United States

Department of the Interior

U.S. Geological Survey

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Geological Investigations

Naval Petroleum Reserve No. 4

Alaska

Preliminary Report No. 29

PRELIMINARY REPORT ON THE STRATIGRAPHY AND STRUCTURE OF THE UPPER UTUKOK AND KOKOLIK RIVERS AREA

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November 1950

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ILLUSTRATIONS

STRATIGRAPHY AND STRUCTURE OF THE UPPER UTUKOK AND KOKOLIK RIVERS AREA, ALASKA

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INTRODUCTION

U. S. Geological Survey Navy Oil Unit Party 1 examined the surface geology of the area of the upper Utukok River and east fork of the Kokolik River from June 28 to September 3, 1950. The party consisted of six men: E. G. Sable and M. D. Mangus, geologists; C. L. Hummel and P. H. Shannon, field assistants; R. D. Gerard, cook; and L. E. Hall, weasel mechanic. Three weasels were used for transportation in the field.

The area examined approximates 1,000 square miles and is in the extreme southwest corner of Naval Petroleum Reserve No. 4. It is bounded on the west by Iligluruk Creek (east fork of the Kokolik) and on the east by Driftwood Creek. With the exception of Driftwood Creek, major streams were ascended to their headwaters in the De Long Mountains. A traverse southward over the Utukok-Kugururok Rivers divide was successfully completed, providing a "tie-in" with the work of Navy Oil Unit Party 7. Several traverses were made 8 miles north of the Driftwood anticline and to the west fork of the Colville River.

The objectives of this part of the summer's work were (1) the geologic mapping and stratigraphic study of the rocks exposed in this area, and (2) measurement of stratigraphic thicknesses of sediments older than those exposed in the Driftwood anticline. Geology was plotted on vertical and trimetrogon oblique aerial photographs. Altitudes were established by altimeter traverses.

The northern part of this area was previously investigated by members of the Navy Oil Unit. In 1947 R. M. Thompson and W. L. Barksdale[1] visited outcrops along the Utukok River, and in 1949 R. M. Chapman and E. G. Sable[2] examined exposures along the Kokolik River. (See fig. 1, index map.)

1/ Thompson, R. M., and Barksdale, W. L., Stratigraphy and structure of the Utukok River with notes on the Corwin-Cape Beaufort region, Alaska: U. S. Geological Survey Navy Oil Unit Report No. 4, 1947.

2/ Chapman, R. M., and Sable, E. G., Stratigraphy and structure of the Kokolik and Kukpowruk Rivers area, Alaska: U. S. Geological Survey Navy Oil Unit Report No. 33, 1949.

Topography.--The upper Kokolik-Utukok Rivers area lies in the physiographic provinces of the Arctic Foothills and the Brooks Range, and can be roughly divided into four physiographic belts.

North of the Driftwood anticline, Nanushuk group rocks occur in large synclinal mesas and cuestas, characteristic of the Northern Foothills section of this area. These are separated by wide featureless flats underlain by shale of the Torok formation zone A. The maximum relief of this area is approximately 1,500 feet.

South of the Driftwood anticline, which marks the boundary between the Northern and Southern Foothills sections, are lowlands which are underlain by nonresistant shale of the Torok formation. In this lowland belt, from 3 to 5 miles in width, outcrops occur in cutbanks along the larger streams.

Four miles south of the Driftwood anticline, a linear belt approximately 8 miles wide extends to the mountain front. This belt trends approximately N. 75° E. to east and consists of rubble-covered whaleback and hogback ridges, irregularly shaped hills, and cone-shaped knobs. Most of the northern part of this belt is covered by tundra. These topographic features are characteristic of areas underlain by infolded and faulted Cretaceous and Triassic rocks.

The Brooks Range province at the heads of the Utukok and Kokolik Rivers is topographically expressed as a group of high mountains and high rubble-covered hills that expose Devonian to Lower Cretaceous rocks. The Range trends from N. 55° E. to east. Altitudes are as high as 4,300 feet; the maximum relief is approximately 2,000 feet. Major north-flowing streams are usually moderately incised, with tundra- and gravel-covered floodplains; south-flowing tributary streams of the Kugururok River are deeply incised, with high canyon walls that provide good exposures of Cretaceous, Triassic, and Mississippian rocks.

STRATIGRAPHY

Sedimentary rocks identified in the upper Kokolik-Utukok Rivers area include Devonian rocks, Mississippian Lisburne limestone, Triassic Shublik formation, Lower Cretaceous Okpikruak and Torok formations, and the Lower Cretaceous Nanushuk group.

A geologic map (pl. 1), and generalized and composite stratigraphic sections (pl. 2) of these rocks accompany this report.

The geologic map shows surface geology mapped in 1950 together with that mapped in 1947 by Thompson and Barksdale, and in 1949 by Chapman and Sable, and also shows locations of sections measured in 1950. Because the area is one of extreme structural complexity, the mapping of all contacts of small isolated exposures was not possible, and many of these small outcrops are not shown.

Measurements of thickness and stratigraphic relationships of pre-Nanushuk group rocks were emphasized in the field study, as were faunal and lithologic data. Thicknesses given are approximate and in some cases estimated, based upon section measurements in various parts of the area, structure, gross lithologic features, and fossils. Owing to the complexity of structure, scarcity of complete exposures, facies changes, and erosional breaks, it was not possible to obtain totally reliable thickness measurements throughout the area. Therefore, rocks underlying the Driftwood anticline may vary considerably in lithology and thickness from those exposed in sections 12 to 25 miles farther south. The columnar section (pl. 2) is not specifically applicable to one locality.

Fossils of Devonian and Mississippian age have been examined by A. L. Bowsher, Sr., and those of Cretaceous age by R. W. Imlay. Mississippian identifications are tentative. A cursory examination of a few microfossil samples has been made by H. R. Bergquist.

Devonian rocks

Three small exposures of fossiliferous limestone identified as Devonian in age were examined in the upper Iligluruk Creek area. Two outcrops consist of light olive-gray, soft, coquinalike limestone with small amounts of medium-gray, dense, calcareous siltstone. Black and yellow-brown unfossiliferous shale containing lenses of siltstone and claystone appears to be interbedded with the limestone and siltstone. If the outcrops are Devonian, a maximum thickness of 200 feet is exposed. The third exposure consists of a few feet of medium-gray, dense, crystalline limestone. All limestones in the three localities contained Devonian spirifers and rhynconellids, and one collection was identified as Upper Devonian.

Devonian rocks are faulted with Triassic and Mississippian sequences; the total section thickness or specific stratigraphic position of Devonian rocks is unknown. These exposures mark the first known occurrence of Devonian rocks in the extreme western part of NPR-4. Because of their small area of outcrop, these rocks are not mapped in this report.

Mississippian rocks

Lisburne limestone

The Lisburne limestone in this area can be conveniently divided into three lithologic units for field mapping purposes: lower, middle, and upper.

In general two belts of Lisburne limestone are exposed along the north front of the Brooks Range west of the Utukok River. The belts are roughly parallel, trending approximately N. 80° E. immediately

west of the Utukok River and swinging southward to N. 55° E. on the west fork of Iligluruk Creek.

The northern belt of Lisburne limestone, occurring at the mountain front, is expressed as a series of discontinuous north-facing escarpment ridges which contact younger rocks in reverse fault relationships. In the extreme western part of the area, the bands of limestone broaden and are in complex fold and fault relationships with Triassic and Cretaceous rocks.

Exposed thicknesses of the Lisburne limestone in the northern belt represent only part of the entire Lisburne sequence, and range from 200 feet to 2,200 feet. In general, massive light- to medium-gray limestone and dark nodular cherts of the middle lithologic unit make up the bulk of these outcrops, but the lower lithologic unit is also represented adjacent to the Utukok River, and the upper unit occurs in the vicinity of the west fork of Iligluruk Creek.

Excellent mountain-top exposures of the Lisburne limestone occur in the southern Lisburne belt, which is approximately 1 to 2 miles south of the northern belt. The northern front of the southern belt is also a reverse fault contact. Approximately 6,700 feet of exposed section was examined a half mile south of camp 8A on the east fork of Iligluruk Creek and is believed to represent the major part of the total Lisburne limestone sequence. Neither the top nor the bottom of the section was exposed; the former is definitely a reverse fault contact. No breaks due to structural complexities were observed in the section, and the measurement is believed to be a reliable thickness. The lower, middle, and upper lithologic units are represented. The recognition of possible duplication of beds in this section would necessitate work of considerable detail. Smaller sections of Lisburne limestone 1,800 to 2,550 feet were measured 2 miles west and east of camp 10.

Isolated exposures of undifferentiated Lisburne limestone were examined south of the Utukok-Kugururok divide. They are complexly folded and faulted. Exposures of Lisburne east of the Utukok River were examined adjacent to the river. Descriptions and maximum measured thicknesses of the lower, middle, and upper lithologic units of the Lisburne limestone from oldest to youngest are listed below. Only the lower lithologic unit is delineated on the map (pl. 2) of this report; the middle and upper units are mapped as "Lisburne limestone undifferentiated."

Lower lithologic unit.--Near camp 8A, 4,450 feet of this unit was measured. The sequence consists mainly of dark-gray, silty to argillaceous hydroclastic limestone, platy to massive, occurring in beds 1 to 12 inches thick, and weathering a dark-yellow brown. A few thin beds of red-weathering silty limestone were seen near the base of the sequence. The limestone is nonfossiliferous to abundantly fossiliferous and contains crinoid columnals, brachiopods, gastropods, pelecypods, cephalopods, and a few trilobites. Fauna are listed on the columnar section (pl. 2).

Quartzite, quartzitic siltstone, calcareous siltstone, and calcareous very fine grained sandstone comprise approximately 20 percent of this unit. They are dark gray to blue gray, massive to blocky, dirty, weather dark-yellow brown, form massive ledges as much as 100 feet in thickness, and are abundant only in the lower part of the unit.

The lower lithologic unit differs from the middle and upper units in the silty and argillaceous character of the limestone; presence of quartzite, siltstone, and other clastics; the absence of chert; and the characteristic dark yellow-brown color of weathered outcrops.

The lower lithologic unit of the Lisburne limestone grades upward into the middle lithologic unit; a few medium-gray ("blue-gray") limestone beds characteristic of the middle unit appear in the upper 100 feet of the lower unit. Its upper contact has been placed at the first occurrence of massive chert-bearing limestone characteristic of the middle unit.

Fossils collected from the lower lithologic unit have been tentatively identified by A. L. Bowsher, Sr., as Lower Mississippian, equivalent in age to the first lithologic zone of the Lisburne limestone in the Kanayut Lake area, and younger than the "red limestone" of the Noatak formation in the Kanayut Lake area. If this age is correct, then a greatly thickened argillaceous and arenaceous sequence equivalent in age to the lower 200 feet of the Lisburne limestone of the Kanayut Lake area occurs in the upper Utukok-Kokolik Rivers area. The lower unit can be easily mapped in the western area, and may deserve a new member name. This sequence has not been previously measured, although it has been observed in thin rubble bands as far east as the Etivluk River.3/

Middle lithologic unit.--A section of 1,980 feet of this unit was examined near camp 8A. Both lower and upper contacts were exposed, and are conformable.

Approximately 60 percent of this zone consists of light- to medium-gray ("blue-gray"), massive to blocky, hydroclastic, and in part fossiliferous limestone, that occurs in resistant units as much as 50 feet thick. Most of the limestone is dense and finely crystalline, but occasionally coarsely crystalline to granular, and contains some beds of highly crinoidal "gravelly" limestone. A bituminous odor from fresh fracture surfaces is common. A few medium-gray dolomite beds less than 1 foot thick were observed; however, these are not common and were seen only in a few sections.

3/ Mangus, M. D., and others, Stratigraphy and structure of the Etivluk and Kuna Rivers area, Alaska: U. S. Geological Survey Navy Oil Unit Report No. 35, page 5.

Dark-gray to black chert, occurring as irregular nodules and lenses 1 to 1½ feet thick, constitutes approximately 30 percent of this unit. Sporadic fossils occur in the chert and it is believed that the major part of it is secondary in origin. Siliceous recementation of fractures in limestone was observed in several localities.

The middle lithologic unit contains a fauna of crinoids, brachiopods, horn corals, and a few trilobites. These have been tentatively identified as equivalent to the first, second, and perhaps the lower part of the third lithologic zones of the Wachsmuth member in the Kanayut Lake area. The upper part of the middle lithologic unit may be equivalent to the Alapah member of eastern areas. Designations of fossils and their approximate stratigraphic position are given on the columnar section (pl. 2).

Several smaller sections of this unit approximating the above thickness were measured at the heads of the Utukok River and Iligluruk Creek.

Upper lithologic unit.--A minimum of 200 feet and a maximum of 500 feet are postulated for the thickness of the upper lithologic unit of the Lisburne limestone in this area. The entire sequence was not exposed in any one locality, and the gross lithologic features so closely resemble rocks in the lower part of the Triassic Shublik formation that the exact section thickness is not known.

Dark-gray to sooty black, thick-bedded chert and dark-gray very fine grained, in part laminated, thin-bedded dense limestone constitute the major part of the section. Chert appears to be predominant and occurs in units as much as 50 feet thick. Minor amounts of black sooty shale were observed in some outcrops. No phosphatic zones were noted.

Brachiopods, gastropods, and cephalopods are scarce in limestone and shale. Identification of these has tentatively placed the upper lithologic unit in the Kiruktagiak member of the Lisburne limestone. A partial faunal list includes:

Lingula sp.
Leiorhynchus sp. B.
Munella cf. M. adonis (Bell)
Dictyoclostus cf. D. fliegeli (Paekelmann)
Mourlonia sp.
Rayonoceros vaughanum (Girty)
Chonetes cf. C. oklahomensis (Snyder)
"Productus" sp. indet.
Productella hirsutiformis (Girty)
Lyrogoniatites ? sp.

In 1949, 1,300-1,400 feet of dark-gray limestone, black chert, and black shale was measured on the Kukpowruk River.4/ It is believed to be part of the Lisburne limestone, and may in part be correlative with the upper lithologic unit described above. A possible thickening of this facies may occur westward from the Utukok-Kokolik area.

In general, the Wachsmuth member appears to thicken and the Alapah member to thin correspondingly in this area in comparison to Lisburne sections examined at Kanayut Lake. Areal distribution and reliable thickness measurements of the Lisburne limestone were too restricted to gain an idea of a possible northward facies change.

The Lisburne limestone in this area may be unsuitable for petroleum accumulation. Three favorable-looking limestones in the middle lithologic unit were sampled. These show effective porosity of less than 1.7 percent and are impermeable. The Lisburne is highly fractured but silica material occurs as fracture fillings in the middle and upper lithologic units, and chert forms a moderate percentage of the rock.

Pennsylvanian rocks

No rocks of Pennsylvanian age were recognized in the field. One shale sample from a locality on upper Iligluruk Creek contains conodont fragments tentatively identified by H. R. Bergquist as Pennsylvanian in age. This occurs in a faulted sequence of black and brown shales that contain nodules and lenses of claystone and calcareous siltstone. No Pennsylvanian rocks are shown in plate 1 of this report.

Upper Triassic rocks

Shublik formation

Rocks of Upper Triassic age are sporadically exposed in the Southern Foothills province. They are intricately folded, locally faulted with Cretaceous rocks, and are reflected in obscure east-northeast linear trends. In the Brooks Range province, bands of varying thickness are in extremely complex relationship with Devonian, Mississippian, and Cretaceous rocks.

In most outcrops of the Shublik formation the complex structure is undecipherable. No complete section of these rocks was found, and isolated exposures of 10 to 400 section-feet provided poor bases for correlation. Twelve hundred feet is estimated to be the total thickness of the Shublik formation, but a maximum of 1,500 feet and a minimum of 1,000 feet is not unlikely.

Bedded varicolored chert, thin-bedded cherty limestone, and shale constitute the bulk of the Shublik formation in this area. Chert beds are as much as 2 feet thick, and dense cherty units of 125 feet in thickness are present.

4/ Chapman, R. M., and Sable, E. G., Op. cit., pp. 4-5, p. 1A, p. 33A.

The lower 400 feet of the Shublik formation is predominantly a chert sequence, with thin interbeds of siltstone, limestone, and shale. Dark-gray to black, orange-weathering cherts are predominant, but maroon and green cherts containing Pseudomonotis are also present. The lower contact with Lisburne limestone was never found exposed, but is thought to be conformable.

Higher in the Shublik formation, approximately 200 feet of green-gray, blue-gray, olive, black, banded, glassy chert interbedded with thin-bedded green and black hard shale and gray, dense cherty limestone, was measured in various localities. This sequence contains scattered Pseudomonotis and Halobia (?) shells, black cannonball concretions, and nodules of pyrite.

Approximately 400 feet of dull-grey, olive, and green chert are interbedded with medium-gray and olive-gray siliceous shale and argillite, which are overlain by maroon, green, and black clay shale and silt shale. The latter units are believed to cap the section. Nodules and lenses of silty chert and siltstone occur in the clastics of this section. No megafossils were found.

Other small exposures of cherty sequences were impossible to correlate with known sections, due to complicated structural relationships.

Normal contacts of Shublik formation with Cretaceous rocks show wide variations both in Shublik lithology and in the overlying sequences. Rocks of the Shublik formation are overlain in the Brooks Range province by the Okpikruak formation of Lower Cretaceous age. In the foothills belt, near camp 9 on the Utukok River and camp 13 on Driftwood Creek, various units of the Torok formation appear to normally overlie an irregular surface of Shublik formation cherts and shales. An erosional hiatus is inferred; the pre-Cretaceous erosion surface may have been one of high relief, or one of complexly folded and/or faulted rocks.

No oil shale was encountered in the Shublik formation but Torok formation conglomerates contained a few oil shale cobbles. The Triassic oil shale is a nonresistant rock and if present it may be covered in the area examined.

Jurassic rocks

No known rocks of Jurassic age were seen in the upper Utukok-Kokolik Rivers area. Four hundred to 450 feet of unfossiliferous gray and green chert, and maroon, green, and black shale are believed to overlie fossiliferous Triassic rocks. Because of the similarity to Triassic chert and lack of other evidence, this sequence is tentatively placed in the uppermost part of the Shublik formation.

Lower Cretaceous rocks

Pre-Nanushuk group Lower Cretaceous rocks in the upper Utukok-Kokolik Rivers area have been tentatively subdivided into two major units, the Okpikruak formation and the Torok formation. The Torok has been further subdivided into four lithologic units.

Rocks of the Okpikruak and Torok formations are generally similar to those exposed in areas further east and consist of fine to coarse clastics. A notable exception is the Torok upper siltstone-shale unit which is prominent only in western areas.

No good evidence for a separate basin of Cretaceous deposition in western areas could be determined from field work. Further comparative laboratory and field studies are needed to determine the extent and nature of these sediments.

Okpikruak formation

Aucella-bearing rocks, herein designated as Okpikruak formation, is almost entirely confined in areal distribution to the Brooks Range province in the Utukok-Kokolik area. One thin linear belt, tentatively placed in the Okpikruak formation, occurs in the foothills section 1½ miles north of camp 6.

The Okpikruak formation exposed in the Brooks Range province is an easily mappable unit. The distinctive red-brown weathered surfaces and scattered Aucella crassicollis and shell fragments serve to distinguish this sequence from younger, coarsely clastic sequences.

In the vicinity of camp 7A at the head of the west fork of Iligluruk Creek, 1,620 feet of Okpikruak formation was measured. This is believed to represent the total thickness of the formation in this locality. The lower contact was obscured by rubble; the upper contact was conformable and gradational into shales of the lower shale-siltstone sequence of the Torok formation. In other exposures, Okpikruak conglomeratic siltstone, shale, and sandstone of the Okpikruak formation overlie various rocks of the Triassic Shublik formation and the Lisburne limestone. The contact appears conformable in most places, but high-angle folding, common in the area, makes stratigraphic relationships obscure.

Approximately 50 percent of the Okpikruak formation consists of dark green-gray to dark-gray, hard, massive to platy, poorly sorted sandstone, siltstone, and granule to pebble conglomerate. Massively cross bedded and lensing units are common. Creamy-weathering, dark-gray, dense lithographic limestone nodules and lenses are scattered throughout the section. Fissile to platy, dark-gray and dark gray-green, well-indurated shale and medium-gray siltstone and sandstone make up the remainder of the formation.

Massive pebble to boulder conglomerates crop out in the vicinity of camp 8A, camp 10, and in southernmost exposures of the Okpikruak formation. These conglomerates occur near the base of the formation and range in thickness from 5 to 400 feet. Constituents of the conglomerates range from granules to boulders 15 feet in diameter. These are subround to angular, and include Shublik formation chert and limestone, black chert, fossiliferous Lisburne limestone, gray-green quartzitic sandstone, quartzite, white quartz, mafic igneous rock, and schistose rock, well cemented in a silty and sandy matrix. Wood fragments are common. The entire aspect of the conglomerate is one of hasty and chaotic deposition. Interbedded sandstones and siltstones contain Aucella crassicollis. Percentages of rock types in these basal Okpikruak conglomerates vary considerably in different localities. In exposures at the head of the Utukok River, mafic igneous pebbles and cobbles are predominant. These exposures occur less than 2 miles north of exposed igneous rocks. Five miles west, at the head of the east fork of Iligluruk Creek, constituents of the conglomerates are mainly Triassic and Mississippian cherts. No exposed igneous rocks are present within 4 miles of these conglomerates. Although the evidence is not conclusive, it is believed the Okpikruak formation in the Brooks Range province was deposited from a nearby source area.

A distinctive sequence of light-pink to dark-gray massive, clean quartzites and quartzitic siltstone, green and maroon shale, and coquinoid limestone bearing Aucella crassicollis, Aucella sp. and Aucellina sp. occurs in a narrow band north of camp 6 and extends in intermittent exposures from Adventure Creek to the Kokolik River. A minimum thickness of 225 feet was measured. Upper and lower contacts are not exposed, and the exact position of the sequence is unknown. It was seen in no other part of the area and may represent only a local facies. On the basis of faunal determinations this sequence is tentatively placed in the Okpikruak formation, and is believed to occur in the upper part.

The Okpikruak formation was formerly assigned an early Lower (Neocomian) Cretaceous age because of the occurrence of Aucella crassicollis, but a few Aucellina sp. believed to be of late Lower (Albian) Cretaceous age occur near the top of the formation and are apparently associated with Aucella crassicollis. As a result, uncertainty exists regarding the reliability of these fossils as specific time markers in Lower Cretaceous rocks of this region.

Rocks of the Okpikruak formation are slightly to noncalcareous and well-indurated. One sample from the upper part of the formation has a porosity of 7.32 percent but is impermeable. No direct evidence of petroleum accumulations was noted in the Okpikruak formation.

Torok formation

A post-Okpikruak sequence of fine to coarse clastic rocks believed to be 12,300 feet thick and almost devoid of fossils, is tentatively assigned to the Torok formation in the upper Utukok-Kokolik rivers area.

Upon the completion of micropaleontologic studies, a revision of the Torok formation may be necessary. At present it is subdivided into four lithologic units in this area. They are, in ascending order: lower shale-siltstone unit, conglomerate unit, upper siltstone-shale unit, and zone A shale unit. Clear-cut contacts between these units are not exposed; however, all are believed to be conformable and gradational contacts. If angular relationships do exist, they are obscured by structural complications in the area.

Lower shale-siltstone unit.--Eight hundred feet of this unit was measured in three separate localities: camp 7A, Iligluruk Creek; camp 9, Utukok River; and camp 13, Driftwood Creek. At camp 7A, the lower shale-siltstone unit overlies the Okpikruak formation; at camp 13 it rests on an irregular surface of Shublik formation chert, limestone, and shale. The measurements are believed to represent almost a total thickness of the unit, which is believed to be approximately 900 feet thick.

Rocks of this unit consist largely of dark-gray to black fissile silt shale and clay shale 6 inches to 15 feet thick. These are interbedded with dark-gray to black, hard, noncalcareous, highly micaceous, platy to blocky siltstone that contains reverse impressions of scour markings, tiny ripple marks, fine cross bedding, mud flows, worm trails and undeterminable pelecypods, and a few pyrite nodules. The siltstones weather dull gray to purplish. Siltstone beds are usually less than a foot thick, but a few beds as much as 25 feet thick occur in the upper part of the section interbedded with gray-green sandstone and granule conglomerate of the Torok formation.

A fairly regular alternation of siltstone and shale beds is persistent in large outcrops and resembles cyclic deposition. This feature combined with the dense character and dark color of the siltstone is distinctively characteristic of this unit. In a belt north of the mountain front the lower shale-siltstone unit is highly infolded with the Torok and Okpikruak (?) formations; these are mapped as "Undifferentiated Lower Cretaceous rocks."

Conglomerate unit.--At camp 9 on the Utukok River 1,300 feet of this unit is well-exposed. The contacts were obscure. The unit is topographically expressed by sharp hogback ridges in a persistent band that strikes N. 60°-70° E. and crosses all major drainages. On Driftwood Creek this band is approximately 4 miles wide and narrows westward to a width of a half mile on the west fork of Iligluruk Creek. From stratigraphic relationships on either side of the band it appears that this areal "thinning" represents a stratigraphic thinning of this unit westward rather than disappearance owing to a plunging structure. Since the thickness is believed to vary, no one measurement can be considered adequate for the whole area. The unit may be as much as 1,700 feet thick directly south of the Driftwood anticline.

Green-gray to medium dark-gray, moderately calcareous, graywacke-type sandstone and granule conglomerate constitute 50 percent of the unit. These occur in massive, well-indurated, lenslike beds as much as 10 feet thick, and contain mud lumps, fucoidal markings, shale pebbles, wood fragments, and a few pebbles and cobbles of white quartz, varicolored chert, and oil shale. They weather yellow green to red brown. Medium to dark-gray silt shale and clay shale with some beds of gray siltstone and sandstone constitute the remainder of the unit.

One fragment of an unidentified ammonite was found in this unit west of the Utukok River at the headwaters of Adventure Creek. On Driftwood Creek, 1½ miles south of camp 12, thin beds of coquinoid limestone containing Aucellina sp. and Aucella sp., dark-gray and gray-green shales containing nodular cherty limestone appear to be interbedded with gray-green sandstone and conglomerate, and are believed to lie near the top of the conglomerate unit.

The conglomerate unit may in part be correlative to the upper siltstone-shale unit of the Torok formation. Thin discontinuous traces of conglomeratic sandstone occur in the latter unit on the south flank of the Driftwood anticline, and were seen in several exposures of this unit in other localities.

Upper siltstone-shale unit.--This unit is exposed in the core of the Driftwood anticline and also in a N. 70° E.-trending belt 3 to 6 miles south of the anticline where it is expressed as a series of linear whaleback ridges. The belt contains intricately folded rocks, and widens from east to west. At Driftwood Creek, the width of the belt is 2 miles; on Iligluruk Creek its width is 5 miles. Structural measurements based on sporadic outcrops in the Driftwood anticline along the Utukok River reveal a thickness of approximately 4,000 feet exposed on both flanks. One and one-half miles south of camp 5 on Iliguruk Creek, 3,100 feet of this unit occurs in a relatively uncomplicated section. Approximately 4 miles south of camp 5, 900 to 1,000 feet of another section was measured. The latter section contains rocks similar to the first two but they are slightly coarser grained and more poorly indurated, and are thought to lie near the base of the unit. On the basis of areal distribution, the unit is believed to be thicker than the latter two measurements combined, and is estimated to be 4,400 feet thick. It may be as much as 5,000 feet thick.

Siltstone, sandstone, conglomeratic lenses, clay shale, and silt shale constitute this unit. The coarser clastics comprise approximately 30 percent to 50 percent of the rocks and vary in thickness from 6 inches to 25 feet. They are medium gray to olive gray, moderately micaceous, highly calcareous, and moderately to well-indurated. Prominent fucoidal markings, mud-flow phenomena, worm trails, carbonaceous material, and shale pebbles are common. A very finely cross bedded to laminated appearance is characteristic of the siltstones. Lenses of green-gray conglomerate and conglomeratic sandstone occur in the upper and lower parts of the section. Dark-gray nodular to blocky silt shale and clay shale make up the remainder of the rock in this unit; these are indistinguishable from Torok formation zone A shales.

Six samples of clastics of the Torok formation tested for porosity and permeability yielded maximum results of 7.93 percent and 1.2 millidarcys. The dirty, calcareous, and usually well-indurated character of the rocks is typical of this formation.

Zone A shale unit.--The zone A shale unit of the Torok formation is exposed in stream-cuts of the lowland areas south and north of the Driftwood anticline. The southern area, 2 to 7 miles wide, is structurally a synclinorium. North of the anticline, anticlinal structures of Nanushuk group rocks are breached to the zone A shale unit.

Approximately 5,200 feet of zone A was examined in good but discontinuous exposures on Adventure Creek, from the Driftwood anticline southward. A fairly distinctive sandy zone lies approximately 500 feet below the top of this section. This zone occurs north of the Driftwood anticline, 4 miles north of camp 3, and appears to be roughly 1,000 feet below the base of the Nanushuk group. The total section of zone A is therefore believed to be approximately 5,700 feet thick.

The zone A shale unit, a monotonous sequence of predominating clay shale and silt shale, contains thin interbeds of medium-gray calcareous siltstone and very fine grained sandstone. The shales are medium, dark, and olive gray, thin nodular to blocky, dull, moderately calcareous, and in part laminated. Locally they contain iron-stained beds with abundant coaly material.

The sandy zone, roughly 1,000 feet below the top of zone A, consists of medium-gray, dark yellow-brown-weathering calcareous siltstone and sandstone with associated mud flows. Carbonaceous fragments are common; one indistinct pelecypod, resembling Tellina sp. of Nanushuk group, zones B-C, was found. A sandy and shaly sequence with 2 feet of bentonitic claystone interbedded was examined in an isolated cut along the Utukok River. This may be correlative with the above-described sandy zone.

Within 50 feet of the base of the zone A shale unit, a shale sequence containing lenses and nodules of buff-colored claystone, dark-gray chert pebbles, gray silty limestone exhibiting cone-in-cone structure, and septarian concretions, forms a distinctive sequence. This was observed only on the north flank of the Driftwood anticline.

An increase in siltstone and sandstone occurs in the upper part of zone A.

Zones B-C Undifferentiated.--Detailed stratigraphic and structural studies were undertaken in the Utukok-Kokolik Rivers area by Navy Oil Unit parties in 1947[5] and 1949.[6] In 1950, party 1 made no attempt at

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5/ Thompson, R. M., and Barksdale, W. L., Op. cit.
6/ Chapman, R. M., and Sable, E. G., Op. cit.

detailed description or measurement of sections in the Nanushuk group, but concentrated on relationship and position of the Torok formation-Nanushuk group contact.

Southernmost exposures of Nanushuk group rocks are in prominant cuestas and mesas of broad synclines, separated by breached anticlines. In Meat Mountain, 2 miles north of the Driftwood anticline, approximately 1,900 feet of Nanushuk group, zones B-C, are exposed; and in syncline 2 on the Kokolik River 6 miles west of the Driftwood anticline 3,800 feet of zones B-C and 1,000 feet of zones D-E were measured.

Basal rocks of zones B-C include thick resistant units of massive to platy, gray, calcareous siltstones and sandstones interbedded with dark gray calcareous shales. Cretaceous pelecypods are rare.

The Torok-Nanushuk contact has been placed at the lowermost ledge-forming sandstone of zones B-C. Below these "ledges," scattered outcrops and heaved blocks reflect a predominant shale sequence with scattered large lenses of siltstone and sandstone. This is a lithologic contact and should not be considered as a time boundary.

Previous investigations in 1947 suggested that an angular unconformity between zones B-C ("Upper Cretaceous" - 1947) and Torok formation zone A ("Killik group" - 1947) was exposed on the east bank of the Utukok River 7 miles north of camp 2. A re-examination of these outcrops failed to yield such clear-cut relationships; rather than an unconformity, a progressive change of dip over a short stratigraphic interval was observed. A quick steepening of dips such as this is common on flanks of anticlines in the Nanushuk group in the western areas of NPR-4, and the above-mentioned exposures appear to be in such a structural position. The Torok-Nanushuk contact is believed to be conformable and gradational.

IGNEOUS ROCKS

Exposed igneous rocks in the Utukok-Kokolik Rivers area are present only in the vicinity of the Utukok River headwaters, and in south-flowing drainage heading against the Utukok-Kugururok Rivers divide. Jagged mountains 1 to 2 miles in breadth reflect igneous rocks south of the Utukok River, and a few smaller exposures occur in upper Utukok drainage.

These rocks are of mafic composition, are dark green, finely to coarsely crystalline, and weather dark red brown. They suggest tabular to pluglike bodies, which appear to be faulted and folded with Mississippian, Triassic, and Cretaceous sedimentary rocks. Complex structural relationships and lack of well-exposed contacts make age determination of these igneous rocks uncertain; they appear to intrude Mississippian and Triassic rocks, and to be in fault relationship with rocks of Cretaceous age. Okpikruak formation basal conglomerates contain pebbles and cobbles of mafic igneous rocks; therefore, some igneous intrusions occurred in pre-Cretaceous time.

Structure and interpretations

Regional structural trends of pre-Nanushuk group rocks in the Southern Foothills and Brooks Range provinces parallel the southward swing of the Brooks Range along its western extension. In the upper Utukok-Kokolik Rivers area a strong N. 70° E. trend is common. Further west, in the area of the Kukpowruk River headwaters, a pronounced N. 50° E. trend occurs. This change may be due to either a change in direction of tectonic movement or a regional plunge to the west.

In the area mapped there is a regional south dip and progressively older rocks are encountered from north to south.

In the Southern Foothills province, numerous tight folds generally parallel the trend of the mountain front and are predominant over faulting, in contrast to extensive reverse faulting at the north front of and within the Range. The folding diminishes northward from the Range, and Nanushuk group rocks north of the Driftwood anticline are exposed in relatively simple folds.

Southward from the Driftwood anticline, a synclinorium of complexly folded incompetent Torok zone A shale unit is succeeded by sharply folded and faulted older Cretaceous rocks. As a result of this type of structure, and from lack of sufficient exposure, major structures, if present in this belt, could not be delineated. Triassic rocks are exposed as infolds or are in fault relationship with Cretaceous sequences and are so complexly folded, faulted, and crushed that little can be done in the delineation of structure.

At the mountain front and within the Range, reverse faults of considerable displacement bring Triassic and Mississippian rocks in contact with rocks of Cretaceous age. With the exception of the southern belt of competent Mississippian rocks, extremely complex relationships occur within the mountain front. The Mississippian rocks are thrust over younger sediments but appear to maintain a normal succession within the unit.

Near the head of the Utukok River a northward "bulge" of linear structural trends appears to reflect areas of igneous rock to the south. These trends may be the result of intrusion associated with orogenic movements, or of igneous rock masses acting as "buttresses" during post-intrusive tectonic movements.

Contacts between the Okpikruak formation and older rocks appear to be conformable but sharp. However, in its normal contacts the Okpikruak formation overlies rocks of such a variety of types and ages that an erosional unconformity of considerable magnitude appears to be present. Known Triassic and Mississippian rocks occur as constituents of coarse Okpikruak clastics which are believed to have been deposited close to their source area. This infers that Triassic and

Mississippian rocks were exposed to erosional agencies at the same time, either in a region of high relief or in one containing folded and/or faulted rocks. One possible explanation of present relationships would involve shallow-angle thrust faulting of pre-Cretaceous formations; erosion; deposition of Cretaceous sediments; and subsequent tectonic movements involving a second disturbance.

Surface exposures of Okpikruak formation appear to be almost entirely limited to the Brooks Range province and only one thin belt, tentatively assigned to the Okpikruak, was recognized in more northerly areas. This may be due to a northward facies change, or to an erosional unconformity between the Okpikruak and Torok formations, with most of the Okpikruak formation being eroded north of the Range. If the latter be true, subsurface Okpikruak rocks may not be present in the Driftwood anticline vicinity.

PETROLEUM POSSIBILITIES

1. No definite evidence of eastward plunge is apparent from surface studies of the Driftwood anticline, although some suggestions of this are present.

2. Torok formation sandstones and siltstones are usually well indurated and calcareous. Conglomerates are poorly sorted. No significant results were obtained from porosity-permeability determinations.

3. Okpikruak formation sandstones and conglomerates are poorly sorted, hard, and of low porosity.

4. No oil shales were seen in the Shublik formation, most of which consists of impervious rocks. Cherts are highly fractured, however.

5. The Lisburne limestone appears to be of low porosity throughout. Three samples showed a maximum porosity of 1.66 percent; two of these were impermeable; one was unsuitable for testing. Only a minor percentage of dolomite is present, and secondary (?) chert is common. The Lisburne limestone is highly fractured, but some siliceous recementation has taken place. A bituminous odor was noticed in limestones of the middle lithologic unit and in fractured cherts of the upper lithologic unit.

6. All structures south of the Driftwood anticline are exceedingly complex. Not one simple structure of good dimensions is exposed. High-angle reverse faulting and intense drag folding occur along the entire mountain front.

7. No oil or gas seeps, asphaltic residues, or other direct indications of petroleum accumulation were found.

8. Possible source beds may lie in the middle and upper lithologic units of the Lisburne limestone.

SUMMARY

1. Three small exposures of Devonian limestone faulted with younger rocks were examined in the upper Utukok-Kokolik Rivers area. The total section thickness is unknown.

2. Lisburne limestone crops out in the Brooks Range province of the upper Utukok-Kokolik area. An apparently uncomplex section of approximately 6,700 feet was measured. The Lisburne limestone in this area has been tentatively divided into three lithologic units: lower, middle, and upper. The lower unit consists of silty limestone and quartzite, and is approximately 4,400 feet thick. Massive limestone and nodular chert comprise the middle unit; approximately 2,000 feet were measured. The upper unit is believed to be 300 feet thick, and possibly as much as 500 feet. Black bedded chert, black limestone, and black shale are representative rock types of this unit. All three units contain fossils.

3. One small exposure of black and brown shales was tentatively identified as Pennsylvanian in age on the basis of microfossils.

4. The Triassic Shublik formation is believed to be about 1,200 feet thick. Varicolored chert, cherty limestone, maroon, green, and gray shale and minor amounts of siltstone are represented. Some cherts and limestones are fossiliferous. The upper part of this formation may include rocks of Jurassic age.

5. Pre-Nanushuk Lower Cretaceous rocks are divided into two units: the Okpikruak formation and the Torok formation. The Torok formation is further subdivided into four lithologic units: lower shale-siltstone unit, conglomerate unit, upper siltstone-shale unit, and zone A shales. The Okpikruak formation is about 1,650 feet thick and consists of argillaceous sandstones and siltstones, shales, local quartzites, and coquinoid limestone. The fossil Aucella is common. No definite erosional break was evident between the Okpikruak and Torok formations; however, Okpikruak rocks crop out only in restricted areas, and this may reflect an erosional unconformity. The lower unit of the Torok formation consists of approximately 900 feet of dark-gray shale and dense siltstone. The Torok conglomerate unit, similar in appearance to coarse clastics of the Okpikruak, is at least 1,300 feet thick in part and may be correlative to the overlying upper siltstone-shale unit. The upper unit, a sequence of gray calcareous siltstone, sandstone, and shale, is believed to be 4,400 feet thick, but may be as much as 5,000 feet. A predominantly calcareous shale sequence with thin interbeds of siltstone constitutes zone A and appears to be 5,700 feet thick. No unconformities were recognized within the Torok formation.

6. Zone A of the Torok formation appears to be conformable and gradational with Nanushuk group zones B-C.

7. Few large structures south of the Driftwood anticline can be delineated. Extremely tight folding and some faulting is common in the Southern Foothills section, and reverse faulting is pronounced in the Brooks Range. A regional westward plunge may exist.

8. In general the porosity and permeability of the rocks in the area mapped are low. Fracturing is common but fractures are filled with secondary minerals. Oil shales do not crop out in this area and no seeps or asphaltic residues were seen. With the exception of the Driftwood anticline the area is structurally very complex.