United States
Department of the Interior
U.S. Geological Survey
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Geological Investigations
Naval Petroleum Reserve No. 4
Alaska

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STRATIGRAPHY AND STRUCTURE OF THE OKPIKRUAK AND
KIRUKTAGIAK RIVERS AREA, ALASKA

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By
William W. Patton, Jr.
and
Irvin L. Tailleur

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INTRODUCTION

Navy Oil Unit Party 4, during the summer field season of 1949, examined the surface geology of the area of the Okpikruak and Kiruktagiak Rivers. The party consisted of six men: two geologists, two field assistants, a weasel mechanic, and a cook. Three weasels were used for transportation in the field.

The area covered is bounded on the west by the Okpikruak River, on the east by the Chandler River, and on the south by the north front of the Brooks Range. Tuktu Bluff on the Chandler River and its westward extension forms the northern boundary. The area is drained by the Chandler, Kiruktagiak, Ayiyak, Okokmilaga, and Okpikruak Rivers.

The objectives of this summer's work was the geologic mapping and stratigraphic study of the rocks that crop out in this area. All outcrops were visited and the geology was plotted on vertical and trinistrogon oblique aerial photographs. Altitudes were established by an altimeter traverse.

Parts of this area had been investigated previously by members of the Navy Oil Unit. During the summer of 1945 George Gryc, E. J. Webber, and Karl Stefansson visited outcrops along the Chandler and Kiruktagiak Rivers and in the vicinity of Castle Mountain.

In the same year L. A. Warner and C. E. Kirschner examined outcrops along the Okpikruak River in conjunction with their survey of the Killik and Colville Rivers. R. L. Detterman included detailed stratigraphic studies of cutbanks near the confluence of the Kiruktagiak and Chandler Rivers in his geological mapping of the lower Chandler during the summer of 1948.

TOPOGRAPHY

The Okpikruak-Kiruktagiak Rivers area lies wholly within the southern foothills section of the Arctic Foothills province. The area can be divided into three physiographic belts that extend east-west across the area.
A high south-facing escarpment extends from Tuktu Bluff on the Chandler River across the northern margin of the area. Immediately south of this escarpment is a featureless lowland, 6 to 10 miles wide, broken only by a few low ridges adjacent to the scarp. The belt is underlain by the finer-grained, nonresistant members of the Torok formation, and outcrops are limited to cutbanks.

To the south is a belt, 5 to 10 miles wide, of long, east-trending, rubble-covered, hogback ridges, flat-topped bluffs; small, irregularly shaped buttes and knobs; and two massive mesa-like synclinal mountains, Castle Mountain and Fortress Mountain. These features are topographic expressions of the infolded coarse clastic facies of the Torok formation, of mafic igneous intrusives, and of resistant Triassic chert beds. The best outcrops in the Okpikruak-Kiruktagiak River area are in this belt which is referred to below as the Castle Mountain-Fortress Mountain infolded belt.

A gravel pediment of late Tertiary or Pleistocene age lies between the infolded belt and the north front of the Brooks Range. Bedrock outcrops are limited to the valleys of incised rivers and a small dissected area south of Fortress Mountain. The area has a maximum relief of approximately 1,400 feet; the highest point is the top of Castle Mountain, at an altitude of 3,726 feet.

**GEOLOGY**

**Stratigraphy**

The sedimentary rocks that crop out in the Okpikruak-Kiruktagiak Rivers area are the Mississippian Lisburne limestone, the Triassic Shublik formation, the Jurassic Kingak formation(?) and the Lower Cretaceous Okpikruak and Torok formations and the Nanushuk group.

Aside from gathering lithologic and faunal data, a concerted effort was made to determine the thicknesses and stratigraphic relationships of these lithologic units. The results of this work are set forth in the form of a composite stratigraphic column (pl. 2 and 3). It should be emphasized that, except for the Lisburne limestone, all thicknesses given are approximate. A large percentage of the rocks of the Okpikruak, Torok, and Shublik formations are nonresistant and therefore are not well exposed anywhere in the area. The complicated structure throughout most of the area make reliable thickness measurements even in the better exposed sections impossible.

The stratigraphic column presented is an assemblage of incomplete sections logged at various localities. Correlation between these sections was made on the basis of structure, gross lithologic features, maximum-minimum thickness measurements, and fossils. In view of the facies changes that occur, particularly in the Torok formation, the column is not specifically applicable to any one locality.
Mississippian rocks

Lisburne limestone.—The bulk of the Lisburne limestone is well-exposed along the north front of the Brooks Range. In the Okpikruak-Kiruktagiak Rivers area, however, exposures are limited to small isolated outcrops on the crests of breached anticlines.

The most extensively exposed section is about 1 mile north of the range on the Kiruktagiak River and Monoitis Creek, where 370 feet of Lisburne is exposed from the center of a breached anticline to the base of the overlying Triassic shales (pl. 2).

The lower 150 feet of this section is predominantly a massive, gray-buff, crystalline, bioclastic limestone. This sequence is capped by an 8-foot bed of dark, bituminous or carbonaceous chert. On the basis of the lithologic characteristics and a scant fauna, A. L. Bowsher, Sr., believes that this lower 150 feet can be tentatively correlated with the Alapah member of the Lisburne at Kanayut Lake which he described.

The upper 220 feet of this section consists of black, bituminous(?), phosphatic, cherty, and shaly limestones that carry a distinctive upper Mississippian fauna. No corresponding section has yet been recognized in the Brooks Range, although Bowsher reports finding a few phosphatic beds near the top of the Lisburne at Chandler Lake. Over much of the Range, erosion may have stripped away these less resistant beds. It is proposed, on the basis of the distinct lithologic characteristics, to call this unit the Kiruktagiak member of the Lisburne limestone. The stratigraphic position of this member with reference to the overlying Shublik formation (Triassic) and the underlying massive limestone (Alapah(?)) lead the writers to believe that it is younger than the Alapah member as described by Bowsher in the Kanayut Lake area.

The bottom 40 feet of the Kiruktagiak member is poorly exposed and consists of gray-black phosphatic and bituminous(?), limestones and shaly limestones. Black, dense, ammonite-bearing calcareous concretions as much as 3 feet in diameter occur locally. These beds overlie the 8-foot chert bed at the top of the Alapah member with no apparent discordance. The phosphatic zone is overlain by 175 feet of dark, cherty, bituminous(?), limestone, shaly limestone, and shale. This is capped by 5 to 6 feet of fossiliferous, pyritic black shale. The contact with the overlying red and green shales of the Shublik formation is not exposed, but there is no apparent discordance in dips between the two sections over the 30- to 100-foot covered interval which separates them.

A narrow belt of limestone crosses the Kiruktagiak Valley at the Notch where the Lisburne is exposed along the crest of an anticline. The exact stratigraphic sequence of the beds could not be deciphered because of structural complications, but several horizons of the Kiruktagiak member were recognized. Black phosphatic or bituminous(?)

1/ Bowsher, A. L., Sr., Personal communication.
shales with hard calcareous concretions were found also to be abundantly fossiliferous. The shales appear to be overlain by dark, bituminous(?), cherty limestones.

Two narrow belts of Lisburne limestone extend east-west between the East and Middle Forks of the Okpikruak River. They are marked by a series of sharp jagged ridges of black, bituminous(?), chert and limestone. Although there are no exposures between the East Fork of the Okpikruak and the Okokmilaga Rivers, outcrops of similar rocks in the Okokmilaga Valley indicate that these belts are probably continuous across the interstream area. The fossils and lithology strongly suggest that these rocks belong to the Kiruktagiak member.

Several fossil collections from the Kiruktagiak member have been examined by A. L. Bowsher, Sr. Mr. Bowsher has assigned this member to uppermost Mississippian on the basis of these fossils:

Leiophrynchus sp.
Martinia sp.
Moorefieldella sp. undet.
Productella sp.
Tropidostrophia griffithi (McCoy)
Chonetes sp.
Campylla sp.
Dimorphoceras sp.
Endochus sp.
Girtooceras sp. (immature)
Goniastites cf. G. chostawanus Shumard
Homooceras? sp.
Copocardium sp.
Aviculopecten sp.
Mooreceras? cf. M. vaughaniunum (Girty)
Mooreceras? sp.
Pseudomastagonaras sp.
productid of the Dictyoclostus inflatus type
productid, undet.
Cruithyris? sp. undet.
Moorefieldella aff. M. eurekensis (Malcott)
Leda sp. undet.
Glabrocinclulus sp. undet.
Laxoceras? sp. undet.
orthoceroid cephalopod
Paravarchites sp.

In 1943 George Gryc made a collection at The Notch on the Kiruktagiak River from the Kiruktagiak member of the Lisburne limestone. He found the following:

Campyella sp.
Bectrites sp.
Mooreceras cf. M. crebriliratum (Girty)
Numerous small exposures of Lisburne limestone crop out throughout the Okpikruak-Kiruktagiak Rivers area. Practically all, however, have been reduced to rubble and not enough data could be gathered to correlate them with known sections in the Brooks Range and on the upper Kiruktagiak River. Two poorly preserved fossils were found at one small exposure a mile north of Horseshoe Mountain: a cyrinothrytid brachiopod and Diplazoma aff. P. hastata (Sowerby). On the basis of these two fossils, A. L. Bowsher, Sr. believes the outcrop probably belongs to the lower Lisburne. As Triassic cherts crop out about 40 feet to the south, it would appear that a considerable thickness of upper Lisburne is missing through faulting, pre-Shublik erosion, or nondeposition.

**Triassic rocks**

Shublik formation.--Triassic rocks are widespread south of the Castle-Mountain-Fortress Mountain infolded belt, but exposures are limited to disconnected cutbanks along the major streams or to scattered rubble ridges and low knobs in this belt of close folding. Isolated outcrops indicate another band of Triassic strata 1 to 3 miles north of Castle Mountain and Fortress Mountain.

Parts of the Triassic section are excellently exposed along the Middle Fork of the Okpikruak River and also along Monotis Creek near the front of the Range. A composite section (pl. 2) established from these outcrops represents, as far as determinable, the minimum thickness of the Shublik formation in the Okpikruak-Kiruktagiak Rivers area.

The lower 310 feet of the Monotis Creek section is composed of several varieties of shale. In stratigraphic order they are:

1. green, red, and dark-colored silt-clay shales and siltstones, 150 feet thick;
2. black fissile shales with a zone of olive-drag bedded chert near the top, 80 feet thick;
3. carbonaceous or bituminous shales, locally woody oil shales, calcareous paper shales, and minor lenses and beds of fossiliferous limestone 80 feet thick. The succeeding 150 feet is dominantly a black medium-bedded chert. Carbonaceous shale partings and thin interbeds are abundant. A 25-foot carbonaceous-calcareous shale break occurs in the upper part. Forty-five feet above the base of this chert sequence are two thin, persistent, fossiliferous limestone beds. A 20-foot zone of interbedded, dark- to medium-gray, finely crystalline limestone, cherty limestone, and oil shale caps this section.

Rocks of Triassic age are exposed in numerous cutbanks on the Middle Fork of the Okpikruak River. A complete sequence from the top of the Lisburne to the base of the Okpikruak is partly exposed on the flank of an overturned anticline 3 1/2 miles south of the junctions of the Forks. Here, the maximum possible thickness for the Triassic was computed to be 3,280 feet, of which the upper 450 feet is covered.

Parts of this section are exposed farther south along the Middle Fork. The sequence from older to younger is: (1) black bedded cherts with minor carbonaceous or bituminous limestone beds; only the uppermost
part of this sequence is well-exposed; (2) a zone of limestone similar to the top beds described on Monotis Creek; (3) a 175-foot thickness of well-indurated, medium-gray to medium-green, locally calcareous siltstones which are not readily distinguishable from basal Okpikruak rocks; (4) a 250-foot section of green to medium gray, somewhat glassy, bedded cherts and a red shaly chert zone near the top.

Above the glassy cherts the lithology changes noticeably. Eighteen hundred feet of section is exposed between the glassy cherts and the base of the Okpikruak formation on the limb of the anticline on the Middle Fork. Nearly the same thickness crops out along Ohkonagoon Creek. In both places the sections consist of an alternating series of well-indurated, hackly, dark, commonly purple or green shale; dark-gray, purple-banded siltstone; and, locally, light-gray to white, very fine grained sandstone. In the basal part the rocks are coarser, darker, and contain scattered carbonaceous fragments. The siltstone generally has rippled bedding surfaces and abundant scour casts. No fossils were found in either section. Several outcrops of these beds elsewhere are darker red and green, probably because of more intensive weathering. These rocks of the upper unit of the Triassic may be differentiated from the Cretaceous rocks by their greater degree of induration, the lighter color, the cleaner character of the coarser facies and the scarcity of carbonaceous material.

The age of the lower cherty sequence is established as Triassic on fossil evidence. The general stratigraphic relationships of the upper siltstone-shale unit are not certain because, apparently, this sequence has a restricted occurrence as a result of pre-Killik erosion. But in the localized area of exposure, no break in the depositional sequence from the lower unit to the upper unit was recognized. Therefore, the upper shale-siltstone unit has been included with the lower cherty unit in the Shublik formation. Further field studies are needed to establish with certainty the age and stratigraphic relationships of the upper shale-siltstone sequence.

Fossil collections were made from two horizons in the lower cherty section exposed at Monotis Creek. The fossils have been identified by Dr. Bernhard Kummel; the first horizon occurs in a zone of limestone 250 feet above the top of the Lisburne:

- *Clara*, *Orthoceras* sp.
- *Protachitoides* sp.
- ammonites undet.
- pelecypods undet.

These specimens were poorly preserved but Dr. Kummel has tentatively assigned them to Lower Triassic (Scythian). This is the only locality where Lower Triassic fossils were found and is the only reported occurrence of Lower Triassic in Alaska.
The second fossil horizon is several hundred feet higher in the sequence at the same locality. It carries the palaeopod Halobia sp. Elsewhere in the Okpikruak-Kiruktagiak area Halobia sp. is found in association with Pseudomonotis subcircularis and therefore is probably Upper Triassic (Norian) in age. No major unconformity was recognized in the well-exposed sequence which separates these two fossil horizons.

Several other collections were made from the Upper Triassic rocks in the area. They include:

- Monotis sp.
- Monotis cf. M. alaskana Smith
- Placunopsis sp.
- Pseudomonotis subcircularis Gabb
- Halobia aff. M. alaskana Smith
- Halobia cf. M. gigantea Smith

Jurassic(?) rocks

Kingak formation(?) -- Rocks which are probably of Jurassic age were found in only one locality in the Okpikruak-Kiruktagiak Rivers area. They crop out on rubble ridges and cutbanks near the headwaters of Fortress Creek. The sequence consists of interbedded dark-green, argillaceous sandstone, dark-gray siltstone and shale, and minor lenses of dark-gray semicrystalline limestone. The section is so badly folded and faulted that thickness measurements were not possible.

These rocks were traced into the gravel pediment on the south and west sides of their outcrop area. On the northeast they appeared to be in contact with cherty beds of the Shublik formation. Several mafic intrusives are localized along the contact. Exposures are not adequate to determine the stratigraphic relationships of these beds to the Shublik.

In one of the cutbanks that exposes these sediments several poorly preserved fossils were found: Inoceramus sp. and a fragment of an ammonite which Dr. Ralph Inlay has identified as similar to Pseudodolioceras. Pseudodolioceras occurs in the Jurassic Kingak shale in the Canning River area and in the Jurassic Kialagvik of southern Alaska.

These outcrops are the first reported occurrence of Jurassic rocks in the foothills belt west of the Canning River.

Lower Cretaceous rocks

Until this year the investigations of the Navy Oil Unit have been confined largely to the Cretaceous rocks belonging to the Nanushuk group. This section has been subdivided into formations, members, and tongues, and into time-rock units (zones B, C, D, etc.).

As a result of their summer's work the writers have broken the pre-Nanushuk-Lower Cretaceous rocks into two major mappable units: the Okpikruak formation and the Torok formation. The Torok has been further
subdivided into two members. The relation of these named units to earlier versions of stratigraphic nomenclature is shown in table 1.

Additional field and laboratory studies are needed to define more exactly the lateral extent and the nature of the upper and lower contacts of these units.

**Okpikruak formation**

In the Okpikruak-Kiruktagiak Rivers area the Okpikruak formation crops out south of the Castle Mountain-Fortress Mountain infolded belt and in several places on the flanks of the Castle Mountain syncline. The unit most commonly crops out as long low rubble ridges but is best exposed in two outcrops on the Okpikruak River and one on a tributary to the Kiruktagiak.

The characteristics which distinguish the Okpikruak formation from the Torok formation are: (1) the abundance of *Aucella crassicollis* Keyserling; (2) the cleaner, more quartzose character of the sandstones; (3) the scarcity of carbonaceous matter above the basal sandstones and conglomerates; (4) ripple and scour marks on the sandstones and siltstones; (5) iron-rich sandy limestone lenses and concretions which weather rusty brown; (6) the monotonous repetition of interbedded fine-grained sandstone, calcareous sandstone, siltstone, and shale through-out most of the sequence. On aerial photographs, outcrops of this unit cannot readily be distinguished from the overlying Torok formation.

In a cutbank on the Okpikruak River a 2,000-foot section of the Okpikruak formation is chiefly a series of interbedded fine-grained, green, argillaceous sandstone, dark calcareous sandstone, and dark shale (pl. 3). The sandstone and calcareous sandstone make up about 60 percent of the section. *Aucella* occurs throughout. At the bottom of this sequence is 20 feet of coarse sandstone and chert-gravel conglomerate. A 500- to 600-foot covered interval separates these beds from Shublik cherts. Thus, provided there is no major faulting, the Okpikruak formation here has a maximum thickness of 2,500 feet and a minimum thickness of 2,000 feet. Parts of the same section are exposed several miles to the south of the Middle Fork of the Okpikruak where the maximum thickness was calculated to be 2,500 feet. Again the basal 500 feet is not exposed.

One mile south of Fortress Mountain, Shublik cherts are directly overlain by a 300-foot sequence of fine-grained, green and gray argillaceous sandstone with lenses of chert-pebble conglomerate and a 100-foot section of dark clay shale (pl. 3). The conglomerate consists of angular to subangular chert fragments, rounded oil-shale pebbles, and scattered carbonized plant fragments in a fine-grained sandy matrix. This sequence is separated from Shublik cherts by a covered interval of 30 feet. At numerous other places south of the Castle Mountain-Fortress Mountain infolded belt, these basal sandstones have been infolded with Shublik shales and cherts. In addition to chert
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<td>Zone B Tuktu sandstone member</td>
<td>Zone B Tuktu sandstone unit</td>
<td>Zone B Tuktu tongue</td>
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<tr>
<td>Namashuk group</td>
<td>Torok unit</td>
<td>Namashuk group</td>
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<tr>
<td>Zone A Torok shale member</td>
<td>Tuktu formation (Zone A)</td>
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<td>Kilik group</td>
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and oil shale, several of the conglomerates contain pebbles of crinoidal limestone (Listburne), green, fine- to medium-grained mafic igneous rock, and green quartzite. Four miles south of Fortress Mountain, a zone of boulder conglomerate 20 feet thick rests directly on an irregular surface of chert of the Shublik formation. Although the relationships there are partly obscured, no great angular discordance is apparent.

In a cutbank on a tributary of the Kiruktagiak about a mile north of The Notch, a 950-foot section of the Okpikruak formation is exposed (pl. 3). In this series of _Aucella_ -bearing green argillaceous sandstone, calcareous sandstone, shale and siltstone, the proportion of shale is considerably greater than in the Okpikruak section.

Based on the occurrence of _Aucella crassicollis_, the Okpikruak formation is assigned to Neocomian (early Lower Cretaceous).

**Torok formation**

**Lower member.**—The lower member of the Torok formation crops out on the flanks of the Castle Mountain and Fortress Mountain synclines and in a band 3 to 4 miles wide north of the Castle Mountain-Fortress Mountain infolded belt. Exposures are limited to cutbanks of which the most extensive are along the Kiruktagiak and Chandler Rivers.

The lower member is composed predominantly of dark clay and silt shales. These shales cannot be readily distinguished from shales of the upper member of the Torok formation and Okpikruak formation, but in the area studied it is a mappable unit because of its stratigraphic position between the underlying Okpikruak formation or Shublik formation and the overlying basal sandstone and conglomerate of the upper member.

Practically everywhere the shales have been intricately folded. On the Kiruktagiak River, west of Castle Mountain, however, a relatively uncomplicated section overlies Shublik cherts and shales of the Shublik formation and underlies basal conglomerates and sandstones of the upper member (pl. 3). Here the lower member measured 1,750 feet thick and is composed of dark clay and silt shales with silty, somewhat septate, ellipsoidal concretions. Thin beds of fine-grained, green, argillaceous sandstone occur through the section; carbonaceous material and fossil wood are abundant.

In the band of the lower member exposed north of the Castle Mountain-Fortress Mountain infolded belt, lenses and concretions of limy siltstone that weather bright yellow-red are common.

A fossil fish skeleton of the Aspidorhynchidae family was found in an exposure of the lower member on Torok Creek.
Upper member.—The greater part of the rocks of the Torok formation has been assigned to the upper member. More study, however, may reveal that a further break-down of this great thickness is possible. The upper member is exposed in the Castle Mountain-Fortress Mountain infolded belt and just south of the Tuktu escarpment.

Briefly, the upper member consists of a thick series of dark shale, siltstone, graywacke 1/, and graywacke conglomerate which were deposited in a marine environment. The coarse clastic facies is concentrated along the southern margin of the Castle Mountain-Fortress Mountain infolded belt, but the coarse beds grade out into shale a short distance to the north. There are also appreciable facies changes in an east-west direction. No reliable stratigraphic horizon could be traced throughout the area. Fossils are generally scarce and are nonexistent through much of the sequence.

The only unbroken section of the upper member of the Torok formation is at Castle Mountain. From the basal graywackes and conglomerates overlying the lower member to the top of the conglomerates which cap Castle Mountain, the section is 8,460 feet thick (pl. 3).

The basal graywackes and graywacke conglomerates at Castle Mountain were deposited on a scoured surface of the lower member. The basal section is approximately 650 feet thick and consists of medium- to coarse-grained, green graywackes with irregular lenses of chert-pebble and granule conglomerate. The section grades upward into shale. Carbonized plant fragments and oil-shale pebbles are abundant. *Inoceramus* sp. is present locally.

In the Fortress Mountain area, the basal coarse clastic facies crops out on the Canoe Hills. Here the section consists of interbedded shale, graywacke, and graywacke conglomerate. In addition to chert these conglomerates contain cobbles and pebbles of gray, crystalline, bioclastic limestone, green diabase, green quartzite, black bituminous limestone, and wood fragments. These are imbedded in a highly argillaceous, poorly consolidated matrix which locally has shaly partings. At several horizons, large, subangular chunks of shale and siltstone are imbedded in the matrix.

To the west on Okok Creek the basal coarse clastics are even more erratic. Angular chunks of graywacke, chert, and carbonized wood fragments are scattered at random through an irregularly bedded silt, shale, and graywacke matrix. Outcrops of the same zone occur on the Okokmilaga and Okpikruak Rivers. *Lemuroceras* was found at the latter locally.

In the Castle Mountain area, the basal conglomeratic section is overlain by a monotonous sequence, several thousand feet thick, of

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1/ The graywackes are sandstone which contain, besides quartz, significant amounts of angular and subangular fragments of both non-resistant and resistant rocks and minerals set in a dark, highly argillaceous, and often calcareous, matrix. They are typically poorly sorted.
dark silt and clay shales with some fine-grained, green graywacke and siltstone. *Aucellina* was found in these shales at several localities on the Kirukttagiak River. This shale section is overlain by 900 feet of fine-grained graywacke with lenses of chert-granule and chert-pebble conglomerate. These beds are well-exposed on Castle Creek but apparently grade into shale rather abruptly, as they were not recognized on the north side of Castle Mountain.

At least 3,000 feet of dark shale separates these coarse clastics from those which cap Castle Mountain. The few thin beds of graywacke and conglomerate scattered through these shales on the south side of Castle Mountain are not present on the north side.

On the southeast face of Castle Mountain the 3,000-foot sequence of shale is capped by 1,300 feet of coarse green graywacke and graywacke conglomerate. These conglomerates, like those below, are composed chiefly of subround chert pebbles in a graywacke matrix. Carbonaceous matter is abundant. Gray bioclastic limestone, black bituminous limestone, green quartzite, and pink, gneissic granite pebbles are common in the upper 500 feet. No white vein-quartz pebbles were found.

A 1,500-foot section of the upper member of the Torok was also measured three quarters of a mile to the north at the center of the Castle Mountain syncline. The upper part of this section differs little from the southern 1,300-foot section. The lower part, however, is essentially dark shale. When the two sections are correlated by the direct tracing of beds, it is apparent that the lower 300 feet of the conglomerate in the southern section grades into shale within three quarters of a mile (pl. 3).

The upper member is also exposed in a belt, 3 to 4 miles wide, that extends east-west across the northern part of the area. The best outcrops are along the Chandler River where in 1948 R. L. Detterman measured a sequence 4,160 feet thick between the lower member and the overlying Tuktu sandstone (pl. 3). The 500 feet of green to gray graywacke and chert-granule conglomerate at the base of this section is believed to be correlative with the basal coarse clastics of the upper member at Castle Mountain. Several species of *Lemuroceras* and one *Baudanticeras* were found in these beds on the Chandler River by the writers. Between these graywackes and the Tuktu sandstones is about 3,000 feet of clay and silt shale with lenses and concretions of dark silty limestone.

The presence of *Lemuroceras*, *Baudanticeras*, and *Aucellina* in the upper member indicates an age of Albian (upper Lower Cretaceous).

**Lower part of Nanushuk group**

**Tuktu tongue (zone B).** Sandstone of the Tuktu tongue crops out along the northern boundary of the Okpikruak-Kirukttagiak Rivers area. As this unit has been studied in detail by several parties in the past, it was given only a cursory examination in 1949. On the Chandler River
Detterman found it to be 1,040 feet of a fine- to medium-grained, argillaceous, locally fossiliferous, green sandstone. A few pebbles of white vein quartz appear in the upper half, and near the top are a narrow lens of quartz and chert-pebble conglomerate, coal, and several beds of yellow-red sandstone.

This sandstone overlies the Torok formation. Everywhere a covered interval of from 50 yards to a half mile separates the two units. Near the contact the sandstones dip from 10° to 20° N., but the crenulated shale of the Torok formation dips on the average of 30° to 50° N. This discrepancy may indicate an angular unconformity or may have resulted from the relative competency of the sandstone and shale.

### Igneous rocks

The only igneous rock found in the Okpikruak-Kiruktagiak area is a fine- to medium-grained mafic intrusive. With the exception of two large masses at Horseshoe Mountain and on the west side of the Kiruktagiak River 7 miles south of Horseshoe Mountain, the rock generally occurs as small scattered outcrops within the areas of Shublik exposures. Many exposures are small, pluglike bodies elongated parallel to the strike of the host strata. In several places, these separated exposures are aligned, which probably indicates discontinuous intrusion along linear zones of weakness parallel to the regional trend. In numerous other places, sill-like relationships were evident in the outcrop and areal plan: thin layers of the igneous rock alternate with thin beds of chert; tabular bodies, 20 to 50 feet thick and up to one-half mile long, parallel the strike of the country rock. The thicker masses, with the exception of Horseshoe Mountain, show similar elongation in the direction of regional trend.

No microscopic study of this season's collection has been made, but previous work has shown the rock to have a gabbro-basalt composition. Megascopically, the rock has a fine- to medium-grained, even texture and is dark green. Minor variations in texture and color were noted over the area, but there were no great differences in composition. Local changes in appearance are probably due to assimilation of country rock.

The outcrops of igneous rock are deeply weathered because the feldspar breaks down readily, but they stand in slight relief because the rock as a whole resists erosion. The alteration of the feldspars to calcite and the subsequent leaching of the calcite commonly produce a porous texture.

The effect of the intrusive rock upon its host was generally slight, particularly in the cherts, shales, and sandstones. At The Notch, a tabular body 350 feet thick was intruded along the contact of Lisburne limestone and chert of the Shublik formation. The limestone near the contact has been recrystallized, silicified, and impregnated with veinlets of calcite.
The igneous rocks appear to be intrusive everywhere except at Horseshoe Mountain, where some fine-grained and amygdaloidal textures are suggestive of extrusion. Thin-section studies are necessary before conclusions as to the relationships at Horseshoe Mountain can be made.

Nowhere was it established that the igneous rock is intrusive into Okpikruak or younger strata. Pebbles and cobbles of mafic igneous rocks are present in the basal conglomerates of the Okpikruak and Torok formations. On the evidence now available, the age of the intrusive activity would fall between post-Shublik and pre-Lower Cretaceous.

Structure

Orogenic movements associated with deformation of the east-trending Brooks Range are reflected in the Okpikruak-Kiruktagiak River section of the foothills region by a complex series of folds, generally paralleling the strike of the mountain front. In contrast to the thrusting prevalent at the front of the Range, compressional stresses were here relieved more by folding than by faulting. The folding diminishes northward from the Range. A regional dip to the north prevails.

Between the front of the Brooks Range and the Castle Mountain-Fortress Mountain infolded belt, pre-Torok strata have been compressed into a myriad of short, sharp, overturned folds. The outcrop pattern resulting from this close folding is well-developed south of Fortress Mountain (pl. 1).

Several larger folds are exposed along the Kiruktagiak River and between the Middle and East Forks of the Okpikruak. They could not be related across the interstream areas because of cover. The smaller folds appear to be secondary on these larger structures.

In the infolded belt, the Torok formation has been warped into a broad syncline. Attitudes on the upper beds of the upper member, which occur at the top of Castle Mountain, are gentle and regular. Attitudes on older Torok strata west of Castle Mountain, however, show greater deformation, even across the center of the major syncline. In the area surrounding Castle Mountain, some basal beds of the upper member have been overturned and faulted. As there is no apparent major angular break within the Torok sequence, folding must have been progressive and also contemporaneous with deposition.

The general east trend of the large syncline is interrupted at several localities along the infolded belt. In each case, the western segment has been displaced northward relative to the segment east of the break in continuity. Over a distance of 15 miles, the cumulative effect of these offsets has been to displace the major synclinal axis at the Okpikruak River 4 to 5 miles north of its position at Castle Mountain. Several major streams cross the infolded belt along lines that mark these offsets. Projections of the lines or zones that terminate the Fortress Mountain segment coincide with zones of north-south structures in the closely folded belt south of Fortress Mountain. The above evidence suggests that north-south zones of intense disturbance are present.
Horn Cretaceous

Nanushuk group, Prince Creek formation

Zone 1.—Rocks lithologically resembling the nonmarine Prince Creek formation of the Umiat area were examined in three isolated exposures on the lower Kokolik River.

Approximately 40 feet of section crops out in two low bluffs 32 miles above the mouth. The exposures consist of sandstone, conglomerate, ironstone, and a medium-gray, tough clay which occurs only as slump. The sandstone is medium to dark gray, usually quite friable, massive to shaly-bedded, noncalcareous, and weathers light gray. Cross bedding is prominent. Conglomerate beds within the sandstone are lenticular and range from 6 to 18 inches thick. Conglomerate constituents include well-rounded pebbles of chert, light-gray quartzite, and clay ironstone. One 6- to 8-inch layer of ironstone nodules is present. Carbonaceous plant fragments are common throughout the outcrop. The gray clay showed no definite bentonitic properties.

One slumped outcrop, 27 miles above the mouth of the Kokolik, contains a highly bentonitic clay. It is associated with talus of very fine grained, medium-gray poorly to well-indurated sandstone, siltstone, ironstone, and carbonaceous shale, and has been mapped as Zone I.

Gubik formation

The only exposure of the Gubik formation that was seen is on the Kukpawruk River approximately on the axis of Syncline 7. The Gubik forms a terrace deposit that unconformably overlies the uppermost zones D-E (?) beds of this area.

The 68 feet of section is composed of unconsolidated, very fine grained sand, silt, and clay, with scattered granules and pebbles of chert, white quartz, quartzite, and argillite. The color ranges from yellowish brown to dark gray and black (where carbonaceous material occurs). Pelecypods and gastropods are common.
As already pointed out, the sediments in the lower member and in the lower part of the upper member of the Torok are more deformed than those above. These rocks must have been subjected to active compressional stresses even during deposition. Under these conditions of sedimentation, it might be expected that numerous small unconformities would develop. Several such breaks were observed in the Okpikruak-Kiruktagiak area. North of Fortress Mountain, conglomerates of the upper member crop out very close to Shublik cherts. Apparently some of the lower member has been eroded away. On the west side of Fortress Mountain, conglomerates of the upper member lie unconformably on dark shales. A similar situation exists west of Castle Mountain. None of these unconformities could be traced very far.

No outcrops of the Torok formation were found south of the Castle Mountain-Fortress Mountain infolded belt. The concentration of coarse clastics along the southern margin of the infolded belt and the abrupt wedge-out of these clastic members into shale proves that the source area and shoreline, during the time of deposition, were very close. It is doubtful that these marine sediments ever existed as far south as the Brooks Range. The Castle Mountain-Fortress Mountain infold may mark the location of a rapidly sinking offshore marine trough during late Lower Cretaceous time. The infold, as it is now known, was in the process of formation during the time of deposition of Torok sediments.

The occurrence of Okpikruak strata a mile north of the Brooks Range indicates that the source for these sediments lay at least as far south as the present range.

As noted above, there apparently was a break in deposition and a period of erosion following Okpikruak time. Based on fossil evidence, the extent of this hiatus would be from Neocomian to Albian.

No such extensive break was noted between the lower member and the upper member of the Torok formation. Minor unconformities between these two units were observed in several places, but from the base to the top of the Torok formation the series is essentially continuous.

The basal graywackes and conglomerates of the upper member of the Torok at Castle Mountain have been correlated with the basal coarse clastics of the 4,160-foot section which R. L. Detterman measured below the Tuktu tongue at Tuktu Bluffs. The two sections could not be correlated directly above the basal members.

White quartz pebbles occur in the upper half of the Tuktu tongue, but no quartz pebbles were found in any of the conglomerates at Castle Mountain. It is assumed, therefore, that the top beds of the upper member of the Torok at Castle Mountain are older than the upper half of the Tuktu sandstone tongue, and are probably older than the entire Tuktu. If this reasoning is valid, it would appear that the 4,160 feet of the upper member at Castle Mountain has thinned to less than 5,000 feet 13 miles to the north. This is not surprising in view of the abrupt northward wedge-out of the coarse clastics at Castle Mountain. An unconformity at the base of the Tuktu tongue would also account for the thinning.
SIGNIFICANT PETROLEUM FEATURES

1. Much of the dark, bituminous (?) limestone in the Kiruktagiak member of the Lisburne limestone has what is described as an "oil shale" odor. It is particularly noticeable on a freshly broken surface.

2. Oil shales are present in the lower cherty section of the Shublik formation. A 15-foot zone on Monotis Creek is the thickest section exposed.

3. Asphaltic material generally associated with vein calcite is common as fracture-fillings in the Torok formation. On Fortress Mountain, a Torok conglomerate bed consists of angular chert granules cemented by asphaltic material.

4. No good reservoir sandstones were recognized on field inspection. The cleanest sands appear to be those at the base of the Okpikruak formation.

SUMMARY

1. A 220-foot section of dark, bituminous (?), cherty limestone and shale overlies the Alapah member of the Lisburne limestone. This section differs markedly from the Alapah limestone below and, therefore, is made a new member of the Lisburne and named the Kiruktagiak member.

2. The Triassic Shublik formation is believed to be 3,280 feet thick. The lower 1,000 feet of the formation has two fossil horizons of distinctly different ages; fossils from the lower horizon are Lower Triassic (Scythian) and those from the upper horizon are Upper Triassic (Norian). The upper 2,280 feet of nonfossiliferous shale and siltstone is exposed in only one place where it appears to conformably overlie the lower 1,000 feet, and therefore has been tentatively assigned to the Shublik formation.

3. Sandstone, siltstone, and shale thought to be correlative with the Jurassic Kirgak shale of the Canning River area crop out only in the foothills belt west of the Canning River area. The thickness and stratigraphic relationship of these rocks to the older and younger rocks could not be determined. The sandstone-siltstone-shale sequence of Kirgak (?) formation in the Okpikruak-Kiruktagiak Rivers area differs considerably from the Kirgak at its type locality.

4. In the area studied the pre-Namushuk Lower Cretaceous rocks can be subdivided into two mappable units: the Okpikruak formation and the Torok formation. The Torok formation can be further subdivided into two members. The Okpikruak formation is about 2,400 feet thick and consists of shale and argillaceous sandstone which differ somewhat from those in the Torok formation. The fossil Aucilla is common. The formation appears to be separated from the overlying Torok formation by an erosional break. The lower member of the Torok is about 1,750 feet thick and consists predominantly of dark shale which does not differ from the shale of the over- and underlying stratigraphic units because of its
stratigraphic position. The upper member is 8,460 feet thick at Castle Mountain and there consists of shale and of graywackes and conglomerates that wedge out and grade northward into shale. Thirteen miles to the north the upper member is not more than 5,000 feet thick; except for 500 feet of graywacke and conglomerate at the base, it is composed chiefly of shale. There is no widespread unconformity between the upper member and the lower member of the Torok formation.

5. The presence or absence of an unconformity at the base of the Tuktu sandstone cannot be established.