United States

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U.S. Geological Survey

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Preliminary Report 40

STRATIGRAPHY AND STRUCTURE OF THE SHAVIOVIK AND CANNING RIVERS AREA, ALASKA

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By

A. Samuel Keller and Robert H. Morris

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STRATIGRAPHY AND STRUCTURE OF THE SHAVIOVIK AND CANNING RIVERS AREA, ALASKA

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INTRODUCTION

During the 1952 field season, U. S. Geological Survey (Navy Oil Unit) party 1 studied the stratigraphy and structure in the area between the westernmost fork of the Shaviovik River and the Canning River. In addition to these large rivers, the area is drained by the Juniper Fork and the Kavik River, major tributaries of the Shaviovik River. The area studied, approximately 1,400 square miles, is bounded on the south by mountains made up of Lisburne limestone, on the east by the Canning River, on the west by the West Fork of the Shaviovik River, and extends to latitude 69°45'N. The area lies wholly within the Brooks Range and Arctic Foothills provinces.

Party 1 consisted of six men: A. S. Keller and R. H. Morris, geologists; J. Downs and H. G. Richards, field assistants; L. G. Barbin, cook-field assistant; and T. F. Derrington, weasel mechanic. The party utilized three weasels for transportation of equipment and personnel during the field season. Work was initiated on the Shaviovik River on June 9, 1952, and early snows forced the conclusion of the investigation on August 22, 1952.

In 1947, G. Gryc and M. D. Mangus made reconnaissance studies of the rocks in parts of this area by boat traverse down the Kavik and Canning Rivers 1/. G. Gryc revisited outcrops on the Canning River for short periods during the summers of 1950 and 1951. No other work of a geologic nature has been done in this area during recent years.

The primary objective of the 1952 party was to study in detail the nature, extent and petroleum possibilities of the structural high in the area of the West Fork of the Shaviovik River; this high was indicated by studies by Navy Oil Unit party 1 in 1951 2/ and 3/. A secondary objective of the party was to complete correlation of upper Paleozoic and Mesozoic formations between this area and the area west of the Itkillik River 2/.

1/ Gryc, G., and Mangus, M. D., Preliminary report on the structure and stratigraphy of the Shaviovik and Canning Rivers area, Alaska: U. S. Geological Survey Navy Oil Unit Prelim. Rep. 10, 1947.

2/ Keller, A. S., and Detterman, R. L., Preliminary report on the stratigraphy and structure in the Shaviovik and Sagavanirktok Rivers area, Alaska: U. S. Geological Survey Navy Oil Unit Prelim. Rep. 36, 1951.

3/ Keller, A. S., The Shaviovik structural high: Report to the Advisory Committee NPR-4., April 1952.

The area was mapped on vertical photographs (scale, 1:20,000) and transferred to trimetrogon drainage maps at scales of 1:40,000 and 1:96,000. An altimeter traverse was carried concurrently with the geologic mapping and altitudes were referred to approximate sea level.

GENERAL GEOLOGY

The Shaviovik and Canning Rivers area is divisible into two distinct physiographic provinces: the Brooks Range province and the Arctic Foothills province. Only the northerly part of the Brooks Range province was studied. Within this physiographic belt, the peaks of resistant Lisburne limestone attain altitudes of approximately 4,500 feet. Relief ranges from 2,000 to 2,500 feet. The Foothills province lies north of the mountain range. Relief in this area is less than 1,500 feet. In the southern part of this province the Sadlerochit and Kingak formations, resistant sandstones, form east-trending hogbacks and cuestas. The monotony of the northern part of the province is interrupted only by cuestas of gently folded sandstone of the Ignek formation and sandstone and conglomerate of the Kavik formation.

The major streams of the area are consequent streams with well-developed floodplains. Dendritic and trellis drainage patterns are well-developed by the tributaries of the major streams. Extensive ice fields have developed in wide floodplain areas associated with larger streams, with the stratified ice locally exceeding 10 feet in thickness. Gravel terraces are present along the major streams, and interstream areas are sparsely covered with remnants of older pediment (?) gravels. In the lowland area to the north are numerous small lakes, many of which are decreasing in size by encroaching of the tundra and by lowering of outlet levels. Where lakes have been drained, old shoreline scars and swampy tundra basins remain. The partly drained lakes are particularly conspicuous in areas where the underlying bed rock is shale.

Pleistocene montane glaciation has been extensive in the larger river valleys.

STRATIGRAPHY

Sedimentary rocks in the Shaviovik and Canning Rivers area include the Permian Sadlerochit formation; the Triassic Shublik formation; the Jurassic Kingak formation; the Lower Cretaceous Okpikruak formation; the Lower Cretaceous Ignek formation (lower member); the Upper Cretaceous Ignek formation (upper member); and the Tertiary Kavik formation.

As a result of the season's work, Cenozoic, Mesozoic, and Paleozoic rocks east of the Shaviovik River may be correlated with those west of this area. These correlations are discussed in the following pages. Correlated columnar sections have been prepared to facilitate study of these formations, and are presented on plate 2.

Because no detailed fossil examinations have yet been completed, it must be emphasized that positions of mapped contacts, as well as the ages of some of the formations, are subject to change. For the present, geologic contacts and ages of rocks are based largely on direct field analysis.

Owing to the nature of this investigation no detailed study was made of pre-Permian rocks. For a detailed analysis of Lisburne formation and older rocks in adjoining areas, reference is made to Preliminary Report 42 [1].

Permian system

Sadlerochit formation

Rocks of the Sadlerochit formation are confined to a relatively narrow geographic belt 1 to 3 miles wide that flanks the mountains of Lisburne limestone. Owing to its resistant nature, the basal part of the Sadlerochit formation in places is found as erosional remnants that cap anticlinal cores of Lisburne limestone. The ferruginous weathering, characteristic of the basal and upper parts of the formation, plus the tendency of the upper horizon to form east-trending cuestas, are criteria for identification of the Sadlerochit formation in this area.

The formation attains its maximum thickness of 2,100 ± feet on Kemik Creek and thins to the east and north. Thicknesses measured were: Kemik Creek, 2,100 ± feet; Juniper Fork, 2,000 ± feet; Pogopuk Creek, 2,000 ± feet; Kavik River (south), 1,500 feet; Kavik River (north), 1,500 feet; and Canning River, 1,200 ± feet. These sections are presented on plate 2. An isopachous map based on the limited data available is presented in plate 5.

In general the formation may be divided into three major units: a lower heavy-bedded unit that ranges from 300 to 500 feet in thickness in the area, and becomes more coarsely clastic northward; a middle ferruginous-weathering silt shale and thin-bedded dense siltstone unit that ranges from 300 to 700 feet in thickness and becomes only slightly sandier northward; and an upper massive-bedded siltstone, sandstone, and cyclic-bedded siltstone-silt shale unit that ranges from 400 to 900 feet in thickness. The heavy-bedded siltstone and sandstone within this unit also become slightly more coarsely clastic northward.

The Kemik Creek section (column A, pl. 2) is not well-exposed. The basal part of the section consists of approximately 500 feet of massively bedded, hard, well-indurated, cherty to siliceous siltstone and fine-grained, dark-gray, limonite-flecked quartzitic rock. The siliceous siltstones are blue gray to greenish with wax-brown to rust-brown weathered

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[1] Brosgé, W. P., Dutro, J. T., Mangus, M. D., and Reiser, H. N., Stratigraphy and structure of selected localities in the eastern Brooks Range area, Alaska: U. S. Geological Survey Navy Oil Unit Prelim. Rep. 42, 1952. (in preparation)

surfaces. Subvitreous chert occurs as lenses and as interbeds. Within the basal 75 feet productid-type brachiopods, Spirifer sp., horn corals, and gastropods are common. The fossil-bearing beds are a rust-brown weathering, siliceous, light-gray limestone. Small-scale quartz veins and prismatic calcite occur throughout the massively bedded unit. The contact with the Lisburne formation appears to be structurally conformable.

The middle unit of the Kemik Creek section is exposed only as rubble. As such it consists of approximately 700 feet of light-gray sandy siltstone that weathers rust brown to metallic gun-metal blue, and light yellow-red weathering shale.

Overlying this series is approximately 900 feet of cyclic-bedded sandstone, siltstone, and silt shale. The sandstone and siltstone are dense, siliceous, predominantly thin bedded but locally massive, light gray to dark yellow red. Minor small-scale cross bedding is present in the laminated siltstones. Limonite concretions occur locally throughout the unit. Fucoidal markings and ripple marks are present, predominantly in the upper part of the upper unit.

The contact with the overlying Shublik formation is unexposed.

The Juniper Fork section (column B, pl. 2) compares closely in facies and thickness with that at Kemik Creek. The basal unit is 600 feet thick and consists of massively bedded cherty argillitic siltstone and subvitreous gray to green chert. Horn corals are present in coquinoid cherty limestone near the base of the unit. A 4-foot bed of cherty light-gray limestone with strong fetid odor, and containing spirifer-type brachiopods, occurs 132 feet above the base of the section. A similar appearing 13-foot limestone unit occurs between 208 and 225 feet above the base of the section and contains abundant corals, spirifer-type and other brachiopods, and excellently preserved bryozoa. Quartz veins, locally as much as 1 foot thick, are present throughout much of the 600 feet. The contact of this unit with the Lisburne limestone is structurally conformable.

Overlying this 600-foot section is approximately 600 feet of poorly exposed, nonresistant, ferruginous-weathering silt shale and thin-bedded siliceous siltstone.

The upper 800-foot unit varies but little from that described in the Kemik Creek section. However this section is composed of a slightly more marginal (near shore) facies. Ripple marks and fucoidal markings increase in abundance, and pelecypods occur in the more marginal appearing, very fine grained sandstones. Gastropods and ammonites (?) were noted in float but their position in the section could not be determined. The 20-foot unit immediately underlying the contact with the Shublik formation consists of interbedded platy silt shale and very fine, laminated, dense siltstone. The contact with the overlying Shublik formation is structurally conformable.

The basal unit of the 2,000 ± foot Pogopuk Creek section (column C, pl. 2) consists of 400 feet of massive- to thin-bedded, dark-gray to dark blue-gray, limonitic weathering subvitreous chert. Brachiopods are present 120 feet above the base in a dark blue-gray, limonitic weathering, 4-foot silicified limestone bed. A strong fetid odor is given off when the rock is freshly broken. The limestone grades upward into olive-colored chert which contains abundant minute pyrite crystals. The contact of the basal unit with the underlying Lisburne limestone is structurally conformable.

Overlying the basal 400 feet is a covered interval of approximately 700 feet. The topographic expression of this interval suggests a correlation with the nonresistant middle units of the Juniper Fork and Kemik Creek sections.

Overlying this 700-foot covered interval is 900 feet of interbedded and cyclic-bedded sandstone, siltstone, and silt shale. Sandstone and siltstone beds as much as 2 feet thick are interlayered with 6- to 8-foot beds of silt shale. The sandstone is very fine to medium-grained, well-indurated, locally siliceous, medium gray with limonitic weathering, and locally has a white efflorescence. The uppermost sandstone beds are more deltaic in appearance. In addition to being micaceous and carbonaceous, they exhibit ripple marks and small-scale cross bedding. The contact with the Shublik formation is structurally conformable. The Permian-Triassic contact is marked by a pebbly ferruginous zone and a break in lithology.

The Kavik River sections (columns D and E, pl. 2) are the best controlled sections in the area. Inasmuch as the sections are but a few miles apart, forming the north flank and south flank of an anticline with a core of Lisburne limestone, it is feasible to discuss them together. The Kavik River sections are structurally conformable with the underlying Lisburne limestone. A composite of the two is presented below:

	Triassic-Permian contact
70 feet	Top of section marked by 3-foot bed of rust-weathering, very fine grained, micaceous, ripple-marked, noncalcareous sandy siltstone. Remainder of section interbedded to cyclic-bedded, dirty, cross-bedded, fucoidal marked, siltstone and ferruginous weathering hackly silt shale in beds ranging from one-fourth inch to 2 inches thick.
50 feet	Dark-gray, ferruginous-weathering hackly silt shale.
50 feet	Interbedded, ferruginous-weathering, hackly-fracturing silt shale and dark-gray silicified siltstone and metallic-weathering subvitreous chert in beds up to 2 feet thick. Cross bedding in fine laminations in the more sandy siltstone.

100 feet	Cyclic-bedded ferruginous-weathering hackly silt shale and finely laminated, dark-gray, noncalcareous silicified siltstone.
50 feet	Same as above. Shale shows more yellow-red oxidation. Cross bedding is more pronounced in the sandy, finely laminated siltstone.
68 feet	Monotonous series of cyclic-bedded dark-gray, cross-bedded, locally silicified siltstone and platy, rust weathering, silt shale in 4-inch beds. Few dense light-gray, finely cross bedded and laminated siltstone and micaceous, ripple-marked shaly siltstone.
50 feet	Cyclic-bedded siltstone and silt shale similar to that described above.
32 feet	Covered interval.
100 feet	Cyclic-bedded, ferruginous-weathering silt shale and dark-gray siltstone, in 2- to 8-inch beds. Cross bedding in finely laminated sandstone lenses in the silt shale.
87 feet	Covered interval.
65 feet	Section same as above. Upper 30 feet weathers pronounced rust brown and becomes slightly more massive than siltstones described above.
50 feet	Section similar to above. Beds in siltstone average 1/2 inch thick. Medium-gray siltstone is cross-bedded where finely laminated.
50 feet	Dark-gray, finely laminated, cross-bedded, locally siliceous siltstone in beds from 1/2 inch to 2 inches, cyclicly interbedded with red-brown-weathering silt shale.
50 feet	Interbedded yellow-brown-red weathering, hackly fracturing silt shale and dark gray, massive-bedded, black, cherty to finely laminated siltstone.
61 feet	Covered interval.
27 feet	Section same as that described above. Upper 6 feet more massive, finely laminated with blocky fracture.
50 feet	Hackly, ferruginous-weathering silt shale. Few small siltstone concretions. Ammonite present in rubble.

50 feet	Ferruginous-weathering silt shale. Spheroidal, rust-weathering siltstone concretions containing a profuse ammonite and pelecypod fauna. This horizon is correlative with that seen on Kashivi Creek, the Ivishak River, and Flood Creek during the 1951 field season 5/. Fossils identified from this horizon are considered to be of Permian age.
50 feet	Hackly-fracturing silt shale, weathering orange, yellow, rust, and metallic hues. Pyritic, dark-gray, locally finely laminated siltstone lenses and beds up to 1 inch thick.
50 feet	Little or no change from above.
50 feet	Section consists of ferruginous-weathering, hackly silt shale to paper shale and dark-gray pyritic siltstone lenses and beds. Slaglike weathering coats much of the shale. Locally the siltstone is finely laminated. One ammonite fragment was found on a bedding plane 12 feet from top of section.
80 feet	Covered interval.
60 feet	Argillitic, massively bedded, siliceous, rust weathering blue-gray siltstone. Grades locally into subvitreous chert.
80 feet	Same as above.
20 feet	Section identical with above. Several lenses of silicified blue-gray limestone contain a profuse poorly preserved brachiopod-bryozoa fauna.
50 feet	Argillitic 3- to 5-foot bedded, dark gray-blue, rust-weathering, limonite-specked siliceous siltstone and blue-gray subvitreous chert.
	Permian-Mississippian contact.

The most pronounced change in the Sadlerochit formation occurs in the Canning River area and is doubtless due to the closer proximity of the Canning River section (column F, pl. 2) to the post-Mississippian shoreline which appears to have been to the north and east (pl. 5). In the Canning River area Permian rocks are not particularly well exposed, and column F, plate 2, represents a composite section pieced together from several localities in the immediate vicinity.

5/ Keller, A. S., and Detterman, R. L., 1951, op. cit.

The basal part of the Canning River section consists of approximately 300 feet of interbedded clay shale, silt shale, siltstone, and sandstone. Limestone is more abundant than in sections previously described, and brachiopods and bryozoa are profuse throughout the basal 300 feet. The section overlies the Lisburne limestone with no apparent angularity. A silicified black chert conglomerate occurs at the contact. In general the basal 300 feet is considerably less cherty than basal Permian rocks seen elsewhere. The pink-banded sandstone is fine- to medium-grained, massive, pink weathering, and noncalcareous. Although less siliceous than in other areas, the sandstone is very tight.

Overlying the basal unit is 600± feet of ferruginous-weathering hackly-fracturing silt shale. In the southernmost occurrence of the formation on the east side of the Canning River, the profuse ammonite-pelecypod faunal horizon seen elsewhere is 170 feet above the base of the middle unit.

The 300-foot upper unit consists predominantly of a massive, pink weathering, pink-banded, very fine to fine-grained sandstone similar to that described in the basal 300 feet. Interbedded are cyclic-bedded silt shale and dense siltstone. The contact with the Shublik formation appears to be conformable.

Triassic system

Shublik formation

Triassic rocks crop out in a narrow belt 1 to 2 miles wide which can be traced across the front of the Brooks Range from the Shaviovik River to the Canning River and along the west flank of the Shublik mountains. The distinctive dark color and exceptionally fossiliferous nature of the Shublik formation make it an easily recognized marker unit.

Lithologically the formation consists of distinctive, dark-gray to black limestone, limy clay, and silt shale with minor amounts of dark-gray siltstone and fine-grained calcareous sandstone.

The basal part of the Shublik formation is phosphatic siltstone, shale, and very fine grained sandstone. The shale is limy, blocky, irregularly bedded in units up to 10 inches thick, is clayey to silty, and contains abundant dark-gray nodules up to 2 inches in diameter. The weathered surface has an irregular, patchy, white efflorescence. Phosphatic nodules weather with a blue-white chalky coating.

The upper part of the Shublik formation consists of clay to silt shale with interbeds of dark-gray limestone. This series grades upward to a predominantly limestone facies. The limestone varies from sandy to cherty and an abundant fauna generally characterizes this part of the formation. All lithologic types of the Shublik formation produce a strong fetid odor on fresh fracture.

In the vicinity of Kemik Creek the Shublik formation is predominantly calcareous siltstone and very fine grained, tight, medium-gray to dark-gray sandstone. The siltstone and sandstone are irregularly bedded, contain dark-gray mud pellets up to 1/2 inch thick and have hackly fracture. The section is not sufficiently well exposed to afford a reliable thickness measurement, but it probably does not exceed 400 feet.

A section 280 feet thick was measured 3 miles southeast of camp 3 on Juniper Fork (column B, pl. 2). The contact of the section with the underlying Sadlerochit formation is structurally conformable, and is marked by a 1-foot thick ferruginous weathered zone of siltstone and shale of the Sadlerochit formation. The lower 80 feet of the Shublik formation in this vicinity consists of a basal clay shale which grades upward into a silt shale and siltstone unit. The clay shale is black with small phosphatic nodules. The silt shale is dark gray to black with interbeds of medium-gray, slightly calcareous, dense siltstone as much as 2 feet thick. Cleavage is fairly well developed in the siltstone. Dark blue-black nodules with blue-white weathering are common. The upper part of the 80-foot section is 30 feet of thin-bedded black fissile shale and 1/4-inch beds of limestone that weathers with white efflorescence, and the top 6 to 8 feet is dense, silty, dark-gray limestone with black nodules. Overlying this unit is an upper 200-foot poorly exposed section of black limy silt shale and heavy-bedded black limestone. This limestone unit contains an abundant Upper Triassic fauna of Monotis sp. and Halobia sp. The contact with the overlying Kingak formation is not exposed.

A well-exposed 220-foot section was measured on Kavik River 1/2 mile south of camp 5, (column E, pl. 2). Both lower and upper contacts are exposed and no angular break is evinced either with the underlying Sadlerochit formation or the overlying Kingak formation.

The lower contact is marked by a 3-foot zone of noncalcereous black siltstone with abundant nodules as much as 2 inches in diameter. Considerable yellow staining is present in the siltstone. The upper part of this siltstone contains thin interbeds of black shale. Overlying the 3-foot zone is 12 feet of medium-gray, slightly calcareous, heavy-bedded (as much as 2 feet thick) nodular siltstone. The siltstone grades upward into a 62-foot zone of black earthy limestone containing Monotis (?) sp. and Halobia sp. The upper part of the limestone is medium gray, dense, nodular, and locally bioclastic. Overlying the bioclastic limestone is 11 feet of medium-gray, dense, bedded limestone with interbeds of black limy shale. Above this is 30 feet of interbedded gray dense limestone, black earthy limestone, and limy clay shale; next above is 25 feet of interbedded massive medium-gray, locally bioclastic limestone and blocky clay shale. Fossils in this zone include ammonites, smooth-shelled pelecypods, and brachiopods. Overlying this series is 27 feet of fossiliferous interbedded black limy shale and limestone capped by 6 feet of massive limestone. Abundant Monotis sp. and Halobia sp. occur within this horizon. A 44-foot fossiliferous zone of interbedded bioclastic limestone, limy shale, and massive-bedded, medium-gray, calcareous siltstone forms the uppermost unit of the section.

The Shublik formation changes but little in facies or thickness anywhere within the area of geologic traverse.

Jurassic system

Kingak formation

As the Kingak formation in the area of the Shaviovik River is nonresistant, poorly exposed shale, its thickness can only be estimated. In the vicinity of Kemik Creek the thickness of the shale unit is estimated to be 2,800 ± feet. The shale is black, fissile, and generally noncalcareous. Thin ironstone lenses impart ferruginous staining to the shale. Medium-gray dense siltstone is present as lenses and interbeds. Pentacrinus sp. is associated with the ironstone lenses in the lower part of the section. On the Kavik River these fossils were found in place approximately 200 feet above the base of the formation.

In the vicinity of Kemik Creek a 220-foot sandstone unit previously designated as basal Okpikruak formation 6/ (Lower Cretaceous) overlies the Jurassic shale unit. Aucella bronni found in this sandstone unit indicates an Upper Jurassic age for this sequence. The 220-foot section consists of subgraywacke-type quartzose sandstone which is medium-bedded, fine- to medium-grained, and light gray with common iron staining. Most of it is slightly argillaceous, noncalcareous, and well-indurated. The base of the unit contains several lenses of ferruginous quartz-grit conglomerate. This distinctive sandstone facies occurs as resistant linear east-trending ridges in a complex of tight folds and steep reverse faults. It is traceable eastward to the Kavik River and either shales in that direction or is stripped by post-Okpikruak erosion east of longitude 146°40'W.

On the west side of the Canning River approximately 3 miles south of camp 7, a series of long cutbanks expose a thick section of Kingak formation. The section is present on the north flank of a major west-plunging synclinorium and is composed of black paper shale and dark-gray siltstone interbedded with medium-gray clay and silt shale. Lenses of blue-black limestone, limy siltstone concretions, and ironstone which contains Middle and Upper Jurassic ammonites occur throughout the section. The Canning River cuts against the west bank along this Kingak formation outcrop and some of the section is inaccessible. The section is believed to be a minimum of 2,500 feet and a maximum of 4,000 feet thick. The top of the formation was not seen.

Four fossil horizons in the Kingak formation exposed along the Canning River are Lower Jurassic (Liassic), Pentacrinus subangularis var. Alaskan; Middle Jurassic (Bajocian), Pseudolioceras sp.; Middle Jurassic (Callovian), Arcticoceras sp. and Cosmoceras sp.; and Upper Jurassic (Oxfordian), Amoeboceras sp., Aucella bronni 7/.

6/ Keller, A. S., and Detterman, R. L., op. cit.
7/ Gryc, G., and Mangus, M. D., personal communication.

Cretaceous rocks

Okpikruak formation

The Okpikruak formation may be readily identified only on Kemik Creek (column I, pl. 2) where it conformably (?) overlies the Jurassic Kingak formation. Dark-gray, nodular to earthy clay and silt shale comprise the greater part of the 500-foot section exposed in this vicinity. Buff to gray, dense, hard, and noncalcareous to limy siltstones are present as beds and lenses. Fossils are generally restricted to the siltstone lenses and commonly are pyritized. Fossils from this section identified by Dr. Ralph Imlay include Aucella okensis Pavlow; Aucella subokensis Pavlow, and Aucella cf. A. uncitoides Pavlow.

Owing to the similarity of the Okpikruak formation and the Kingak formation, Okpikruak rocks cannot be readily distinguished as such over much of the area. However, the formation is believed to have been eroded from considerable portions of the area during the pre-Ignek formation erosional interval. Further fossil identification may clarify those parts of the map (pl. 1) where the Okpikruak formation-Kingak formation is mapped as an undifferentiated unit. It is unlikely, however, that more than 1,500 feet of the Okpikruak formation is present anywhere within the mapped area.

Ignek formation

The part of the geologic column formerly referred to as UK1 8/ has been redefined as Ignek formation, lower member and that portion referred to as UK2 and UK3 8/ has been redefined as Ignek formation, upper member. Fossil and microfossil analyses indicate that the lower member is Lower Cretaceous in age and the upper member, Upper Cretaceous in age. Both members reflect oscillation of Cretaceous seas by their marine and nonmarine strata. The lower clastic sequence consists of sandstone and shale; and the upper member is tuffaceous bentonitic sandstone, shale, and tuff, overlain by a monotonous sequence of coaly, woody, locally clean sandstone and shale. In general the contact is arbitrarily placed between the lower clastic unit and the first bentonitic tuffaceous zone; and the formation has been divided into the two members only where fossil and lithologic differences are evident. Elsewhere the formation is mapped as an undifferentiated unit.

Ignek formation, lower member. The lower member ranges in thickness from approximately 500 feet to 1,600 feet in the area of traverse, and rests unconformably on an eroded surface of Kingak formation and Okpikruak formation shale. Column J, plate 2, represents a composite 1,000 to 1,500-foot section in the vicinity of Fin Creek. The basal part of the section consists of platy siltstone, ferruginous weathering, medium-grained sandstone and shale. A poorly preserved pelecypod-brachiopod fauna is

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8/ Gryc, G., and Mangus, M. D., op. cit.

present in a booklike carbonaceous siltstone near the base of the section. This is overlain by platy to blocky, medium-gray siltstone and carbonaceous, cross-bedded, fine-grained sandstone. Locally ferruginous-weathering limy siltstone concretions are present. One 20-foot, quartzose, massive, fine-grained, light-gray sandstone horizon is present within this sandy unit. The contact with the tuffaceous sediments of the upper member is not exposed.

A 1,600-foot section of the lower member was measured in an isolated syncline on Juniper Fork (column H, pl. 2). The syncline rests unconformably on a Kingak-Okpikruak formation eroded land surface. The basal 200 feet consists of dark-gray to green, micaceous, medium-grained graywacke sandstone. This facies grades upward into a deltaic-appearing, interbedded unit of ripple-, fucoidal-, and mud flow-marked, micaceous, carbonaceous graywacke sandstone, siltstone, and silt shale. The uppermost beds are rust brown weathering, quartzose, light gray, very fine to fine-grained, clean-appearing sandstone. The top of the section was not seen.

On the Canning River 445 feet of the lower member of the Ignek formation is exposed in a complex series of faults and tight folds 3 to 5 miles south of camp 6. The section rests disconformably (?) on shale and glauconitic sandstone of the Kingak formation. The contact with the upper member is not exposed. A log of the section from top to bottom is as follows:

235 feet	Dark-gray to black fissile paper shale with ferruginous-weathering ironstone concretions and lenses. Disseminated pyrite and marcasite occur in the unfossiliferous lenses.
165 feet	Sandstone; medium to light gray, fine-grained, noncalcareous, with light yellow to reddish brown weathering on the bedding planes. Three fossil horizons are associated with the reddish-brown-weathering zones: 4 to 6 feet below the top of the unit; 100 feet above the base of the unit; and 8 feet above the base of the unit. All three fossil horizons carry similar fauna, including Tellina sp., Protocardium sp., and Dentalium sp. Ironstone concretions as much as 4 inches in diameter are present near the base of the unit. The sandstone is dirty in the basal 50 feet and clean in the upper part. Locally present are conglomeratic lenses of well-rounded white quartz and olive and black chert pebbles; the conglomeratic lenses are massive and cross-bedded.
15 feet	Siltstone, irregularly bedded, dark gray, weathering yellow to red brown. Siltstone grades upward to fine sandstone.
30 feet	Clay shale, medium gray with ironstone lenses and nodules.
_____	Contact with Kingak formation.

The presence of a typical Zone B-C (Nanushuk group) fauna within this section precludes the presence of any Torok formation equivalent in this area. Thus the relatively thick (2,6004 feet) section of Torok formation-Nanushuk group equivalent of the Ignek formation on the Ivishak River 9/ appears to have thinned eastward due to onlap of the formation over a high present in pre-Ignek formation time in the eastern area.

Ignek formation, upper member. In general, the upper member consists of a basal bentonitic shale series and a thick upper shale-siltstone series with minor sandstone beds. The basal bentonitic-tuffaceous layers have been altered to silicified tuffs along zones of intense deformation. This phenomenon is apparently due to the reaction of mineralizers in fluids ascending along faults and fractures. The age of this phase of faulting is discussed in the section on structure. Outcrops of these silicified tuffs are restricted in occurrence to Fin Creek, Juniper Fork, and Kavik River along a major west-trending fault zone. Because of the intense deformation, only partial sections are exposed and thickness measurements are necessarily poor.

The best exposures of the basal bentonitic-tuffaceous series are on Juniper Fork. Bottom and top contacts were not seen. The base of the section is medium-gray paper shale with 1-foot interbeds of multi-color-weathering, light-gray, porcelain-textured siliceous tuff. Massive calcareous concretions up to 5 feet in diameter occur within the section. Kerosene odor emanates from the concretions when the rock is freshly broken. The presence in the shale unit of Spongodiscus B, Archicorys A, Dictyomitra C indicate an Upper Cretaceous age for the section 10/.

The basal unit grades upward into a predominantly silicified tuff series approximately 200 feet thick. Tuffs are light gray to blue gray, weather various hues of yellow, red, green, and orange, and occur in beds from 2 to 8 inches thick. Shale and bentonitic partings are present. Noncalcareous concretions as much as 3 feet in diameter occur in lenses. Approximately 80 feet of medium-gray paper shale with 2- to 3-inch interbeds of bentonite overlies the silicified tuffs. The bentonite series is estimated to be from 300 to 500 feet thick.

The upper part of the upper member is predominantly a siltstone and shale facies. The basal part consists of locally conglomeratic, clean, salt and pepper-textured, fine- to coarse-grained sandstone and interbedded, medium-gray, carbonaceous, coaly siltstone, silt shale and sandstone. This series is overlain by a monotonous sequence of light- to medium-gray, buff-weathering fine sandstone, siltstone, and silt shale with abundant inclusions of coaly wood and plant remains. Fucoidal and mud-flow markings are present on the siltstone and sandstone bedding planes. Ironstone concretions are common throughout the series.

Thickness estimates for the total upper member range from 2,500 feet to 4,000 feet.

9/ Keller, A. S., Detterman, R. L., 1951, op. cit.
10/ Bergquist, H. R., personal communication, 1952.

Tertiary (?) series

Kavik formation

As a result of the 1952 field season, that part of the column formerly referred to as UK4 [11] has been redefined as Kavik formation. This sequence is believed to be of Tertiary age, and a tentative correlation with the basal part of the Sagavanirktok formation is suggested.

The formation is exposed as synclinal mesas and as flanks of anticlinal structures in the vicinity of camps 11, 12, and 13. The section is best exposed as cutbanks along Fin Creek where 1,500+ feet of section is preserved, (column J, pl. 2).

The basal 700 feet of this section consists of poorly to semi-consolidated interbedded conglomerate, conglomeratic sandstone, and siltstone. The conglomeratic constituents consist of granules, pebbles, and cobbles of very well rounded white quartz, olive and black chert, and locally up to 30 percent rounded to subangular silicified tuff and tuffaceous material, in a clean beach-sand matrix. The tuffaceous material is believed to have been derived from the lower part of the upper member of the Ignek formation. Conglomerates lense abruptly. The sandstones range from fine- to coarse-grained, are cross-bedded in units as much as 4 feet thick, and are predominantly of beach-sand variety. Colors vary from light buff to gray and pink. Firm iron cementation occurs only in local stringers and lenses. Porosity and permeability in the semi-consolidated sandstone of course is high. Wood and coaly fragments occur sporadically throughout the sandstone. Sandstone from this unit on the Kavik River yielded an oil cut [12].

The upper 800 feet of the formation consists of interbedded siltstone, shale, coal, and sandstone. The siltstone is medium to light gray, slightly calcareous, friable to semi-consolidated, and weathers very light gray. The shale is light gray, clayey, and is associated with thin-bedded to 3-foot massive coal beds. The coal is of low rank, has a waxy lustre and burns with difficulty. Sandstone in the upper part is quite similar to that in the basal 700 feet.

Although no marked angular discordance is definitely apparent between the Kavik formation and the upper member of the Ignek formation, the presence of detrital tuffaceous material and silicified tuffs in the Kavik formation conglomerates indicates a regional break in deposition between these units.

STRUCTURE

As might be expected, the structure of the Foothills belt is reflected in the folds apparent in the Brooks Range front. West of Kemik Creek along this front, 20° west plunge is evinced in the Lisburne limestone structure [13].

11/ Gryc, G., and Mangus, M. D., op. cit.
12/ Gryc, G., and Mangus, M. D., op. cit.
13/ Keller, A. S., and Detterman, R. L., op. cit.

East of Kamik Creek, east plunge of comparable magnitude exists to Kavik River. A structural high is thus defined approximately at longitude 147°15'W. As is further evinced by the closed Shaviovik anticline, this high extends at least as far north as latitude 69°35'N. The work of party 3 in the mountains south of the area of this report indicates that the Shaviovik structural high extends at least 40 miles south of the front of the Brooks Range 14/.

East plunge in the mountain front at Kavik River and several structures north of the mountains indicate a structural low paralleling the high in a northwest-southeast direction. This structural low is also apparent as far as 40 miles south of the Brooks Range mountain front 14/.

The mountain front swings north along the Canning River owing to the west plunge of the strata. The Canning River is localized along this plunge at the contact of the Lisburne limestone and the less resistant younger formations. East of the Canning River the mountain front flattens out in an east-west direction along the Katakturuk River then swings south at the Hulahula River. This swing plus the evidence that the Sadlerochit mountains are doubly plunging strongly suggests that a north-south structural high of magnitude at least equivalent to the Shaviovik structural high is present on the Katakturuk River.

As might be expected folding and faulting were most intense proximal to the Brooks Range proper and the forces dissipated northward along the Shaviovik River drainage and westward from the Canning River. Folding and faulting within the mountains in the area was not however as intense as that reflected in the mountains west of the Itkillik River to the southwest. Folds in this eastern area reflect epeirogenic uplift in contrast to the more intense orogenic folding and faulting of the southwestern part of the Reserve.

For the most part faults in the Lisburne limestone front reflect overturning of anticlinal axial planes with subsequent rupturing and thrusting of the south flank over the north. Displacement on these faults seldom exceeds several hundred feet.

Two major thrusts on the east side of the Canning River several miles east of camp 7 can be traced westward into the subsurface. The manifestation of this thrusting is a series of high-angle reverse faults and sharp folds in the surface structures between the West Fork of the Shaviovik River and Kavik River. The "anticline" approximately on latitude 69°27'N., south of the Ignek formation contact 7 miles northeast of camp 1 (pl. 1), is probably an expression of a rolled high-angle reverse fault due to thrusting at depth. Along the high-angle reverse faults which are probably an expression of the thrusting at depth, solutions have apparently silicified the tuffs of the lower part of the Upper member of the Ignek formation. Inasmuch as silicified tuffs are found as detritus in the basal part of the Kavik formation, prevailing evidence indicates a post-Ignek formation, pre-Kavik formation stage of thrusting.

14/ Brosgé, W. P., Dutro, J. T., Mangus, M. D., and Reiser, H., op. cit.

Anticlines in the area in general are asymmetric, with shallow south flanks and steep north flanks. Two are worthy of consideration as possible drilling sites. The more southerly of these, Kemik anticline, is flanked by the Upper Jurassic sandstone horizon 2,800± feet above the base of the Kingak formation. It has steep flanks and marked east plunge. The western plunge (?) is cut by a transverse fault. Depth to the Lisburne limestone on this structure should not exceed 5,000 feet.

Inasmuch as the Shaviovik anticline represents the best drilling site in the area, it is described separately in the following pages.

Regional Significance of Structure and Stratigraphy

As shown on plate 5, a pre-Permian high is inferred to the north and east. Permian sediments were shed southward into a subsiding trough in the Sagavanirktok River area. This postulation is borne out by the near-shore characteristics of the formation in the northern part of the area and by the thickening and shaling of the formation southward 15/. A gentle upwarp at the close of Permian time is reflected in the marginal facies of the formation. Conformability of the Permian-Triassic sediments indicates no major stage of folding during this period.

A quiescent blanket type of deposition is indicated in Triassic time, as the Shublik sediments change but little in lithology or thickness anywhere in the area of geologic traverse.

The shaly nature of the Kingak formation indicates a subsiding trough in this area in Jurassic time, with sediments shed from a considerable distance to the south. Slow upwarp and emergence is reflected in the quartzose sandstone unit 2,800± feet above the base of the formation. This gentle upwarp may be a manifestation of the beginning of the intense diastrophic movements in the southwestern part of the Reserve.

Gentle submergence of the area during Lower Cretaceous (Okpikruak formation) time is reflected in the shale composition of the sediments. No major folding is apparent during this period.

In post-Okpikruak time, the area was uplifted and differentially eroded. This is borne out by the unconformable relationship of the Ignek formation with the underlying formations. Inasmuch as the Ignek formation sediments are predominantly subgraywacke, uplift of this area must of necessity have been quite gentle.

Oscillation of the Cretaceous seas in later Cretaceous time is reflected in the transgressive and regressive marine and nonmarine strata of the Ignek formation. Local evidence indicates a stage of folding within the Ignek formation in what would probably be the break between Lower and Upper Cretaceous sediments. However evidence for this is not conclusive.

15/ Keller, A. S., and Detterman, R. L., op. cit.

As has been previously explained, silicified tuffs occurring as detritus in the conglomerates of the Kavik formation indicate a major break between Ignek formation time and Kavik formation time, accompanied by major folding.

At least one stage of folding is in evidence after deposition of the Kavik formation.

The Shaviovik Anticline

The Shaviovik anticline is a closed structure approximately 15 miles long, with a north-south minimum total structural relief of 2,900 feet over a linear distance of $3\frac{1}{2}$ miles. A minimum of 900 feet of closure is provable in an area delimited by the 1,500-foot contour shown on plate 3. The anticlinal trend can be traced eastward across the Canning River to a doubly plunging anticline in the Lisburne formation on the Katakturuk River. The western limit of the anticlinal trend was not followed beyond the area shown on plate 1. Along this anticlinal trend west plunge exists from the Canning River to approximately 6 miles west of Kavik River; the plunge reverses to east from this point to the Juniper Fork; and from that point plunges west to approximately 2 miles west of the west fork of the Shaviovik River. A minimum closure of 900 feet has been interpreted for the anticline (pl. 3). The eastern plunge is based on interpretation which will be discussed fully in this section. Exposures west of Juniper Fork, although poor on the north flank of the structure, are sufficient control for contour lines on the basal bed of the Kavik formation.

As is indicated by the strikes on the flanks of the structure along the Canning River, west plunge exists in this vicinity and continues to approximately 5 miles west of the Kavik River. At this point 9° west plunge is indicated by the strike of the sandstone-shale sequence of the Ignek formation, (pl. 1). Using structure traces and structure-controlled (?) drainage (ref. pl. 3), the Ignek formation has been interpreted to close off on the west plunge approximately 6 miles west of Kavik River. Evidence in favor of such an interpretation is as follows:

1. Nine degree west plunge of structure approximately 2 miles east of the contact line (pl. 1).

2. Swing in structure trace 25, which traced eastward must align close to the Kavik formation-Ignek formation contact (pl. 3).

3. Indication of continued west plunge in strikes of vegetal traces west of trace 25.

4. The presence of a resistant north-south ridge approximately $1\frac{1}{2}$ miles west of the easternmost stream cut by the anticline (pl. 3). Inasmuch as the Ignek formation consists of nonresistant shale and siltstone in this area, and inasmuch as the Kavik formation consists of resistant conglomerate and sandstone, this ridge is considered to be formed by the Kavik formation.

On Juniper Fork along the approximate location of the high the Kavik formation basal bed (trace 1, pl. 3) dips 17°-24° on the south flank and averages 40° of dip on the north flank. Using the relative elevations of the bed on each flank, and projecting the dips, a restored altitude of 2,400 feet is indicated over the arch of the anticline. Inasmuch as the eastern ridge is approximately 1,500 feet in elevation at the point intersected by the axis of the anticline (pl. 3), a minimum 900 feet of east plunge is indicated. Using the high point on the ridge, the contours have been arbitrarily pro-rated and assigned from the Juniper Fork arch. The relatively high dips in the Ignek formation in the breach of the anticline on Juniper Fork (pl. 1, pl. 3) is added assurance of the minimum interpreted east plunge of structure.

Westward from Juniper Fork control is sufficient to contour a minimum west plunge of 1,500 feet. Minimum closure is therefore computed at 900 feet.

As contoured on the basal bed of the Kavik formation, the anticline appears to be an asymmetric fold with gentle south flank and steep north flank. The steepness of the north flank is accentuated particularly at the point of west plunge along the West Fork of the Shaviovik River where 9° south dip reverses to 40°-50° north dip. Although the north flank is steep, no definite indication of faulting was seen in the outcrops of the Ignek formation and Kavik formation either at this point or on the north flank exposed on Juniper Fork. In the Ignek formation in the latter area considerable rubble is present and reliable dips are difficult to obtain. Where dip measurements may be ascertained they vary from 38° to 54° north. The overlying Kavik formation dips 34° to 50° north.

No outcrop is present on the anticlinal axis except traces 1 and 23 (pl. 3) on the western extremity of the west plunge. The swing in these traces indicates no post-Kavik formation stage of faulting on the axis. Vegetal traces along the axis in the breach between Juniper Fork and the West Fork of the Shaviovik River indicate a relatively gentle arching over the axis.

Shales of the Ignek formation 2,000 to 3,000 feet south of the axis on Juniper Fork vary in dip from 26° to 50° south. Average dip in this section is 33°.

It should be emphasized that the map presented as plate 3 represents contours drawn on the basal bed of the Kavik formation (Tertiary ?), and that this structure represents but one stage of folding (post-Kavik formation). As has been previously explained, at least one stage is indicated in post-Ignek pre-Kavik time and one stage in post-Okpikruak pre-Ignek time. A possible third stage of folding may have been during Ignek time (interval between Lower and Upper Cretaceous). Thus, although the surface structure represents but one stage of folding, rocks older than Ignek formation may have undergone at least three and possibly four stages of folding.

Estimate of depth to Lisburne limestone ranges from 6,500 to 9,300 feet. The range in these figures is due to the poor exposures and resulting questionable thicknesses of the units to be penetrated. The section is further complicated by several unconformities with resultant differential erosion of section across the area. Plate 4 represents a composite generalized column showing representative estimates of thickness and facies of section to be encountered on the Shaviovik anticline. A breakdown of these units is as follows:

Ignek formation, upper member. A minimum of 1,500 feet of section is considered to have been stripped in the breach of the anticline. An estimated 1,500 to 2,500 feet of section remains to be penetrated. Control on this section is poor. In the lower part of this unit, horizon No. 1 (pl. 4) offers a clean salt-and-pepper-textured, fine- to medium-grained noncalcareous sandstone unit as a reservoir. This unit was seen on the Canning River. It is unexposed in the area immediately south of the anticline.

Ignek formation, lower member. This unit is considered to be 1,000 to 1,500 feet thick. It offers horizon No. 2 which is present 9 miles south of the anticline. The facies is a quartzose, very fine to fine-grained sandstone.

Okpikruak-Kingak formations undifferentiated. The combined formations are approximately 3,600 feet thick in the area immediately south of the anticline. The amount of section to be penetrated will depend upon the amount of post-Okpikruak formation erosion. The sections are predominantly shale. A 220-foot sandstone unit (horizon No. 3) offers the only hope of reservoir conditions. This sandstone is quite similar to that of horizon No. 2.

Shublik formation. The Shublik formation is considered to be a maximum of 400 feet thick, and is predominantly limestone and limy shale. Horizon No. 4 is a sandstone exposed 25 miles south of the anticline. The sandstone is dark and very tight. The present of sandstone within the unit, however, is encouraging and the unit may become cleaner over the high.

Sadlerochit formation. As is indicated on plate 5, 1,200 feet of section may be expected to be penetrated. The isopachous map was drawn from existing control. The alinement of the basin in an east-west direction is based on the control shown and by the 200- to 700-foot equivalent of the Sadlerochit formation at Topagoruk Test Well No. 1. The section offers three horizons, all of which are tight. If the rocks are less silicified at depth on the anticline, reservoir conditions may exist in the section.

For detail on thickness and facies of Lisburne limestone, reference is made to Preliminary Report 42 16/.

16/ Brosgé, W. P., Dutro, J. T., Mangus, M. D., and Reiser, H. N., op. cit.

Using dips on trace 1 (pl. 3) on either side of the high on Juniper Fork, a southward inclination of from 8° to 11° is indicated on the axial plane of the structure. The placing of a rig, however, would be contingent both on this degree of inclination and on the surface dips in the Ignek formation on the south flank of the structure. With the angle of dip ranging from 26° to 50° 2,000 feet south of the axis on Juniper Fork, it would be hazardous to place a rig more than 1,000 feet off the structure. With these limitations a drill site has been proposed approximately 1,000 feet off structure (pl. 3). The position 1½ miles west of Juniper Fork has been chosen to take advantage of an apparent flattening of the anticlinal arch in this direction. The area east of Juniper Fork has not been considered as a drilling site because of absence of outcrops and lack of control.

SUMMARY

1. Rocks of Mississippian to Tertiary (?) are are exposed in the area.

2. The Sadlerochit formation ranges in thickness from 2,100± feet on Kemik Creek to 1,200± feet on the Canning River. The formation has nearshore facies characteristics in a northerly and easterly direction.

3. Triassic sediments are blanket type and probably do not exceed 400 feet in thickness in the area.

4. The Kingak formation may be as thick as 4,000 feet in the area.

5. The Okpikruak formation is 500+ feet thick in the area and is missing over portions of the area owing to post-Okpikruak erosion.

6. The lower member of the Ignek formation ranges from 500 to 1,600+ feet in thickness in the area and is Lower Cretaceous in age.

7. The upper member of the Ignek formation is estimated to be between 3,000 and 4,000 feet thick in the area and is Upper Cretaceous in age.

8. The Kavik formation is 1,500+ feet thick in the area.

9. Unconformities are indicated between the Okpikruak formation and the Ignek formation and between the Ignek formation and the Kavik formation.

10. Uplift of this eastern area was of epeirogenic nature.

11. A north-south structural high extends from 40 miles south of the Brooks Range front to latitude 69°40'N. along longitude 147°15'W.

12. A north-south structural high is indicated on the Katakturuk River.

13. Minimum closure on the Shaviovik anticline is 900 feet.

14. Depth to Lisburne limestone on this structure is estimated to be between 6,500 and 9,300 feet.