on the poorly exposed south flank. The Ninuluk seems to be much thicker on the south flank than on the north. If the inferred base has been incorrectly placed too low in the sequence, the displacement on the faults may be about 500 feet.

There is no conclusive evidence of faulting along the anticline for about 6 miles west of the cross fault. The sequence on the north flank from vertically dipping Grandstand Formation to gently dipping Ninuluk Formation is probably a normal sequence. Just west of the area of plate 52, however, a longitudinal fault lying a short distance south of the anticlinal axis has been traced for about 3 miles.

WEASEL CREEK ANTICLINE

Weasel Creek anticline is the northernmost of the steep anticlines in the Maybe Creek area and is the only structural feature on which pre-Ninuluk rocks are exposed in the basin area northeast of Knifeblade Ridge and northwest of the Colville valley. It is a straight, narrow doubly plunging fold about 15 miles long that trends N. 80° E. along the south side of Maybe Creek valley from Weasel Creek to the Prince Creek divide. Midway, the anticline apparently bifurcates; a branch trends N. 70° E. down the north flank of the fold into a zone of high-angle faults. The highest part of the anticline is interpreted to be along this northern branch. The anticline is unbreached except by the transverse gorge of Weasel Creek and so forms a smooth, straight ridge parallel to and about 500 feet above the level of Maybe Creek. Rocks of the Ninuluk-Niakogon unit form the entire ridge, except at the east end, where pre-Ninuluk rocks are inferred to crop out along the fault zone. Structural closure on the main axis is about 600 feet, but there may be as much as 1,000 feet of closure against the fault zone.

The anticline is asymmetrical; the axial plane dips 88°–77° S. near the west end of the fold. The bedding on the south flank dips gently, from 3° to 5°. On the north flank similar gentle dips occur along the Ninuluk-Seabee contact 1 to 1½ miles north of the inferred location of the crest, but about 1 mile north of the crest is a linear zone of steeper dips, ranging from 10° to 20°, which can be traced almost the whole length of the fold. The northern branch of the axis lies just south of this zone of 10° to 20° dips. The crest of the fold is locally sharp.

MAPPING

Weasel Creek anticline has been contoured on the uppermost of three key sandstone units at the top of the Ninuluk-Niakogon unit (units 4, 5, 6, 9, and 11, strat. section 9); for the regional map these contours have been projected to the general datum at the top of Seabee Formation (pl. 52). The three key units crop out extensively along Weasel Creek on the south flank of the anticline, and the upper two of these key units have been correlated with two sandstones that crop out almost the full length of the north flank of the anticline along the zone of 10° to 20° dips. Contours on the western half of the anticline are based on elevations of these key beds determined by Ray and Fischer in the field. On the eastern half of the anticline, outcrops are lacking except on Maybe Creek and in the zone of 10° to 20° dips; most of the structure there has been mapped from bedding traces, largely vegetation, that appear on the aerial photographs. Contours there are based on dips and stratigraphic thicknesses both estimated from aerial photographs, and on random field-determined elevations along the ridgetop.

Dips at the crest of the anticline are known only in the section exposed at Weasel Creek (fig. 118), where the lower silty, shaly beds of the Ninuluk Formation are apparently more tightly folded than the upper thick sand beds; the folding is accompanied by bedding-plane slippage, and thinning of beds over the axis is likely. In the exposed section the hilltops are composed of sandstone in the upper part of the Ninuluk Formation, and *Inoceramus*-bearing beds in the basal part of the formation crop out near stream level. All beds exposed in the west wall of the valley appear to dip gently and to flatten toward the crest of the fold. In the east wall of the valley the upper beds of the Ninuluk Formation exposed on the south flank of the anticline approach and apparently cross the crest with similar gentle dips, but the basal *Inoceramus*-bearing beds exposed near creek level dip more steeply. At the crest of the fold these lower beds reverse sharply and dip 35° to 45° N., the dip diminishing to 10° within three-quarters of a mile of the crest. Ray noted much slickensiding of bedding surfaces in this steeply dipping axial zone but no faults.

The position of the anticline crest is known certainly only at the Weasel Creek exposures, where it coincides approximately with the crest of the ridge. For the rest of the length of the anticline it is certain only that the fold crest is at or within half a mile north of the ridge crest. All beds on the south slope of the ridge apparently dip to the south. Bedding traces right at the ridge top run in a straight line along the

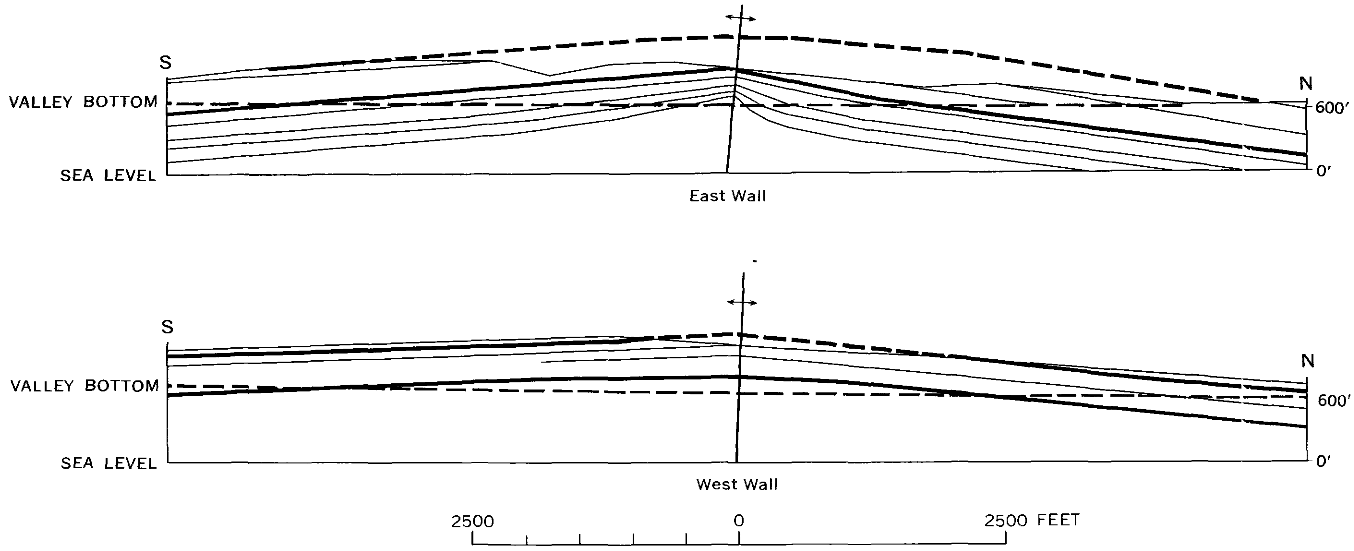


FIGURE 118.—Schematic cross sections of Weasel Creek anticline. Exposures are in the east and west walls of Weasel Creek valley. No vertical exaggeration.

ridge; a southward dip can be determined for these beds only at Weasel Creek. The straightness of the ridge-top traces may be due either to the straightness and fairly uniform altitude of the ridge crest or to very steeply dipping beds just at the axis. On the north slope of the ridge there are no known north dips between the ridge crest and the zone of 10° to 20° dips north of the northern branch of the fold. The few dips that are apparent are either south dips or are east dips down the eastern nose of the anticline. The axis has been drawn along the zone of straight-line traces on the ridge crest because (1) that is its known location at Weasel Creek, and (2) if the straight traces are due to abrupt steepening of the dip, it is likely that they occur at the axis as they do in the lower exposures on Weasel Creek. However, within the limits of the known dips in the area east of the Weasel Creek exposures, the axis might be as much as half a mile north of its mapped location and might even be coincident with the mapped northern branch.

The location chosen for the anticline axis affects the amount of relief and plunge shown by the structure contours. As mapped, the crest of the western half of the anticline stands 600 feet structurally above Ninuluk syncline and 1,200 feet above Lupine syncline. However, the contour elevations along the crest of the axial ridge are controlled at only two points. At Weasel Creek the key beds are exposed at the axis. Five miles east of Weasel Creek the uppermost key sandstone is exposed half a mile south of the ridge crest. Projected from this outcrop, the elevation of the contoured horizon at the ridge crest there is only 150 feet (±100 ft) higher than it is at the crest of the anticline at Weasel Creek and 150 feet higher than it is at the zone of 10° to 20° dips three-quarters of a mile north of the ridge crest. If, at this point, the crest of the anticline is at the crest of the ridge as shown, then the anticline has a broad, flat top as shown on figure 2 and a westward plunge of only 30 feet per mile to Weasel Creek. If, however, the crest of the anticline is north of the crest of the ridge, then the crestal elevation may be as much as 400 feet greater than shown. If the dips steepen abruptly in the zone of linear traces along the ridgetop, the crestal elevation may be even higher. In either of these cases the anticline would be structurally higher than it is shown on plate 52, westward plunge in the western half would be steeper, and the crest would be sharp rather than broad and flat. As contoured the fold is convex and the uppermost beds of the Ninuluk-Nial-ogon unit arch gently over the crest, as do the upper beds sketched in the Weasel Creek section (fig. 118). In the other two cases the fold would have concave flanks and be sharply keeled at the crest like the lower beds sketched in figure 118.

The structurally highest part of the anticline is at the east end. Whereas the lowest beds exposed at Weasel Creek are only a few hundred feet below the *Inoceramus* zone at the base of the Ninuluk Formation, combined field and photointerpreted data show that beds 500 to 900 feet lower occur at the east end of the northern axis and also in the fault zone at the east end of the northern branch. Where this fault zone crosses Maybe Creek valley, about 100 feet of sandstone, shale, and coal dipping 33°–60° NW. and striking N. 40°–60° E. are exposed in a cutbank. Near the middle of the exposed section *Inoceramus* occurs in the float (fig. 119). Slickensides are common; ripple marks indicate that the section is right side up. Aerial photographs show that these exposures are within a 1,800-foot-wide zone of straight parallel bedding traces that strike N. 70° E., indicating that the steep dips continue beyond the exposures. If the dips are equally steep all across this zone, beds of the Chandler Formation that are about 900 feet stratigraphically below the *Inoceramus*-bearing beds must occur along the southeast edge of the zone.

On the main axis there is no field stratigraphic control east of the head of Weasel Creek, but the stratigraphic interval between the beds at the head of Weasel Creek and those at the east end of the anticline may be estimated from the dips of a succession of faint bedding traces along the south flank. The possible error of this estimate is large. The oldest beds on the structurally highest part of the main axis are estimated to be as much as 1,000 feet stratigraphically below the *Inoceramus* zone; the oldest beds just south of the fault zone along the axial trend of the northern branch are estimated to be 900 to 1,400 feet stratigraphically below the *Inoceramus* zone. The minimum estimated thicknesses of these intervals have been used in contouring. If the maximum estimates are more nearly correct, then the beds in the east are even older and the anticline even higher than shown. In any event, both branches of the anticline are several hundred feet higher in the east than they are in the west. From this high point a gentle westward plunge averages 50 feet per mile, and a steep eastward plunge, about 400 feet per mile. The measure of eastward plunge is based on the computed 6° E. dip of traces

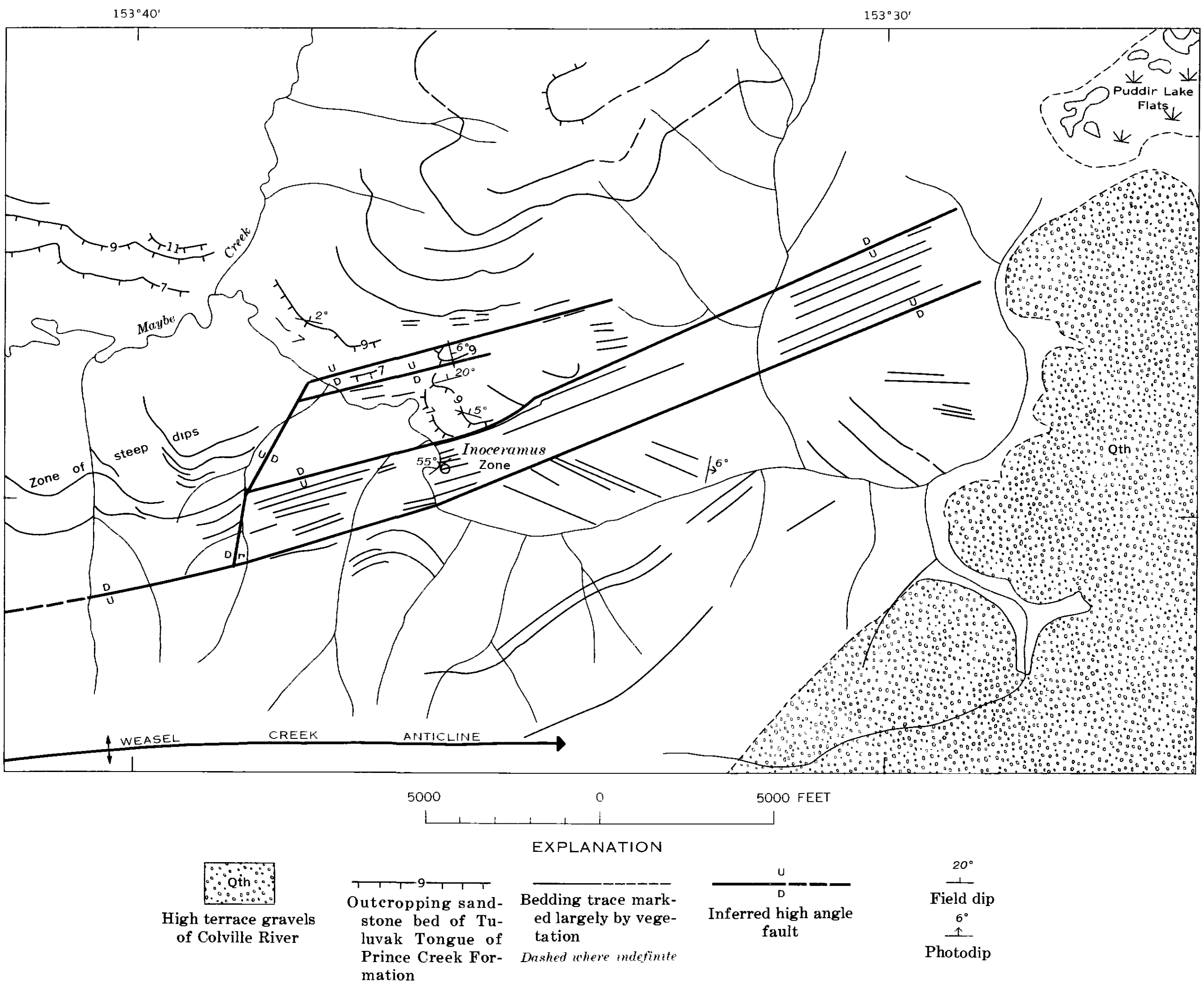


FIGURE 119.—Weasel Creek anticline fault zone.

that vee eastward into Maybe Creek and on the inferred location of the base of the Seabee Formation at the east end of the anticline.

A covered transverse fault may cut off the east end of the fault zone. The east end of the whole structural feature is hidden by terrace gravels and by alluvium in the Puddin Lake flats at the head of Prince Creek. On the far side of this covered zone are beds inferred to be Seabee Formation that dip west and south from the nose of Fossil Creek anticline. The steep eastward plunge of Weasel Creek anticline is sufficient to carry the outcropping Ninuluk and inferred Chandler Formation of that anticline beneath these Seabee beds. Within the fault block, however, there is no indication of east plunge. The Ninuluk and inferred Chandler beds in that block apparently strike straight into the Puddin Lake flats. It is therefore likely that the rocks in the fault block are cut off from the younger rocks on Fossil Creek anticline by either a very sharp transverse monocline or a transverse fault under the alluvium.

FOSSIL CREEK ANTICLINE

In the Umiat-Maybe Creek region Fossil Creek anticline extends for 16 miles from the head of Prince Creek S. 80° E. to the Colville River. For half this distance it is covered by alluvium and high-terrace gravels of the Prince Creek-Colville River flats. The gravel-covered zone divides the mappable anticline into two parts, a small doubly plunging high having 100 feet and possibly 200 feet of closure at the head of Prince Creek and the main and relatively higher part of the anticline south of the Colville River. Rocks down to the Chandler and Grandstand Formations are exposed along the main axis and the Tuktu Formation is locally thrown up against these rocks along a high-angle fault south of the axis (Detterman and others, 1963). This higher part of the anticline is continuous from the Chandler River to the north bank of the Colville River, where the Grandstand Formation is exposed at the axis in river cuts below the terrace gravel. On the closure at the head of Prince Creek, however, the oldest rocks exposed are the *Inoceramus* zone at the base of the Ninuluk Formation. These rocks occur in the breached core of the fold and are overlain by Seabee beds that plunge west beneath the Puddin Lake flats and east beneath the Prince Creek-Colville River flats. Although the axis of this part of the anticline cannot be traced east across the gravel-covered area, it lies on the projection of the axis of the main part of the anticline and is inferred to be continuous with it. The small fold in the Ninuluk and Seabee Formations plunges east under the covered area. The Chandler Formation is exposed just beyond the cover. The anticline must therefore reverse its plunge at a saddle beneath the covered area. This inferred saddle is part of the Colville line of reversal.

MAPPING

The anticline at the head of Prince Creek was mapped by Detterman and Bickel in 1953 (written commun. 1953). The anticline there forms a cluster of small hills at the foot of the Prince Creek syncline escarpment and is breached by a tributary of Prince Creek. The only rocks exposed near the axis are a unit of calcareous sandstone and limestone and a bed of *Inoceramus*-bearing conglomerate about 50 feet higher in the section. The calcareous sandstone has been mapped on both flanks of the fold and around the east end. On the south flank it is repeated in a narrow zone of northwest-striking traces that cut diagonally across the flank. This discordant zone has been mapped from photographs as a small horst (section *C–C′*, pl. 52). No outcrops occur between this Ninuluk sandstone and the basal sandstone of the Tuluvak Tongue, but beds of the Seabee Formation that are not mappable in the field appear as vegetation bands on the aerial photographs and have been traced around the north flank. The stratigraphic positions of these beds have been estimated from the field-determined dips and elevations of the Tuluvak Tongue and Ninuluk Formation beds above and below, and these estimated positions control the structure contours down the westward plunge of the fold.

The west end of the anticline is hidden by the alluvium around Puddin Lake. Fossil Creek anticline might extend across the alluvium to join either Weasel Creek or Titaluk anticline. Its westward plunge appears continuous with the westward plunge of the end of Titaluk anticline, but there must be a reversal or fault between it and the eastward plunge of Weasel Creek anticline.

TITALUK ANTICLINE

Titaluk anticline trends N. 70° W. for 37 miles from Puddin Lake to the Ikpikpuk River. West of the Ikpikpuk the trend changes to N. 85° W. and the anticline continues 50 miles farther, almost to the Meade River. In the Maybe Creek area the fold is broad and gentle, having dips of only 1° or 2°, and is not faulted. It is very slightly asymmetrical, the steeper limb being to the north. The dip of the axial plane, as computed from the surface expression of the fold, is to the south but is less than 1° off vertical. The crestal plane, as shown by seismic mapping of subsurface horizons, dips northward. The net plunge of the fold is 700 feet eastward across the mapped area; its maximum relief is in the western part of the area, where the crest rises 1,000 feet structurally above Lupine and Banshee synclines to the south and 800 feet above Billy syncline to the north. In the eastern part of the area the crest of the fold is at most only 400 feet above the adjacent synclines. On the higher western half of the structure, the Ninuluk-Niakogon unit and the sandy facies of the Seabee Formation are exposed along the axis. Gentle dip slopes on the standstone of these two formations rise to a broad and sinuous axial ridge that divides the drainage of the Arctic Foothills from that of the Arctic Coastal Plain. On the lower eastern half of the anticline, the shale of the Seabee Formation is exposed along much of the axis and the axial area is topographically lower than the mesas of Tuluvak sandstone on the flanks.

The eastward plunge of the anticline, though dominant, is not continuous. The surface geology shows two saddles in the crest of the fold, one at Baby Creek and the other at the head of Maybe Creek. In addition, seismic work shows a third saddle near the Ikpikpuk River. At each of these saddles the eastward plunge is reversed, and at Baby Creek the axis is offset as well. The saddle at Baby Creek divides the crest of the fold into two broad domes around which the structure contours close. The western dome, centered at the head of Kay Creek, is the larger of the two, having 400 feet of vertical closure over an area of 40 square miles. Titaluk test well 1 was drilled within this area of closure, about half a mile south of the high point on the axis. The eastern dome, its high point on the divide between Baby Creek and Anak Creek, has at least 50 feet of closure over an area of 6 square miles. However, as the eastern part of the fold has been breached to the shale of the Seabee Formation, none of the key sandstones can be traced across the crest to control the contour elevations at the high point of the eastern dome or in the Baby Creek saddle. Projected dips from the flanks indicate a maximum crestal elevation 50 feet higher and therefore a maximum closure 50 feet greater, than that shown on the structure-contour map (pl. 52). In addition, the next-to-the-highest contour mapped may close in the saddle, indicating a possible closure of 150 feet over an area of 16 square miles.

The minor eastern dome is a point of bifurcation of the anticline. A very low subsidiary anticline outlined by the 500-foot structure contour extends southwestward from the dome, around the end of Banshee syncline, and crosses Maybe Creek near the mouth of Banshee Creek. The axis of this small anticline has not been mapped farther west owing to lack of control, but it must lie along the south side of Maybe Creek between Banshee and Lupine synclines approximately as shown on plate 52, section *A–A′*.

MAPPING

Titaluk anticline was mapped by Ray and Fischer in 1946 and by Brosgé and Kover in 1949. Both parties contoured the basal sandstone of the Tuluvak Tongue, which is widely exposed from the head of Maybe Creek to Kay Creek and which has been projected west of there. The contours are controlled by closely spaced plane-table elevations on the key sandstone traces.

The location of both the eastern and the western ends of the anticline axis in the Maybe Creek area is poorly controlled. The east end of the anticline disappears in the Puddin Lake flats. For its last 3 miles, the axis is mapped only from bedding traces on the aerial photographs. On the basis of the few dips estimated from these traces, the axis is believed to trend due east there. The eastward prolongation of this trend across the Puddin Lake flats would carry the axis well north of the axis of Fossil Creek anticline. The westward plunge of Titaluk anticline from Puddin Lake to Maybe Creek seems, however, to be a continuation of the west plunge of Fossil Creek anticline, and the photointerpreted control is not strong enough to disprove a connection between the two axes.

At the west end of the mapped area, surface geological control of the location of the axis has been supplemented with seismic control. The surface axis is accurately located (pl. 52) in the area of outcrop of sandstone 1 of the Ninuluk Formation on the high point of the anticline at the head of Kay Creek. Fifty feet of westward plunge in a mile is provable there. In the area of outcrop of sandstone 4 (Seabee Formation), 3 to 5 miles farther west, a surface axis also is accurately located. The amount of mappable reversal across this axis is small, but it has been assumed to be a continuation of the main anticline axis. Structure contours can be projected up to and across this axis from the south. These contours indicate a total of 380 feet of westward plunge from the high at Kay Creek to a point 1½ miles east of the Ikpikpuk River at an average rate of 60 feet per mile, locally 125 feet per mile. These contours cannot, however, be closed to the north of this axis except by inference, because there are no bedding traces to the north. Conceivably this western part of the axis might represent a minor wrinkle, and the main axis of the fold might actually run farther north through the gap in the contours. Dip control at the Ikpikpuk is scanty, and it is therefore possible that the axis may cross the river as much as three-quarters of a mile north of its mapped location. If the axis mapped 4 to 6 miles west of the high point of the dome should be only that of a minor fold, then the contours that cross it would not necessarily cross the main axis, and most of the westward plunge of the dome would be unproved.

To check this possibility, United Geophysical Co., Inc., in 1950 ran a net of seismic survey lines along the doubtful part of the axis west of the high (party 144, 1950, lines 11–50 through 14–50). Two phantom seismic horizons were contoured, horizon A about 1,900 to 2,100 feet below the base of the Tuluvak Tongue and horizon B about 2,000 feet lower, near the base of the Grandstand Formation. The contours on horizon A are reproduced on plate 52 with original elevations adjusted to the 1946 Umiat datum. The crest line outlined by these contours is almost coincident with that mapped from the surface exposures. However, the westward plunge is only half the rate of that mapped on the surface and is reversed at a saddle about 4 miles from the Ikpikpuk River. The contouring on horizon B (not shown) shows the same configuration as that on horizon A, but the crest, although parallel to that on horizon A, is 1¼ miles farther north. This reversal of plunge shown by the seismic horizons is in an area where the surface geology shows no reversal but shows only a marked decrease in the rate of westward plunge—from 125 feet per mile to 25 feet per mile. At the surface, however, the westward plunge must also reverse within 3 or 4 miles west of the subsurface saddle, for photointerpreted dips indicate that the regional eastward plunge resumes just west of the Ikpikpuk River.

The northward migration of the crest with depth is accompanied by a northward decrease of the interval between horizons A and B from 2,000 feet to 1,800 feet. The indicated convergence of horizons over the anticline, as well as the inclination of the crestal plane northward toward the steeper limb of the fold, is in accord with the stratigraphic evidence found in the Ninuluk Formation and Tuluvak Tongue that the anticline was growing during their deposition.

WOLF CREEK ANTICLINE

Wolf Creek anticline has been traced about 70 miles. From its eastern end at the head of Wolf Creek, the anticline trends N. 65° W. to within 10 miles of the Ikpikpuk River, from where it trends almost due west to the Titaluk River. The eastern part of the anticline trends northwestward from well within the foothills belt to the edge of the Arctic Coastal Plain so that only the easternmost third of the part of the fold mapped in this report lies within the foothills area of good exposures. The fold there has been breached to the Seabee Formation. Scarps of Tuluvak sandstone rim the anticline and curve across its east-plunging nose. In the shale of the Seabee Formation at the foot of these scarps, Wolf Creek and its tributaries have cut parallel valleys along both flanks of the anticline. Between these longitudinal valleys a thick sandstone near the base of the Seabee Formation arches across the axis to form an axial ridge. Transverse streams have breached this sandstone at two places to expose the Ninuluk-Niakogon unit. The western part of the fold lies at the edge of and partly within the Arctic Coastal Plain. The Gubik Formation mantles part of the anticline there, and the only known outcrops are those of the Ninuluk Formation in the banks of the Ikpikpuk River. The Seabee Formation as well as the Ninuluk, however, may occur along the axis east of the river. The scanty surface data there are supplemented by the seismic traverse across the fold.

Wolf Creek anticline is narrow and linear and apparently is higher and steeper in the east than in the west. In the eastern part the average dip of the beds is 6°; the maximum dip, 12°. The crest of the fold there rises to 1,100 feet above Billy syncline to the south and 2,000 feet above Prince Creek syncline to the north. A normal fault, downthrown on the south side and about 3½ miles long, is parallel to and about half a mile south of the axis (section *B–B′*, pl. 52). In the western part dips are less than 4°; those on the seismic section, only 2°. The maximum known relief above Billy syncline is only 500 feet; the relief above the syncline to the north is unknown (section *A–A′*, pl. 52). In both parts of the area the north limb of the fold is slightly steeper than the south limb and the computed dip of the axial plane is to the south, less than one-half degree from vertical. The crestal plane, as shown by the seismic work, is vertical.

Apparently, like Titaluk anticline, the crest of Wolf Creek anticline is separated into two high areas by a saddle north of Baby Creek. Unlike Titaluk anticline the computed elevation of the contoured horizon on the eastern high is greater than that on the western high by 400 feet. The actual difference may be less than this, because the elevation on the western high is known only at the seismic traverse line, which does not necessarily cross the highest part.

The eastern high is only 6 miles from the end of the anticline. In that distance the fold plunges 800 feet eastward and merges with the south flank of Prince Creek syncline. The westward plunge from the high is gentler but is obscured where the axis approaches the Arctic Coastal Plain. The high has proved closure of 200 feet over an area of 4 square miles and possible closure of 600 feet over 26 square miles. Wolf Creek test wells 1 and 3 were drilled about one-third of a mile south of the axis in the highest part of the area of proved closure, and Wolf Creek test well 2 was drilled about 1 mile north of the axis in the area of possible closure.

MAPPING

The map of the eastern high is based on fieldwork by Ray and Fischer in 1946 and by Stefansson and Thurrell in 1947 and on well data and photointerpretation. Two key horizons were mapped by planetable —the basal Tuluvak sandstone, which rims the anticline, and a sandstone 230 feet above the base of the Seabee Formation (sandstone A, pl. 52) whose bluffs can be traced across the axis about 2 miles west of the wells and also about 3 miles east of the wells.

The normal fault mapped south of the axis is interpreted from an abrupt steepening of the southward dip of Seabee beds from less than 10° to 55° in Wolf Creek valley east of the wells and from the apparent truncation of the key Seabee sandstone bed at the steep dip zone. A lineation apparent on aerial photographs strikes westward along the steep dip zone toward a similar lineation in the valley in which the wells are located. The fault has been drawn along this line. The fault plane is assumed to dip steeply south with the bedding. The throw cannot be computed, but as the Seabee sandstone present north of the fault line is not repeated in the thick shale section to the south, the northern block including the anticline crest is probably upthrown.

The proved closure of the high is based on the elevation of outcrops of the key bed, Seabee sandstone A, and on its projected elevation at test wells 1 and 3. Because the plunge eastward from the wells is as much as 800 feet, the provable closure is limited by the amount of provable westward plunge. Test well 2 is in Wolf Creek valley just below the bluff formed by sandstone A. The stratigraphic interval between sandstone A and the beds at the top of the well (Section 11, pl. 54; unit 37, strat. section 11) is computed to be 100 feet from field-measured elevations and dips. A good electric log and lithologic correlation of well 2 with wells 1 and 3 permits projection of the horizon of sandstone A to these well sites near the axis. According to this correlation the sandstone A horizon is 210 feet higher at test well 3 and 225 feet higher at test well 1 than it is where it crops out on the crest of the anticline 2 miles to the west. As test well 1 is about 1,000 feet south of the crest of the anticline, the projected elevation of sandstone A at the crest near the well may be as much as 275 feet higher than its altitude in the outcrop to the west.

No other horizons can be traced across the crest west of the outcrop of sandstone A, and no further westward plunge can be proved. However, about 10 miles west of the wells, the outcrop of the base of the Tuluvak Tongue approaches the axis from both flanks. Where the base of the Tuluvak is traced to within half a mile of the axis, the estimated crestal elevation is about 600 feet ($\pm$200 ft) lower than it is at the wells. Because no lower crestal elevation is known west of the wells, 600 feet is the maximum estimated closure of the eastern high. The point of reversal of plunge between the eastern and western highs of the anticline is probably in that area. Because the topographic relief is small, the fold should be lowest where the Tuluvak Tongue crops out closest to its crest, and as far as it can be mapped, the Tuluvak is closest to the axis there. Immediately to the west is a zone of subdued topography and of no outcrops in which the Tuluvak Tongue has not been differentiated from the Seabee. It is probable that this featureless zone within the foothills is largely due to the presence of easily eroded shale of the Seabee Formation and that the sandstone beds of the Tuluvak actually are not preserved there.

In the subdued area and westward along the edge of the Arctic Coastal Plain to the Ikpikpuk River, information is scant and the few surface dips are estimated from aerial photographs. The north flank of the anticline is buried under the Gubik Formation and the surface location of the axis can only be inferred. However, the seismic section along the line 7 miles east of the Ikpikpuk (United Geophysical Co., Inc., party 144, line 13–50, section *A–A′*, pl. 52) clearly shows the anticline. The crestal plane, shown by seismic horizons A and B, is vertical. The base of the Tuluvak Tongue, as projected northward along the seismic section from Titaluk anticline, is 200 feet higher there than it is in the probable saddle to the east. This difference indicates an eastward plunge from the Ikpikpuk. West of the seismic line the fold is hidden by the Gubik Formation and alluvium and must be projected across a covered zone more than 15 miles wide to join the photomapped axis near the Titaluk River.

UMIAT AND SQUARE LAKE ANTICLINES

The Umiat and Square Lake anticlines together make up a single fold with an overall trend of about N. 70° W. in the Umiat-Maybe Creek region. A saddle and an offset in the axial trend of the fold between Bowman Creek and Judy Creek (long 153° W.) separate a closed structural high centered at Umiat from a high centered at Square Lake. The Umiat high lies in the foothills and is well exposed. It has been mapped for 25 miles in the area of this report and its axis has been traced an additional 55 miles southeastward beyond the Colville River by field and seismic work (Detterman and others, 1963). The Square Lake high lies at the edge of the Arctic Coastal Plain and is poorly exposed. It is mapped almost entirely from seismic data and photointerpretation. During the field investigations and drilling, the two highs were considered separately as Umiat anticline and Square Lake anticline. These names are retained even though the two anticlines make up a single structural trend.

UMIAT ANTICLINE

Umiat anticline is a rather broad, low fold, but the axial zone is reverse faulted, and a zone of steeply dipping beds extends for about 8 miles along the north side of the fault zone. The south limb is upthrown as much as 2,000 feet relative to beds north of the fault zone, and the proven structural closure of approximately 900 feet at Umiat (pl. 56) is on the south limb, against the fault. Total closure is probably at least 2,000 feet over an area of about 65 square miles (fig. 117). Seven oil wells and three dry holes have been drilled south of the fault zone and one dry hole to the north.

SURFACE INDICATION OF FAULTING

The principal fault or fault zone on the Umiat anticline appears to coincide with or lie a short distance north of the crest of the fold. The sandstone of the Barrow Trail Member outline a fairly symmetrical anticline near Umiat (pl. 56). On the south flank these beds dip uniformly about 6° to 7°, and on the north flank dips in this unit steepen from 3° in the western part to about 9° near Umiat Mountain. Just north of the crest of the anticline, however, the calcareous sandstone member of the Seabee Formation forms a linear series of ridges that extends eastward about 8 miles in a straight line from near Umiat test well 1 to Umiat Mountain. The straightness of this feature indicates that dips along this ridge are quite steep, and this is borne out by the outcrops. Foran's mapping shows vertical bedding at several places along the trend of this sandstone. Dips of 55° N. were observed in small sandstone outcrops both east and west of Bearpaw Creek. Two miles east of Umiat test well 1, the lower shale member dips 75° N. and dips of 80° and 85° were observed on and just north of the ridge about 1 mile northeast of Umiat test well 1.

North of the linear ridge the dips decrease rather abruptly to as low as 20° within 1,000 feet. From there northward the decrease is more gradual. South of the sandstone beds on the ridge the decrease in dip is more abrupt, and except at a few localities, the next observable dips in the underlying shale are nearly horizontal. The faults occur in a covered zone several hundred feet wide. Direct evidence of faulting is seen in only one locality. On the east side of Bearpaw Creek, a quarter of a mile south of the ridge, three bedding traces on sandstones of the Ninuluk Formation are downthrown to the north about 50 feet. West of Bearpaw Creek this fault is not evident, but there the fault probably passes north of the northernmost sandstone trace of the Ninuluk.

The fault zone has been mapped in the Seabee Formation and Tuluvak Tongue for about 14 miles west from the point where it is concealed by alluvium of the Colville River near Umiat Mountain. It may extend at least 5 miles farther west inasmuch as Foran's mapping shows vertical beds in the Rogers Creek Member at several places along the axis as far west as long 152°40′ W.

SUBSURFACE INDICATION OF FAULTING

At least nine fault occurrences can be proved or inferred in Umiat test wells 1, 2, 8, and 10 by using electric logs and lithologic and paleontologic data. These fault occurrences all appear to involve repetitions of parts of the stratigraphic succession. Because they are detected in vertical bore holes, these repetitions must result from reverse or thrust faults rather than from normal faults. These faults are herein described by giving the vertical displacement as measured by the thickness of the repeated beds. The net displacement on a fault may actually be several times the vertical displacement because of inclination of the fault plane and the probability of a horizontal component of movement.

Faulting was first discovered at Umiat in wells 1 and 2 by use of electric logs. In March 1950 Karl VonderAhe, of Arctic Contractors, discovered the fault at 2,010 feet in well 1; a few days later F. M. Robinson, of the U.S. Geological Survey, discovered the fault at 2,400 feet in well 2 (R. G. Reese, written commun., 1950). These two faults and additional faults at approximate depths of 5,100 feet in well 2, 350 feet in well 8, and 210 feet and 1,430 feet in well 10 have been discussed by Collins (1958a) and Bergquist (1958a). The writers also interpret the electric log of well 1 to indicate a 50-foot fault at about 3,390 feet and a 190-foot fault at 4,155 feet. An additional fault in well 10 at 495 feet also appears probable. In summary, the nine proved or probable fault occurrences in the Umiat wells are:

Umiat test well	Approximate depth (feet)	Approximate vertical displacement (feet)
1	2, 010	[1] 757
		[2] 775
	3, 390	50
	4, 155	190
2	2, 400	550
	5, 100	[3] 1, 300
8	350	385
10	210	340
	495	240
	1, 430	[3] 100

[1] This report.
[2] Collins (1958a).
[3] Minimum.

The authors interpret the section in Umiat test well 10 to show a 340-foot fault at 210 feet and a 240-foot fault at 495 feet rather than the single 580-foot fault at 210 feet postulated by Collins (1958a, p. 171). Units of sandstone about 90 feet thick occur at three places in the upper 750 feet of well 10, and the authors consider these to be one unit of the Ninuluk Formation repeated twice by faults. Apparently Collins considered the sandstone at 410 to 495 feet in well 10 to be the same as the sandstone in the lower part of the Seabee Formation in well 11 (1809 to 1864 ft). From her lithologic description (1958a, p. 171–172), however, it appears to be identical with the other two Ninuluk sandstones at 70 to 160 feet and 650 to 740 feet in well 10. The shale sections both above and below the sandstone at 410 to 495 feet yielded microfossils of Seabee age, but these microfossils are notably absent in the sandstone interval. Bergquist (1958a, p. 203) stated:

"*Seabee formation (210–645 ft.)*.—Fossils were rare. *Inoceramus* prisms occurred in samples from 240–370 feet, and a few specimens of *Gümbelitria albertensis*, in samples from 240–270 feet. *Gaudryina irenensis* and *Trochammina ribstonensis* Wickenden occurred sparingly in samples from 360–370 feet. Low in the formation was a similar zone with *Inoceramus* prisms in every sample from 515–630 feet, *Gümbelitria albertensis* from 535–605 feet, and *Gaudryina irenensis*? in one sample (595–605 feet)."

SEISMOGRAPH SURVEY

The seismic work indicated on the map and on parts of sections *B–B′* and *C–C′* of plate 56 was originally done by United Geophysical Co., Inc., party 46, August to November 1946. Reflections were plotted using the velocity function $V=7{,}650+0.6Z$ feet per second, where the term $0.6Z$ represents a 0.6-foot per second increase in velocity per foot of depth. The average strike and dip shown for the shot points given on plate 56 were derived from resolution of the average line component with the average cross component. A resolved strike at a particular depth did not differ from the average strike at a given shot point by more than 10° (W. R. Fillipone, written commun., 1946).

From shot point 12 on line 1–46 north to the end of that line, the reflections are of good quality and many continuous horizons exist. Between shot points 1 and 6 at the south end of the line, the reflections are fair but do not extend very deep and appear to be in a disturbed zone. No continuous reflections were found between shot points 6 and 12, but three poor reflections were recorded at shot point 8 at 1,120 to 1,400 feet below sea level, and at refraction shot point 38 (1,000 ft south of shot point 8) several deep reflections could be picked at about 7,750 to 12,750 feet below sea level. In both these places the dip component shown by plotting these reflections is about 2° S. On lines 2–46 continuous reflections were recorded between shot points 31 and 35. Good reflections were obtained for a spread distance of 960 feet south of shot point 35, giving dips of 23° to 30° N. No recognizable reflections were obtained at shot points 36 and 37.

Lines 1–46 and 2–46 were reinterpreted and replotted in 1950 by United Geophysical Co., Inc., party 144, using the velocity function $V=10{,}850$ feet per second. The results of this work differ from that described previously not only in depth but in a few other details. The replotted reflecting horizons are shown in sections *B–B′* and *C–C′* of plate 56. The reflections at shot point 8, most of those between shot points 12 and 13, and those immediately south of shot point 35 are not shown by the reinterpretation, but a few reflections of questionable quality are added between shot points 9 and 12 and between 35 and 37. From shot point 13 to the north end of line 1–46, about 5 percent of the reflections plotted is questionable; of the rest, about one-half is reliable and one-half is of poor quality. Between shot points 1 and 6 and between 31 and 35, all reflections plotted are of poor quality.

In constructing the parts of sections *B–B′* and *C–C′* of plate 56 that coincide with seismic lines, the contacts between the stratigraphic units have been projected parallel to the seismic reflections as nearly as possible. Some contacts coincide with reflections; this is particularly notable for the Torok-Grandstand contact north of shot point 13 shown on section *C–C′*. The writers, however, make no claim that the reflections that appear to coincide with the various contacts actually represent energy reflected from the contacts in question.

SQUARE LAKE ANTICLINE

Square Lake anticline is incompletely mapped and its western extent is unknown. The mapped part trends N. 85° W. from Judy Creek to Keith Creek at the northern edge of the foothills, where the Tuluvak Tongue and Rogers Creek Member form low hills along the anticline axis, flanked by cuestas of Barrow Trail sandstone. West of Keith Creek the Barrow Trail cuesta is lacking on the north flank, and the Gubik Formation of the Arctic Coastal Plain overlaps the fold. The axis can therefore be traced at the surface only as far west as Keith Creek. Westward from Keith Creek to Wolf Creek, few dips are apparent at the surface and only seismic mapping outlines the anticline.

The fold is low and gentle; only 600 feet of relief is indicated by the seismic data. Surface dips estimated from aerial photographs as well as those shown by the seismic profiles are only 2° to 3° (sections *B–B′* and *C–C′*, pl. 52). The fold is doubly plunging from a high on Keith Creek and has a closure of 200 feet over an area of 23 square miles, as indicated by the seismic data. Square Lake test well 1 is on Keith Creek within the area of closure, about 5,000 feet north of the axis and about 50 feet structurally below it. The fold, as shown by contours on the phantom seismic horizon, is symmetrical; but as the axis mapped from surface dips is slightly south of the line of flexure of the seismic contours, the crestal plane may dip northward. The surface axis, however, is not located accurately enough to prove this.

The westward extent of the fold beyond the axis outlined from surface and seismic data between Judy Creek and Wolf Creek is uncertain. Seismic traverses north of the anticline show a part of another small high having about 100 feet of closure 4 miles N. 30° W. of the nose of the main fold on Wolf Creek and joined to it by a saddle. It is not known whether this high is part of the main fold or whether the main fold continues due west and the high is only a minor bifurcation. It may well be part of the main fold, however, for the offset of structure shown here is similar in distance and direction to the offset of the anticlinal trend between Square Lake and Umiat anticlines.

MAPPING

Square Lake anticline has been mapped from seismic surveys, photointerpretation, and well data. The seismic contours are from traverse lines 14–51 through 25–51, party 144, United Geophysical Co., Inc., 1951 (pl. 52). The only direct stratigraphic information is from Square Lake test well 1, whose upper 700 feet was in rocks of the Tuluvak Tongue, and from shothole cuttings (shot holes 19, 27, 29 and 30, line 15–51–144) that contain Schrader Bluff microfossils. In addition, the cuesta of the Barrow Trail Member of the Schrader Bluff north of the axis can be identified on aerial photographs by its topographic expression. This member also crops out 4 to 7 miles south of the anticline and has been identified there in the field. The correlation of the subsurface geology, as projected from the well and seismic lines, with the surface geology, as interpreted from aerial photographs, is poor.

The contact of the Barrow Trail Member and the underlying Rogers Creek Member has been traced to the south flank of the anticline from Umiat. The basal contact of the Rogers Creek Member with the Tuluvak Tongue, however, has not been identified; its location has been inferred from the assumed thickness of the Rogers Creek Member and has been extended by following faint, discontinuous bedding traces approximately at the inferred horizon. Because the actual thickness of the Rogers Creek Member is not known here but has been projected from the sections measured at Prince Creek and Umiat, the stratigraphic position of the mapped base may be wrong. The accuracy with which the chosen horizon has been traced can be gaged by the consistency of its stratigraphic relation to the contoured seismic horizon. The approximate interval from the seismic horizon to the base of the Rogers Creek Member as mapped here is 2,850 feet just north of the axis near Judy Creek, about 2,500 feet on the north flank of the anticline near Keith Creek, and 2,600 to 2,640 feet along the south flank of the anticline in the area between Judy Creek and the west fork of Keith Creek.

The seismic contours tie the photogeology to the well geology. The highest identifiable horizon in the well is the base of the Tuluvak Tongue. The contoured phantom seismic horizon, at a depth of 2,200 feet in the well, is about 1,500 feet below the base of the Tuluvak Tongue. As the average thickness of the interval between the seismic horizon and the photomapped base of the Barrow Trail Member on the north flank of the anticline is 3,330 feet, the total thickness of the Tuluvak Tongue and Rogers Creek Member appears to be about 1,800 feet, 500 feet greater than at Wolf Creek. However, the construction of the phantom seismic horizon is based on reflectors near the base of the Grandstand Formation, so the apparent discrepancy in thickness may be anywhere in the section between the lower Grandstand and the base of the Barrow Trail Member.

Sections *B–B′* and *C–C′* (pl. 52) show a discrepancy in dip between profiles projected from the well parallel to the phantom seismic horizon and profiles plotted from surface mapping on the north flank of Prince Creek syncline. Between the outcrops of Barrow Trail Member in the syncline and the seismic-contoured section on the flank of the anticline is an area of little control underlain by the Rogers Creek Member. Formational contacts of the Ninuluk and younger formations projected northward across this area from their plotted locations beneath the syncline to their plotted locations at the end of the seismic line are almost level; some even dip slightly northward. The seismic horizon, however, shows a 2½° S. dip. There is no surface indication of a fault in this area. The dip discrepancy could be accommodated by abrupt thickening of the pre-Barrow Trail units at the syncline axis. Some of the units in the Colville Group are known to thicken northward from Wolf Creek to Square Lake, the Seabee Formation by 350 feet and the Tuluvak Tongue by at least 100 feet, but there is no reason to suppose an abrupt change. The rate of northward thickening of the Seabee from Wolf Creek to Square Lake is no different from its rate of northward thickening from Weasel Creek to Wolf Creek. The sections therefore have been plotted to show a constant rate of northward thickening, and the contacts have been dashed in the poorly controlled area.

STRUCTURE ON THE LOWER COLVILLE RIVER

From the mouth of the Chandler River to Ocean Point, the Colville River flows due north almost at right angles to the strike of the folds. Sheer bluffs on the left bank of the river expose the structure of the uppermost Cretaceous rocks in almost continuous section from the zone of open foothill folds northward to the relatively undisturbed Arctic Coastal Plain. These bluffs were mapped in 1947 by Stefansson and Thurrell and, in part, in 1945 by the Navy party of Rogers and McConnell, who contoured the structure from about 4½ miles south of the site of Sentinel Hill core test 1 to about 2 miles north of the well. Their field observations have since been supplemented by vertical high-level aerial photographs and by low-level oblique aerial photographs of the bluff faces. Figure 120 shows the structure in the bluffs from the mouth of the Chandler River to within 3 miles of Sentinel Hill, as well as the profile of seismic horizon A in the Chandler Formation (United Geophysical Co., Inc., party 144, 1950) along the line of the riverbank. The figure has been compiled from both the field data and the low-level oblique aerial photographs.

Gubik anticline, at the mouth of the Chandler River, is the northernmost of the anticlines in the foothills. Northward from its crest, the Upper Cretaceous beds descend more than 2,000 feet to the Arctic Coastal Plain over a distance of 20 miles. Most of Gubik anticline, including the highest part of the crest, lies east of the Colville River, where it has yielded gas from Gubik test wells 1 and 2 (Robinson, 1958). In the area of this report the westward-plunging nose of the fold can be traced westward from the Colville River for only 3 miles at the surface and for only 7½ miles on the subsurface seismic contours. These subsurface contours, however, show that the anticline may continue northwestward through a low saddle as a fold of low relief that extends past Henry Creek.

Northward from the crest of Gubik anticline, the exposed beds descend 1,500 feet into Dogbone syncline and then rise by only 100 feet over Sentinel Hill anticline. Together, Dogbone syncline and Sentinel Hill anticline make up a belt of almost flat-lying rocks that is 7 miles wide at the Colville River. Both structural features lie within the zone of bedrock foothills at the meridian of the Colville River, but in their westward extension beyond the Kogosukruk River the syncline lies partly and the anticline probably lies entirely within the Arctic Coastal Plain.

The axes of both structural features are clearly defined by the surface geology and by the subsurface seismic contours at the Kogosukruk River, where Sentinel Hill anticline rises about 300 feet above Dogbone syncline. However, both plunge eastward, becoming broader and lower as they approach the Colville, where their crests are ill defined at the surface except where exposed in vertical section by the river. Along the trend of each of these structural features in the upland area between the Colville and the Kogosukruk Rivers, photointerpretation shows not one, but a series of axes, no one of which appears to represent a major reversal. The axis of Dogbone syncline apparently bifurcates. Subsurface seismic contours show it to be a flat-bottomed syncline in this area, and each of the two surface axes lies along one of the lines of inflection at the edge of the basin. Only the northern one of these two axes appears in the section exposed by the river, however. On Sentinel Hill anticline, three anticlinal axes are exposed in the Colville bluffs. The northern and southern of these axes trend into the single axis mapped at the Kogosukruk River, but the middle axis, which has not been traced west of the bluffs, lies at the high point of the anticline in the bluffs and corresponds most closely with the crest shown by the subsurface seismic contours. The subsurface crest is clearly defined and shows no evidence of bifurcation. Moreover, the structure of the anticline shown at depth has more relief than that at the surface, rising about 400 feet above Dogbone syncline, and its crest is about half a mile north of the crest exposed in the bluffs. As at Titaluk anticline, the relation of the crest mapped at depth to that mapped at the surface may indicate growth of the fold during deposition.

The north flank of Sentinel Hill anticline corresponds to the topographic break between the foothills

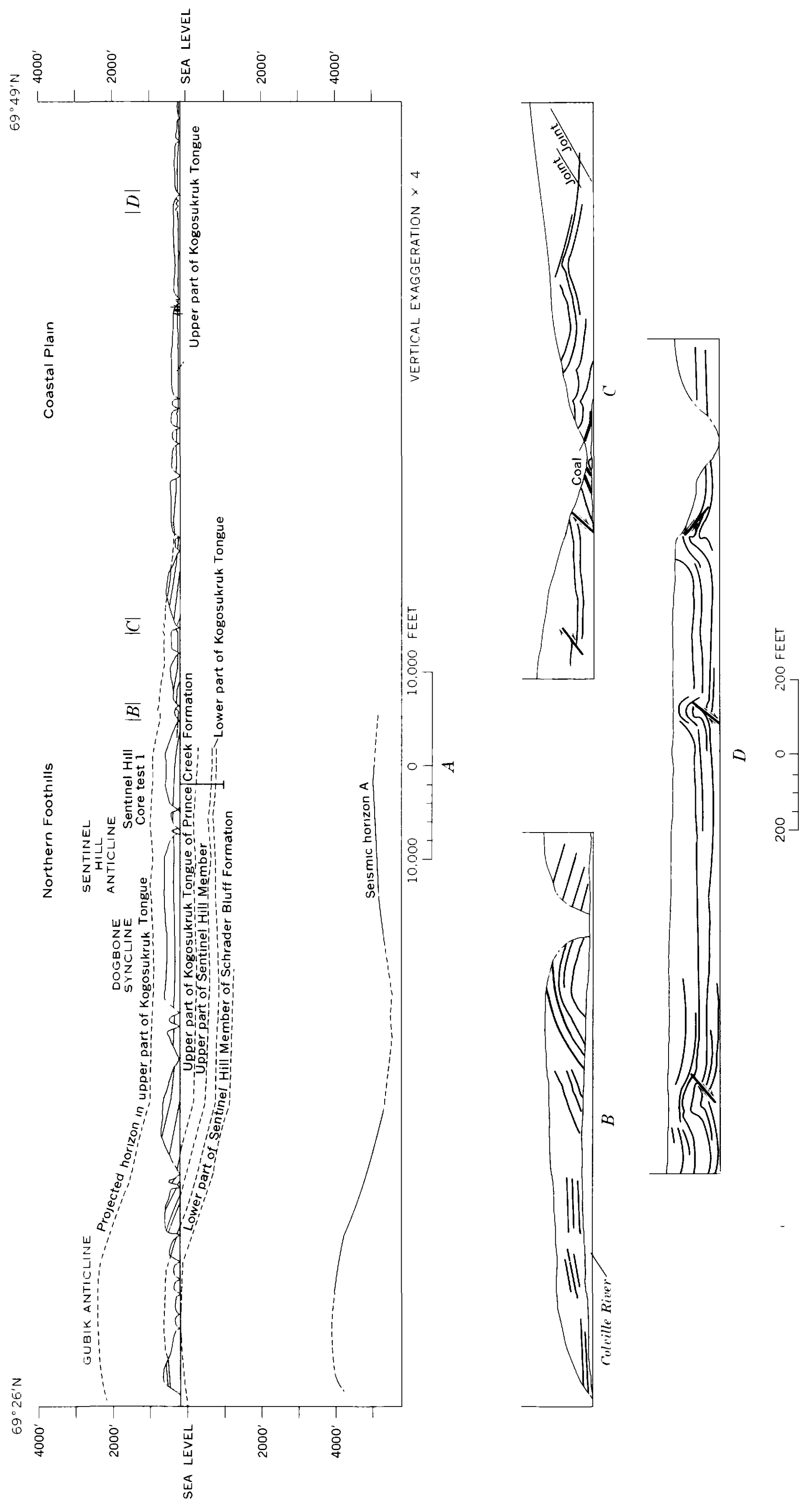


FIGURE 120.—Structure along the lower Colville River. Profile *A* is of the Colville bluffs from lat 69°26′ N. to lat 69°49′ N. projected into a north-south section. Profiles *B*, *C*, and *D* are large-scale sketches of minor folds shown in profile *A*.

and the Arctic Coastal Plain. Over a distance of 7½ miles, the beds dip northward 700 feet; beyond there they are almost flat lying, and only the uppermost few hundred feet of the known Cretaceous section is exposed in the bluffs from the foothills margin to Ocean Point. As shown by the subsurface seismic contours, the regional strike in this part of the Arctic Coastal Plain is almost parallel to the northward course of the Colville, and the regional dip is eastward at a rate of 50 to 80 feet per mile toward the Tertiary basin in the Itkillik-Kuparuk area. Thus the apparently level beds shown beneath the Arctic Coastal Plain in figure 120 are exposed in a section that is parallel rather than transverse to the regional dip.

In these almost flat-lying beds of the Arctic Coastal Plain the eastward-trending structural pattern of the foothills is reflected in minor folds and faults. Some folds, such as the syncline at lat 69°44′ N. are gentle undulations in the regional dip, but most of the folds mapped in this part of the Arctic Coastal Plain represent small, abrupt upward displacements of the otherwise flat beds. The faults likewise are mostly high-angle reverse faults having displacements of less than 10 feet; normal faults are sparse. The most prominent folds are illustrated by sketches of the river-bluff profiles and of conspicuous beds traced from the low-level aerial photographs (fig. 120*B*, *C*, and *D*) and by figure 121, a photograph of the northernmost of the three folds shown in figure 120*D*. River level forms the base of each sketch. These minor folds, having flank dips of 12° to more than 40°, are much steeper and tighter than those exposed in the neighboring foothills; however, they affect only small areas. The largest of these minor folds is the northernmost anticline mapped on the flank of Sentinel Hill anticline (fig. 120*B*). This fold is about 1,000 feet wide and has about 150 feet of relief. The rest of the folds have less than 60 feet of relief, and most of them are only 100 to 200 feet wide; the smallest are interstratal folds less than 10 feet high and 20 feet across. The larger folds affect the entire thickness of rocks, 100 to 200 feet, exposed in the bluffs, but interstratal folds involving a thickness of only 20 to 30 feet of rocks were noted by Stefansson, and folds involving less than 15 feet of rocks can be seen on the low-level aerial photographs of the bluffs. The small interstratal folds are all in a sequence of coal, clay, silt, and bentonite that is 100 to 200 feet below the top of the known Cretaceous section. As far as is known, all the minor folds occur in the relatively incompetent rocks in the upper 600 feet of the section. Probably the effects of even the larger of these folds are limited stratigraphically. The middle fold of the three large folds shown in figure 120*D* can be seen to give way downward to a reverse or thrust fault (see also Schrader, 1904, pl. 13*A*). The beds at river level may well be undisturbed. Similarly, the southernmost of the three folds shown in this sketch may die out upward. The horizon projected above the surface in figure 120*A* has been drawn to show two of the minor folds extending well above the surface, but only to make their location clear.

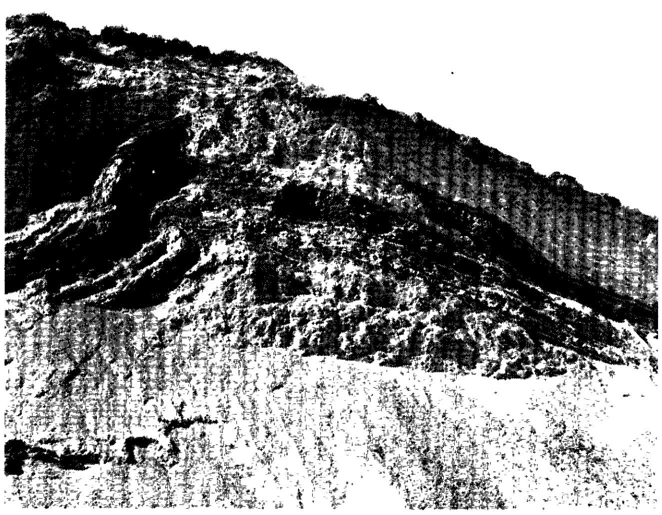


FIGURE 121.—Folded coal beds in the Kogosukruk Tongue of the Prince Creek Formation in the Colville River bluffs. Photograph by Boston University Physical Research Laboratories.

Both the folds and the faults appear to be part of the same system of folding. The folds pass into faults (fig. 120*D*) or are closely associated with them (fig. 120*C*), and the reverse faults, like the anticlinal folds without associated synclines, provide structural shortening through upward relief only. Both the folds and the faults are truncated by the Gubik Formation and are probably restricted to beds that were close to the surface at the time of folding.

All these minor structural features probably resulted from the same forces that produced the larger ones of the foothills. As in the foothills, the axial planes of the small folds dip south and the predominant direction of dip of the fault planes is to the south. The axial planes of the larger folds are vertical or inclined to the north, but where some of these larger folds are exposed to a great depth relative to their size, it can be seen that the northward inclination of their axes results from surface underthrusts which give way at depth to overthrusts from the south (fig. 120*D*). In this respect these folds closely resemble the model folds made by Link (1931), who demonstrated that in a pressure box affording only upward relief the underthrusts form at the surface and die out downward, whereas the overthrusts form at depth and die out upward.

AGE OF FOLDING

In the Umiat-Maybe Creek region evidence has been found for only one major period of folding of the exposed rocks and for the assignment to this orogeny of an age no more precise than Late Cretaceous or Tertiary. All the Cretaceous formations of the region are involved in structural features that appear to be part of a single east-trending fold system. The intensity of folding in this system decreases northward toward the Arctic Coastal Plain. Consequently, the youngest preserved Cretaceous rocks have been less intensely folded than the older rocks exposed farther south, but within the Cretaceous rocks of the region, there has not yet been found an angular unconformity large enough to indicate that the rocks to the south were folded before deposition of the younger rocks.

Both the Sentinel Hill Member of the Schrader Bluff Formation and the Kogosukruk Tongue of the Prince Creek Formation, the youngest of the Cretaceous units, are involved in major folds. In Dogbone syncline and Sentinel Hill anticline, folded rocks of both the Sentinel Hill Member and the Kogosukruk Tongue are truncated by the undisturbed Gubik Formation, and at Ocean Point the basal marine Gubik sand, which contains fossils of Pleistocene or possibly Pliocene age, truncates a normal fault in the youngest known beds of the Kogosukruk Tongue.

The hitaus between the Kogosukruk Tongue and the Gubik Formation at Ocean Point probably represents latest Cretaceous and all Tertiary time. The Tertiary hiatus is smaller 50 to 150 miles east of the Umiat-Maybe Creek region. The earlier Tertiary there is represented by the Sagavanirktok Formation and the later Tertiary by fossiliferous beds on Carter Creek (MacNeil, 1957, p. 100). About 100 miles east of Umiat both the Sagavanirktok Formation and the underlying Cretaceous rocks are folded together (George Gryc, oral commun.), and at Carter Creek the Tertiary rocks dip steeply (Leffingwell, 1919, p. 129–130).

Although the major orogeny that produced the present structure in the Umiat-Maybe Creek region occurred during Tertiary time, regional warping and local folding also took place during Late Cretaceous time, as shown by the unconformity between the Ninuluk and Seabee Formations and by textural and thickness variations in the Upper Cretaceous rocks. The Ninuluk-Seabee unconformity in this region is erosional and has no angular discordance, and according to Imlay and Reeside (1954, p. 242), the hiatus can represent no more than a minor part of the Cenomanian. In addition to the regional uplift indicated by this unconformity, the growth of Titaluk anticline and possibly of Weasel Creek anticline during Late Cretaceous time is indicated by localizatior of some of the Upper Cretaceous sandstone facies along the present structural trends. In the Ninuluk Formation one of the sandstone beds exposed at Weasel Creek is coarser grained at the axis of the anticline than on the south flank; and in the Maybe Creek area, sandstone 1 is restricted to the crest of Titaluk anticline. The basal sandstone of the Tuluvak Tongue is coarsest in a belt parallel to the crest of Titaluk anticline, and the next higher sandstone is finest in a belt along the present line of the Baby Creek structural low. These few lithologic indications of the growth of the structural features during deposition are supported by the seismic evidence, which is interpreted to show that Titaluk anticline and possibly Sentinel Hill and Square Lake anticlines have some characteristics of supratenuous folds. At Titaluk anticline the seismic and surface horizons converge over the anticline crest, and the crest as mapped at depth is displaced northward down the steeper limb from the crest mapped at the surface. At Sentinel Hill anticline the subsurface and the surface horizons also converge, and at Square Lake and Sentinel Hill anticlines the subsurface crests are similarly displaced northward from their surface crests. All these interpretations indicate that structural features grew during the Late Cretaceous on sites where the final features were produced by Tertiary orogeny.

OIL AND GAS RESOURCES

The purpose of exploration in Naval Petroleum Reserve No. 4 was to evaluate potential production of oil and gas. In the Umiat-Maybe Creek region 20 test wells have been drilled, penetrating all the large anticlines except Fossil Creek and Weasel Creek: 11 are on Umiat anticline, 3 on Wolf Creek anticline, 3 on Knifeblade anticline, and 1 each on Sentinel Hill, Square Lake, and Titaluk anticlines. From these test wells a medium-size oil field has been discovered at Umiat; small potential gas fields have been found at both Umiat and Square Lake; and a good show of gas has been found at Wolf Creek. Holes in the other anticlines were dry. The geological, engineering, and production data for each of these wells are given in detail by Robinson (1959a), Collins (1958a, 1959), and Robinson and Collins (1959). The data from their reports are summarized here in table 1. Estimates of the reserves of oil and gas at Umiat and Square Lake are from the exploration reports by Arctic Contractors (written communs., 1953).

Drilling in the area began at Umiat in 1945. Oil seeps in the river flats at the base of Umiat Mountain had been known to the Eskimos and were examined by a U.S. Bureau of Mines party in 1943 (Ebbley, 1944). After the discovery of the Umiat anticline by Lt. W. T. Foran in the spring of 1944 and his detailed mapping of it that summer, a location was chosen for the first deep test.

The well was spudded in by a Navy Construction Battalion and shut down at a depth of 1,816 feet. The next spring the well was reopened by Arctic Contractors, who completed the well under contract to the Navy and drilled all subsequent wells. The first well was dry, and in 1946 and 1947 a shallow core test (Umiat test well 3) and a second deep test (Umiat test well 2) were drilled closer to the apex of the anticline. The shallow well produced about 25 barrels of oil per day from sand at the top of the Grandstand Formation, but the deep well had only shows of oil in the same sand. To test the possibility that the fresh water in the rotary drilling mud was sealing off the oil sand either by swelling the interstitial clay particles or by freezing in the pore spaces in the deep permafrost zone, drilling was begun again in 1950 using cable tools and drilling with brine. Umiat test well 4 was drilled about 1,000 feet northeast of well 3, and Umiat test well 5 was drilled about 200 feet northeast of well 2. Both were oil wells, producing 100 and 400 barrels a day, respectively, from sandstone of the Grandstand. In addition to the oil sand found at the top of the Grandstand in the earlier wells, a second sand about 300 feet lower in the formation produced oil in well 5. Three more wells were then drilled in the south flank of the anticline to outline the area of oil accumulation there. In test well 7, the farthest downdip, water was found in the sandstone of the Grandstand about 1½ miles south of the axis. In test well 6, a quarter of a mile to the north, and in test well 9, at the same structural elevation as well 5 but 2 miles farther to the west, the same sandstone produced oil. The axial zone of the anticline was tested by wells 8 and 10. Both wells penetrated the axial fault at a depth of about 225 feet and produced oil from the upper sandstone of the Grandstand in the lower fault block; in addition, well 8 produced gas from the lower sandstone. Test well 11, about half a mile farther down the north flank and entirely in the lower fault block, was a dry hole finding water in both sandstone beds. All these were cable-tool holes except wells 9 and 11, which were drilled with rotary equipment using oil-base or oil-emulsion mud.

To 1965 more than 40,000 barrels of oil has been produced by the pumping tests at Umiat. The oil has a gravity of 36.0° to 37.2° API and contains about 35 percent gasoline and naphtha. The pour point ranges from less than 5° to minus-25°F., the Saybolt viscosity is 36 to 44 seconds at 100°F., and the sulfur content is less than 0.1 percent. A topping plant rigged up in Umiat produced, from this crude, gasoline and diesel fuel that were burned in the camp vehicles and drilling equipment. The oil was also used to make oil-emulsion mud for rotary drilling.

Estimates of the total recoverable oil reserves at Umiat have been made by the U.S. Bureau of Mines and by various private commercial organizations. These estimates range from 2 million to 122 million barrels, but most range from 30 million to 100 million barrels. The variation in estimates is largely due to the variation in the recovery factors chosen. Estimates of the size of the productive area range only from about 5,000 to 7,000 acres, whereas the recovery factors used range from 8 to 32½ percent. The low recovery figure represents an estimate of low productivity in the permafrost zone; the high recovery figure is based on assumed production by repressuring with gas injection. Most of the estimated reserves are in the two sandstone beds of the Grandstand, one in the upper 100 feet of the formation, the other 400 to 500 feet below the top of the formation. More than 80 percent of the estimated recoverable oil in these two sandstone beds is in the southern upthrown fault block of the anticline.

In Umiat test well 8 near the crest of the anticline, the lower sandstone also produced gas at the rate of almost 6 million cubic feet per day. The size of the gas-bearing area around this well is unknown, but assuming an area of 419 acres, Arctic Contractors have estimated a recoverable reserve of 4.7 billion cubic feet.

In addition to production from the Grandstand Formation, oil was also produced in Umiat test well 10 from a sandstone in the Ninuluk Formation. This sandstone crops out on the south flank of the anticline and is presumably unproductive there, but where present in the subsurface on the north flank of the anticline, it is estimated to contain from 7 to 15 percent of the total recoverable oil in the field. Small shows of oil have also been found in the sand units of the Seabee Formation and the Killik Tongue of the Chandler Formation.

After the successful tests of the Grandstand Formation at Umiat, eight test wells were drilled in the anticlines in the adjacent foothills to the west in hope of finding sandstone beds of the Grandstand in the same facies belt as those at Umiat. Five of these wells were drilled with cable tools and brine, and Wolf Creek test well 3 was drilled with rotary equipment and oil-emulsion mud. The Square Lake and Titaluk wells, however, were drilled with fresh-water mud.

The only field west of Umiat that is estimated to have commercially valuable reserves is the potential gas field at Square Lake; the gas there did not come from the Grandstand, but came from two thick sandstones in the basal 250 feet of the Seabee Formation. Gas flows did come from the Grandstand at Wolf Creek, but they were too small in volume and pressure to be valuable. Wells on Titaluk and Knifeblade anticlines had small shows of oil and gas in the Grandstand but, like the Wolf Creek wells, were dry holes.

Arctic Contractors estimate the total recoverable gas reserves of Square Lake to be 33 to 58 billion cubic feet. Formation water was produced with the gas from each of the gas sands in this well, and the electric log indicates a gas-water contact within each sand. The well is only about 40 feet structurally below the crest of the anticline, but since the crest is broad and flat, Arctic Contractors have estimated that the gas cap covers about 2,800 acres and that gas free from water could be produced by drilling 30 feet higher on the anticline.

Wolf Creek test well 1 produced gas at the rate of 1.3 million cubic feet per day at a pressure of 8 pounds per square inch from the top of a sandstone unit 150 feet below the top of the Grandstand Formation. At this point the well had to be junked, and Wolf Creek test well 3 was drilled about 500 feet west of well 1 but produced only 406,000 cubic feet per day from the same upper sandstone. The lower sandstone of the Grandstand in this well produced at an even lower rate.

The failure to find oil reserves in the Grandstand Formation west of Umiat may be accounted for partly by the character of the sandstone and partly by the local structure and drilling conditions at the individual wells. Despite the wide range in grain size of the Grandstand sandstone in the western wells, tests of core samples show that they are as a whole far less permeable than the sandstone at Umiat. (See p. 516.) According to F. R. Collins and F. M. Robinson (written commun., 1955), the sandstone of the Grandstand at Umiat is, as a whole, cleaner than that in the foothills wells to the west and contains less interstitial clay and mica. Because the Grandstand Formation at Umiat is only about half as thick as it is in the other wells, they interpret the relative cleanness of the sandstone there to be the result of winnowing and reworking of the sediments in a part of the sedimentary basin that subsided less.

In addition to the unfavorable measured permeabilities, only one of the eight western wells was drilled under conditions similar in both structural situation and drilling methods to the producing wells at Umiat. The Knifeblade wells were drilled by cable tools but were on a breached anticline. After the wells were drilled it was determined that at least part of the steeply dipping beds penetrated by the wells in the southern fault block crop out updip between the wells and the fault trace. Most of the beds penetrated in the northern block probably also crop out updip (pl. 55). Bitumen, which is common in the sandstone of the Grandstand in both the wells and the outcrops, is evidence that oil has been lost from the formation. The Square Lake and Titaluk wells were drilled with rotary drill using water-base mud, as was the unsuccessful Umiat test well 2. At Wolf Creek the first two wells were cable-tool holes, but the first well on the crest of the anticline was junked just as it entered the top sandstone of the Grandstand, and the second well, 500 feet lower on the anticline, penetrated only 68 feet into the Grandstand Formation before reaching the safe drilling limit of the rig. Wolf Creek test well 3 was drilled with oil-emulsion mud adjacent to well 1. This was the only well of the eight that penetrated the complete Grandstand Formation in a good structural situation and without the use of fresh-water drilling mud.

Fossil Creek and Weasel Creek anticlines are the only anticlines in the foothills of this region not tested by drilling. Both are closed anticlines. Minor faults occur on the south flank of Fossil Creek anticline, and a major fault zone occurs along the northern axis of Weasel Creek anticline. If the photointerpretation is correct, most of the closure on Weasel Creek anticline is against this fault zone; a similarly faulted anticline at Umiat has proved to be a good trap.

Weasel Creek anticline is a prominent high in the generally low Maybe Creek structural basin, and, together with Fossil Creek anticline, forms a linear element within the basin that trends northeast, oblique to the regional strike (fig. 117). This structural situation suggests that these two anticlines may lie in a favorable facies belt of the Grandstand Formation. The relative cleanness and permeability of the producing sandstone of the Grandstand at Umiat have been attributed to winnowing of the sand on an anticline that grew during deposition. There is evidence that some anticlines grew approximately in their present locations in Late Cretaceous time. The transverse trends may reflect still older highs and lows. If so, Weasel Creek anticline, as an unusually high faulted structural feature projecting into the Maybe Creek basin transverse to the regional strike, might be the site of an older high on which favorable Lower Cretaceous sandstone like that at Umiat may be found.

HEAVY-MINERAL STUDIES OF THE UMIAT-MAYBE CREEK REGION

By Robert H. Morris

In the Umiat-Maybe Creek region numerous samples of sandstone were taken for heavy-mineral study. The primary purpose of this study was to determine the existence of heavy-mineral zones and their relation to the various stratigraphic units. Samples were collected by Stefansson, Whittington, Ray, and Fischer in 1946; Detterman, Webber, Whittington, and Troyer in 1947; Brosgé and Kover in 1949; and Whittington in 1951. The samples were prepared in the Geological Survey laboratory at Fairbanks, Alaska. They were disaggregated and treated with dilute hydrochloric acid to remove the carbonates. The disaggregate was sieved, and the material passing the 80-mesh screen and retained on the 235-mesh screen was separated into light, medium, and heavy fractions using bromoform (sp gr 2.79) and methylene iodide (sp gr 3.0). Slides of the heavy fraction were prepared using canada balsam ($N=1.54$) or aroclor ($N=1.66$).

DESCRIPTION OF HEAVY MINERALS

Apatite and (or) andalusite.—Colorless to yellow elongate prisms of apatite and andalusite occur. Many grains have inclusions (carbonaceous?) zonally arranged parallel to the c axis. Most grains are fresh angular fragments, although well-rounded grains occur sporadically. Many grains are indeterminate optically, but solubility and insolubility in hydrochloric acid indicates that both apatite and andalusite are present.

Augite.—Grains of augite are light olive green, irregularly shaped, and have poor cleavage.

Biotite.—Two forms of biotite occur. In samples from the Nanushuk Group biotite grains are ragged lobate-edged dark-brown cleavage plates, which are commonly mottled. In samples from the Colville Group biotite occurs as rust-brown or dark-brown fresh subhedral plates, some with bubblelike (gaseous?) inclusions.

Chloritoid.—Subhedral to euhedral light-green to light-blue-green chloritoid occurs, generally as hexagonal plates. Relief is high, and birefringence, weak. Grains are pleochroic; x=light green to light olive green, y=light blue green. Owing to orientation, no color for the z ray can be determined. The general appearance is similar to mica but the chloritoid grains are easily distinguished by their higher relief and distinctive pleochroism. Many grains have rodlike inclusions (minute minerals?).

Garnet.—Both pink and colorless garnet grains are present. In samples from Nanushuk Group rocks, surfaces of the grains are etched, whereas in samples from the Colville Group, surfaces of most grains are marked by conchoidal fractures. Euhedral grains are very scarce.

Glaucophane.—Angular prismatic cleavage fragments of glaucophane occur. Pleochroism is intense; x=colorless or very light blue, y=violet, and z=bright blue.

Hornblende.—The several varieties of hornblende present may be distinguished by color. Color and pleochroism of the varieties are listed in the following table. Grains are angular to subangular and exhibit good prismatic cleavage.

Variety	x	y	z
Blue green	Very light green	Green	Blue green.
Light green	Colorless	Light green	Dark green.
Olive green		Greenish brown	Olive green.

Muscovite.—Colorless ragged lobate-edged cleavage plates of muscovite.

Picotite.—Dark-brown isotropic picotite grains, whose relief is very high, even in aroclor, are angular and marked by conchoidal fractures.

Tourmaline.—Subround to angular prismatic grains of tourmaline. Color varieties include olive green, brown, mauve, and dark blue.

Zircon.—Many varieties of zircon are present. Color varieties include pale lavender, pale yellow, and colorless. Crystal varieties range from simple crystals, which are first-order prisms and pyramids, to complex forms, which are first- and second-order prisms and ditetragonal dipyramids. Length-to-width ratios of the various forms are 1.5:1 to 3:1 for the complex forms and more than 4:1 for the simple forms. Colored crystals are generally complex, but colorless types are simple forms, many of which contain numerous bubblelike (gaseous?) inclusions. Another crystal form exhibits zonal growth markings. Only a few grains are rounded; others are fresh angular euhedra.

Opaque heavy minerals.—Magnetite, ilmenite and leucoxene, and authigenic pyrite are the opaque minerals found. They are nondiagnostic for zonation purposes.

HEAVY-MINERAL ZONES

Plate 57 shows the stratigraphic occurrences of the various minerals. The chart is compiled so that each sample is placed in its relative position within the stratigraphic section except those occurring in the hornblende and glaucophane zones. These two zones are believed to be stratigraphic equivalents and for convenience, samples are grouped according to the designated zone. Within each of these zones, however, samples are plotted in relative stratigraphic position.

Samples from the Grandstand and Chandler Formations are characterized by a suite of minerals that includes garnet, tourmaline, zircon, picotite, biotite, muscovite, chloritoid, hornblende, and apatite and (or) andalusite. Within this suite the most significant feature is the persistence of zircon grains that have zonal growth markings. This persistence and the lack of other suitable criteria is the basis for establishing the zoned-zircon zone. Within the zone there are considerable variations in the relative abundance of the constituent minerals. Garnet and tourmaline show the most conspicuous variations. Tourmaline is more abundant in the Grandstand Formation, and garnet is more abundant in the Chandler Formation. This apparent trend may be related to the differing depositional factors of marine and nonmarine strata. Also of interest is the great abundance of muscovite occurring in the basal part of the Chandler Formation. Similar mineralogic occurrences have been noted in samples from the basal part of the Chandler Formation in other areas of northern Alaska.

Minerals characteristic of the Ninuluk Formation include garnet, zircon, tourmaline, picotite, biotite, muscovite, chloritoid, hornblende, apatite and (or) andalusite, and glaucophane. Zircon grains include many varieties, the most distinctive of which are slender colorless types having length-to-width ratios greater than 4:1. Although glaucophane occurs in one sample from the Grandstand Formation, its first persistent stratigraphic occurrence is in the Ninuluk Formation, wherein it is limited geographically to the western part of the region in the vicinity of Maybe Creek and the Ikpikpuk River. The samples containing glaucophane are therefore designated as characterizing the glaucophane zone whereas in the eastern part of the area samples from equivalent strata contain hornblende and euhedral zircon grains having length-to-width ratios greater than 4:1 and characterize the hornblende zone. In addition to occurrences in this region, both zones are recognized in the adjacent area south of the Colville River and in several of the test wells.

Samples from the Seabee Formation and the lower part of the Tuluvak Tongue of the Prince Creek Formation contain garnet, zircon, tourmaline, picotite, biotite, muscovite, chloritoid, apatite and (or) andalusite, hornblende, and glaucophane. Mineralogically this suite of minerals is similar to that in the Nanushuk Group. Differences are apparent, however, in grain shape and in varieties of some minerals. The most significant such differences are the following: Garnet grains marked by conchoidal fractures are more abundant than those that are etched; hornblende grains include, in addition to the light-green and blue-green varieties present here and in older strata, an olive-green to greenish-brown variety; biotite grains are fresh rust-brown to dark-brown subhedral plates rather than ragged-edged fragments.

Biotite grains, though not present in all samples, are generally very abundant in the Seabee and the lower part of the Tuluvak Tongue. Biotite zone is the name applied to the same stratigraphic interval in wells in the Gubik, Umiat, and Simpson areas, and its usage here seems justifiable even though some samples are atypical. Fresh subhedral biotite grains are lacking locally in sandstone beds in the basal part of the Seabee Formation. Possibly these sandstone beds are, in part, reworked Ninuluk Formation. Throughout the Seabee Formation and the Tuluvak Tongue are numerous beds of bentonite and bentonitic sandstone and shale. The close association of fresh biotite grains with these bentonitic sediments indicates that the biotite grains were derived from the same volcanic ejecta. During periods of maximum volcanic activity, the resulting deposits would be enriched in biotite, whereas during the quiescent stages the deposits would tend to be barren of biotite. The volcanic origin of the biotite grains may explain their absence in some beds in the higher parts of the section. All gradations of the relative abundance of biotite grains could be expected, depending upon the degree of admixing of other normal detrital constituents.

In the Rogers Creek, Barrow Trail, and Sentinel Hill Members of the Schrader Bluff Formation, the suite of minerals is similar to that in the Seabee Formation and the Tuluvak Tongue. There are, however, conspicuous differences in the relative abundance of garnet and biotite. Fractured garnet grains are very abundant, and biotite grains are sporadic. The fractured garnet zone is therefore established as characteristic of samples from the Rogers Creek, Barrow Trail, and Sentinel Hill Members.

ZONES IN THE SUBSURFACE

Test wells drilled in the Umiat-Maybe Creek region penetrated strata in which several of the heavy-mineral zones have been recognized. Table 6 lists the wells and the range (depth given in feet) of each of the mineral zones as defined by the available samples. The writer's detailed quantitative heavy-mineral data for these wells are given in reports on subsurface geology (Collins, 1958a, p. 93, 110, 120, 192, pl. 10;

TABLE 6.—*Heavy-mineral zones in test wells*

Well	Depth	Formations	Zone
Sentinel Hill			
Core test 1	152–1023	Prince Creek and Schrader Bluff.	Fractured garnet.
Umiat			
Test well 1	750–3001	Seabee, Ninuluk, Chandler, Grandstand, and upper part of Torok.[1]	Hornblende.
	3498–4188	Torok	Zoned zircon.
	5995	Torok	Augite.
2	400–1034	Grandstand	Hornblende.
	?–1632?	Torok	Zoned zircon.
3	257–361	Grandstand	Hornblende.
11	118–1824	Prince Creek and Seabee	Biotite.
	2049–2386	Ninuluk and Chandler	Hornblende.
	2813–3005	Lower part of Grandstand	Zoned zircon.
Square Lake			
Test well 1	237–1880?	Prince Creek and Seabee	Biotite.
Wolf Creek			
Test well 3	1553?–3520	Grandstand and Torok [1]	Zoned zircon.
Knifeblade			
Test well 1	1290–1490	Grandstand	Zoned zircon.
2A	460–1540	Grandstand	Zoned zircon.
Titaluk			
Test well 1	2660–3460	Grandstand	Zoned zircon.

[1] Topogoruk Formation of Robinson, Rucker, and Bergquist (1956).

1959, p. 441–442, 470; Robinson, 1959a, p. 392–393, 412; Robinson and Collins, 1959, p. 499).

The upper part of the hornblende zone in Umiat test well 1 as defined in table 6 includes strata of the Seabee Formation. As stated in the discussion of the heavy minerals of the Seabee Formation, biotite is generally abundant but may be lacking where sediments of the Ninuluk Formation were reworked and incorporated in the basal part of the Seabee. This condition may have been attained in Umiat test well 1, and the depth given for the upper limit of the hornblende zone (750 ft) therefore would in error. The hornblende zone in Umiat test well 1 is excessively thick in comparison with that of the other wells; however, about 1,000 feet of the hornblende zone is repeated by faulting. In addition, the available samples from the other Umiat wells do not represent the maximum extent of the hornblende zone.

Within the hornblende zone in the Umiat wells sporadic occurrences of glaucophane indicate that although glaucophane is generally restricted to the western part of the Umiat-Maybe Creek region, some was transported as far east as Umiat.

The best correlation among the wells is shown by the zoned-zircon zone, which is recognized in all wells drilled to a sufficient depth to penetrate it.

Umiat test well 1 penetrated another mineral zone which is representative of strata not present in surface exposures in the Umiat-Maybe Creek region. A sample from 5,995 feet contains much augite and is referred to the augite zone. In the Kurupa-Oolamnagavik Rivers area (Chapman and others, 1964) the augite zone is representative of the lower part of the Torok Formation and the Fortress Mountain Formation.

INTERPRETATION

The augite grains in the sample from 5,995 feet in Umiat test well 1 were probably derived from mafic igneous rocks in the source area to the south, which contains fairly numerous outcrops of mafic igneous rocks believed to have been emplaced during Jurassic time.

The suite of minerals present in the zoned-zircon zone, the hornblende zone, and the glaucophane zone indicate derivation from a source area that is composed predominantly of metamorphic rocks but also includes older sedimentary rocks and minor quantities of igneous rocks. The etched garnet grains occurring in the three zones indicate active intrastratal solutions.

As previously stated, the fresh biotite grains of the biotite zone are believed to have been derived from volcanic ejecta.

In the upper part of the Colville Group, the characteristic suite of minerals indicates a source area very similar in composition to that from which the sediments of the Nanushuk Group were derived.

LITHOLOGY AND PALEONTOLOGY OF SAMPLES FROM SHOTHOLES NEAR UMIAT

Holes were drilled by crews of United Geophysical Co., Inc., party 46, from August to November 1946. Whittington, Thomas Steinburn, and G. O. Gates collected the samples from holes 8, 9, 11, and 20 and most of those from holes 12, 13, and 16. The rest of the samples, about 60 percent of the total, was collected by the drill crews. At several of the shot points it was necessary to drill two or more holes, and in a few instances as noted below, samples were collected from two holes at the same shot point. Most of the holes were drilled with a small rotary rig, but a cable-tool rig was used to complete holes 1 to 7 and 38 because cave-ins prevented the rotary rig from successfully drilling through the alluvial gravels underlying the Colville River flood plain. Location and approximate stratigraphic position of all holes drilled except 11a are shown on the map and sections of plate 56. Except as otherwise noted, microfossils were identified by H. R. Bergquist (pl. 58).

Shotholes 1 to 7

[Bedrock in holes 1 to 5 is probably in the Seabee Formation; in hole 6, the Ninuluk Formation; and in hole 7, the Killik Tongue of Chandler Formation. No samples were collected from these holes. Figure 116 illustrates the nature of the alluvium based on the driller's logs. The driller's description of the bedrock in each hole is given below]

Hole	Depth (feet)	Description
1	23–45	Shale and bentonite.
2	31–45	Sandy shale and bentonite.
3	23–45	Do.
4	29–45	Shale and much bentonite.
5	24–42	Shale and bentonite.
6	25–40	Blue shale.
	40–44	Sandy shale.
7	41–47	Shale.
	48	Sandstone.

Shothole 8

[Killik Tongue of Chandler Formation. Coaly material, mostly in the form of grains and carbonaceous partings in sandstone and siltstone, is present in small amounts in many of the samples, but it has not been listed in the descriptions given below. Samples described are from the second hole drilled at this shot point. Some samples were collected from the first hole but were used only for microfossil separation. No microfossils were found in samples from either hole]

Depth (feet)	
0–5	Shale, silty, light-olive-gray, 40 percent grayish-olive very fine grained to fine-grained micaceous sandstone, and a trace of coarse sand.
5–10	Shale, medium-dark-gray to olive-gray, and 15 percent light-olive-gray siltstone.
10–15	Sandstone, medium-grained to very coarse grained, pale-olive, friable, 40 percent medium-dark-gray to olive-gray shale, and 10 percent light-olive-gray siltstone.
15–25	Shale, olive-gray, and as much as 5 percent medium- to coarse-grained sandstone.
25–35	Shale, olive-gray, and 45 percent medium- to coarse-grained dusky-yellow friable sandstone.
35–40	Shale, olive-gray, and 5 percent light-olive-gray siltstone.
40–50	Sandstone, medium- to fine-grained, light-gray to dusky-yellow, olive-gray shale in equal amounts, and 10 to 15 percent light-olive-gray siltstone.
50–60	Siltstone and silty shale, light-olive-gray, 25 percent medium-grained to very fine grained light-olive-gray sandstone, and 20 percent olive-gray shale. Some bentonite in lower half.
60–65	Shale, 35 percent siltstone and silty shale, 15 percent sandstone, and some bentonite, all as above.
65–75	Sandstone, fine-grained to very fine grained, dusky-yellow to yellowish-gray, 25 to 30 percent olive-gray shale, and in lower half 25 percent pale-olive siltstone and a trace of ironstone.
75–80	Shale and 45 percent siltstone and 5 percent sandstone, all as above.
80–85	Sample missing.
85–95	Shale, olive-gray, and 10 percent pale-olive siltstone.
95–100	Shale, olive-gray, and 35 percent fine-grained to very fine grained light-olive-gray sandstone.
100–105	Sandstone as above, 35 percent medium-dark-gray shale, 10 percent olive-gray shale, and 5 percent brownish-gray shale.
105–110	Sandstone, very fine grained to silty, light-olive-gray, 30 percent medium-gray shale, and 10 percent olive-gray shale.
110–125	Sandstone, fine-grained to very fine grained, pale-olive, and 30 percent medium-gray shale.

Shothole 8—Continued

Depth (feet)	
125–135	Shale, medium-gray, 45 percent pale-olive fine-grained sandstone to siltstone, and a trace of ironstone.
135–150	Shale and 15 percent sandstone-siltstone rock, as above.
150	Total depth.

Shothole 9

[Killik Tongue of Chandler Formation. Microfossils absent]

Depth (feet)	
0–5	Shale, olive-gray, and 5 percent coarse to fine sand.
5–10	Sandstone, fine- to coarse-grained, friable, and medium-dark-gray to olive-gray shale in equal amounts.
10–15	Shale and 10 percent sandstone, both as above.
15–30	Shale, olive-gray to light-olive-gray, and 10 percent sandstone as above.
30–40	No samples.
40–45	Shale, dark-gray to light-olive-gray, and 20 percent friable fine- to coarse-grained sandstone.
45–50	Sandstone and 40 percent shale, both as above.
50–55	Shale and 20 percent sandstone, both as above.
55–100	No samples.
100	Total depth.

Shothole 10

[Killik Tongue of Chandler Formation. Microfossils absent]

Depth (feet)	
0–10	Shale, olive-gray.
10–15	Sandstone, fine-grained to siltstone, olive-gray, 1 percent olive-gray shale, and 1 percent dark-reddish-brown shale.
15–20	Shale, olive-gray to light-olive-gray, 10 percent sandstone as above, and 2 percent moderate-reddish-brown shale.
20–65	Sandstone, fine- to medium-grained, friable, yellowish-gray to light-olive-gray; 40 percent dark-gray to light-olive-gray shale in upper 5 ft and 5 percent or less below.
65–75	Sandstone and 30 percent shale, both as above.
75–80	Shale and 20 percent sandstone, both as above.
80–95	No samples.
95	Total depth.

Shothole 11

[This hole was near the east margin of the alluvial flat in the valley of Bearpaw Creek at an elevation of 405 ft. At this place the topographic base of pl. 56 appears to be in error, the creek being drawn 100 to 150 ft too far west and the 400-ft contour being carried too far upstream. After routine washing many of the samples were still very dirty and contained many nonlithified plant fragments. The dirt and plant fragments appear to be contamination introduced by progressive thawing of the frozen alluvium in the upper 15 to 20 ft of the hole. Many of the samples contain coal, which probably also came from the alluvium, because some of the dirtiest samples contained the most coal. The tuff and much of the sandstone and siltstone may also be from the alluvium. The geologic mapping indicates that the bedrock at this place is the lower shale member of the Seabee Formation. Microfossils are absent]

Depth (feet)	
0–15	No samples.
15–20	Shale, grayish-olive, containing a few fragments of sandstone and a few chert granules.
20–25	No samples.
25–40	Shale, olive-gray.
40–50	Shale, olive-gray, as much as 10 percent coal, 8 percent light- to moderate-brown shale, and 4 percent sandstone.
50–55	No samples.
55–60	Shale, olive-gray, 25 percent moderate-brown shale, 2 percent coal, and 2 percent sandstone.

Shothole 11—Continued

Depth (feet)

60–75 Shale, sandstone, and coal. Very dirty samples contaminated with large amounts of surface vegetation.

75–80 Sand and silt containing some coal, shale, and surface vegetation. Sample rather dirty.

80–125 Shale, olive-gray, averages 25 percent sandstone, siltstone, and tuff, 10 percent coal, and 5 percent moderate-yellowish-brown shale. Samples clean; only one had a noticeable amount of surface vegetation. Very little sand and silt.

125 Total depth.

Shothole 11a

[This hole was 195 ft west of hole 11 at an elevation of 411 ft, 6 ft higher than hole 11. Probably this location was at the base of the steep slope on the west side of the valley of Bearpaw Creek. The microfossils (pl. 58) probably indicate that the rock in the hole is part of the Colville Group. Apparently it is part of the lower shale member of the Seabee Formation, although the Ninuluk Formation crops out almost as far north on the east wall of the valley. The fault contact between the Seabee on the north and the Ninuluk and Killik on the south probably lies only a short distance south of this hole. The sandstone at a depth of 15 to 25 ft probably represents alluvial material, a slope-wash deposit derived principally from the Ninuluk that is tributary to and grades into the alluvium in Bearpaw Valley. A less likely interpretation is that the sandstone might be part of the Killik Tongue in fault contact with the Seabee at a depth of about 25 ft]

Depth (feet)

0–15 No samples.

15–25 Sandstone and sand, rather variable in appearance, mostly fine to medium grained and pale to dark yellowish brown, ranging from rather friable to very hard. The sand includes many chert fragments and quartz granules and pebbles. About 10 percent of the sample is reddish-brown ironstone or ferruginous shale, and 1 percent is siltstone and gray shale.

25–65 Shale, silty, olive-gray, containing as much as 10 percent sandstone, siltstone, and ironstone. Bottom sample includes a few fragments of black chert.

65 Total depth.

Shothole 12

[Upper shale member of Seabee Formation. Two holes at this place were sampled, the first from 10 ft to 195 ft and the second from the surface to the total depth of 70 ft. Except for the interval 0 to 10 ft, samples as described came from the first hole, but samples from 10 to 70 ft in the second hole show a lithology similar to that of those from the same interval in the first hole. Microfossils are shown in pl. 58]

Depth (feet)

0–10 Sand, moderate-yellowish-brown, largely medium to fine; some is coarse to granule size.

10–30 Shale, medium-light gray to medium-gray, and olive-gray to light-olive-gray shale in approximately equal amounts; averages about 15 percent light-olive-gray siltstone and 5 percent very fine grained sandstone.

30–60 Shale, olive-gray to moderate-brown, averages 4 percent sandstone and siltstone, and 1 percent medium-dark-gray shale.

60–95 Shale, olive-gray to moderate-brown, averages 15 percent medium-gray shale, 10 percent sandstone and siltstone, and traces of coal.

95–100 Sample is about half silt and sand. Remainder as above.

100–120 Shale, olive-gray to moderate-brown, and medium-gray shale in equal amounts; 5 percent sandstone and siltstone.

120–135 Shale, medium-gray, 15 percent light-olive-gray to moderate-olive-brown shale, and 5 percent sandstone and siltstone.

Shothole 12—Continued

Depth (feet)

135–195 Shale, medium-dark-gray to medium-gray, an average of 10 percent sandstone and siltstone, and 1 percent olive-gray shale.

195 Total depth.

Shothole 13

[This hole, about 1,500 ft east of Umiat test well 11, begins in the beds transitional between the Rogers Creek Member of the Schrader Bluff Formation and the Tuluvak Tongue of the Prince Creek Formation. Because of the transitional nature of these beds, the placement of the contact must be arbitrary. Certainly the very coaly section below 160 ft belongs in the Tuluvak Tongue, but the overlying beds containing both microfossils and sparse coal could be assigned to either unit. Arbitrarily the contact has been placed at 100 ft. Ground level at the hole is 582 ft, 101 ft higher than the kelly bushing and 118 ft higher than ground level at well 11 (Collins, 1958a, p. 179–180). The very coaly section at a depth of 160 to 200 ft in the hole apparently corresponds to the coaly section at 30 to 60 ft in well 11, which would put the shothole about 30 to 40 ft lower structurally than the well. On the basis of this correlation, the upper 150 ft of beds in the shothole represents a section not drilled in the well; this explains why the microfauna found in the shothole (pl. 58) was not found in the well. The first hole at this place was sampled from 60 to 200 ft and a later hole was sampled from the surface to 50 ft.]

Depth (feet)

0–25 Shale, silty, olive-gray.

25–30 Siltstone, light-brown, 25 percent olive-gray silty shale, and 15 percent yellowish-gray siltstone.

30–35 Siltstone, yellowish-gray to dark-yellowish-orange, and 15 percent olive-gray silty shale.

35–40 Shale, silty, olive-gray, and 20 percent yellowish-gray siltstone.

40–45 Siltstone, yellowish-gray, 20 percent coal, 20 percent coaly siltstone, and 20 percent olive-gray silty shale.

45–50 Shale, silty, light-olive-gray, 35 percent yellowish-gray to dark-yellowish-orange siltstone, and 1 percent coal and coaly siltstone.

50–60 No samples.

60–65 Sandstone, fine-grained, to light-gray to dark-yellowish-orange siltstone, containing 30 percent medium-gray to olive-gray shale and 5 percent coal and coaly siltstone.

65–70 Shale, medium-gray to moderate-yellowish-brown, 5 percent sandstone and siltstone, and 1 percent coal.

70–75 Shale as above and 30 percent medium- to fine-grained sandstone.

75–80 Shale as above, 25 percent sandstone as above, and 15 percent medium-light-gray to dark-yellowish-orange fine-grained sandstone to siltstone.

80–85 Shale as above, 15 percent sandstone and siltstone, and 10 percent coal and carbonaceous shale.

85–95 Shale, light-olive-gray to moderate-brown; 15 percent medium- to fine-grained friable sandstone, 10 percent fine-grained sandstone to siltstone, and 2 percent coal and carbonaceous shale.

95–100 Shale, medium-gray to moderate-brown, 20 percent sandstone and siltstone, 20 percent coal, and 5 percent carbonaceous shale.

100–125 Shale, olive-gray to moderate-olive-brown, an average of 15 percent sandstone and siltstone, and 5 percent coal.

125–150 Shale, medium-gray to moderate-olive-brown, an average of 25 percent sandstone and siltstone, and a trace of coal and carbonaceous shale.

150–155 Sandstone, very fine grained, light-gray, 35 percent shale as above, and 5 percent coal and carbonaceous shale.

Shothole 13—Continued

Depth (feet)

155–160 Approximately equal amounts of coal, medium-gray silty shale, medium-dark-gray shale, olive-gray to moderate-brown shale, and very fine grained sandstone.

160–170 Coal, 25 percent medium-gray to moderate-brown shale, and 10 per cent sandstone and siltstone.

170–175 Coal, 30 percent medium-gray to moderate-brown shale, and 20 percent light-gray friable fine-grained sandstone.

175–180 Coal, 25 percent medium-light-gray fine- to very fine-grained sandstone, 15 percent medium-gray shale, and 10 percent very light gray bentonite.

180–185 Coal and medium-gray silty shale, in equal amounts, 20 percent sandstone and siltstone, and 10 percent light-olive-brown to dark-brown shale.

185–200 Coal and coaly siltstone, 25 percent medium-gray silty shale, and 10 percent sandstone and siltstone.

200–375 No samples.

375 Total depth.

Shothole 14

[Rogers Creek Member of Schrader Bluff Formation. Microfossils are listed on pl. 58]

Depth (feet)

0–5 Shale, olive-gray, and bentonite.

5–10 Shale, olive-gray.

10–15 Tuff, very light gray, and bentonite.

15–25 Shale, medium-dark-gray.

25–30 Shale, yellowish-gray, silty or tuffaceous.

30–35 No samples.

35–40 Tuff, very light gray, 10 percent light-gray tuff, and 10 percent medium-dark-gray shale.

40–65 Shale, olive-gray, and very light gray to white tuff decreasing in amount from 25 percent at top of interval to a trace at the base.

65–70 Tuff, very light gray to white, 20 percent olive-gray to medium-dark-gray shale, 10 percent white chalcedony, and 5 percent light-brownish-gray siltstone.

70–75 Shale, olive-gray, 30 percent pale-brown siltstone, 10 percent light-brownish-gray siltstone, and 10 percent light-gray to white tuff.

75 Total depth.

Shothole 15

[Rogers Creek Member of Schrader Bluff Formation. Microfossils reported by H. R. Bergquist are listed on pl. 58. Tappan (1951a, p. 5–6) reported *Spiroplectammina mordenensis* as well as *Neobulimina canadensis* and *Praebulimina venusae* from the 20-ft depth in this hole]

Depth (feet)

0–15 No samples.

15–20 Shale, light-brownish-gray, and traces of ironstone and tuffaceous siltstone.

20–25 Shale, light-brownish-gray, and 30 percent silt to very fine sand and 5 percent ironstone.

25–30 Shale, light-brownish-gray.

30–35 Shale, light-olive-gray, silty or tuffaceous, and bentonite.

35–40 Siltstone, light-brownish-gray, 30 percent fine to coarse sand and light-brownish-gray sandstone containing black chert granules and pebble fragments, 20 percent olive-gray shale, and an undetermined percentage of bentonite.

40–45 No samples.

45–50 Shale, olive-gray, silty or tuffaceous, and 10 percent fine- to medium-grained light-brownish-gray sandstone.

Shothole 15—Continued

Depth (feet)

50–55 Sandstone, very fine grained to medium-grained, light-brownish-gray.

55–60 No samples.

60–65 Sandstone, fine-grained, light-brownish-gray, bentonitic-appearing, and 5 percent olive-gray siltstone and some bentonite.

65–75 No samples.

75 Total depth.

Shothole 16

[This hole begins about 200 ft above the base of the Barrow Trail Member of Schrader Bluff Formation. The first hole at this place was drilled and sampled to 65 ft. At that depth it became necessary to abandon the hole, and a second hole was begun a few feet away. As samples were collected in the upper 65 ft in the second hole, they were combined with those of corresponding depth from the first hole. The sparse microfauna is shown on pl. 58]

Depth (feet)

0–5 Sand, dark-yellowish-brown.

5–20 Sand and sandstone, fine-grained to very fine grained, pale-olive. White tuff in angular to rounded sand-sized fragments constitutes 40 percent of the sample in the middle 5 ft and 60 percent in the lower 5 ft. Some bentonite in all samples.

20–25 Sandstone, fine-grained, tuffaceous, pale-olive.

25–40 Shale, silty, hard, olive-gray to medium-gray, 30 percent pale-olive fine-grained to very fine grained tuffaceous sandstone, and 10 percent very light gray to olive-gray siltstone. Some bentonite in lower 5 ft.

40–70 Sandstone, fine-grained to very fine grained, tuffaceous, light-gray to pale-olive, and 1 to 2 percent clay ironstone.

70–85 Shale, silty, medium-dark-gray to olive-gray, and sandstone as above, in equal amounts, containing 20 percent medium-light-gray siltstone.

85–90 Shale as above, 15 percent dark-yellowish-brown shale, 20 percent sandstone as above, and 20 percent siltstone as above.

90–115 Sandstone, fine-grained to very fine grained, tuffaceous pale-olive, 10 percent medium-light-gray siltstone, 10 percent medium-dark-gray to olive-gray shale, and 5 percent dark-yellowish-brown shale. Sandstone in lower 5 ft is rather friable and probably bentonitic.

115–150 Sandstone as above, 5 percent siltstone as above, and 15 percent medium-dark-gray to olive-gray shale.

150–160 Coal, 35 percent sandstone as above, 15 percent siltstone as above, and 10 percent medium-dark-gray to olive-gray and dark-yellowish-brown shale.

160–175 Sandstone, fine- to medium-grained, slightly tuffaceous, friable, probably bentonitic, 20 percent pale-olive fine-grained to very fine grained tuffaceous sandstone, 10 percent medium-light-gray siltstone, 10 percent olive-gray to medium-dark-gray shale, and 10 percent coal.

176 Total depth.

Shothole 17

[The top of this hole is a short distance, perhaps 20 ft, below the top of the Barrow Trail Member of the Schrader Bluff Formation. Microfossils absent]

Depth (feet)

0–5 No samples.

5–10 Sandstone.

10–15 Sandstone, 10 percent brown siltstone, and 10 percent white tuff. Unwashed sample contained bentonite.

Shothole 17—Continued

Depth (feet)

15–20 Siltstone or tuff, light-gray, and 5 percent light-gray shale.
20–25 Sandstone and 5 percent medium-gray shale.
25–50 Sandstone.
50–55 Sandstone and 5 percent medium-gray shale.
55–60 Shale, medium-gray, and 10 percent sandstone.
60–65 Siltstone, sandy, light-gray, and 10 percent medium-gray shale.
65–70 Sandstone and 40 percent medium-gray shale.
70–75 Shale, medium-gray, and 10 percent light-gray siltstone.
75 Total depth.

Shothole 18

[This hole began in the Sentinel Hill Member of the Schrader Bluff Formation and penetrated the top of the Barrow Trail Member at about 50 ft. Microfossils absent]

Depth (feet)

0–5 No samples.
5–10 Shale, medium- to dark-gray, and 5 percent tan siltstone or very fine grained sandstone.
10–15 Sandstone or sandy tuff, buff. Bentonite in unwashed sample.
15–20 Siltstone or tuff, light-gray, and 40 percent medium-gray shale.
20–25 Shale or tuff, light-gray, and 10 percent medium-gray shale.
25–30 Shale or tuff, light-gray, and medium-gray shale, in equal amounts.
30–35 Shale, silty, or tuff, light-gray and medium-gray.
35–40 Shale, medium-gray, and 30 percent light-gray shale or tuff.
40–45 Shale, light-gray, 30 percent medium-gray shale, and 10 percent grayish-white tuff.
45–50 Shale, light- to medium-gray.
50–55 Sandstone and 20 percent light- to medium-gray shale.
55–60 Tuff, grayish-white, 30 percent light-gray shale, and 10 percent sandstone.
60–65 Sandstone, siltstone, and light- to medium-gray shale, in equal amounts, containing 10 percent grayish-white tuff.
65–70 Sandstone, friable, and 1 percent coal.
70 Total depth.

Shothole 19

[Sentinel Hill Member of Schrader Bluff Formation. The single microfossil specimen is listed on pl. 58]

Depth (feet)

0–15 No samples.
15–20 Sand or friable sandstone. The driller's logs of both holes at this place report sandy ice as the formation drilled in the upper 20 to 22 ft. This sample probably represents an unconsolidated slope-wash deposit.
20–25 Shale, medium- to dark-gray, and 10 percent sand or sandstone.
25–30 Siltstone, light medium gray, and 20 percent medium-gray shale.
30–35 Shale, medium-gray, and 20 percent light-medium-gray siltstone.
35–40 Sandstone, light-gray, very fine grained.
40–45 Sandstone as above and 30 percent dark-gray shale.
45–50 Shale, medium-gray, and 10 percent light-gray siltstone.
50–55 Sandstone or sandy tuff and 40 percent medium-gray shale.

Shothole 19—Continued

Depth (feet)

55–60 Siltstone, medium-gray, and 20 percent sandstone.
60–65 Siltstone or tuff, medium-gray, and 10 percent sandstone.
65 Total depth.

Shotholes 20 to 26

[Sentinel Hill Member of Schrader Bluff Formation. For various reasons no samples have been available to describe lithologically. Holes 22 and 23 were not sampled; samples from holes 21, 24, and 25 were lost; shothole 26 was not drilled. The unsplit samples from hole 20 were processed in their entirety for microfossils, no material being reserved for the lithologic description. The driller's logs indicate that the sections drilled in these holes are largely clay and shale which contain considerable amounts of bentonite and minor amounts of tuff and sandstone. Driller's terms for the major constituents were clay, shale, hard shale, blue shale, blue and yellow shale, and blue clay and for the minor constituents, bentonite, broken bentonite, ledge, white rock, lime, thin sandstone ledges, thin layers of brown sand, broken ledges of sandstone, and rock. While washing some of the samples Whittington estimated the bentonite content. At the interval 35 to 65 ft in hole 20 bentonite made up from a small amount to 20 percent of the various samples, and at 15 to 60 ft in hole 24 moderate-yellow bentonite was present in each sample in amounts ranging from 5 to 30 percent. Microfossils from hole 20 are shown on pl. 58]

Shothole 27

[Ayiyak Member of Seabee Formation. Microfossils absent]

Depth (feet)

0–35 Sand, fine to medium, and moderate-brown to moderate-reddish-brown shale making up one-third of the upper 5 ft and averaging 5 percent for the rest of the interval.
35–40 Shale, moderate-brown, 15 percent fine to very fine sand, and 10 percent medium-dark-gray shale.
40–50 Shale, moderate- to light-brown, and fine to very fine sand, in equal amounts, containing medium-gray shale making up 25 percent of the upper 5 ft and 5 percent of the lower 5 ft.
50–55 Sandstone and sand, fine-grained to very fine grained, light-brownish-gray, and 5 percent moderate-brown shale.
55–60 Sandstone, very fine to fine-grained, light-olive-gray, 25 percent light- to moderate-brown shale, and 5 percent medium-gray shale.
60–65 Sand and sandstone, mostly fine grained but ranging from very fine to medium-grained, 5 percent moderate-brown shale, and 5 percent medium-gray shale.
65–70 Sandstone, fine-grained to very fine grained, 10 percent moderate-brown shale, and 5 percent medium-gray shale.
70–75 Sand and sandstone, very fine to fine-grained, 30 percent light- to moderate-brown shale, and 20 percent medium-gray shale.
75 Total depth.

Shothole 28

[Seabee Formation at about the contact of the calcareous sandstone and upper shale members. As did hole 11, this hole also began in the frozen alluvium along Bearpaw Creek. The coal and much of the sand were probably introduced into the circulating mud by progressive thawing of the unconsolidated deposits. Microfossils absent]

Depth (feet)

0–5 Sand, silt, clay, and plant fragments, 10 percent gray and brown shale, and a trace of coal.
5–10 No sample.
10–15 Sand and sandstone, very fine to fine-grained, and 5 percent brown and gray shale.
15–20 Sand and about 25 percent shale.
20–25 No samples.

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Sholhole 28—Continued

Depth (feet)

25–30 Sand and sandstone, mostly fine grained but ranging from medium-grained to very fine grained, pale-yellowish-brown, and 5 percent gray and brown shale.

30–35 No samples.

35–40 Sand and sandstone, fine- to medium-grained, 5 percent medium-light- to medium-dark-gray shale, 3 percent light- to moderate-brown shale, and 2 percent coal.

40–45 Sand and sandstone, medium-grained to very fine grained and 15 percent brown and gray shale.

45–50 Sand and sandstone, very fine to medium-grained, and 40 percent medium-dark-gray shale.

50–55 Sand and sandstone, medium-grained to very fine grained, pale-yellowish-brown, 25 percent medium-dark-gray shale, and a trace of coal.

55–60 No samples.

60–65 Sand, very fine to medium, pale-yellowish-brown, and 5 percent medium-dark-gray shale.

65–70 Sand, very fine to medium, 45 percent medium-dark-gray shale, and 5 percent moderate- to light-brown shale.

70–75 Sand and sandstone, medium-grained to very fine grained, pale-yellowish-brown, and 15 percent medium-dark-gray shale.

75 Total depth.

NOTE.—Shotholes 29 and 30 were not drilled.

Shothole 31

[The top of this hole is about 200 ft above the base of the Barrow Trail Member of Schrader Bluff Formation. Microfossils absent]

Depth (feet)

0–25 Sandstone, fine-grained, tuffaceous, hard except for the upper 5 ft and part of the lower 5 ft; dusky yellow to yellowish gray in upper 10 ft and very light gray to light gray below.

25–30 Bentonite, silty, yellowish-gray, and 5 percent medium-gray shale.

30–35 Siltstone or tuff, pale-olive, and 5 percent medium-gray shale.

35–40 Shale, medium-gray, and light-gray siltstone, in equal amounts, containing 10 percent fine-grained sandstone.

40–65 Sandstone, very fine grained, tuffaceous, somewhat friable, yellowish-gray; contains medium-gray to medium-dark-gray shale making up 25 percent of the lower 5 ft and a trace to 5 percent of the other samples.

65 Total depth.

Shothole 32

[This hole begins about 75 ft above the base of the Barrow Trail Member of Schrader Bluff Formation. On the basis of the location it would be expected that the rock would be largely sandstone, and on the same basis the rock in hole 33 should be largely shale. The driller's logs confirm this, listing sandstone and bentonite for hole 32 and shale and bentonite for hole 33. However, samples labeled as being from hole 32 are largely shale and those labeled as being from hole 33 are largely sandstone. It is thus assumed that the samples were incorrectly labeled. The lithology described here for hole 32 is based on samples labeled hole 33. Microfossils were absent from samples labeled hole 33.]

Depth (feet)

0–15 Sand and sandstone, fine- to medium-grained, mostly stained light brown in the lower part; bentonite in upper part.

15–25 Sandstone, very fine to fine-grained, light-brown.

25–30 Sand, very fine to medium, a few fragments of fine-grained sandstone, bentonite, and 35 percent very fine grained light-brown sandstone.

Shothole 32—Continued

Depth (feet)

30–35 Sandstone, fine-grained, light-brownish-gray, and bentonite.

35–40 Sandstone, very fine to fine-grained, light-olive-gray, and bentonite.

40–45 Sandstone, very fine to fine-grained, moderate-yellowish-brown, bentonite, and 30 percent grayish-brown shale.

45–65 Sand and sandstone, very fine to fine-grained, light-brown, and bentonite. The lower 5 ft is about half moderate-brown to grayish-brown shale or ironstone.

65 Total depth.

Shothole 33

[Rogers Creek Member of Schrader Bluff Formation. The apparent mixup of samples from holes 32 and 33 is noted above. The samples described here are labeled for hole 32. Microfossils from samples labeled hole 32 are shown under hole 33 on pl. 58.]

Depth (feet)

0–5 No samples.

5–25 Bentonite and graudally increasing amounts of other rock types—medium-dark-gray partly silty shale at 10 to 20 ft, light-olive-gray siltstone at 15 to 25 ft, and yellowish-gray tuff at 20 to 25 ft.

25–40 Siltstone grading to very fine grained sandstone, light-olive-gray, shaly; minor amounts of bentonite.

40–65 Shale, silty, light-olive-gray; 75 percent of sample is medium-dark-gray shale at 50 to 55 ft, 50 percent at 60 to 65 ft, and 10 to 25 percent at other depths. Minor amounts of bentonite at 40 to 45 and 60 to 65 ft. Small amount of yellowish-gray tuff at 55 to 60 ft.

65 Total depth.

Shothole 34

[Rogers Creek Member of Schrader Bluff Formation. Microfossils are shown on pl. 58]

Depth (feet)

0–5 Plant fragments, shale, and silt.

5–10 Shale, silty, moderate-yellowish-brown.

10–35 Shale, olive-gray. Sample at 20 to 25 ft is 40 percent medium-gray silty shale and at 30 to 35 ft, 60 percent medium-gray shale.

35–55 Shale, light-olive-gray, partly silty, 60 to 100 percent of the various samples; 0 to 25 percent is olive-gray shale, and 0 to 15 percent is medium-gray shale.

55–60 Shale, olive-gray, 10 percent medium-light-gray shale, and a few fragments of sandstone and siltstone.

60–65 Shale, olive-gray, 3 percent medium-gray shale, 3 percent mottled yellowish-gray to white tuff, and 2 percent olive-gray fine-grained sandstone.

65 Total depth.

Shothole 35

[This hole is at the approximate contact between the Rogers Creek Member of the Schrader Bluff Formation and the Tuluvak Tongue of the Prince Creek Formation. Microfossils absent.]

Depth (feet)

0–10 Shale, moderate-brown to pale-brown, and bentonite.

10–15 Shale, moderate-brown, 40 percent very fine to fine-grained sand, 1 percent medium-gray shale, and a trace of black carbonaceous shale.

15–20 Shale, moderate-brown.

20–25 Sandstone, fine-grained, light-brown, 35 percent moderate-brown shale, 15 percent very fine grained sand, and some bentonite.

25–30 Shale, moderate-brown.

Shothole 35—Continued

Depth (feet)	
30–35	Shale, moderate-brown, 30 percent light-brown fine-grained sandstone, 1 percent black carbonaceous shale, and some bentonite.
35–40	Shale, moderate-brown, 5 percent fine-grained sandstone, and some bentonite.
40–45	Shale, moderate-brown, 40 percent fine-grained sandstone, 5 percent medium-gray shale, and some bentonite.
45–55	Shale, light- to moderate-brown, 5 to 10 percent light-gray shale, and a slight amount of bentonite.
55–60	Shale, light-gray to medium-light-gray, 35 percent light-brown shale, and some bentonite.
60–65	Shale, medium-light-gray, 10 percent coal or coaly shale, 5 percent light-brown shale, and some bentonite.
65	Total depth.

Shothole 36

[This hole probably penetrated beds near the base of the calcareous sandstone member of the Seabee Formation. Because the dip at this place is probably very steep, the 55 ft drilled probably represents beds only a few feet thick. Microfossils absent.]

Depth (feet)	
0–10	Sand and sandstone, fine-grained, light-olive-gray. From 5 to 35 ft there are small amounts of an extremely fine grained white substance in all samples.
10–20	Sandstone as above, and 30 percent and 45 percent dark-gray to grayish-black shale.
20–25	Sandstone as above and medium-dark-gray shale, in equal amounts.
25–30	Shale, dark-greenish-gray, and 5 percent very fine grained sandstone.
30–35	Shale, dark-greenish-gray, and 20 percent dusky-yellow to light-olive-gray shale.
35–40	Shale, medium-dark-gray to olive-gray.
40–45	Sand and sandstone, very fine grained, light-olive-gray.
45–55	Sandstone, very fine to fine-grained, light-brownish-gray.
55	Total depth.

Shothole 37

[Lower shale member of Seabee Formation. The arbitrarily defined Seabee-Ninuluk contact should not be far below the bottom of the hole, and the true contact between the two shale formations may have been penetrated by the hole, but the microfossils give no indication of the presence of the Ninuluk. The sandstone at 10 to 25 ft is considered to be key sandstone bed F (pl. 56), which forms a bedding trace to within 2,000 ft of the hole in the area to the south and southeast. Sandstone F is at the surface at Umiat test well 9 and the top of the Ninuluk is estimated to be at 50 ft in that well, so at the shothole the interval between sandstone F and the Ninuluk is apparently greater than it is at the well. Microfossils reported by H. R. Bergquist are listed on pl. 58. Tappan (1962) reported *Neobulimina subcretacea* from the Grandstand Formation at a depth of 65 ft in this hole. The top of the Grandstand should be at least 400 ft below the bottom of the hole. This reported occurrence may be due to mislabeled samples, contamination, or misidentification]

Depth (feet)	
0–5	No samples.
5–10	Shale, silty, dark-yellowish-brown, and bentonite.
10–25	Sandstone, very fine grained, light-olive-gray, 0 to 15 percent olive-gray shale, and some bentonite.
25–35	Shale, olive-gray, 0 to 5 percent sandstone as above, and some bentonite.
35–50	Siltstone to very fine grained sandstone, light-olive-gray, 20 to 40 percent olive-gray shale, and some bentonite.
50–65	Shale, olive-gray, in part silty, some bentonite, and a trace of coal.
65	Total depth.

Shothole 38

[Not sampled. The driller reported alluvial materials to a depth of 38 ft (fig. 116), and he described the bedrock from 38 to 65 ft as frozen shale and bentonite. The bedrock is probably part of the Killik Tongue of the Chandler Formation]

STRATIGRAPHIC SECTIONS

LOWER CRETACEOUS ROCKS

SECTION 1.—*Chandler Formation on Colville River at Aupuk anticline*

[See pl. 53. Section is made up of rocks exposed at three cutbanks on south side of Colville River from 3 to 9 miles west of mouth of Aupuk Creek. Units 1 to 9 are from westernmost exposure. Units 11 to 25 are in mile-long cutbank about 5 miles west of creek; exposure presents noteworthy lateral variations in lithology and thickness. Units 27 to 47 are from the easternmost exposure, where crest of anticline and subsidiary fold on north flank can be seen. The western and middle cutbanks were measured by Chapman in 1946 and by Reynolds in 1950. The section in the eastern cutbank was measured by Thurrell in 1946 on the north flank of the fold. In 1950 Reynolds examined this exposure but primarily on the south flank and in less detail. South flank exposures may include stratigraphically higher beds than any recorded from north flank. Eberlein and Chapman in 1950 computed thicknesses for units 10 and 26. In these computations, bedding attitudes were projected nearly parallel to strike for relatively long distances; therefore, the thicknesses shown for these long covered intervals are of a relatively low order of accuracy]

	Thickness (feet)	*Distance below top of composite section (feet)*
CHANDLER FORMATION:		
Killik Tongue:		
1. Poorly exposed but apparently dominantly shale	?	?
2. Clay-ironstone talus	2±	0–2±
3. Sandstone, light-gray to light-olive-gray, very fine grained, in lensing and wedging beds ranging from ¼ in. to 3 in. thick. Some interbedded silty shale, clay ironstone, and ferruginous sandstone. Coaly laminae. Carbonized plant remains common on bedding planes. Abundant slickensides in this unit at one place	9	2±–11
4. Bituminous coal containing interbedded claystone, shale, and clay ironstone. Coal in beds 6 to 10 in. thick	7±	11–18±
5. Sandstone, medium-gray, very fine grained, shaly; contains abundant clay-ironstone layers and nodules	7	18±–25
6. Poorly exposed. Interbedded sandstone, sandy and silty shale, and light- to medium-gray clay; unit contains minor amounts of clay ironstone and one bed of bony bituminous coal. Carbonized plant remains common. Sandstone is light gray, fine to very fine grained, shaly bedded	12±	25–37±
7. Shale and claystone, dark-gray, friable, spheroidal-weathering. Small clay-ironstone concretions. One 6-in.-thick bed of carbonaceous sandstone. (46ACh161, barren)	6	37±–43
8. Slumped medium-gray sandy shale, carbonaceous shale and coaly shale; several massive claystone layers and a few concretionary clay-ironstone layers. (50ARe313a, barren)	15±	43–58±

SECTION 1.—*Chandler Formation on Colville River at Aupuk anticline*—Continued

CHANDLER FORMATION—Continued Killik Tongue—Continued	*Thickness (feet)*	*Distance below top of composite section (feet)*
9. Shale, apparently similar to units 7 and 8	15±	58±–73±
10. Covered	500±	73±–573±
11. Interbedded sandstone, siltstone, and shale. Sandstone, light- to medium-gray, very fine grained, silty and shaly. Some sandstone is ripple marked and crossbedded and contains streaks and pods of coaly material. One silty sandstone bed ranges in thickness from 1 to 6 ft and another, from 3 to 6 ft. Shale is mostly silty. A few ironstone layers about 1 in. thick. A persistent 8-in. coal bed occurs 10 ft above base of unit. Weathered color of rocks in unit is predominantly grayish orange. (50ARe338, taken from 10 to 15 ft above base, barren)	50	573±–623
12. Bituminous coal, shiny, hard, well-jointed	1	623–624
13. Interbedded sandstone and shale. Beds lens abruptly. At one place the upper half is sandstone and the lower half, shale. At other places there are two sandstone beds and two or three shale beds. Sandstone, light- to medium-gray, moderate-brown-weathering very fine grained, silty; contains some ironstone lenses and bands and some plant fragments; bedding varies from evenly layered to irregular and massive. Shale, medium-gray, mostly silty; some is light olive gray	12	624–636
14. Shale and claystone, dark-gray, silty to sandy. Locally a 6- to 8-in. ironstone layer, and at one place a 1-ft medium-grained sandstone having dusky-red patches. The topmost beds of this unit grade laterally into a 3-in. coal bed and a gradational coaly, sandy clay ironstone that is dark gray to grayish brown and weathers a conspicuous grayish to yellowish orange. Farther along the coal is 6 in. thick and is underlain by 3 ft of well-bedded silty sandstone. Minor thrust fault in this unit, offsetting beds 2 to 2½ ft. Upward, fault dies out or swings into bedding plane at top of unit. (50ARe341, from lower half, barren)	12	636–648
15. Sandstone, medium-gray, fine-grained to very fine grained, silty, well-bedded to shaly bedded. At one place carbonaceous and crossbedded with a 1- to 2-in. ironstone interbed. Thickness varies from 3 to 6 ft	4	648–652
16. Shale, olive-gray, silty in part. A few lenticular clay-ironstone layers 4 to 6 in. thick. Locally the basal few inches is a light-olive-gray to medium-gray, very fine grained, shaly, carbonaceous sandstone	11	652–663
17. Shale, olive-gray, chunky to fissile, very crumbly. (46ACh171, *Ammodiscus rotalarius* Loeblich and Tappan, *Haplophragmoides topagorukensis* Tappan?, *Verneuilinoides borealis* Tappan, *Gaudryinella irregularis* Tappan)	3	663–666
18. Bituminous coal containing two laterally persistent 1-in. layers of coaly, very fine grained sandstone. Thickness ranges from 2 to 2½ ft. Sample 46ACh170 (U.S. Bur. Mines lab. Nos. 45916 and C–69403; for description and analyses, see Chapman and others, 1964)	2	666–668
19. Sandstone, medium-gray, very fine grained, shaly; grades laterally into argillaceous siltstone. Thickness ranges from 1 to 2½ ft	2	668–670
20. Bituminous coal, bony coal, coaly and carbonaceous shale in beds as much as 1 ft thick separated by 2- to 3-in. silty shale beds. Thickness of unit ranges from 1 to 4 ft	3	670–673
21. Sandstone, light- to medium-gray, very fine grained; carbonaceous flecks; shaly laminae to 3-in. layers; slight rusty stain. Upper 2 ft is light olive gray to yellowish gray and is highly fractured into soft angular chunks	7	673–680

SECTION 1.—*Chandler Formation on Colville River at Aupuk anticline*—Continued

CHANDLER FORMATION—Continued **Killik Tongue—Continued**	*Thickness (feet)*	*Distance below top of composite section (feet)*
22. Covered interval. Lateral variations in lithology and thickness may have caused omission of about 10 to 20 ft of strata at this place	10±	680–690±
23. Sandstone, light-gray, fine-grained to very fine grained; in layers 4 in. to 1 ft thick; irregularly crossbedded, contains interbedded conglomerate and conglomeratic sandstone, coarse-grained sand size to 2-in. pebbles. Abundant carbonized plant remains. Small amount of ironstone. Highly fractured and jointed, many of the joints cutting across white quartz and black chert pebbles. Laterally conglomerate disappears and part of sandstone becomes shaly	6	690±–696
24. Interbedded shale and sandstone. Shale is mainly medium gray and silty, but some is carbonaceous and very fissile. Sandstone is light to medium gray, very fine grained, and mostly shaly bedded, fucoidal markings on some bedding surfaces. Some of sandstone weathers grayish orange and some, a marked reddish orange. Thin coal in lensing layers. In lower part, 6-in. layer of sandy ironstone. Locally the basal bed is a massive-appearing shaly sandstone that lenses out	13	696–709
25. Shale, olive-gray, mostly silty, and olive-gray argillaceous siltstone, in beds ⅛ in. to 2 in. thick; several ironstone layers, 1½ to 5 in. thick, and ironstone concretions, 4 to 8 in. in diameter. Locally, a few inches below the top is a 7-in. bed of bituminous to shaly coal	9	709–718
26. Covered	200±	718–918±
27. Sandstone, medium-gray, pinkish-gray- to light-brown-weathering, crossbedded; in part very fine grained and shaly in ¼-in. to 1-in. beds; in part fine to coarse grained in thicker beds; contains carbonaceous material and wood fragments	15	918±–933

SECTION 1.—*Chandler Formation on Colville River at Aupuk anticline*—Continued

CHANDLER FORMATION—Continued **Killik Tongue—Continued**	*Thickness (feet)*	*Distance below top of composite section (feet)*
28. Covered. Some soft shaly coal in this area. On the south flank of the anticline is a 3-ft coal bed at about this level	20±	933–953±
29. Sandstone similar to unit 27, but here contains some pebbly layers; pebbles mainly subrounded quartz but some are ironstone and some coal; pebble size ¼ in. to 2 in., average ½ in.	15	953±–968
30. Covered	15±	968–983±
31. Shale, silty	4	983±–987
32. Interbedded silty shale, siltstone, and very fine grained medium-gray sandstone. Shale in 1- to 3-in. layers and siltstone and sandstone in ½- to 1-in. beds. Some ironstone in ¼- to ½-in. beds and in ½- to 1-in. concretions in the sandstone. Sandstone has well-defined oscillation ripple marks. Siltstone has mud swirls. Carbonaceous flakes throughout	8	987–995
33. Similar to unit 32 but contains no sandstone	5	995–1,000
34. Covered	5	1,000–1,005
35. Sandstone, shaly, very fine grained	2	1,005–1,007
36. Silty shale. Basal 2 in. is coal and next 6 in. is clay containing yellow weathered streaks (bentonitic?) (46ATh165, *Ammodiscus rotalarius*? Loeblich and Tappan, *Haplophragmoides topagorukensis*? Tappan, *Ammobaculites fragmentarius* Cushman, *Verneuilinoides borealis* Tappan, *Gaudryinella irregularis* Tappan, *Psamminopelta bowsheri* Tappan, *Trochammina ribstonensis* subsp. *rutherfordi*? (Stelck and Wall). This sample is unusually fossiliferous, and all seven species are common to abundant. In number and variety of forms this sample resembles samples from the Tuktu and upper part of the Torok Formations. It is likely that this unit is only a short distance above the Tuktu Formation (H.R. Bergquist, oral		

SECTION 1.—*Chandler Formation on Colville River at Aupuk anticline*—Continued

CHANDLER FORMATION—Continued Killik Tongue—Continued	Thickness (feet)	Distance below top of composite section (feet)
commun., 1959). 50ARe325a, from the south flank, probably about this level, barren)	8	1,007–1,015
37. Sandstone, massive, fine- to medium-grained, yellowish-gray; weathers pale yellowish green and has scattered light-brown patches. Plant remains. Crossbedded. Beds 1 to 8 in. thick, averaging 2 in. Extensively jointed. This sandstone is extensively exposed on both flanks of the fold and can be followed from the south flank over what appears to be the main crest of the anticline to the north flank and down the north flank across a subsidiary anticline. The brecciated zone of unit 38, occurs just north of the crest of the subsidiary anticline	30	1,015–1,045
38. Brecciated zone in crumpled nonresistant beds. Unit apparently consists primarily of silty shale in ¼- to ½-in. beds but includes some very fine grained sandstone, sandy siltstone, ironstone lenses, and a 2-in. coal bed	8±	1,045–1,053±
39. Siltstone	25	1,053±–1,078
40. Covered. Includes coal having vitreous luster	10	1,078–1,088
41. Interbedded very fine grained sandstone and shaly siltstone including 6-in. bed of coaly very fine grained sandstone	35	1,088–1,123
42. Coal, very good grade, in 1- to 3-in. layers	4	1,123–1,127
43. Shale containing 1-in. coal in middle	1	1,127–1,128
44. Siltstone	3	1,128–1,131
45. Sandstone, very fine grained, crossbedded	4	1,131–1,135
46. Siltstone	3	1,135–1,138
47. Interbedded sandstone and siltstone. Top 2 in. is a very good grade of coal and next 2 in. is gradational from coal to sandstone	15	1,138–1,153
Total (incomplete), Killik Tongue of Chandler Formation	1,153	

SECTION 2.—*Chandler and Grandstand Formations south of Knifeblade Ridge*

[See pl. 53. Top of section 1.5 miles south of Knifeblade test well 2A. Section extends northward 1.8 miles. Measured by Whittington in 1951. All thicknesses calculated using altimeter elevations and distances scaled from aerial photographs. Correlation of units 6 to 18 with log of Knifeblade test well 2A (Robinson, 1959a) is shown in fig. 122]

CHANDLER FORMATION: Killik Tongue:	Thickness (feet)	Distance below top of measured section (feet)
1. Covered.		
2. Bedding trace. Sandstone (rubble), tan, mostly coarse-grained, clean, very friable; has salt-and-pepper appearance. Grain size varies from medium-grained to very coarse grained and granule conglomerate. The very coarse grained sandstone and granule conglomerate are darker tan, less friable, and in thinner slabs. Scattered pebbles of quartz and chert and a few of shale and clay ironstone	20±	0–20
3. Covered. On aerial photographs there are several faint bedding traces, but none of these are visible to the ground observer	1,025	20–1,045±
4. Bedding trace. Small amount of rubble of a hard fine-grained sandstone	10±	1,045±–1,055±
5. Covered. Collar of Knifeblade test well 2A 65 ft above base of unit	480	1,055±–1,535
6. Coal bed uncovered by bulldozer. Correlated with coal bed at 69–75 ft in Knifeblade test well 2A	2	1,535–1,537
7. Covered	23±	1,537–1,560±
8. Bedding trace. Probably same unit as sandstone at 87–113 ft in Knifeblade test well 2A	10±	1,560±–1,570±
9. Covered	25±	1,570±–1,595±
10. Bedding trace. Sandstone (rubble), light-gray, medium-grained, clean, friable; salt-and-pepper appearance. Probably same as sandstone at 137–144 ft in Knifeblade test well 2A	10±	1,595±–1,605±
11. Covered	25±	1,605±–1,630±
12. Bedding trace. Sandstone (rubble), light-gray, fine- to medium-grained, fairly clean, hard. Probably same as sandstone at 168–185 ft in Knifeblade test well 2A	10±	1,630±–1,640±

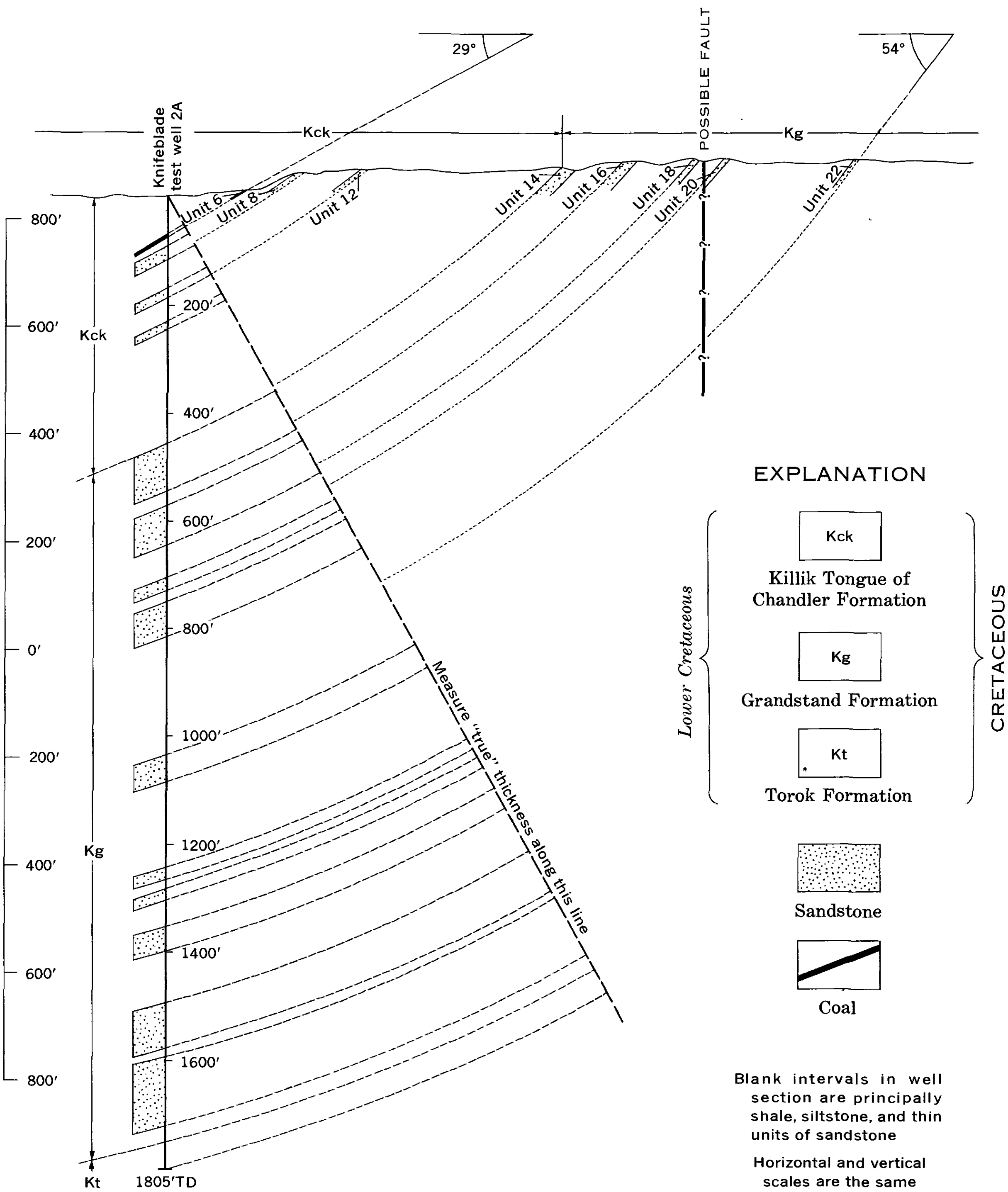

FIGURE 122.—Correlation of units of stratigraphic section 2 with the log of Knifeblade test well 2A (Robinson, 1959a), based on the assumption of cylindrical folding.

SECTION 2.—*Chandler and Grandstand Formations south of Knifeblade Ridge*—Continued

	Thickness (feet)	Distance below top of measured section (feet)
CHANDLER FORMATION—Continued		
Killik Tongue—Continued		
13. Covered	230±	1, 640±–1, 870±
Total (incomplete), Killik Tongue of Chandler Formation	1, 870	
GRANDSTAND FORMATION:		
14. Sandstone outcrop and rubble on prominent bedding trace. Upper part is brownish-tinged medium-grained sandstone, salt-and-pepper appearance, fairly clean, in part slightly calcareous; colors solvents brownish black. Lower part is silty fine-grained sandstone, ranging from light-gray, hard, moderately calcareous, to brownish-gray, moderately hard, noncalcareous; colors solvents medium brown. Correlated with upper part of sandstone at 455–545 ft in Knifeblade test well 2A	20	1, 870–1, 890
15. Covered	55	1, 890–1, 945
16. Bedding trace. Probably same unit as lower part of sandstone from 455–545 ft in Knifeblade test well 2A	20	1, 945–1, 965
17. Covered	75	1, 965–2, 040
18. Bedding trace. Probably same unit as sandstone at 570–645 ft in Knifeblade test well 2A	10	2, 040–2, 050
19. Covered. Possible fault in this interval	30	2, 050–2, 080
20. Bedding trace. Outcrop made by bulldozer. Sandstone, medium-light-gray to brownish-gray, fine-grained to very fine grained, hard, slightly to moderately calcareous	10	2, 080–2, 090
21. Covered	185±	2, 090–2, 275±
22. Bedding trace	10±	2, 275±–2, 285±
23. Covered. Base of unit at probable anticline axis	145±	2, 285±–2, 430
Total (incomplete), Grandstand Formation	560	

Section 3.—*Grandstand Formation on Knifeblade Ridge*

[See pl. 53. Section is 1.5 miles northwest of Knifeblade test well 1 where highest part of ridge is formed by vertically dipping Grandstand Formation in north limb of anticline. Section extends S. 20° W. across crest of ridge for approximately 1,200 ft. Section based primarily on photointerpretation and field data on lithology and structure obtained by Whittington in 1947]

	Thickness (feet)	Distance below top of measured section (feet)
CHANDLER FORMATION:		
Killik Tongue:		
1. Covered.		
GRANDSTAND FORMATION:		
2. Bedding trace. Probably sandstone	60	0–60
3. Covered. Probably mostly shale	180	60–240
4. Bedding trace. Probably sandstone	60	240–300
5. Covered. Probably mostly shale	240	300–540
6. Bedding trace. Probably sandstone	30	540–570
7. Covered. Probably mostly shale	110	570–680
8. Bedding trace. Probably sandstone	20	680–700
9. Covered. Probably mostly shale	30	700–730
10. Bedding trace. Probably sandstone	10	730–740
11. Covered. Probably mostly shale	30	740–770
12. Bedding trace. Probably sandstone. About 0.8 mile to the east this trace is covered with sandstone (rubble) that is olive gray, very fine to fine grained, highly silty and argillaceous, noncalcareous, and fairly hard. Apparently in beds 1 to 3 in. thick	20	770–790
13. Covered. Probably mostly shale	50	790–840
14. Bedding trace. Probably sandstone. About 0.8 mile to the east this trace is covered with sandstone rubble similar to that in unit 12	30	840–870
15. Covered. Probably mostly shale	60	870–930
16. Bedding trace. Sandstone rubble	40	930–970
17. Covered. Probably shale	10	970–980
18. Bedding trace. Sandstone (rubble), light-olive-gray, fine-grained, moderately argillaceous, noncalcareous, rather friable, apparently in 1- to 3-in. beds	60	980–1, 040
19. Covered. Probably shale	20	1, 040–1, 060
20. Bedding trace. Sandstone (rubble), light-brown (due to numerous small limonitic patches; unweathered color probably light gray), fine- to medium-grained, friable, slightly argillaceous, noncalcareous, subdued salt-and-pepper appearance. Apparently massive or in beds several inches thick in upper part and more thinly bedded in lower part	140	1, 060–1, 200
Total, Grandstand Formation	1, 200	
TOROK(?) FORMATION:		
21. Covered.		

SECTION 4.—*Chandler and Grandstand Formations between September Creek and Knifeblade Ridge*

[See pl. 53. Top of section 1.5 miles southwest of September Creek at lat 69°10′ N., long 154°39′ W. Section extends 2 miles southwestward to Knifeblade test well 1 and thence 0.5 mile farther. Measured by Whittington and Troyer in 1947 and Whittington in 1951. Thicknesses calculated using altimeter elevations and distances scaled from aerial photographs. Thicknesses of bedding traces having no exposed rock are arbitrary]

NINULUK FORMATION (see section 5).

CHANDLER FORMATION: Killik Tongue:	Thickness (feet)	Distance below top of measured section (feet)
1. Covered. Coal blossom 65 ft below top	80	0–80
2. Bedding trace. No rock visible	5	80–85
3. Covered. Coal blossom about 10 ft below top	120	85–205
4. Bedding trace. No rock visible	10	205–215
5. Covered	165	215–380
6. Coal. Duller than unit 11	2	380–382
7. Bentonite, light-gray	1±	382–383
8. Covered. Coal blossom 5 ft above base	102	383–485
9. Bedding trace. Sandstone (rubble), light-gray to light-olive-gray, fine- to medium-grained, hard, slightly calcareous	5±	485–490
10. Covered	100	490–590
11. Coal, bright	2	590–592
12. Bentonite, light-gray	1±	592–593
13. Covered. Sandy soil 50 ft above base	207	593–800
14. Sandstone, dark-gray, fine-grained and silty, hard, slightly calcareous	1	800–801
15. Float of coal and clay ironstone	2±	801–803
16. Covered	47	803–850
17. Siltstone, dark-gray, slightly calcareous, carbonaceous particles very common	1	850–851
18. Shale, dark-gray, silty. Includes 1-in. bed of clay ironstone	3	851–854
19. Covered	46	854–900
20. Bedding trace. Sandstone (rubble), mostly medium-dark-gray, fine-grained to very fine grained, hard, reddish-weathering; some is medium to fine grained, clean, soft, and gray weathering. Some small clay-ironstone concretions	15	900–915
21. Covered	115	915–1, 030
22. Bedding trace. Sandstone rubble and conglomerate pebbles	10	1, 030–1, 040
23. Covered	60	1, 040–1, 100
24. Bedding trace. Small amount of dark-gray very fine grained sandstone rubble	10	1, 100–1, 110
25. Covered	165	1, 110–1, 275
26. Bedding trace. Small amount of highly weathered, fine-grained sandstone rubble	10	1, 275–1, 285

SECTION 4.—*Chandler and Grandstand Formations between September Creek and Knifeblade Ridge*—Continued

CHANDLER FORMATION—Continued Killik Tongue—Continued	Thickness (feet)	Distance below top of measured section (feet)
27. Covered	35	1, 285–1, 320
28. Locally conspicuous bedding trace that appears to lens out laterally in a short distance. Sandstone (rubble); most is coarse grained, soft, clean, partly conglomeratic; toward top, part is light gray, medium grained, moderately hard, and a little is fine to very fine grained. Pebbles and cobbles consist of quartz, chert, and quartzite. Considerable clay ironstone about middle of interval	30	1, 320–1, 350
29. Covered	70	1, 350–1, 420
30. Bedding trace. Sandstone (rubble), light-gray, medium-grained, soft, clean; salt-and-pepper appearance	10	1, 420–1, 430
31. Covered	140	1, 430–1, 570
32. Bedding trace. Medium- to coarse-grained friable sandstone rubble, highly weathered	5	1, 570–1, 575
33. Covered	45	1, 575–1, 620
34. Bedding trace. Sandstone (rubble), light-gray, medium-grained, friable, fairly clean; salt-and-pepper appearance; contains a few chert and quartz pebbles. The sandstone in part appears to be filling a channel in the underlying coal-bentonite section, but the exposure is poor	20	1, 620–1, 640
35. Mostly coal and light-gray bentonite. Exposure incomplete. One coal bed is at least 3 ft thick	10	1, 640–1, 650
36. Covered	315	1, 650–1, 965
37. Bedding trace. Highly weathered sandstone rubble	10	1, 965–1, 975
38. Covered	190	1, 975–2, 165
39. Bedding trace. Highly weathered sandstone rubble	10	2, 165–2, 175
40. Covered. Bedding traces visible on aerial photographs, but not apparent to the ground observer, occur 65 ft below top of unit and 150 ft above base. Collar of Knifeblade test well 1 is 115 ft below top of unit. Base of unit is at horizon considered equivalent to the base of the Killik Tongue at 1,145 ft in Knifeblade test well 1	1, 215	2, 175–3, 390
Total, Killik Tongue of Chandler Formation	3, 390	

SECTION 4.—*Chandler and Grandstand Formations between September Creek and Knifeblade Ridge*—Continued

GRANDSTAND FORMATION:	*Thickness (feet)*	*Distance below top of measured section (feet)*
41. Covered. Considered equivalent to the upper part of the sandstone found at 1,145 ft in Knifeblade test well 1	245	3, 390–3, 635
42. Bedding trace. Sandstone (rubble), yellowish-gray, fine- to medium-grained, rather hard to hard, in part slightly calcareous, mostly limonitic weathering	10	3, 635–3, 645
43. Covered	235	3, 645–3, 880
44. Irregular area of highly weathered sandstone rubble. Grain size, very fine to coarse	20	3, 880–3, 900
45. Covered	135	3, 900–4, 035
46. Area of highly weathered sandstone rubble	10	4, 035–4, 045
47. Covered	235	4, 045–4, 280
48. Area of obscure bedding trace or traces. Sandstone (rubble), olive-gray, fine-grained, rather hard, gray-weathering. Incipient cleavage	10	4, 280–4, 290
49. Covered.		
Total (incomplete), Grandstand Formation	900	

UPPER CRETACEOUS ROCKS

SECTION 5.—*Prince Creek, Seabee, and Ninuluk Formations on September Creek*

[See pl. 54. Top of section at lat 69°13′ N., long 154°33′ W. Section extends southward 2.5 miles to September Creek, thence southwestward 2 miles. Measured by Whittington and Troyer in 1947 and Whittington in 1951. Fossiliferous shale unit measured with hand level; rest of section, from altimeter elevations and distances scaled from aerial photographs]

PRINCE CREEK FORMATION: **Tuluvak Tongue:**	*Thickness (feet)*	*Distance below top of measured section (feet)*
1. Sandstone, very coarse grained, and conglomerate of granules, pebbles, and cobbles of chert, quartzite, and quartz	50	0–50
Total (incomplete), Tuluvak Tongue of Prince Creek Formation	50	
SEABEE FORMATION:		
2. Covered	100	50–150
3. Sandstone, greenish-gray, fine-grained, noncalcareous, slightly argillaceous. Rubble only	10±	150–160
4. Covered	90	160–250
5. Conspicuous bedding trace; covered, probably sandstone	25±	250–275
6. Covered	220	275–495

SECTION 5.—*Prince Creek, Seabee, and Ninuluk Formations on September Creek*—Continued

SEABEE FORMATION—Continued **Tuluvak Tongue—Continued**	*Thickness (feet)*	*Distance below top of measured section (feet)*
7. Slumped shale	50	495–545
8. Shale, dark-gray, bituminous, fissile; thin interbeds of yellow bentonite and siliceous siltstone	35	545–580
9. Shale as above; concretions of black sublithographic limestone containing plant fossils; beds of black sublithographic limestone and of light-gray coquinoid limestone. Coal lenses as much as ½ in. thick. (USGS Mesozoic loc. 26553 (47AWh296) and 47AWh294, see fig. 101*D* and table 2)	14	580–594
10. Slumped shale as in unit 8	16	594–610
11. Shale and bentonite as in unit 8 (47AWh295, see fig. 101)	4	610–614
12. Slumped shale as in unit 8	11	614–625
13. Covered	125	625–750
Total, Seabee Formation	700	
NINULUK FORMATION:		
14. Bedding trace and chert-pebble horizon in the soil	5±	750–755
15. Covered	3±	755–758
16. Small amount of coal in soil	1±	758–759
17. Covered	1±	759–760
18. Sandstone, light-gray, fine-grained, clean, hard to very friable, weathers light gray (friable rock) to dull reddish brown (hard rock). Hard rock is partly calcareous. Bedding ranges from several inches in thickness to finely laminated. Some small-scale crossbedding. Sporadic chert pebbles. One fairly persistent pebble horizon near base. A few nodules of clay ironstone	30	760–790
19. Covered	15	790–805
20. Several knee-deep patches of bentonite in the streambed probably represent a bentonite bed at about this horizon. Bentonite is dull cream color, very plastic and greasy	5±	805–810
21. Covered	60	810–870
22. Conspicuous bedding traces. Weathered sandstone rubble. Sandstone, very fine grained; in upper part, moderate reddish brown and ferruginous; in lower part, light olive gray and highly argillaceous	55	870–925
Total, Ninuluk Formation	175	
CHANDLER FORMATION: **Killik Tongue (see section 4, fig. 3).**		

SECTION 6.—*Prince Creek and Seabee Formations on Lower Maybe Creek*

[See pl. 54. Section measured from axis of Banshee syncline southward 2 miles to Maybe Creek along valley of a small stream that enters Maybe Creek about 4 miles above mouth of September Creek. Upper 434 ft of section measured from planetable elevations by Brosgé and Kover in 1949; lower part of section by tape and barometer by Brosgé and Reiser in 1952]

	Thickness (feet)	Distance below top of measured section (feet)
PRINCE CREEK FORMATION:		
Tuluvak Tongue:		
1. Sandstone, gray; yellow-weathering; very fine, fine-, and medium-grained; thin-bedded; calcareous. Locally contains siltstone. Thickness ranges from 13 to 31 ft (sandstone 9)	31	0–31
2. Covered. Local coal float	61	31–92
3. Sandstone, yellow-gray, brown-weathering, medium- to coarse-grained, very calcareous. Local conglomerate and ironstone. Absent to the south and locally can be seen in outcrop to grade southeastward from conglomeratic very coarse grained sandstone to nonconglomeratic medium-grained sandstone (sandstone 8)	17	92–109
4. Covered	42	109–151
5. Sandstone, gray to yellow-gray, yellow-weathering, medium- to coarse-grained, mostly calcareous. Locally conglomeratic and locally includes gray-green fine-grained sandstone. Thickness ranges from 17 to 30 ft. Basal sandstone of Prince Creek Formation (sandstone 7)	30	151–181
Total (incomplete), Tuluvak Tongue of Prince Creek Formation	181	
SEABEE FORMATION:		
Ayiyak Member:		
6. Covered	20	181–201
7. Sandstone, gray, yellow-weathering, fine-grained, thin-bedded, calcareous. Found only on the bluff overlooking Maybe Creek between this locality and Banshee Creek (sandstone 6)	14	201–215
8. Covered. Locally the basal part or all this unit may be sandstone similar to unit 7	36	215–251
9. Covered	140±	251–391±
10. Sandstone, dark-gray, yellow-weathering, fine- to medium-grained, thin-bedded, calcareous. Surface trace of this sandstone pinches out eastward and disappears along line of section (sandstone 5)	43	391±–434
Total, Ayiyak Member of Seabee Formation	253	
11. Covered	155	434–589

SECTION 6.—*Prince Creek and Seabee Formations on Lower Maybe Creek*—Continued

	Thickness (feet)	Distance below top of measured section (feet)
SEABEE FORMATION—Continued		
Ayiyak Member—Continued		
12. Shale. 4 feet above base is 6-in. bed of dark-gray fine-grained limestone. (52ABe77 and 78, barren)	20	589–609
13. Shale. About 7 ft above base is 1-ft bed of gray-brown fine-grained calcareous sandstone. (USGS Mesozoic loc. 20413 (46ARy68), from float probably derived from this sandstone, fig. 101 and table 2; 52ABe79, barren)	10	609–619
14. Shale. 6-in. bed of dark-gray very fine grained, very calcareous sandstone containing about 50 percent calcite. (52ABe80, barren)	10	619–629
15. Shale. (52ABe81 and 82, barren)	20	629–649
16. Shale. 2-in. bed of coarse-grained sandstone near top. (52ABe83, barren)	10	649–659
17. Interbedded shale and sandstone. Sandstone is brown gray, coarse grained, fucoidal, thin bedded, and constitutes 50 percent of unit. (52ABe84, barren of microfossils; *Inoceramus* prisms abundant)	10	659–669
18. Shale; very thin beds of sandstone near top and bottom. (52ABe85, barren)	10	669–679
19. Shale. (52ABe85, barren)	10	679–689
20. Shale and mudstone, yellow-weathering. In upper part, 1- to 4-in. bands of bentonite and limonitic clay locally cemented by vuggy aragonite(?). At base, fossiliferous concretions of black, very fine grained, finely laminated limestone. The concretions are about 6 in. thick and 2 ft in diameter and are broken by a polygonal network of calcite-filled joints. (USGS Mesozoic loc. 26572 (52ABe75), see fig. 101 and table 2; 52ABe87, barren)	10	689–699
Total (incomplete), Shale Wall Member of Seabee Formation	265	
Total (incomplete), Seabee Formation	518	

SECTION 7.—*Composite section of Prince Creek, Seabee, and Ninuluk Formations near Titaluk test well 1*

See pl. 54. [Section generalized from many local sections measured by Brosgé and Kover in 1949, between the head of Fry Creek and the Ikpikpuk River north of Kay Creek. Sections measured from planetable elevations]

	Thickness (feet)	Distance below top of measured section (feet)
PRINCE CREEK FORMATION:		
Tuluvak Tongue:		
1. Sandstone, gray, gray-weathering, fine- to medium-grained, platy (sandstone 9)	13	0–13
2. Covered	51	13–64

SECTION 7.—*Composite section of Prince Creek, Seabee, and Ninuluk Formations near Titaluk test well 1*—Continued

	Thickness (feet)	Distance below top of measured section (feet)
PRINCE CREEK FORMATION—Continued		
Tuluvak Tongue—Continued		
3. Sandstone, gray, gray-yellow weathering, coarse- to medium-grained, thin-bedded, calcareous (sandstone 8)	14	64–78
4. Covered	26	78–104
5. Sandstone, gray, coarse-grained, very calcareous, has one pebble. Present only locally. (This sandstone and the one below are included in sandstone 7.)	41	104–145
6. Sandstone, gray to brown, yellow-weathering, fine- to medium-grained, thin-bedded, very calcareous. Locally contains pebbles and coaly streaks. This is the basal sandstone of the Tuluvak Tongue	14	145–159
Total (incomplete), Tuluvak Tongue of Prince Creek Formation	159	
SEABEE FORMATION:		
Ayiyak Member:		
7. Covered, probably shale	170	159–329
8. Sandstone, gray, fine-grained, friable, thin-bedded to crossbedded, calcareous	15	329–344
9. Sandstone, dark-gray, yellow-weathering, fine-grained, hard, massive, calcareous. Most conspicuous sandstone north of Maybe Creek. (This sandstone and the one above are included in sandstone 5.)	60	344–404
Total, Ayiyak Member of Seabee Formation	245	
Shale Wall Member:		
10. Covered	155	404–559
11. Mostly covered. Local float of chert pebbles at top. Bed of bentonite 1½ ft thick at base	15	559–574
12. Partly covered. Mostly sandstone. Coal float near top	17	574–591
13. Sandstone, gray, yellow-weathering, very fine, fine- and medium-grained, thin-bedded, crossbedded, calcareous. Locally contains pebbles as large as 2½ in. in diameter. Locally has ironstone at base (sandstone 4)	18	591–609
14. Covered	38	609–647
15. Sandstone, medium-gray, greenish-gray medium-grained, very calcareous; contains ironstone and clay galls. Locally distributed. Absent west of Kay Creek. (Included in sandstone 3.)	12	647–659
16. Covered	13	659–672

SECTION 7.—*Composite section of Prince Creek, Seabee, and Ninuluk Formations near Titaluk test well 1*—Continued

	Thickness (feet)	Distance below top of measured section (feet)
SEABEE FORMATION—Continued		
Shale Wall Member—Continued		
17. Sandstone, light- to medium-gray, medium-grained, calcareous; and sandstone, ironstained, coarse-grained; containing ½-in. pebbles. Locally distributed. Absent along Ikpikpuk River and north of Titaluk test well 1. (Included in sandstone 3.)	15	672–687
18. Covered	10±	687–697±
19. Sandstone. Present only southeast of Kay Creek. (Included in sandstone 3.) Base of this sandstone is base of Seabee Formation	5	697±702
Total, Shale Wall Member of Seabee Formation	298	
Total, Seabee Formation	543	
NINULUK FORMATION:		
20. Sandstone, gray, yellow-weathering, medium-grained, massive; contains abundant mica and limonite. Found at only one locality. (Included in sandstone 2.)	22	702–724
21. Sandstone, yellow-gray, medium-grained, thin-bedded, calcareous. Found at only one locality. (Included in sandstone 2.)	26	724–750
22. Sandstone, medium-gray to yellow, fine-grained, massive to platy, calcareous. Locally is rusty weathering and contains leaves. Thickens at expense of the overlying sandstone. Most widely distributed unit of sandstone 2, but nevertheless is absent north and east of Kay Creek	7	750–757
23. Covered	41	757–798
24. Sandstone, red, fine-grained, platy, very calcareous, fossiliferous. (USGS Mesozoic loc. 25372 (49ABe50), see fig. 99 and table 1). (Upper part of sandstone 1.)	7	798–805
25. Sandstone. In part, gray, medium grained, and in part, gray to brown, rusty weathering, locally friable, noncalcareous, fine grained. Locally is granule to pebble conglomerate. This unit and unit 24 make up the upper part of sandstone 1 and are present only east of Kay Creek on the structural high near Titaluk test well 1	16	805–821
26. Sandstone, medium-gray, fine- to medium-grained, partly calcareous. Locally contains chert and quartz pebbles. Locally weathers to unconsolidated sand. Thins away from the structural high near Tita-		

SECTION 7.—*Composite section of Prince Creek, Seabee, and Ninuluk Formations near Titaluk test well 1*—Continued

NINULUK FORMATION—Continued	Thickness (feet)	Distance below top of measured section (feet)
luk test well 1. (Lower part of sandstone 1) (47AWb340, barren)	31	821–852
27. Sandstone, gray to yellow, medium-grained, ripple-marked, calcareous; interbedded with gray shale and bituminous black paper shale. Papery calcareous siltstone at base. (USGS Mesozoic loc. 25373 (49-ABe55) and 47AWb341, from approximately this unit; see fig. 99 and table 1)	47	852–899
28. Covered, probably shale	55	899–954
29. Sandstone, red, very fine grained, noncalcareous	5	954–959
30. Coal and amber	1	959–960
31. Sandstone to siltstone, gray, laminated, crossbedded, very fine grained; thin coal beds and shale	7±	960–967±
32. At top and bottom of unit are 1-ft-thick beds of coal containing amber underlain and overlain by bentonite beds. Rest of unit is silty yellow clay containing thin coal beds	10	967±–977
Total (incomplete), Ninuluk Formation	275	

SECTION 8.—*Prince Creek, Seabee, and Ninuluk Formations on Weasel Creek*

[See pl. 54. Section on lower 3 miles of Weasel Creek, north flank of Weasel Creek anticline; computed from photogrammetrically determined elevations and field data obtained by Ray and Fischer in 1946]

PRINCE CREEK FORMATION: Tuluvak Tongue:	Thickness (feet)	Distance below top of measured section (feet)
1. Covered. Near top includes two beds, possibly of sandstone, that form traces visible on aerial photographs	145	0–145
2. Float of conglomerate pebbles at top of bluff. Base of unit is approximate base of Tuluvak Tongue	10±	145–155±
Total (incomplete), Tuluvak Tongue of Prince Creek Formation	155±	
SEABEE FORMATION:		
3. Covered. Probably shale and some sandstone. Weathers to mud. Probable bentonite at top	110	155±–265
4. Covered	120±	265–385±
5. Probably bentonitic shale. Weathers to conspicuous bare patches of white mud	100±	385±–485±
6. Covered. Base of unit is unconformity at base of Seabee Formation	80±	485±–565
Total, Seabee Formation	410	

SECTION 8.—*Prince Creek, Seabee, and Ninuluk Formations on Weasel Creek*—Continued

NINULUK FORMATION:	Thickness (feet)	Distance below top of measured section (feet)
7. Sandstone, gray, "salt-and-pepper," yellowish-weathering, coarse-grained; interbedded with pebble conglomerate that has coaly partings. Clay galls and plant fragments at base	25	565–590
8. Covered	80	590–670
9. Sandstone. In part, tan, fine- to medium-grained, calcareous, and in part, conglomeratic, noncalcareous	15	670–685
Total (incomplete), Ninuluk Formation	120	

SECTION 9.—*Seabee and Ninuluk Formations on Weasel Creek*

[See pl. 54. Composite section measured along the lower 7 miles of Weasel Creek on the north and south flanks of Weasel Creek anticline. Measured from planetable elevations by Ray and Fischer in 1946]

SEABEE FORMATION:	Thickness (feet)	Distance below top of composite section (feet)
1. Probably bentonitic shale. Weathers to extensive patches of gray and brown mud	100	0–100
2. Covered. Base of unit is approximate horizon of the unconformity at the base of the Seabee Formation on the south flank of Weasel Creek anticline as traced northward from Ninuluk Creek syncline	40	100–140
Total (incomplete), Seabee Formation	140	
NINULUK FORMATION:		
3. Mostly covered. Near top of unit is a bed that makes a trace apparent on aerial photographs. 30 feet above base of unit is a 10-foot-thick lens of yellow-weathering very fine grained crossbedded sandstone that appears to pinch out against the sandstone of unit 4 below. Unit 3 is probably lacking on the north flank of Weasel Creek anticline where the probable equivalent of unit 1 is only 40 ft above unit 4	175	140–315
4. Sandstone, gray to gray-green to red-brown, fine-grained to very fine grained, locally coarse-grained, calcareous. Lenticular pebble to cobble conglomerate. Lower part locally noncalcareous. Contains plants and clay galls	25	315–340
5. Sandstone, gray, fine-grained to very fine grained, platy to massive, calcareous; locally contains conglomerate. Plant remains preserved. Coal float at top	15	340–355

SECTION 9.—*Seabee and Ninuluk Formations on Weasel Creek.*—Continued

NINULUK FORMATION—Continued	*Thickness (feet)*	*Distance below top of composite section (feet)*
6. Sandstone, red-brown, fine-grained to very fine grained, calcareous; locally contains conglomerate. Coal float at base	35	355–390
7. Covered	70	390–460
8. Bentonite	2	460–462
9. Sandstone, noncalcareous, green to tan, fine- to medium-grained; in a few places conglomeratic on the flanks of Weasel Creek anticline; becomes coarse grained on the axis. 3 miles west of Weasel Creek this unit is massive pebble conglomerate containing few lenticular beds of sandstone. 1-ft coal at base of unit	18±	462–480±
10. Covered. Coal float containing amber 15 ft above base	65	480±–545
11. Siltstone, gray, 3-ft-thick, thin-banded; contains plant remains; overlies calcareous gray to green very fine to fine-grained sandstone, some of which is crossbedded. Fossils in both siltstone and sandstone (USGS Mesozoic locs. 20415, and 20416 (46ARy89, 89A), see fig. 99 and table 1)	10	545–555
12. Covered	5	555–560
13. Silty shale and sandstone, interbedded	30	560–590
14. Sandstone, fine- to medium-grained, massive to shaly	10	590–600
15. Silty shale and sandstone, interbedded	45	600–645
16. Covered	35	645–680
17. Coal and bentonite	5±	680–685±
18. Granule-pebble conglomerate, poorly sorted, and fine- to coarse-grained noncalcareous sandstone containing fossil leaves	20	685±–705
19. Covered	45	705–750
20. Shale and silty shale. Coal at top of unit	10	750–760
21. Sandstone and siltstone, gray, fine-grained, ripple-marked, calcareous. Varies to gray medium-grained massive to platy noncalcareous sandstone. Both containing fossils (USGS Mesozoic loc. 20423 (46AFi-45), see fig. 99 and table 1)	10	760–770
22. Covered	80	770–850
23. Sandstone, crossbedded siltstone, shale, and coal (46AFi49, see fig. 99 and table 1)	15	850–865
24. Covered	50	865–915
25. Sandstone, gray, very fine grained, noncalcareous, massive to slabby; contains a few conglomeratic beds and thin lenses of siltstone. Lowest exposure on Weasel Creek (USGS Mesozoic loc. 20417, 20418 (46ARy100A, B), see fig. 99 and table 1)	50	915–965
Total (incomplete), Ninuluk Formation	825	

SECTION 10.—*Composite section of Prince Creek and Seabee Formations near the head of Maybe Creek*

[See pl. 54. Section generalized from various local sections measured from planetable elevations by Ray and Fischer in 1946 and Brosgé and Kover in 1949, between Baby Creek and head of Maybe Creek. Upper 300 feet of Prince Creek Formation is from single, poorly controlled section just east of Maybe Creek in the Lupine syncline]

PRINCE CREEK FORMATION: Tuluvak Tongue:	*Thickness (feet)*	*Distance below top of composite section (feet)*
1. Conglomerate of white chert pebbles in light-gray fine-grained sandstone matrix. Grades into sandstone	25	0–25
2. Covered. Thickness approximate	248	25–273
3. Conglomerate, pebble-to-granule, and brown-weathering fine-grained sandstone	15	273–288
4. Covered. Coal float at top	35	288–323
5. Conglomerate, granule-to-pebble, in matrix of coarse sandstone and limonite. Locally grades into coarse-grained sandstone. Pinches out laterally (sandstone 13)	13	323–336
6. Tuff, rusty-weathering, carbonaceous, and gray tan- to orange-weathering medium-grained noncalcareous sandstone. Present in Lupine syncline; absent to north (sandstone 12)	12	336–348±
7. Covered	34	348±–382
8. Sandstone, tan-weathering, medium-grained, noncalcareous; and orange-weathering tuffaceous clay. Present in Lupine syncline; absent to north	13	382–395
9. Covered	43	395–438
10. Sandstone, gray-green to gray-yellow and red, fine- to medium-grained. In western part of area the unit is pebble conglomerate and coarse-grained sandstone containing plant fragments. Present in Lupine syncline; absent to north (sandstone 11)	20	438–458
11. Covered	16	458–474
12. Tuff, yellow-gray, and sandy bentonite. Found at only two localities, both in the north	9	474–483
13. Sandstone, gray-green to gray-brown, ferruginous to calcareous, locally conglomeratic. Present north of Lupine syncline only (sandstone 10)	15	483–498
14. Covered. Coal float near top	30	498–528

SECTION 10.—*Composite section of Prince Creek and Seabee Formations near the head of Maybe Creek*—Continued

	Thickness (feet)	Distance below top of composite section (feet)
PRINCE CREEK FORMATION—Continued		
Tuluvak Tongue—Continued		
15. Sandstone and conglomerate. In part, light gray and brown limonitic conglomerate and coarse to medium grained conglomeratic sandstone. In part, gray to gray-green locally red-weathering fine- to medium-grained calcareous sandstone; and gray, gray-green and red fine- to very fine-grained noncalcareous sandstone containing ironstone, clay galls, and plant fossils; locally conglomeratic (sandstone 9). Unit is locally absent north of Lupine syncline	30	528–558
16. Coal, locally 6 to 12 ft thick, overlies bentonite	11	558–569
17. Clay, gray	9	569–578
18. Covered	35	578–613
19. Sandstone. In north, gray to gray and red, fine-grained, calcareous sandstone; contains coaly plant fragments. In south, gray to gray-brown medium- to coarse-grained conglomeratic sandstone. Locally bears silicified wood. Absent south of Lupine syncline axis and east of Anak Creek (sandstone 8)	20	613–633
20. Covered. Coal and ironstone float	20	633–653
21. Sandstone, gray. In part, fine to medium grained, and in part, coarse grained, calcareous. Limited distribution. (Upper part of sandstone 7.)	15	653–668
22. Sandstone, gray-green to red, fine-grained to silty, calcareous; platy, but locally massive. Along Maybe Creek contains sparse chert pebbles. Thickness varies from 10 to 55 ft, but unit is persistent. (sandstone 7). USGS Mesozoic loc. 26530 (46ARy47) (fig. 101 land table 2) may be from this unit or from unit 23	30	668–698
Total (incomplete), Tuluvak Tongue of Prince Creek Formation	698	
SEABEE FORMATION:		
Ayiyak Member:		
23. Sandstone, gray, very fine grained, very calcareous, and calcareous siltstone containing black chert pebbles as much as 1 in. in diameter. Dark-gray fine-grained limestone having much cone-in-cone structure. (USGS Mesozoic loc. 26536 (49AKr4). 46ARy145x from near the base of this unit. 46ARy145a may be from this unit or from unit 22. See fig. 101 and table 2)	25	698–723

SECTION 10.—*Composite section of Prince Creek and Seabee Formations near the head of Maybe Creek*—Continued

	Thickness (feet)	Distance below top of composite section (feet)
SEABEE FORMATION—Continued		
Ayiyak Member—Continued		
24. Covered	17±	723–740±
25. Siltstone, gray	11	740±–751
26. Covered	7	751–758
27. Partly covered. Gray very fine grained noncalcareous and fossiliferous calcareous sandstone. Gray noncalcareous siltstone. Concretions of gray yellow-weathering very fine grained limestone having much cone-in-cone structure and containing few pebbles of chert and quartz. (USGS Mesozoic loc. 26537 (49ABe32), see fig. 101 and table 2)	35	758–793
Total (incomplete), Ayiyak Member of Seabee Formation	95	
Shale Wall Member:		
28. Shale, black, and ¼-in. beds of bentonite and siltstone. Concretions of dark-gray fine-grained limestone, as large as 2 ft in diameter	19	793–812
29. Shale and siltstone, gray, and fossiliferous concretions of gray yellow-weathering fine-grained limestone. One black chert pebble found in south. (USGS Mesozoic loc. 26559 (49AKr19), see fig. 101 and table 2; 49AKr3, 49AKr19mf, and 49ABe29, all barren)	44	812–856
30. Siltstone, gray, interbedded with thin yellow bentonite	35	856–891
31. Covered	30	891–921
32. Paper shale and gray noncalcareous siltstone and bentonite. Fossiliferous concretions of black fine-grained thin-bedded limestone, as much as 4 ft in diameter. At base is bed of bentonite 1½ ft thick. (USGS Mesozoic locs. 26562, 26561 (49ABe2, 24), 46ARy144, 49, see fig. 101 and table 2)	27	921–948
33. Covered	100	948–1,048
34. Shale, black, fissile; contains thin partings of bentonite and coal. Fossiliferous concretions of dark-gray to dark-brown limestone at top and bottom. (USGS Mesozoic locs. 20420, 26558, 26560 (46ARy131, 49AKr1, 49ABe1), 46ARy131c, see fig. 101 and table 2; 49AKr1mf, barren)	10	1,048–1,058
Total (incomplete), Shale Wall Member of Seabee Formation	265	
Total (incomplete), Seabee Formation	360	

SECTION 11.—*Schrader Bluff, Prince Creek, and Seabee Formations and Ninuluk Formation and Niakogon Tongue of Chandler Formation, undifferentiated, near Wolf Creek*

[See pl. 54. Section measured from head of Keith Creek at axis of Prince Creek syncline to Wolf Creek test well 2 on Wolf Creek anticline. Surface section of Seabee Formation computed from planetable elevations by Stefansson and Thurrell in 1947. Prince Creek and Schrader Bluff Formations computed from barometer elevations; total thickness of Prince Creek from planetable elevations by Ray and Fischer in 1946. Well logged by F. R. Collins in 1959]

	Thickness (feet)	*Distance below top of measured section (feet)*
SCHRADER BLUFF FORMATION:		
Barrow Trail Member:		
1. Shale, carbonaceous, silty; interbedded with coaly material, buff-colored tuff, and gray-green fine-grained sandstone	40	0–40
2. Covered	110±	40–150±
3. Sandstone, fine- to medium-grained, friable	10	150±–160
4. Shale, silty, and bentonite, lignite, and abundant plant fragments. Unit includes lowest conspicuous bedding traces in the Barrow Trail Member (46AFi85b, barren; 46AFi84d, barren; 46AFi84e, see fig. 108 and table 3)	100	160–260
5. Covered	50	260–310±
6. Shale, silty shale, sandstone and hard siltstone. (64AFi86b and d, barren)	20	310±–330
Total (incomplete), Barrow Trail Member of Schrader Bluff Formation	330	
Rogers Creek Member:		
7. Covered. Coal float near base	140	330–470
8. Siltstone, shaly, and yellow-red-weathering fine-grained crossbedded siltstone (46AFi83, see fig. 108 and table 3)	40	470–510
9. Covered	60±	510–570±
10. Conglomerate, granule to pebble, in matrix of light-gray friable sandstone	30	570±–600
11. Covered. (47ASt58, see fig. 108 and table 3)	240±	600–840±
12. Sandstone, light-tan-weathering, fine-grained, thin-bedded; interbedded with crossbedded siltstone	10	840±–850
13. Covered	70	850–920
14. Irregularly bedded siltstone	10	920–930
15. Covered	60±	930–990±
16. Sandstone, greenish gray, fine-grained, crossbedded	10	990±–1,000
17. Covered	50	1,000–1,050
Total, Rogers Creek Member of Schrader Bluff Formation	720	
PRINCE CREEK FORMATION:		
Tuluvak Tongue:		
18. Conglomeratic sandstone	20±	1,050–1,070±
19. Covered. Coal float at top	60±	1,070±–1,130±
20. Sandstone, light-tan-weathering, fine-grained to very fine grained; plant fragments	10±	1,130±–1,140
21. Covered	60±	1,140–1,200±
22. Sandstone, medium-grained, friable; contains lenses of granule-pebble conglomerate. Pebbles are mostly chert and quartzite; granules are quartz	20	1,200±–1,220
23. Covered	140±	1,220–1,360±
24. Bentonitic clay and 1-ft bed of bentonite (46AFi77b, barren)	5±	1,360±–1,365±
25. Covered	145±	1,365±–1,510
26. Conglomerate; rounded granules and pebbles, as much as 2-in. in diameter, of black chert and vein quartz. Plant fossils	40	1,510–1,550
27. Covered. Float indicates coal and bentonitic shale	30	1,550–1,580
28. Sandstone, hematitic, medium-grained, shaly, micaceous	30	1,580–1,610
Total, Tuluvak Tongue of Prince Creek Formation	560	
SEABEE FORMATION:		
29. Covered	90±	1,610–1,700±
30. Shale, light-gray, nonbentonitic. Weathers to mud. (46AFi79 a and c, barren)	10	1,700±–1,710
31. Covered	280	1,710–1,990
32. Siltstone and 6-in. bed of clay ironstone (46AFi81c, see fig. 101 and table 2)	10±	1,990±–2,000
33. Covered	60	2,000–2,060
34. Siltstone, dark, shaly; shale and 2-ft of bentonite. (46AFi80, see fig. 101 and table 2)	10	2,060–2,070
35. Covered	112	2,070–2,182
36. Sandstone, fine-grained, calcareous; contains silicified wood. Locally is pebble-granule congolmerate of black chert and vein quartz. Forms conspicuous bedding trace near axis of Wolf Creek anticline. Shown as sandstone A on geologic map, pl. 52	28	2,182–2,210
37. Covered. Base of interval is ground level at depth 6 ft in Wolf Creek test well 2	100	2,210–2,310
38. Covered. Soil and alluvium in top of Wolf Creek test well 2	39	2,310–2,349
39. Clay shale, gray; at depth of 45–75 ft in Wolf Creek test well 2	30	2,349–2,379

SECTION 11.—*Schrader Bluff, Prince Creek, and Seabee Formations and Ninuluk Formation and Niakogon Tongue of Chandler Formation, undifferentiated, near Wolf Creek*—Continued

SEABEE FORMATION—Continued	*Thickness (feet)*	*Distance below top of measured section (feet)*
40. Bentonite, light-yellowish-gray	5±	2,379–2,384
41. Siltstone and clay shale, olive-gray and medium-gray At base, light-olive-gray very fine grained, silty limonitic sandstone. To depth of 130 ft in well	50	2,384–2,434
Total, Seabee Formation	824	
NINULUK FORMATION AND NIAKOGON TONGUE OF CHANDLER FORMATION UNDIFFERENTIATED:		
42. Shale and siltstone, medium-light-gray to black; coal	40	2,434–2,474
43. Bentonite, light-gray; coal and shale	20	2,474–2,494
44. Sandstone, medium-light-gray, very fine grained, calcareous	10	2,494–2,504
45. Shale and siltstone, medium-light- to dark-gray	60	2,504–2,564
46. Sandstone, very fine grained, silty, calcareous	20	2,564–2,584
47. Shale, siltstone, and thin bed of coal	30	2,584–2,614
48. Coal, shiny black, blocky to subconchoidal fracture; interbedded with bentonite and shale	10	2,614–2,624
49. Sandstone, light-gray, very fine to fine-grained	40	2,624–2,664
50. Siltstone and shale, medium-gray	50	2,664–2,714
51. Sandstone, very fine to fine-grained	15	2,714–2,729
52. No sample	5	2,729–2,734
53. Shale and siltstone	70	2,734–2,804
54. Sandstone, very fine to fine-grained	25	2,804–2,829
55. Shale, medium-gray	10	2,829–2,839
56. Limestone, medium-gray, argillaceous; with siltstone, shale, and coal	10	2,839–2,849
57. Shale	20	2,849–2,869
58. Sandstone, very fine to fine-grained, carbonaceous	20	2,869–2,889
59. Shale and siltstone	40	2,889–2,929
60. Sandstone, light-gray, fine-grained	10	2,929–2,939
61. Siltstone and shale, medium- to medium-dark-gray to depth of 650 ft in well	15	2,939–2,954
Total, Ninuluk Formation and Niakogon Tongue of Chandler Formation undifferentiated	520	

NOTE—Remainder of well log omitted to total depth of 1,618 ft.

SECTION 12.—*Schrader Bluff and Prince Creek Formations along Tommy Creek*

[See pl. 54. Section computed by Detterman in 1947 from barometric elevations along the east bank of Tommy Creek between points about 6½ and 7½ miles above its mouth. Additional information from a planetable traverse by Kreidler in 1945 through the equivalent section on the hill just east of Tommy Creek]

SCHRADER BLUFF FORMATION: Barrow Trail Member:	*Thickness (feet)*	*Distance below top of measured section (feet)*
1. Sandstone, light-gray, medium- to coarse-grained, massive	10±	0–10±
2. Covered. Hard coaly shale at base	70±	10±–80±
3. Sandstone, light-gray, medium-grained	10	80±–90
4. Covered	25±	90–115±
5. Tuff	10	115±–125
6. Sandstone, light-gray, medium-grained, tuffaceous	10	125–135
7. Covered. Float is shale and silty shale, coal, and bentonite. At base of unit is exposed bed of bentonite (47ADt302, barren)	102±	135–237±
8. Tuff	3	237±–240
9. Shale, black, papery, bentonitic; has yellow efflorescence. Two coal zones, one 15 in. thick. (47ADt303 barren)	20	240–260
10. Claystone and shale. 1-ft bed of bentonite at middle of unit. Locally near base is light-gray coarse-grained conglomeratic sandstone. This is the lowest unit in the Barrow Trail Member to make conspicuous bedding traces in this vicinity. (47ADt305, see fig. 108 and table 3)	20	260–280
11. Shale and coal, interbedded. At middle of unit an 8-in. bed of bentonite and a 4-in. bed of tuff lie below a 2½-ft bed of subbituminous coal and above a 16-in. bed of lignite. (47ADt306, barren)	20	280–300
12. Covered	10	300–310
Total (incomplete), Barrow Trail Member of Schrader Bluff Formation	310	
Rogers Creek Member:		
13. Covered	185	310–495
14. Partly covered. Shale, bentonite, and some coal in upper half. (47ADt308, see fig. 108 and table 3)	150	495–645
15. Sandstone, dark-gray, fine- to medium-grained, thin-bedded, crossbedded	3	645–648
16. Conglomerate, granule-to-cobble, poorly sorted, crossbedded; contains wood fragments	7	648–655
17. Lignite	2	655–657
18. Shale and bentonite; 8-in. coal bed at base	8	657–665

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SECTION 12.—*Schrader Bluff and Prince Creek Formations along Tommy Creek*—Continued

SCHRADER BLUFF FORMATION—Continued Rogers Creek Member—Continued	*Thickness (feet)*	*Distance below top of measured section (feet)*
19. Shale and bentonite; 2-ft coal bed at base	4	665–669
20. Shale and bentonite	16	669–685
21. Covered	25±	685–710±
22. Sandstone	5	710±–715
23. Covered	120±	715–835±
24. Shale, red, 6-in. thick; overlain by by sandstone and underlain by bentonite	5±	835±–840±
25. Covered	45±	840±–885±
26. Sandstone, light-gray, medium-grained; contains interbedded coal 3- to 12-in. thick	15	885±–900
27. Covered	125	900–1, 025
28. Shale and bentonite	30	1, 025–1, 045
29. Covered	86	1, 045–1, 131
30. Bentonite, 2½ ft thick; lies on dark yellow-brown-weathering fine-grained limestone, 1½ ft thick. Base of limestone taken as approximate base of Rogers Creek Member and of Schrader Bluff Formation	4	1, 131–1, 135
Total, Rogers Creek Member of Schrader Bluff Formation	835	
PRINCE CREEK FORMATION:		
Tuluvak Tongue:		
31. Partly covered. Shale and bentonite containing thin unconsolidated sandy interbeds. (47ADt300, barren)	40	1, 135–1, 175
32. Covered. Shale and bentonite	50	1, 175–1, 225
33. Shale containing bentonite beds as much as 4-in. thick. (47ADt298, see fig. 108 and table 3)	20	1, 225–1, 245
34. Bentonite, greenish yellow	5	1, 245–1, 250
35. Sandstone, light-yellow-red, fine- to medium-grained, agrillaceous, thin-bedded; contains wood fragments. Upper 1 ft includes granule conglomerate composed mostly of black chert	3	1, 250–1, 253
36. Shale, slightly ferruginous, hackly fracture (47ADt294, see fig. 108 and table 3)	15	1, 253–1, 268
Total (incomplete), Tuluvak Tongue of Prince Creek Formation	133	

SECTION 13.—*Schrader Bluff Formation along lower Prince Creek*

[See pl. 54. Section begins about 2 miles up Tommy Creek and extends downstream to a point about 2 miles above mouth of Prince Creek. The top 150 feet of section was measured on the lower 3½ miles of a tributary that enters Prince Creek about 4 miles above its mouth. Section computed trigonometrically by Detterman in 1947. Section, as described here, has been recomputed, is 150 feet thinner than shown on the original computations, and includes additional information obtained by Kreidler and Brown in 1945]

SCHRADER BLUFF FORMATION: Sentinel Hill Member:	*Thickness (feet)*	*Distance below top of measured section (feet)*
1. Shale, silty, yellow-brown weathering, sandy; some crossbedding. Contains plant fragments. (47ADt341, see fig. 109 and table 4)	39	0–39
2. Partly covered. Shale. (47ADt343, 344, 345, see fig. 109 and table 4)	31	39–70
3. Sandstone, dark-gray, very fine grained, platy; from 9 in. to 2 ft thick. Kreidler noted pebbles in this unit	2	70–72
4. Shale and some siltstone and ironstone. (47ADt347, 348, see fig. 109 and table 4)	58	72–130
5. Bentonite, 6 in. thick; overlies massive fossiliferous siltstone. (47ADt363, see fig. 109 and table 4)	8	130–138
6. Shale, in part silty. (47ADt-364, 365, see fig. 109 and table 4)	60	138–198
7. Siltstone and silty shale; contains sparse ironstone concretions. (47ADt366, 367, USGS Mesozoic loc. 19644 (Kreidler) see fig. 109 and table 4)	34	198–232
8. Silty shale and siltstone. (47ADt361 barren; 47ADt360, 359, 358, see fig. 109 and table 4)	76	232–308
Total (incomplete), Sentinel Hill Member of Schrader Bluff Formation	308	
Barrow Trail Member:		
9. Sandstone. In part, green to yellow-red, very fine to fine-grained and crossbedded, and in part, medium-gray and medium-grained. Shell fragments. (USGS Mesozoic		

SECTION 13.—*Schrader Bluff Formation along lower Prince Creek*—Continued

SCHRADER BLUFF FORMATION—Continued Barrow Trail Member—Continued	Thickness (feet)	Distance below top of measured section (feet)
loc. 19643 (Kreidler), see fig. 108 and table 3)	15	308–323
10. Silty shale and siltstone. (USGS Mesozoic loc. 26507 (47ADt354) from float, 47ADt349, see fig. 108 and table 3)	14	323–337
11. Sandstone, dark-yellow-red, very fine grained, crossbedded	5	337–342
12. Shale, in part silty, and siltstone. (47ADt351, see fig. 108 and table 3)	14	342–356
13. Siltstone, dark-yellow-red, crossbedded, sandy	5	356–361
14. Shale, silty. (47ADt353, barren)	29	361–390
15. Covered	100	390–490
16. Shale, bentonitic. Coal float. (47ADt337, 338, 339, see fig. 108 and table 3)	80	490–570
17. Covered	180	570–750
18. Shale, dark, fissile, and beds of bentonite. Middle part covered. (47ADt332, 333, 334, see fig. 108 and table 3)	115±	750–865±
19. Shale. (47ADt331, barren). At top and bottom are beds of sandstone 4 ft or more thick. Upper sandstone is medium green to medium gray, fine- to very fine-grained, crossbedded, massive and fossiliferous (USGS Mesozoic loc. 26506 (47ADt336), see fig. 108 and table 3). Lower sandstone is dark green, fine grained	55	865±–920
20. Covered	55	920–975
21. Sandstone, dark-green, fine-grained to very fine-grained, crossbedded, fossiliferous (USGS Mesozoic loc. 26505 (47ADt330) and 19642 (Kreidler) see fig. 108 and table 3)	12	975–987
22. Tuff, greenish to gray, thin-bedded, crossbedded, silicified; interbedded with black shale. (47ADt328, barren.) Coal at top	15	987–1,002
23. Sandstone, dark- to medium-gray, fine-grained to very fine-grained, thin-bedded; some crossbedded. Interbedded with coal and shale	36	1,002–1,038
24. Shale and coal. Coal beds locally as thick as 3½ ft. (47ADt323, barren.)	12±	1,038–1,050±
25. Tuff, silicified; in thin uneven beds	10	1,050±–1,060
26. Sandstone, light-gray, medium- to coarse-grained, slightly crossbedded. Basal 1 ft has a few chert cobbles and shale fragments	8	1,060–1,068
27. Mostly covered. Shale, dark-gray to black; some ironstone in upper 3 ft. Base of Barrow Trail Member arbitrarily placed at bottom of this interval	32	1,068–1,100
Total, Barrow Trail Member of Schrader Bluff Formation	792	
Rogers Creek Member:		
28. Covered	110	1,100–1,210
29. Sandstone, yellow-red, fine- to medium-grained, thin-bedded	6	1,210–1,216
30. Shell fragments, fine, waterworn, in bentonitic ground mass	3	1,216–1,219
31. Sandstone, medium-red-brown, very fine to fine-grained, crossbedded	5	1,219–1,224
32. Covered	106	1,224–1,330
33. Shale and sandstone. Partly covered	40	1,330–1,370
34. Covered	155	1,370–1,525
35. Sandstone, bentonitic, light-yellow-red, medium- to coarse-grained, friable; contains few plant remains. Kreidler reported pebbles. Bentonite at base	36	1,525–1,561
36. Covered	54	1,561–1,615
37. Shale, interbedded with coal and bentonite. Coal beds total 15 ft in thickness. Bentonite beds as thick as 8 in. (47ADt317, barren; 47ADt318, see fig. 108 and table 3)	80	1,615–1,695
38. Covered. Probably shale	125	1,695–1,820
39. Shale, dark, slightly sandy; contains two layers of fossiliferous limestone concretions. (47ADt316, see fig. 108 and table 3)	20	1,820–1,840
40. Shale containing one layer of fossiliferous limestone concretions. Beds of bentonite as thick as 20 in. (USGS Mesozoic locs. 26528 (47-ADt314), 19641 (Kreidler);		

SECTION 13.—*Schrader Bluff Formation along lower Prince Creek*—Continued

	Thickness (feet)	Distance below top of measured section (feet)
SCHRADER BLUFF FORMATION—Continued		
Rogers Creek Member—Continued		
47ADt315, 312; Kreidler collection 191 is probably from this unit; see fig. 108 and table 3)	20	1,840–1,860
41. Shale, silty, sandy, crossbedded	12	1,860–1,872
Total (incomplete), Rogers Creek Member of Schrader Bluff Formation	772	

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*

[See pl. 54. Composite section measured on the west bank of the Colville River between Umiat and Ocean Point by Stefansson and Thurrell in 1947, Stefansson and Whittington in 1946, and Coats and Gryc in 1944. The descriptions of individual stations in the upper 2,100 ft of section are from Stefansson and Thurrell (written commun., 1948). Their stations are numbered on index map, pl. 54. The remainder of the section is from Stefansson and Whittington (1946), and Coats and Gryc (written commun., 1944)]

	Thickness (feet)	Distance below top of composite section (feet)
PRINCE CREEK FORMATION:		
Kogosukruk Tongue, upper part:		
Station 83		
1. Clay and silt, interbedded; bentonitic near top	30	0–30
2. Tuff (thickness varies, maximum 4 ft)	1	30–31
3. Silt and clay, interbedded. Includes three thin layers of bony coal and carbonaceous shale. Also some thin tuff layers. Unit slightly bentonitic	19	31–50
4. Silt and clay interbeds	20	50–70
Station 232		
5. Clay and silt	10	70–80
6. Bentonite	.5	80–80.5
7. Bone coal	.5	80.5–81
8. Sandy silt	3	81–84
9. Bone coal	.5	84–84.5
10. Silt	3	84.5–87.5
11. Bone coal	.5	87.5–88
12. Silt and clay	25	88–113
13. Sandstone. Basal part is dark green on wet surface. Central part is light green, very fine grained, moderately porous. Top is laminated and has interbeds of carbonaceous material. The 20-ft unit contains a few crossbeds. It has some silty layers	20	113–133
14. Bone coal and carbonaceous silt, bentonitic	20	133–153
15. Bone coal	1	153–154
16. Bentonite, yellow	1	154–155
17. Bentonitic silt	1	155–156
18. Bentonite, gray, silty	3	156–159
19. Bone coal and clay. Three distinct bone coal layers 1 ft thick The clay is bentonitic	8	159–167

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

	Thickness (feet)	Distance below top of composite section (feet)
PRINCE CREEK FORMATION—Continued		
Kogosukruk Tongue, upper part—Continued		
Station 232—Continued		
20. Poorly exposed. Thickness approximate. Primarily silt and clay	60	167–227
[Units 21 and 22 were originally considered to duplicate the basal part of station 232 but because of additional information, it is now believed to intervene between the sections at stations 232 and 231]		
21. Silt	70	227–297
22. Sandstone, dark-gray, fine-grained, hard, platy, carbonaceous, possibly tuffaceous	5	297–302
Station 231		
23. Sandstone, poorly consolidated; has minor layers of silt. At the base is thin conglomerate containing cobbles of chert and quartz as large as 3 in. The sandstone is medium to fine grained, moderately porous, light green gray. (This sandstone becomes silty and crossbedded to the north. It is believed to be beneath unit 22 rather than immediately below unit 20. USGS Mesozoic loc. 26492 (47ASt47) (fig. 109 and table 4) is an approximately equivalent sandstone on the Kikiakrorak River three-quarters of a mile west of the Colville.)	25	302–327
24. Silt and clay, interbedded	30	327–357
25. Sandstone, as in unit 23. Contains several conglomerate layers that have silty ironstone pebbles and white quartz	10	357–367
26. Coal and bone coal	4	367–371
27. Silt, brown, sandy, bentonitic	2	371–373
Station 79		
28. Silt and sandstone, interbedded	5	373–378
29. Shale, carbonaceous	.5	378–378.5
30. Clay, gray	15	378.5–393.5
31. Sandstone, medium-gray, medium-grained, fairly well consolidated, slabby, crossbedded	5	393.5–398.5
32. Coal, bony, and carbonaceous shale	2	398.5–400.5

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

PRINCE CREEK FORMATION—Continued

Kogosukruk Tongue, upper part—Con.	*Thickness (feet)*	*Distance below top of composite section (feet)*
Station 227		
33. Clay and silt, sandy	30	400. 5–430. 5
34. Coal, low-grade	2	430. 5–432. 5
35. Clay and silt, bentonitic	40	432. 5–472. 5
36. Sandstone, bentonitic, fine- to medium-grained, light- to medium-gray, poorly cemented, very friable. A wet sample is unconsolidated. Contains laminae of carbonaceous material	15	472. 5–487. 5
[Section originally interpreted as continuous from here through station 71, but the authors now believe that the upper part of station 71 duplicates most of units 24 through 36. To the south near Sentinel Hill core test 1, the underlying 20.5 ft of interbedded coal and clay (units 36a–36e) pinches out, and the sandstone of unit 36 lies upon a thick sandstone believed by the authors to be the 50-ft sandstone (unit 37) of station 71. The thicknesses and depths for those parts believed to be repetitious are set in italic.]		
36a. Coal	*. 5*	*487. 5–488*
36b. Clay	*2*	*488–490*
36c. Bone coal	*1*	*490–491*
36d. Clay and silt	*15*	*491–506*
36e. Coal, low-grade, thin layers	*2*	*506–508*
37(?). Silt and clay; contain thin layers of carbonaceous material. A 5-ft zone in the middle is laminated sandstone and silty shale	*40*	*508–548*
Station 71 (generalized section)		
24(?)–35(?). Interbedded clay, shale, silt, and ironstone	*150*	*314. 5–464. 5*
Coal, bony	*1*	*464. 5–465. 5*
36(?). Sandstone, fine- to medium-grained, medium-gray, silty	*20*	*465. 5–485. 5*
36(?)a. Shale, carbonaceous, and bony coal	*2*	*485. 5–487. 5*
37. Sandstone, fine-grained, gray, silty; contains ironstone lenses	50	487. 5–537. 5
38. Shale, carbonaceous; contains interbeds of silt	5	537. 5–542. 5
39. Sandstone, silty, bentonitic	25	542. 5–567. 5
40. Shale, carbonaceous; contains clay interbeds and some bentonite	15	567. 5–582. 5
41. Clay, silt, and some sandy silt, interbedded	50	582. 5–632. 5
Station 70		
42. Clay and silt interbeds, bentonitic	15	632. 5–647. 5
43. Clay and interbeds of tuff and bentonite	10	647. 5–657. 5
44. Coal, bony; contains laminae of carbonaceous shale	6	657. 5–663. 5

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

PRINCE CREEK FORMATION—Continued

Kogosukruk Tongue, upper part—Continued	*Thickness (feet)*	*Distance below top of composite section (feet)*
Station 70—Continued		
45. Silt, and sandy clay. (49AGr31, barren)	30	663. 5–693. 5
46. Ironstone	2. 5	693. 5–696
47. Coal, bony	1. 5	696–697. 5
48. Silt and clay interbedded. (49AGr30, barren)	16	697. 5–713. 5
49. Coal, bony	4	713. 5–717. 5
50. Silt. (49AGr29, barren)	4	717. 5–721. 5
51. Coal, bony	2	721. 5–723. 5
52. Covered. Traces of interbedded silt and clay and some ironstone. (49AGr28, barren)	150	723. 5–873. 5
53. Clay and silt. Strong stratification	5	873. 5–878. 5
54. Ironstone	1	878. 5–879. 5
55. Coal, bony; interbedded with carbonaceous clay in 6-in. to 1-ft layers	6	879. 5–885. 5
56. Sandstone, fine-grained; has interbeds of silt. Ironstone lenses as thick as 3 ft	30	885. 5–915. 5
57. Sand, light-gray, very bentonitic; has high silt content and considerable amounts of ironstone. (49AGr27, barren)	45	915. 5–960. 5
58. Clay, interbedded with bony coal; some bentonite. One thin bed of ironstone 2 ft from base	18	960. 5–978. 5
59. Clay and sandy silt; contains thin interbeds of bony coal about 20 ft from base. Strong crossbedding and northward facies change from sandy to more clayey silt. (49AGr25 and 26, barren)	50	978. 5–1, 028. 5
60. Siltstone, sandy (or silty sandstone), thinly laminated and minutely crossbedded. (49AGr24, barren)	20	1, 028. 5–1, 048. 5
61. Pyroclastic section; interbeds of tuff, carbonaceous tuff, bentonite (hard), and a few thin layers of bony coal, clay, and silt	15	1, 048. 5–1, 063. 5
62. Claystone (49AGr23, barren)	2	1, 063. 5–1, 065. 5
63. Coal, bony	1	1, 065. 5–1, 066. 5
64. Clay and sandy siltstone; some ironstone. Unit is greatly iron stained and occurs in even beds about 2-in. thick. (49AGr22, barren)	12	1, 066. 5–1, 078. 5
65. Shale, carbonaceous; some bony coal. Lensing conspicuous	6	1, 078. 5–1, 084. 5

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

	Thickness (feet)	Distance below top of composite section (feet)
PRINCE CREEK FORMATION—Continued		
Kogosukruk Tongue, upper part—Continued		
Station 70—Continued		
66. Largely covered. Basal 30 ft probably a series of carbonaceous shale interbedded with clays. May be same to top (49AGr20 at base, see fig. 109 and table 4)	75	1,084.5–1,159.5
Total (incomplete and italic numbers not included), upper part of Kogosukruk Tongue of Prince Creek Formation	1,159.5	
SCHRADER BLUFF FORMATION:		
Sentinel Hill Member, upper part: [1]		
Station 70—Continued		
67. Sand, fine-grained very loosely consolidated, fossiliferous. Fossils in top 1 ft, also in some ironstone and iron-stained sandstone blocks that apparently overlie this section. (USGS Mesozoic loc. 26494 (47ASt42), see fig. 109 and table 4)	10	1,159.5–1,169.5
68. Covered	60	1,169.5–1,229.5
69. Coal, bony	1	1,229.5–1,230.5
70. Clay	10	1,230.5–1,240.5
71. Coal, bony	2	1,240.5–1,242.5
72. Covered. Some clay shale in section. (47ASt41, abundant spores, no Foraminifera)	30	1,242.5–1,272.5
73. Sandstone, unconsolidated, very bentonitic	5	1,272.5–1,277.5
74. Covered by bentonite slides	25	1,277.5–1,302.5
Station 69		
75. Sandstone, fine-grained light-gray, crossbedded, slabby, cliff-forming. Lenses and nodules of ironstone. Weathers red brown	8	1,302.5–1,310.5
76. Claystone, dark-colored. Weathers medium gray. Soft and very crumbly. Indications of shell fragments, but rock too crumbly to permit collecting of fossils. (47ASt39, 49AGr15, 16, 18, see fig. 109 and table 4)	60	1,310.5–1,370.5
77. Sandstone, medium-grained, gray, slabby; contains scattered pebbles of black chert. Shell fragments present	3	1,370.5–1,373.5

[1] This marine tongue is underlain and overlain by rocks of the Kogosukruk Tongue and is included with the Kogosukruk Tongue on the geologic map, pl. 52.

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

	Thickness (feet)	Distance below top of composite section (feet)
SCHRADER BLUFF FORMATION—Continued		
Sentinel Hill Member, upper part—Continued		
Station 69—Continued		
78. Covered, probably clay similar to unit 79	20	1,373.5–1,393.5
79. Clay shale, brownish	15	1,393.5–1,408.5
80. Clay shale, gray, bluff-forming	6	1,408.5–1,414.5
81. Clay shale, brown, finely laminated. Some thin interbeds of bentonite; carbonaceous streaks. (47ASt38, see fig. 109 and table 4; 49AGr19, barren)	20	1,414.5–1,434.5
82. Covered by bentonite. Appears to be very bentonitic clay shale and clay. Some ironstone lenses are present. One fairly resistant gray shale unit, 3 ft thick, occurs near top. Interbeds of bentonite	20	1,434.5–1,454.5
83. Bentonite, bright-yellow	1	1,454.5–1,455.5
84. Clay shale, thinly laminated, dark-brown to black	20	1,455.5–1,475.5
Total, upper part of Sentinel Hill Member of Schrader Bluff Formation	316	
PRINCE CREEK FORMATION		
Kogosukruk Tongue, lower part:		
Station 69—Continued		
85. Shale, silty; contains one layer of bony coal, 0.4 ft thick, near base. A few thin ironstone lenses and thin interbeds of bentonite	4	1,475.5–1,479.5
86. Shale, clayey, very thinly laminated; some carbonaceous layers	36	1,479.5–1,515.5
87. Clay, dark-gray, bentonitic	12	1,515.5–1,527.5
88. Coal, bony	1	1,527.5–1,528.5
89. Bentonite, yellow	1.5	1,528.5–1,530
90. Coal, bony; contains thin clay and bentonite interbeds	5	1,530–1,535
91. Bentonite, brown and yellow	.5	1,535–1,535.5
92. Clay, bentonitic; contains some shaly and silty lenses and bentonite interbeds	15	1,535.5–1,550.5
93. Shale, carbonaceous. One 0.2-ft layer of bony coal in middle, topped by 0.1 ft of carbonaceous shale overlain by 0.1-ft white ash layer	5	1,550.5–1,555.5
94. Partly covered. Clay, bentonitic, and some ironstone lenses. Appears more shaly and silty toward top	25	1,555.5–1,580.5

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

PRINCE CREEK FORMATION—Continued Kogosukruk Tongue, lower part—Continued *Station 69*—Continued	*Thickness (feet)*	*Distance below top of composite section (feet)*
95. Shale, carbonaceous; some clay and bentonite interbeds	6	1, 580. 5–1, 586. 5
96. Coal, bony, and thin interbeds of bentonite	4	1, 586. 5–1, 590. 5
97. Clay, bentonitic; some sandy lenses	16	1, 590. 5–1, 606. 5
Station 68		
98. Sandstone, friable, fine-grained, bentonitic, medium-gray	25	1, 606. 5–1, 631. 5
99. Clay and silt shale, bentonitic; contains some coal. Top 3 ft is largely bony coal or highly carbonaceous shale	15	1, 631. 5–1, 646. 5
100. Sandstone, medium-grained, medium gray, friable; contains considerable amounts of ironstone nodules and lenses	20	1, 646. 5–1, 666. 5
101. Clay and silty shale; some bentonite layers. One layer of pure yellow swelling bentonite	15	1, 666. 5–1, 681. 5
102. Sandstone, cliff-forming, light- to medium-gray, medium-grained, fairly well indurated; contains scattered pebbles of chert and quartz. Massive, but some thick crossbedding present, especially where laminae of carbonaceous material occur. A few lenses of ironstone, as thick as three-fourths of an inch	8	1, 681. 5–1, 689. 5
103. Partly covered. Probably silt or clay shale. May contain lenses or beds of bentonite and bony coal	25	1, 689. 5–1, 714. 5
104. Sandstone, conglomeratic, light- to medium-gray, medium-grained, thickly crossbedded. Contains conglomeratic layers of pebbles, cobbles, and boulders of chert, quartz, and some tuff. These layers lens and split; maximum thickness 3 ft. Some carbonaceous plant and tree fragments are present (Key horizon, see station 67)	15	1, 714. 5–1, 729. 5

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

PRINCE CREEK FORMATION—Continued Kogosukruk Tongue, lower part—Continued *Station 67* [Upper part of this section repeats most of preceding section. The thicknesses and depths of the repetitious parts are set in italic]	*Thickness (feet)*	*Distance below top of composite section (feet)*
98. Sandstone, very bentonitic, largely covered. Bottom of this sandstone same as bottom of 25-ft sandstone in top of section at station 68	*10*	*1, 621. 5–1, 631. 5*
99. Covered, probably bentonitic clay	*10*	*1, 631. 5–1, 641. 5*
100. Sandstone, light- to medium-gray to yellowish-green, fine- to medium-grained, friable, crossbedded, massive. Abundant ironstone nodules as large as 8 in. in diameter and two ironstone lenses 2 to 3 in. thick	*20*	*1, 641. 5–1, 661. 5*
101. Partly covered. Clay, bony coal, and bentonite. Upper 10 ft appears to be mostly bony coal and thin interbeds of bentonite	*15*	*1, 661. 5–1, 676. 5*
102. Sandstone, light-gray, medium-grained, bentonitic	*10*	*1, 676. 5–1, 686. 5*
103. Partly covered. Dark-colored material, probably somewhat bentonitic clay and shale	*28*	*1, 686. 5–1, 714. 5*
104. Sandstone, conglomeratic, cliff-forming. Sandstone is coarse grained, somewhat friable, light to medium-gray and has thick crossbedding. Conglomeratic layers as thick as 2 ft contain pebbles, cobbles, and boulders of greenish- and bluish-black chert and some quartz. Pebbles 1 to 3 in. most abundant. Conglomerate layers lens and split. Carbonaceous plants and tree fragments present. (Key horizon used in delineating the Gubik anticline. See also section at station 68 where better exposed)	*15*	*1, 714. 5–1, 729. 5*
105. Covered, probably shale or clay	5	1, 729. 5–1, 734. 5
106. Sandstone, hard, massive, fine-grained, light- to medium-gray; contains a few pebbles of black chert near top	4	1, 734. 5–1, 738. 5

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

PRINCE CREEK FORMATION—Continued Kogosukruk Tongue, lower part—Continued	Thickness (feet)	Distance below top of composite section (feet)
Station 66		
[Top of section]		
107. Sandstone, fine-grained, friable, bentonitic, yellow-weathering	7	1,738.5–1,745.5
108. Conglomerate	.5	1,745.5–1,746
109. Coal. Coal is bony. A lens of carbonaceous fine-grained sandstone, 3.5 to 6.0 ft thick, lies in middle of zone. A few thin yellow-brown beds of bentonite in the coal (49AGr12, barren)	13	1,746–1,759
110. Largely covered. Medium-gray fine-grained carbonaceous sandstone present	25	1,759–1,784
111. Coal and clay interbeds, in 0.2- to 0.5-ft layers	2	1,784–1,786
112. Covered	5	1,786–1,791
113. Clay, medium-gray, bentonitic	2	1,791–1,793
114. Sandstone, fine-grained, light-gray, crossbedded (49AGr13, barren)	18	1,793–1,811
Total (italic not included), lower part of Kogosukruk Tongue of Prince Creek Formation	335.5	
SCHRADER BLUFF FORMATION: Sentinel Hill Member, lower part:		
Station 66—Continued		
115. Tuff, stratified, bluff-forming. Bentonite at base. (47ASt33, see fig. 109 and table 4)	25	1,811–1,836
116. Clay, shaly, somewhat bentonitic (49AGr14, location approximate; see fig. 109 and table 4	20	1,836–1,856
117. Clay, very silty, some shaly; minor interbeds of thin bentonite and several ironstone lenses. Cliff forming, weathers red brown (49AGr10 and 11, barren)	80	1,856–1,936
118. Clay; similar to unit 117 but less silty and more shaly. Interbeds of bentonite and lenses of ironstone (47ASt32, see fig. 109B and table 4; 49AGr9, location approximate, barren)	80	1,936–2,016
Station 65		
119. Clay, sandy, carbonaceous, tuffaceous. Some tuff. Weathers out in "needles." Weathered surfaces noticeably medium yellow to yellow red	30	2,016–2,046

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

Schrader Bluff Formation—Continued Sentinel Hill Member, lower part—Continued	Thickness (feet)	Distance below top of composite section (feet)
Station 65—Continued		
120. Bentonite, light-yellow (49AGr8, see fig. 109 and table 4)	1	2,046–2,047
121. Clay, medium- to dark-gray (49AGr7, see fig. 109 and table 4)	15	2,047–2,062
122. Clay, bentonitic; white-weathering	.2	2,062–2,062.2
123. Clay, dark-gray (47ASt30, 49AGr6, see fig. 109 and table 4)	10	2,062.2–2,072.2
124. Bentonite, brown	.1	2,072.2–2,072.3
125. Clay, dark-gray	9	2,072.3–2,081.3
126. Bentonite, tan	.1	2,081.3–2,081.4
127. Clay shale, dark gray, very thinly laminated	7	2,081.4–2,088.4
128. Bentonite, yellow	.1	2,088.4–2,088.5
129. Clay shale, dark-gray (47ASt29, see fig. 109 and table 4)	8	2,088.5–2,096.5
130. Bentonite, brown	.2	2,096.5–2,096.7
131. Clay, dark-gray (47ASt28, 49AGr5, see fig. 109 and table 4)	8	2,096.7–2,104.7
132. Clay; interbedded with several 2- to 3-in. beds of bentonite. Large ironstone concretions present	6	2,104.7–2,110.7
133. Covered, probably similar lithology to unit 132	12	2,110.7–2,122.7
134. Bentonite, yellow-brown	1.3	2,122.7–2,124.0
135. Clay, light-gray, bentonitic	.2	2,124.0–2,124.2
136. Bentonite, light-gray (at base) to yellow-green. Grades into clay above	1.5	2,124.2–2,125.7
137. Pyroclastic section; interbeds of tuff, volcanic ash, bentonite, and clay, 1 in. to 1 ft. thick (49AGr4, see fig. 109 and table 4)	30	2,125.7–2,155.7
138. Tuff, friable	2.5	2,155.7–2,158.2
139. Clay; shaly at base (47ASt25, 49AGr2, 3, see fig. 109 and table 4)	11	2,158.2–2,169.2
140. Silt and shale, carbonaceous, dark-gray (49AGr1, see fig. 109 and table 4)	7	2,169.2–2,176.2
[The descriptions of the underlying 23 ft of Sentinel Hill Member, as well as of the Barrow Trail Member, are compiled from sections measured immediately upstream from station 65 by Stefansson and Whittington in 1946 and Coats and Gryc in 1944]		
141. Shale, silty, black; contains carbonaceous streaks	10.3	2,176.2–2,186.5
142. Bentonite	.2	2,186.5–2,186.7
143. Shale, silty, black	1.5	2,186.7–2,188.2
144. Tuffaceous material, yellowish	.8	2,188.2–2,189
145. Shale, silty, black	2	2,189–2,191

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

SCHRADER BLUFF FORMATION—Continued

Sentinel Hill Member, lower part—Continued

Station 65—Continued	Thickness (feet)	Distance below top of composite section (feet)
146. Tuffaceous material, yellowish	.8	2,191.0–2,191.8
147. Shale, silty, black	8	2,191.8–2,199.8
Total, lower part of Sentinel Hill Member of Schrader Bluff Formation	388.8	

Barrow Trail Member:

Station 65—Continued	Thickness (feet)	Distance below top of composite section (feet)
148. Sandstone, light-gray, very fine grained, mostly hard, crossbedded, massive; contains carbonaceous streaks and layers	15	2,199.8–2,214.8
149. Bentonite	.7	2,214.8–2,215.5
150. Sandstone, fine-grained, laminated	21	2,215.5–2,236.5
151. Siltstone, carbonaceous; irregular fracture; forms massive resistant ledge	5	2,236.5–2,241.5
152. Bentonite	.8	2,241.5–2,242.3
153. Sandstone, fine- to very fine grained, thin-bedded; upper part sparsely fossiliferous	70	2,242.3–2,312.3
154. Covered. Apparently mostly sandstone and shale	21	2,312.3–2,333.3
155. Shale, dark-gray, silty carbonaceous	8	2,333.3–2,341.3
156. Tuff, light-gray, silty, contains dark-gray carbonaceous laminae	1	2,341.3–2,342.3
157. Shale, dark-gray, silty, and thin interbeds of light-gray sandstone	19	2,342.3–2,361.3
158. Bentonite, yellowish-green	.6	2,361.3–2,361.9
159. Sandstone, light-gray, fine-grained, ledge-forming, fossiliferous (USGS Mesozoic loc. 20425 (46ASt33), see fig. 108 and table 3)	25	2,361.9–2,386.9
160. Sandstone, shale and bentonite, poorly exposed	26	2,386.9–2,412.9
161. Shale, dark-gray, somewhat silty, soft and friable	18	2,412.9–2,430.9
162. Sandstone, light-gray, fine-grained, silty, and numerous dark-gray carbonaceous laminae	12	2,430.9–2,442.9
163. Bentonite, yellowish-green to brown	1	2,442.9–2,443.9
164. Tuff, silty, hard; has light- to dark-gray irregular laminae. Poorly exposed except near top	9.5	2,443.9–2,453.4
165. Bentonite, moderate-yellow-green; ironstone and hard shale fragments along contact with shale below	1.2	2,453.4–2,454.6
166. Shale, dark-gray, silty, very soft	.8	2,454.6–2,455.4
167. Sandstone, medium-gray, very fine grained, probably silty, friable. Some ironstone	4	2,455.4–2,459.4
168. Bentonite, yellowish-green	1.5	2,459.4–2,460.9
169. Shale and sandstone	18	2,460.9–2,478.9
170. Sandstone, light- to medium gray, very fine grained	.4	2,478.9–2,479.3
171. Siltstone, light- to medium-gray, banded. A few thin beds of bentonite and a 0.2-ft bed of coal	11	2,479.3–2,490.3
172. Shale, dark-gray, bentonitic	6	2,490.3–2,496.3
173. Sandstone, very fine grained, silty, hard; has light- to medium-gray laminations	3	2,496.3–2,499.3
174. Sandstone, light-gray, yellow- to brown-stained, fine-grained, mostly very friable, slightly banded, somewhat crossbedded	13	2,499.3–2,512.3
175. Covered. Apparently interbedded sandstone and shale	25	2,512.3–2,537.3
176. Siltstone, dark-gray, carbonaceous	1	2,537.3–2,538.3
177. Covered	5	2,538.3–2,543.3
178. Sandstone, light-gray, very fine grained, slabby	1.6	2,543.3–2,544.9
179. Siltstone, medium-gray	7	2,544.9–2,551.9
180. Bentonite, yellowish-green	.9	2,551.9–2,552.8
181. Sandstone, light-gray to very light gray, very fine grained, probably tuffaceous; has extremely hard, dark laminae and considerable crossbedding; fossiliferous (USGS Mesozoic loc. 20429 (46ASt69), see fig. 108 and table 3)	4.5	2,552.8–2,557.3
182. Siltstone, gray, massive	4	2,557.3–2,561.3
183. Sandstone, light-gray, massive, laminated	3.7	2,561.3–2,565
184. Shale and bentonitic shale; grades at base into next unit	5	2,565–2,570
185. Bentonite, dark-olive-green; grades into sandstone at bottom	4	2,570–2,574
186. Siltstone, gray, hard	3	2,574–2,577
187. Shale and sandstone	23	2,577–2,600
188. Sandstone, medium-gray, very fine grained, hard, laminated	.5	2,600–2,600.5
189. Sandstone, light-gray, fine-grained, friable, thin-bedded	5	2,600.5–2,605.5
190. Conglomerate of subrounded chert, quartz, sandstone, and siltstone pebbles as large as		

SECTION 14.—*Prince Creek and Schrader Bluff Formations on the Colville River below Umiat*—Continued

Schrader Bluff Formation—Continued Barrow Trail Member—Continued	*Thickness (feet)*	*Distance below top of composite section (feet)*
Station 65—Continued		
1½ in. in diameter. Sandy and somewhat bentonitic matrix	.5	2,605.5–2,606
191. Coal. Includes some carbonaceous siltstone and one 0.1-ft bed of bentonite	2.4	2,606–2,608.4
192. Siltstone, dark-gray, clayey, soft	1.8	2,608.4–2,610.2
193. Sandstone, light-gray, fine-grained, banded. Includes 0.2-ft medium-gray siltstone bed	2.6	2,610.2–2,612.8
194. Siltstone, medium-gray	.7	2,612.8–2,613.5
195. Sandstone, light-gray, salt-and-pepper, fine-grained. Includes 0.9-ft medium- to dark-gray siltstone bed	4.2	2,613.5–2,617.7
196. Sandstone, light-gray, fine-grained, slabby. Upper part pale green, bentonitic, extremely friable	2.5	2,617.7–2,620.2
197. Sandstone, light-gray, salt-and-pepper, fine-grained, in part bentonitic, mostly friable, slabby, crossbedded	14.1	2,620.2–2,634.3
198. Sandstone, light-gray, red-brown-weathering, very fine grained, massive, cliff-forming, crossbedded, laminated	13.5	2,634.3–2,647.8
199. Sandstone, fine- to medium-grained, massive. Shell fragments	9	2,647.8–2,656.8
200. Shale, brown to green, upper part sandy and bentonitic	31.5	2,656.8–2,688.3
201. Sandstone, thin-bedded	9	2,688.3–2,697.3
202. Shale, green to gray, sandy	4.5	2,697.3–2,701.8
203. Sandstone, light-gray, fine-grained, massive	10	2,701.8–2,711.8
204. Sandstone and ironstone interbedded	1.8	2,711.8–2,713.6
205. Sandstone, light-gray, very fine grained, partly bentonitic, slabby, banded. Few thin siltstone beds	5.5	2,713.6–2,719.1
206. Sandstone, light-gray, very fine grained, banded, slabby to massive, crossbedded. Considerable minor folding (by flowage before consolidation) but beds above and below undisturbed	14	2,719.1–2,733.1
207. Ironstone	.4	2,733.1–2,733.5
208. Sandstone, light-gray; most is fine grained, some medium grained; thin bedded, very crossbedded, some thin lenses of ironstone. Fossiliferous (USGS Mesozoic loc. 19437 (44AC533); see fig. 108 and table 3)	10.5	2,733.5–2,744.0
209. Granule conglomerate	.3	2,744.0–2,744.3
210. Sandstone, similar to above; harder and more massive near bottom	16	2,744.3–2,760.3
211. Siltstone, medium-gray	.8	2,760.3–2,761.1
212. Sandstone, light-gray, fine-grained, friable, slabby, crossbedded	5.2	2,761.1–2,766.3
213. Siltstone, medium- to dark-gray; interbedded with light-gray very fine grained sandstone	2.2	2,766.3–2,768.5
214. Sandstone, light-gray, very fine grained; weathers moderate brown, partly massive, partly slabby and friable	6	2,768.5–2,774.5
Total, Barrow Trail Member of Schrader Bluff Formation	574.7	
Rogers Creek Member:		
215. Covered	165±	2,774.5–2,939±
216. Claystone, dark-gray, carbonaceous; interbedded with very fine to fine-grained sandstone. Some shaly layers. Beds ⅛-in. to 1-ft thick, mostly 1 to 2 in. (46ASt26, see fig. 108 and table 3)	25±	2,939±–2,964±
217. Siltstone, medium-gray. Apparently many thin beds of bentonite. Weathers to round cobbles	18±	2,964±–2,982±
218. Interbedded claystone and sandstone similar to unit 216	20±	2,982±–3,002±
Total (incomplete), Rogers Creek Member of Schrader Bluff Formation	228±	

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