United States

Department of the Interior

U.S. Geological Survey

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Naval Petroleum Reserve No. 4

Alaska

Preliminary Report No. 27

PRELIMINARY REPORT ON THE STRATIGRAPHY AND STRUCTURE OF THE KUKPOWRUK AND KOKOLIK RIVERS AREA, ALASKA

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By

Robert M. Chapman

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November 1949

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PRELIMINARY REPORT ON THE STRATIGRAPHY AND STRUCTURE OF THE KUKPOWRUK AND KOKOLIK RIVERS AREA, ALASKA

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INTRODUCTION

Party and Logistics

U. S. Geological Survey Party No. 6 traversed the area of the Kukpowruk and Kokolik Rivers, northwestern Alaska, during the field season of 1949. The party consisted of Robert M. Chapman, geologist and party chief, Edward G. Sable, geologist, Dale A. Hauck, field assistant, Gordon W. Herreid, field assistant, Paul H. Shannon, cook, and Ralph Solecki, Smithsonian Institution archaeologist who was attached to the party through an arrangement with the O.N.R. With the excellent assistance and cooperation of all the temporary employees, it was possible to complete the geological work in this large area in the time available. Special commendation is due Mr. Solecki, who not only carried on his own investigations but also aided at all times the progress of the geological work.

The party assembled at Umiat in mid-May, and three men and equipment were flown by bush plane on May 17 to the initial field camp on the Kukpowruk River, about 16 miles from the headwaters. Owing to inclement weather and a forced landing of the plane, the other three men and equipment did not reach camp until May 27. At this time sufficient snow remained in the area for safe bush landings. The downriver travel was begun on June 13 in three 18-foot folding canvas boats. Food and some equipment had previosuly been landed by bush plane during April and early May at the initial camp, at six caches along the Kukpowruk, and at six caches along the Kokolik. All of the food was cached in metal drums, and everything was found intact.

Owing to unseasonable weather during June, the work was delayed and the party did not reach the mouth of the Kukpowruk until July 30. At this point the hospitality of the U. S. Coast and Geodetic Survey camp was enjoyed until the party could be moved, in three bush-plane loads, to the large lake on the Kokolik River about 16 miles below the headwaters. Work was begun at this point on August 2, and the traverse completed to the mouth of the Kokolik on September 3. The party was transported to Barrow in three bush-plane loads between September 3 and 6, and returned to Umiat and Fairbanks.

During the season a detailed geologic reconnaissance was made of the river bluff exposures, and of outcrops and traces as far east and west of the rivers as the time and geology warranted. A total of about 225 air-line miles along the rivers was covered. Triangulation nets and elevations were carried by theodolite from the initial camp to the mouth of the Kulpowruk River, where a tie to U. S. Coast and Geodetic Survey stations was made, and from the lake on the Kokolik River to a point about 40 miles above the mouth of this river. Insofar as possible, stations for this net were located on points of geological interest, and additional shots were taken to provide control for geological and aerial photo computations. These data were augmented by barometer traverses.

It is believed that all of the significant exposures of rock that can be reached by a party traveling in boats were examined. If further work is contemplated in this or contiguous areas, weasel transportation will be necessary in order to gather a significant amount of additional data.

Terrain

Parts of the Coastal Plain and Arctic Foothills Provinces are included in this area. The Coastal Plain is characterized by relief of less than 300 feet, many lakes and swamps, poorly defined drainage, and scattered, poorly exposed outcrops only on the major rivers. The Northern Foothills section of the Arctic Foothills Province is a roughly east-trending belt of rolling terrain 40-50 miles wide that is marked by prominent cuesta ridges and mesas which reflect the underlying synclinal and basin structures. River bluff outcrops are excellent, and many additional rock exposures occur along tributary creeks and on the ridges where the vegetal cover is thin to nonexistent. The drainage is good and lakes are rare and very small. The relief is from 300 to 2,200 feet, and averages about 600 feet. The Southern Foothills section of the Arctic Foothills Province lies between the Northern Foothills and the De Long Mountains, the name applied to the western part of the Brooks Range. It is a region of scattered high hills, featureless flats with a few lakes, most of which are small in size, and high, rugged hills and ridges adjacent to the mountains. Drainage is mostly good, streams are small and shallow, and many of the smaller creeks are sharply incised with very little level valley floor. Outcrops are located chiefly on the rivers and small tributaries, and most of the ridges are talus-covered and barren of vegetal cover. The relief is from 500-to 2,500 feet and averages approximately 800 feet.

No serious difficulties in weasel, boat or foot travel are encountered in the Coastal Plain Province and Northern Foothills section. In the Southern Foothills section travel on foot presents no more than usual difficulties. The streams, except at flood stage, are too small and shallow to be practical for boat travel. Weasel travel is feasible in nearly all parts of the section, if care is exercised in choosing routes.

Within this area, airplane landing spots are very limited in the summer. No gravel bars suitable for wheel landings were seen. Except for occasional stretches of river in the lower courses of the Kulpowruk and Kokolik, pontoon landings are possible only on the coastal plain lakes and on two lakes near the north edge of the Southern Foothills; one lies about 6 miles south of Igloo Mountain, and the other, on which Party 6 was landed, is near the Kokolik River. Bus-plane ski-landings can be made within convenient range of most places within the area, except in the foothills province where landings are greatly restricted by the rugged topography.

If additional information is desired on Lower Cretaceous and older rocks in the southwestern part of the N.P.R. No. 4, the headwaters region of the Utukok, Kokolik, and Kukpowruk Rivers contains considerable accessible geology that was beyond the reach of Party No. 6. As a result of an airplane reconnaissance with R. L. Miller in the headwaters of the Kokolik, Kugururok, and Kelly Rivers, of a brief examination of the aerial photos, and of binocular examinations on the ground, it is apparent that there are numerous workable outcrops and rubble traces in the Southern Foothills Province, De Long Mountains, and the foothills on the south side of the mountains.

Exposures of Lower Cretaceous, Triassic, Lisburne, and Noatak rocks were identified with reasonable assurance. In the opinion of the authors, practically all these exposures could be reached by weasel parties and could not be worked effectively by any other method.

STRATIGRAPHY

Mississippian

The Lisburne limestone was examined at one locality close to the head of the Kukpowruk River at about 68° 25' N., and 162° 50' W. Several good outcrops expose approximately 900-1,200 feet of section here. This appears to be the topmost part of the formation, and is faulted into the complex belt of Shublik (Triassic) and Killik (Lower Cretaceous) rocks.

The formation consists of silt shale, clay shale, limestone, chert, and siltstone in order of relative abundance. The silt shale and clay shale are intermixed and often gradational, dark gray to black, fissile, frequently "papery", moderately calcareous to noncalcareous, siliceous in part, and rarely carbonaceous. The shale is in zones from several inches to 100 feet or more thick. The limestone is medium to dark gray and black, lithographic or dense to very finely crystalline, hard, banded with black chert and, in places, with layers and lenses of silt, in beds 1 foot to 50 feet thick. It weathers to light gray with some tan bands. The dark color and dense texture contrast sharply with the light-gray, medium crystalline Lisburne limestone in the areas farther east. It has a moderate to strong petroliferous odor on freshly broken surfaces. A few fragmental and poorly preserved brachiopods of the Spirifer type are present, and fragmental crinoid remains are common. The chert is black and dark gray, banded in part, in beds 2 inches to 20 feet thick, rarely crinoidal, and highly fractured. The siltstone is medium to dark gray, moderately to well-indurated, partly siliceous, often gradational to shale or limestone, highly calcareous to noncalcareous, carbonaceous in part, mostly in thin layers or lenses half an inch to several inches thick. Siltstone forms a minor part of the total section.

All the above rock types are interbedded throughout the section, and many of the contacts are gradational. No zonation of certain rock types or significant variation in the percentage of the types was detected throughout this section. Megafossils are very rare and poorly preserved or fragmental. Calcite and quartz veinlets are common in this section, and a few tiny quartz crystals are present in the talus. No porous, clastic, or coarsely crystalline limestone beds that would be potential oil reservoirs are present in this section. However, the beds contain abundant organic matter.

Pennsylvanian and Permian

No rocks of these ages were recognized.

Triassic

The Shublik formation is exposed at numerous places within a belt trending approximately N 60° E about 2 to 6 miles wide at the north front of the mountains. The Shublik is also present in isolated outcrops believed to be infolded with the Lower Cretaceous rocks as far as 10 miles north of this belt. Owing to the disconnected outcrops, the complex structure, and the lack of key beds, an estimate of the thickness of the section is difficult. It appears to be thin, possibly about 1,000 feet. All the outcrops visited were near the head of the Kukpowruk River. The exposures in the Kokolik River area were beyond the reach of the party.

The rocks are mainly chert and silt shale, and possibly some sandstone. The chert is predominantly medium to dark gray (in contrast to the Lisburne chert) with rare greenish, maroon, and black beds. On weathered surfaces the chert is banded in parts and is brightly variocolored cream, green, red, maroon, tan, and brown, also in contrast to the Lisburne chert. Monotis and/or Halobia fossils were found in the chert at several localities. The beds are mostly thin, and range from half an inch to 6 inches thick. The silt shale is medium gray to black, iron-stained in part, in laminar beds up to 10 feet thick, frequently interbedded with thin chert layers, moderately indurated, fissile, and in part fossiliferous (pelecypods).

It is not possible at present to definitely assign any sandstone to the Shublik formation in this area. Sandstone beds are closely associated with the chert and shale section, but nowhere were they seen interbedded with, in direct contact with, or definitely underlying the chert. These sandstones could also logically be assigned to the Jurassic (?)- Lower Cretaceous, Killik group. The sandstones are light to medium gray and yellowish grey, very fine grained, argillaceous, micaceous, well-indurated, slightly calcareous to noncalcareous, and have very low porosity.

No oil shale was found in this area. Inasmuch as very little of the total bed of Triassic rocks in the Kukpowruk-Kokolik area was exposed, too much importance should not be attached to this statement.

Jurassic

No rocks of this age were recognized.

Lower Cretaceous

Killik Group

These rocks crop out at numerous places within a high foothills belt trending N. 70° E. that is 15 to 24 miles wide and lies immediately north of the Triassic belt. A narrow belt of Killik group also lies between the Triassic belt and the mountains in the Kukpowruk River area. The eastward extension of this sequence could not be reached in the Kokolik River area. It is impossible, on the basis of the data gathered by Party 6, to make more than a guess at the total thickness of section in this area. The outcrops are disconnected, the lithology is similar throughout, megafossils are very rare, the structure is

complex, and neither the upper nor the lower contacts were seen. It is estimated that 2,000 feet is a minimum thickness, but 6,000 feet or more is not improbable.

Silt shale, clay shale, sandstone, siltstone, conglomerate, and limestone, in order of abundance, are the rock types that make up the Killik group. Calcite and quartz veinlets are common in many of the outcrops, and occasionally clear quartz and calcite crystals were found. On the basis of the work done to date, some doubt exists as to the exact division of the Shublik formation and the Killik group, and it is possible that a small amount of gray and greenish-gray chert is present in the Killik group. Also it is possible that some of the sandstone and shale herein described may belong in the Shublik formation.

The silt shale and clay shale are medium to dark gray and rarely yellowish gray, poorly to moderately indurated, partly fissile, often gradational or interbedded with thin siltstone and sandstone, and frequently contorted and slickensided by intense folding and minor faulting.

The sandstone is predominantly light to medium gray and yellowish gray with a relatively small percentage of greenish-gray colored beds, in contrast to the Killik Group as described in the areas farther east. The sandstone is mostly very fine grained, but some is fine to medium grained, and a very little is coarse grained. The rock is moderately to well-indurated, quartzitic in part, argillaceous, micaceous, moderately calcareous to non-calcareous. Some of the sandstone is shaly other is in beds 10 to 20 feet thick, cross-bedded in part. The sandstone is in zones 1 to 50 feet thick. The porosity is uniformly low. Laminae and flecks of carbonaceous plant fragments, ripple marks, pebbles, clay pellets, and iron staining are common.

The siltstone is light to dark gray, rarely greenish gray, partly sandy, moderately to well indurated, in beds ranging from shaly to 6 to 10 inches thick, in units several inches to 20 to 30 feet thick, laminated, cross-bedded, moderately to non-calcareous, and iron stained in parts.

Conglomerate forms a minor percentage of the section. Most of it is granule to small pebble type and grades into sandstone or occurs as lenses or admixture within a sandstone unit. A distinctive basal conglomerate overlies the Triassic cherts south of the Triassic belt at the mountain front. An exposed thickness of 75 feet was seen, and it is composed of granule to boulder size material up to two feet in diameter. The conglomeratic material is gray, greenish gray and black chert (a few pieces of which bear Monotis fossils), white quartz, light gray quartzite, shale, argillite, several basic igneous types, and medium gray limestone, typical of the Lisburne formation, which contains brachiopod fossils.

Limestone was found in three beds at one locality on the Kukpowruk River about 8 miles southwest of Igloo Mountain. The beds are 7 inches, 5 and 4 to 5 feet thick. The thin bed is nearly a coquina of Aucella (?) pelecypods, medium to dark gray, weathered brown to red, shaly to massive, crenulated, and moderately indurated. The thicker beds are medium to dark gray, weathered pale to light yellow, dense to finely crystalline, veined with crystalline calcite, banded with fibrous black calcite layers, and shaly in parts. Cone-in-cone structure is poorly developed in parts. The thicker beds have a strong petroliferous odor when freshly broken. These beds are associated with a unique sequence of clay and mud shale containing calcareous "cannonball"

concretions 1 inch to 5 inches in diameter, hard, red iron-stained siltstone containing Aucella (?) and/or Inoceramus (?) fossils, fossiliferous (Aucella?) siltstone or ironstone concretions that range from 3 inches to 3 feet in diameter, calcareous septarian concretions, and drusy-surfaced, crystalline pyrite concretions. These beds are believed to be high in the section.

Lower Cretaceous (?)

Zones A to C of Nanushuk Group

Zone A, Torok shale member

This sequence of dark gray shale is present in a featureless lowland belt, varying from 3 to 12 miles in width, that lies between the Southern and Northern Foothills. It is also found within the cuesta and mesa country of the Northern Foothills where it is exposed in lowlands along the axes of many of the anticlines that are breached through Zones B and C. Outcrops of this member are limited to river and creek banks and are frequently small and disconnected. This, together with the monotonously similar lithology and complex folding and faulting, makes it impossible to determine the total thickness of the section. Probably the biggest continuous exposure of this shale on the North Slope is on the Kokolik River at 69° 14' N., and 161° 55' W. The river bluff is 4½ miles long and exposes about 6525 feet of this member, although a minimum of 4800 feet and a maximum of 7200 feet also are possible.

This shale sequence had been ascribed to the Killik group in the Utukok area by Thompson and Barksdale. The Killik group, at that time, was defined to include all of the shales up to the Tuktu sandstone member. However, it resembles the Torok shale of the area south of Umiat in lithology, stratigraphic position, thickness, and structural relationship to the adjacent formation, and is therefore referred to the Torok shale member. But this sequence may include some shales of the Killik group.

The rock is almost entirely clay shale and silt shale with perhaps 10 to 15 percent of thin siltstone and claystone. The shales, which are interbedded and intergraded, are medium to dark gray and yellowish-gray, poorly to moderately indurated, moderately calcareous to noncalcareous, fissile to chunky, and have ripple marks and mud flow marks. The siltstone is light to dark gray and yellowish-gray, moderately to well indurated, slightly to highly calcareous, rarely ferruginous, and mostly in layers 1 inch to 3 inches thick but occasionally as much as 10 feet thick. Carbonaceous plant fragments, mica flecks, worm tubes and trails, and mud flow and ripple markings are present. The claystone is similar in appearance and occurrence to the siltstone except for hardness.

The Torok shale member is believed to be conformable with the overlying Zones B and C. This is in contrast to the angular relationship in the Utukok area described by Thompson and Barksdale. It is an incompetent sequence, and, because it is best exposed along the axes of anticlinal zones where the folding is intense, many of the scattered outcrops give the impression of angular discordance with the competent B-C Zones. Although an actual contact of the Torok and B-C was not seen, outcrops that are close to the contact zone shown appear conformable. No evidence on the nature of the Torok-Killik contact was found.

Zones B and C

These are the most prominent zones in the area studied. They are resistant, cuesta and mesa forming units that are exposed throughout the Northern Foothills section. The total thickness of these zones is probably 4600 feet. Silt shale, silstone, and sandstone are the predominant rock types, with minor amounts of conglomeratic sandstone and clay shale. The section seems to be almost entirely marine, and may include an equivalent of the Tuktu sandstone member of the Umiat area.

The silt shale and siltstone are medium to dark gray and yellowish-gray, weathered yellow and yellow-brown, sandy in parts, slightly to moderately calcareous, moderately to well indurated, mostly in beds 3 to 50 feet thick, and cross bedded. Carbonaceous and micaceous flecks and laimnae, woody and coaly fragments, ripple and mud marks, and worm trails, are common. Pelecypods, starfish, and Dentalium are present in parts.

The sandstone is light to medium gray and yellowish-gray, weathered yellow and yellow-brown, silty and gradational to siltstone, mostly very fine to fine grained, with some medium grained. It is generally low in porosity, slightly to moderately calcareous, conglomeratic in minor parts, and otherwise similar in appearance to the siltstone.

A few beds of clay shale were seen. They are medium to dark gray, fissile to chunky, laden with carbonized plant fragments, and interbedded with silt shale. A few ironstone nodules 1 inch to 4 inches in diameter were found in these beds and also in a few sandstones, but they are not as abundant as in the D-E Zones.

Zones B and C are conformably overlain by Zones D and E of the Chandler formation of the Nanushuk group 1/. No clear contact between the two is evident, and they appear in several localities to be gradational. The upper contact of the Chandler formation was not seen. From a careful examination of field observations, it may be possible to subdivide these zones.

Upper Cretaceous

Zones D and E (?) of Nanushuk Group

These zones are present throughout most of the Northern Foothills section but are not as prominent or well exposed as zones B-C. At least 6100 feet of this section is present, and it lies in the centers of the basins and synclines except in the Coastal Plain and north edge of the Northern Foothills where several structures expose only these zones.

The D-E and B-C zones can be distinguished from a distance on the basis of weathering color. Zones D-E weather dark yellowish-orange, whereas zones B-C weather moderate yellowish-brown. Silt shale, clay shale, siltstone, sandstone, ironstone, coaly shale, coal, and conglomerate, in order of relative abundance, make up these zones. They are almost entirely non-marine.

1/ The Chandler formation has been defined to include the nonmarine facies of the upper part of the Nanushuk group, largely Zones D through E.

The silt shale and clay shale are medium to dark gray and yellowish-gray, slightly to non-calcareous, fissile to chunky, poorly to moderately indurated, and in beds several inches to 20-40 feet thick. Carbonaceous plant remains and laminae, ironstone concretions, and mica flecks are common. The shales grade into siltstone, claystone, and carbonaceous and coaly shale in parts.

The siltstone is medium gray to yellowish-gray, slightly to moderately calcareous, sandy, moderately to well indurated, lenticular and cross-bedded, in beds 3 inches to 20 feet thick, weathered yellowish-orange, iron-stained, ripple-marked, and laden with carbonaceous plant material and leaf imprints. A few pelecypods are present in the lower part of the sequence.

The sandstone is light to medium gray and yellowish-gray, weathered yellowish-orange, iron stained, silty in parts, moderately to non-calcareous, very fine to medium grained, mostly low in porosity but with some moderately porous beds, bedded shaly to massive and crossbedded. Carbonaceous, micaceous and coaly material, and ironstone nodules are abundant. Conglomeratic phases are rare. One bed, located 45 miles above the mouth of the Kokolik River, contains abundant asphaltic material and yields abundant tarry residue when extracted with carbon tetrachloride.

Ironstone occurs both in lenticular beds and nodular or concretionary form. It is medium gray, hard, highly calcareous to non-calcareous, and weathers from bright yellow to dark yellow-red. Carbonized plant remains and leaf imprints are common. These beds and nodules are particularly abundant in the coaly sections.

Numerous coal beds are scattered throughout these zones D and E, but they are particularly abundant in the northern part of the outcrop belt and in the upper half of the D-E section. They range from coaly shale and bone to high grade bituminous coal in beds a few inches to 12 feet thick. Several minable bituminous coal beds of good quality are present on both rivers, and frequent use of them is made by Eskimos.

One slumped outcrop, 27 miles above the mouth of the Kokolik contains a highly bentonitic clay. This clay is associated with Chandler formation rocks, and is believed to be high in the D-E zone.

Colville Group

Rocks lithologically resembling the Colville group were examined in two isolated exposures 32 miles above the mouth of the Kokolik River. Approximately 40 feet of section is exposed.

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

Mississippian - Lisburne Formation

At the southernmost headwaters of the Kukpowruk River, a south dipping sequence 900 to 1,200 feet thick was examined. The sequence is parallel to the front of the De Long Mountains, the strike of the beds varies from N. 25° E. to N. 50° E., and the dips increase progressively southward from 30° to vertical. One minor fault, having a total displacement of 10 feet, was recognized.

To the south, the Lisburne formation is directly overlain by steeply south-dipping cherts of the Shublik formation, but the contact is not exposed. The Lisburne section probably represents the upper part of this formation.

The contact of this belt of Lisburne with the rocks to the north is believed to be a thrust fault. The fault is not exposed, but Killik group sandstones are in close proximity, with no visible Shublik formation intervening. (See sketch, fig. 3)

No Lisburne was present in the area worked on the Kokolik River. During a reconnaissance flight south of the Kokolik-Kelly Rivers divide, excellent outcrops of Lisburne formation were seen. At least two major anticlinal structures are exposed.

Triassic - Shublik Formation

The southernmost observed outcrops of Shublik formation are south of the Lisburne formation. A complex sequence of minor folds with steep dips is inferred. An erosional hiatus exists between the Shublik formation and the immediately overlying Killik group, which is infolded with the Shublik.

A structurally complex belt of Shublik formation 1½ miles wide lies immediately south of Camp 1A. This belt roughly parallels the mountain front. Very steep dips are common, and isoclinal folds with plunges up to 55° were examined. The Killik group is exposed both north and south of this area, but no contacts were seen.

The Shublik formation occurs sporadically north of Camp 1A to 3 miles south of Camp 2, and is intensely infolded and faulted with the Killik group. Dips are predominantly south; the faulting is of unknown magnitude.

Jurassic(?), Lower Cretaceous

Killik Group

The basal Killik group south of the Lisburne section abruptly overlies and is infolded with the Shublik formation. Dips are nearly vertical.

North of the Lisburne, and in the Shublik-Killik complex belt south of Camp 1, exposures are poor. A general NE-SW strike and south dips are predominant. Minor folds are common. One tight anticline was observed to plunge 30° East.

North of Camp 1, the folding appears to be broader, but much complexity exists. Some fault relationships occur between Killik and Shublik rocks, and tight folding is present within the major structures. Dips are dominantly south.

At Camp 3 a structure believed to be a major anticline, strikes roughly north-northeast and plunges to the north. Reversals of steep dips within the structure, and faulting of undetermined scale confuse the interpretation.

The structures directly south of Poko Mountain, as shown on aerial photos, have interesting exploration possibilities. One possible dome and several elongate structures exist and are believed to be in the Killik group. They occur between major rivers in a region that is suitable for weasel travel.

Lower(?) and Upper Cretaceous

Nanushuk Group

Structures of the Nanushuk group are exposed in two provinces of the Kokolik-Kukpowruk area: the Northern Foothills and the Coastal Plain. In the former, good exposures of these rocks, with the exception of the Torok shale, permit a fairly accurate structural interpretation. Broad, elongate basin structures are separated by relatively narrow, steep-limbed anticlines. The axes trend in an east-west direction but swing to 30° east and west of north. Anticlinal axes appear to connect diagonally to isolate the prominent basins. Coastal plain exposures are limited to river outcrops, where connections and plunges of axes, and closures of folds cannot be delineated.

The Torok shale member of the Umiat formation, which is 6,500 feet thick on the Kokolik River, is believed to be the basal Nanushuk in this area. Its relationship to the older Killik formation is not known. Field evidence, however, points strongly to a conformable contact between the Torok shale and the overlying Zones B-C.

Thirteen separate synclinal structures in the Nanushuk group are exposed in the Kokolik-Kukpowruk area. Two of these, Poko Mountain and Igloo Mountain, lie at the southern extremity of the Northern Foothills section, and are deeply eroded synclinal mesas surrounded by broad flats. A very thin synclinal remnant occurs immediately north of Camp 17. All three may lie along the same synclinal axis. They consist of Zones-B-C immediately overlying the Torok shale. Dips are very gentle. The remaining ten synclines are classified 1 to 10 on the geologic map (fig. 1), and are numbered from south to north, first on the Kukpowruk and then on the Kokolik. The same number is applied to synclines which extend from one river to another. Two synclines, named in Oil and Gas Sheet 1, extend westward from the Utukok River to the Kokolik. They are: Meat Mountain Syncline and Kokolik Warp Syncline, assigned numbers 8 and 4, respectively.

Three persistent synclinal axes extend from the Kokolik to the Kukpowruk. Two of these, (2 and 5), extend approximately 35 miles. The third and northernmost of these, (6), appears to continue to the Utukok River, a distance of 55 miles. Anticlinal trends can be traced between all three rivers, excepting those in the coastal plain.

Anticlinal axes are generally more complex than is shown on the structure section, and usually consist of two or more small folds and minor faults. They are both symmetrical and asymmetrical.

Unconformable angular relationships of bedding of a local character exist in Zones B-C and in Zones D-E of the Chandler formation. In single outcrops, similar rock types contact one another with pronounced angular relationship. No faults intervene. The angular discordance may possibly result from rapidly shifting conditions of deltaic or flood plain deposition. These angular relationships do not appear to have great lateral extent.

Exposed thicknesses of the Nanushuk group on the Kukpowruk River appear greater than on the Kokolik. The great thicknesses of the Nanushuk group in these areas as compared to 7,600 feet of section on the Utukok River, indicate a thickening of section to the west, estimated to be at a rate of 60 feet per mile.

No major faulting was recognized in the Nanushuk group. Small scale normal and reverse faults, probably of less than 200 feet displacement, exist in close proximity to anticlinal and synclinal axes.

Approximate section thicknesses have been computed on the Kukpowruk River. The structures appear on the generalized cross-section (Figure 2), and include synclines 1-3 and 5-7. No total measurements have been made on the Kokolik.

A summary of structural data follows:

Syncline 1.

Kukpowruk River - A roughly elliptical basin that exhibits the greatest computed section thickness in the southern part of the area, 10,700 feet total (4,600 feet of Zones B-C and 6,100 feet of Chandler formation Zones D-E). South limb - The Torok shale dips 70° to vertical, and 1½ miles north, Zones B-C dip 46°. Near the center the dip flattens rather abruptly from approximately 10°. On the north limb the south dips increase more regularly and average about 25°.

Anticlinal axis between synclines 1 and 2.

At least two tight anticlines occur in the Torok shale. Dips from 55° to vertical are present. One thrust fault, probably of small displacement, was seen. Little or no plunge is present.

Syncline 2.

Kukpowruk - An elongate basin. Extreme dips are 32°. 6,600 feet of section are exposed, including the lower 2,000 feet of Zones D-E.

Kokolik - Dips are 25° and less. Syncline 2 plunges west a short distance east of the Kokolik River. No section thickness has been computed.

Anticline between Synclines 2 and 3.

Kukpowruk - No rock exposed, but broad flats reflect the underlying Torok shale in the axial zone.

Kokolik - Not exposed on the river. One and a half miles east, the structure is highly asymmetrical. Two small anticlines are exposed with an east plunge of 35° to 40°. The north limb of the major structure dips 60°, and the south limb 8° to 10°. Two miles west of the Kokolik the structure appears to plunge west. Closure, if present, is estimated at 200+ feet.

Syncline 3.

Kukpowruk - Dips range up to 50° on the south limb. At the base of Zones B-C an angular unconformity within the basal sandstones was seen in one outcrop. It is believed to be of local character. Minor faulting also occurs in this outcrop. Dips within the syncline decrease gradually toward the axis, which parallels the river in a N. 30° E. direction for five miles. Approximately 4,200 feet of Zones B-C, and 500 feet of Zones D-E are exposed.

Two gentle anticlines and one gentle synclinal flexure separate synclines 3 and 4. Dips are less than 8° and flatten progressively northward to form syncline 5.

Syncline 4 (Kokolik Warp Syncline).

Kokolik - Data on this syncline is not yet compiled. Dips are gentle. Zones D-E are exposed. There are no exposures on the anticlinal axis north of 4. This syncline does not extend to the Kukpowruk River.

Syncline 5.

Kukpowruk - On the south limb, the dips are gentle. The north limb dips steepen abruptly to 55° near the anticlinal axis. Approximately 4,100 feet of section is exposed, and includes some of Zones D-E. This structure lies west of the Kokolik.

Anticline - North of Syncline 5.

Kukpowruk - One symmetrical anticline is exposed. The steepest dips are 55°. A fault of unknown displacement occurs one-half mile north of the axis. The axial zone is eroded to within a few hundred feet of the Torok shale.

Kokolik - The Torok shale comes to the surface, and there are good exposures of this member. Two anticlines and one syncline are exposed. North of these, apparently uninterrupted north dips continue to Syncline 6 where Torok shale conformably underlies Zones B-C.

Syncline 6.

Kukpowruk - The south limb dips up to 55°. The north limb steepens rapidly near the anticlinal axis. 8,600 feet of section is present, of which 3,400 feet are Zones B-C, and 5,200 are Zones D-E. Zones B-C have thinned northward from 4,600 feet thick in Syncline 1.

Kokolik - No data compiled yet. The Chandler formation is exposed. Dips in general are low.

Anticline between Synclines 6 and 7.

Kukpowruk - Slightly asymmetrical. The south limb dips up to 68°, and the north limb to 62° with vertical beds near the axis. The upper part of Zones B-C is exposed.

Kokolik - Not well exposed. Dips are relatively gentle.

Syncline 7.

Kukpowruk - This may be the same syncline as Kokolik Syncline 10. Approximately 10,600 feet of section is exposed, of which 400 feet appear to be Zones B-C, and 10,200 feet to be Zones D-E. A projection of Zones B-C from Syncline 6 would produce a total thickness of 13,600 feet of Nanushuk group above the Torok shale.

Syncline 8 (Meat Mountain Syncline).

Kokolik River - Thicknesses are not compiled. The exposed section appears to thicken westward from the Utukok River. Zones D-E are exposed. The structure does not continue to the Kukpowruk River as shown on Oil and Gas Sheet 1. Torok shale is exposed in the anticline north of Syncline 8, and minor folding is present here.

Synclines 9-10.

Kokolik River - Thicknesses are not compiled. Zones D-E are exposed. The anticlines between and north of these synclines are relatively sharp. Syncline 9 is possibly a westward extension of the Lookout Ridge Syncline. (See section on Oil and Gas possibilities for further information on Syncline 10.)

Colville Group

Thirty-two miles above the mouth of the Kokolik, isolated exposures of Colville group rocks strike east-west and dip 12-16 degrees north. These are the only outcrops of this group recognized in the area.

ECONOMIC GEOLOGY

Summary of Oil and Gas Possibilities

1. The Nanushuk group rocks occurring in the Northern Foothills section and lying stratigraphically above the Torok shale do not offer attractive petroleum possibilities. The anticlines are eroded, or nearly so, to the Torok shale.

2. Areas north of camp 10 on the Kukpowruk and camp 23 on the Kokolik appear structurally most favorable. However, exposures are restricted to river outcrops, with few traces in the surrounding coastal plain.

3. Sandstones tested for porosity and permeability generally showed low results. Sixteen samples have been tested, and the results are shown in Table 1. Porosities in two Killik group samples are 5.0% and 3.75%, and permeabilities are less than 5 millidarcies. Thirteen Nanushuk group samples vary in porosity from 5.0% to 11.3% and average 8.06%. All but two of these lie in the D-E zones. Their permeabilities are less than 5 millidarcies. One Colville group sample has 18.7% porosity, and 44 millidarcies average permeability with extremes of 22 and 70 millidarcies (See Table 1). This could be a potential reservoir rock.

4. One 7-foot silty sandstone on the Kokolik River north of the axis of syncline 10 has a high asphaltic content. About 6 cc. of the sample yielded approximately 1 cc. of brownish-black tarry substance. A strong petroliferous odor was noticed.

The oil sand lies midway between the axis of syncline 10 and the anticlinal axis north of this (See Fig. 5). Exposures of the sand are few and are scattered along 8 river miles in a direction parallel to the strike. Stratigraphically, the oil sand lies in the coaly sequence of the Namushuk group, upper D-E zones. Its exact position is not known inasmuch as no correlations have been made along the Kokolik River. Several beds of very fine grained sandstone and siltstone, from 2 to 14 feet thick, lie within 100 stratigraphic feet of the oil sand. A few of these exhibited a slight petroliferous odor.

The strike of the beds in this region is roughly E-W, and varies from N. 85° W. to N. 85° E. Exposures 1½ miles north of the syncline axis dip 5° to 12° south. One half mile north of this, relatively steep dips from 25° to 70° south are encountered at Sable Station 190. At the west end of this outcrop, an isolated sandstone bed, which is 10 feet above a bed dipping 35 degrees south, dips 7 degrees south. The interval between the two beds is covered. This anomalous relationship may be explained by a tight flexure or fault. The Station 190 sequence, when projected, strikes approximately into the oil sand exposure, 3 miles west. The oil sand, and beds adjacent to it, dip 7° to 14° south, and one exposure 1½ miles north-west dips 7° to 11° south. Three and one-half miles northwest of the oil sand, an anticlinal axis intersects the river. The south flank dips 40° and the north flank dips 9° to 11°. No closure was noted.

From structural observations of the Namushuk group in the Kokolik-Kukpowruk area, dips greater than 40° occur only near anticlinal axes. The steep dips at Station 190, east of the oil sand, imply the presence of an anticline or fault zone. Two explanations of anticlinal possibilities are proposed:

a. The anticlinal axis exposed on the river north of syncline 10 swings southward through a point north of Station 190. However, no significant variation of strikes, necessarily accompanying such a swing, were noted.

b. A minor anticlinal flexure, possibly dying out within 3 miles west, exists between syncline 10 and the anticline that is mapped to the north. The minor axis would lie north of Station 190, and not far from the oil sand.

In either case, the oil sand would be exposed on the south limb of an anticlinal structure. Faulting, of which there is no clear evidence except for the anomalous dips at Station 190, would complicate the interpretation.

Still another possibility, i.e., presence of an angular unconformity in the Station 190 exposures, is so uncertain as to preclude any discussion.

5. An 8 foot coaly shaly bed, near the anticlinal axis north of Syncline 10, produced an oily slick when submerged in water.

6. No indications of petroleum possibilities were noted in the Killik group. The porosity and permeability of the sandstones are uniformly low, and most of the folds are complex and faulted. Thus reservoir and structural conditions are poor.

7. The Lisburne formation in this area appears to be high in organic content and may be a possible source rock. The rocks examined are dense and well indurated and show negligible porosity.

8. No oil and gas seeps were encountered in this area.

Coal Possibilities

The potential coal-bearing part of this area lies north of Latitude 69°15' N. Coal beds varying from a few inches to 12 feet thick occur in the upper part of the Chandler formation, and numerous traces of coaly talus imply the presence of other coal beds in this zone. Samples were taken from a number of the larger beds, but as yet have not been analyzed.

The following determinations that were made on samples collected by Foran in 1923 are given in U. S. Geological Survey Bulletin 772, page 31:

Coal (moisture free), 5 miles inland on Kukpowruk River	13,210 B.T.U.
Coal (moisture free), 25 miles inland on Kukpowruk River	14,360 B.T.U.

FUTURE PLANS

A final report on this area will be completed by April 1950. It is expected that it will follow roughly the same outline as this report but will have a broader scope. A more complete stratigraphic picture will be available when all of the sections that were measured in the field are plotted and correlated, and when all of the megafossil, microfossil, heavy mineral, and porosity-permeability determinations are available. The structural interpretations can be considerably enlarged when all 1:48,000 scale base maps and the new vertical photographs of this area become available.

Correlation of the geology between the Kukpowruk and Kokolik Rivers will be attempted. Extensions of the geology to the east to tie in with the Utukok River traverse, and to the west into the Corwin and Cape Lisburne areas will be made as far as possible.

SUMMARY

A detailed geologic reconnaissance covering 225 airline miles along the Kukpowruk and Kokolik Rivers was completed by Party No. 6 in 1949. Geologic sections from the Lisburne formation through Upper Cretaceous, Zones D-E, and probable Upper Cretaceous, Colville group were examined. Additional work by a weasel party on Mississippian through Lower Cretaceous sections in the southern part of this area would be geologically profitable.

The Lisburne formation is made up of dark gray to black shale, limestone, and black chert. It is moderately fossiliferous. A section 900-1200 feet thick is faulted into the Shublik-Killik belt near the north front of the mountains.

The Shublik formation is composed chiefly of gray chert, silt shale, and possibly some sandstone. Upper Triassic fossils are present in the chert. Due to the complexity of structure and disconnected exposures in the Shublik-Killik complex belt, total section thicknesses of either formation and definite contacts between them could not be determined.

The Killik group, composed of silt shale, clay shale, sandstone, siltstone, conglomerate, and some limestone, is similar to Killik sections in other areas. However, the usual greenish-gray sandstones typical of the Killik Group are not as abundant here. The sandstones here are predominantly medium to dark gray and yellowish-gray. The structure is complicated by faults and tight folds. At least 2,000 feet and possibly 6,000 feet or more are estimated. Neither the upper nor lower contacts were seen.

The Zone A, Torok shale member, composed almost entirely of dark gray silt shale and clay shale with minor amounts of siltstone, is well exposed in a single locality, and 6525 feet of section were measured. The shale is incompetent and usually highly folded and faulted in axial zones. It is believed to be conformable with the overlying Zones B-C. It is possible that this 6525-foot sequence may include some Killik group shales. No evidence on its relationship to the Killik group was found.

Zones B-C, which are predominantly silt shale, siltstone, and sandstone, form outstanding ridges and outcrops. About 4600 feet which thins northward to 3400 feet of almost entirely marine section is present, but the sandstones are not lithologically identical to the typical Tuktu sandstone. The yellowish-brown weathering color helps to distinguish these zones from the overlying Zones D-E which weather yellowish-orange.

Zones D-E are almost entirely non-marine silt shale, clay shale, siltstone, sandstone, ironstone, and coal. The sandstone beds are less common than in B-C, but the porosities are somewhat higher. Good quality bituminous coal beds are present.

A total section of 13,600 feet of Zones B-C and D-E has been computed for syncline 7.

The Coville group is believed to be exposed at one locality within the area.

Thirteen separate synclines and basins are recognized within the Namushuk group. They are broad open folds. Nine anticlines are mapped. They are tightly folded and faulted in the axial zones, and many of them are breached to the Torok shale.

Very few favorable conditions for petroleum are indicated in the area. Neither favorable porosity-permeability nor structures appear in the Mississippian, Triassic, or Killik group rocks, although the Mississippian may offer source bed possibilities. The only favorable structures in the Namushuk group are those which are not breached to the Torok shale. They are in the northern part of the area. Very few attractive closures are indicated. Oneighly asphaltic sand is exposed on the Kokolik River.

Results of porosity-permeability tests and preliminary microfossil examinations made to date are tabulated.

Table 1

Porosity and Permeability Results

Group - Formation - Zone	Sample	Porosity (%)	Permeability (md)
Killik	49ASa-35	5.0	< 5
"	" 41	3.75	"
Nanushuk - Umiat - B-C	" 107	6.5	"
" "	" 108	6.2	"
" "	49ACh-1 2	11.2	"
" Chandler - D-E	" 43	12.3	"
" " "	" 126	9.16	"
" " "	49ASa-106	5.0	"
" " "	" 112	6.6	"
" " "	" 117	8.95	"
" " "	" 119	11.2	"
" " "	" 122	7.35	"
" " "	" 124	11.0	"
" " "	" 131	10.2	"
" " "	" 133	6.54	"
Colville (?)	" 224	18.7	22 (Normal to bedding)
	" "		41 (Random orientation)
	" "		70 (Parallel to bedding)

- Formation - Zone	Sample	Relative Abundance	Tentative Identification
lk	49 ASa-23	Rare	Reophax Haplophragmoides
shuk - Umiat - A	" 48	Very rare	Haplophragmoides
" "	" 52	Very rare	
" "	" 192	Rare	Pelosina Haplophragmoides
" "	" 196	Very rare	Haplophragmoides
" "	" 197	Very rare	
" "	" 198	Very rare	Haplophragmoides
" "	" 201	Very rare	Trochammina
" "	" 204	Rare	Trochammina Haplophragmoides Bathysiphon Reophax
" "	49 ACh-44	Rare	Trochammina Bathysiphon
" "	" 45	Common	Trochammina Bathysiphon Haplophragmoides
" "	" 46	Rare	Ammodiscus Bathysiphon Ammobaculites (?)
shuk - B-C	49 ASa-109	Very rare	Reophax
"	" 111	Rare	Gaudryina Haplophragmoides Trochammina Ostracods
shuk - B-C(?)	Ch49 A-109	Very rare	
"	" 111	Rare	Reophax Trochammina
	119	Abundant	Trochammina Gaudryina Haplophragmoides Glomospira Ammobaculites Bathysiphon
	" 121	Very rare	
shuk-Chandler-D-E	49ASa -58	Rare	Haplophragmoides Glomospira
	49ACh -50	Very rare	
	113	Common	Trochammina Haplophragmoides Ammobaculites Gaudryina
	127	Very rare	Pelosina
	152	Rare	Trochammina Bathysiphon Haplophragmoides

one A samples 49ASa-199, 200, 202; Zones B-C samples 49 ACh-110; and Zones D-E
les 49ASa-132, 134, and 49ACh-49, 128, 129 contain no microfossils.