United States

Department of the Interior

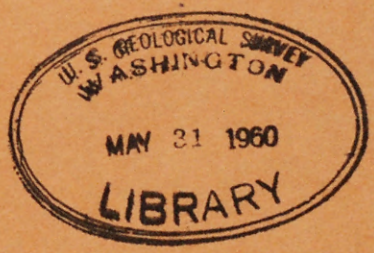
U.S. Geological Survey

Washington

Geological Investigations

Naval Petroleum Reserve No. 4

Alaska



Preliminary Report 39

PRELIMINARY REPORT ON THE STRATIGRAPHY AND STRUCTURE OF THE DRIFTWOOD-NOLUK AREA, ALASKA

1951

United States
Department of the Interior
U.S. Geological Survey
Washington

Geological Investigations
Naval Petroleum Reserve No. 4
Alaska

Preliminary Report 39

PRELIMINARY REPORT ON THE STRATIGRAPHY AND STRUCTURE OF THE DRIFTWOOD-NOLUK AREA, ALASKA

By
E. G. Sable, J. T. Dutro, Jr., and
R. H. Morris

November 1951

CONTENTS

ILLUSTRATIONS

PRELIMINARY REPORT ON THE STRATIGRAPHY AND STRUCTURE OF THE DRIFTWOOD-NOLUK AREA, ALASKA

By

E. G. Sable, J. T. Dutro, Jr., and
R. H. Morris

INTRODUCTION

The Driftwood-Noluk area, approximating 850 square miles, is in the southwest part of NPR-4 and is immediately east of the area worked by U. S. Geological Survey party 1 in 1950.[1] It is bounded on the west by the Driftwood Creek-Utukok River divide, on the east by the east fork of the Nuka River, on the north by the upper Colville River, and roughly by the crest of the De Long Mountains on the south. Parts of the Driftwood-Noluk area were previously visited by W. T. Foran in 1924, and by Gerald FitzGerald and Walter R. Smith in 1925.[2]

U. S. Geological Survey Navy Oil Unit party 4 studied the geology of the Driftwood-Noluk area from May 31 to September 2, 1951. The party consisted of seven men: E. G. Sable, geologist and party chief; J. T. Dutro, Jr., and R. H. Morris, geologists; H. Drewes and R. H. Meade, field assistants; W. L. Nystrom, cook; and L. C. Sutliff, weasel mechanic. Three weasels were used for transportation in the field. On August 11, J. T. Dutro, Jr., left the party for stratigraphic work at Cape Thompson on the Arctic coast, 135 miles west of the Driftwood-Noluk area and 25 miles southeast of Point Hope. This traverse was completed on August 24 and Dutro rejoined the party for the remainder of the season.

The objectives of the summer's work were: (1) geologic mapping and stratigraphic study of rocks exposed in the area; (2) extension of 1950 field work, "tying-in" previously worked areas on the south[3] and west[4] and an attempted tie-in with Navy Oil Unit party 3 of 1951[5]; (3) examination of structure in search of Lisburne limestone at shallow depth in anticlines or "fault-trap" prospects; and (4) determination of possible closure along the supposed eastward extension of the Driftwood anticline.

1/ Sable, E. G., and Mangus, M. D., Stratigraphy and structure of the upper Utukok-Kokolik Rivers area, Alaska: U. S. Geol. Survey Navy Oil Unit Rept. 45, 1951.

2/ Smith, P. S., and Mertie, J. B., Jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, 1930.

3/ Dutro, J. T., Jr., Lachenbruch, M. C., and Lachenbruch, A. H., Stratigraphy and structure of the western Noatak district, Alaska: U. S. Geol. Survey Navy Oil Unit Rept. 39, 1951.

4/ Sable and Mangus, idem.

5/ Tailleur, I. L., Kent, B. H., and Reiser, H. N., Stratigraphy and structure of the Kiligwa River area, Alaska: U. S. Geol. Survey Navy Oil Unit Prelim. Rept. 37, 1951.

All streams were ascended to their headwaters in the De Long Mountains, and several traverses were made over the divide into the upper Nimiuktuk-Kugururok Rivers drainage. A tie-in across the Utukok-Kugururok divide was successfully completed in July. However, a planned eastward traverse on the south side of the mountain crest into Kugururok and Nimiuktuk drainages was impractical because of terrain too rugged for weasel travel.

Geology was plotted directly on 1:20,000-scale vertical photographs, which were available for 90 percent of the area, and on trimetrogon oblique aerial photographs. Altitudes were established by altimeter traverses. Section measurements were made by taping, Brunton compass traverses, and measurements on vertical photographs; they are considered accurate to 5 percent.

TOPOGRAPHY

The Driftwood-Noluk area lies in the Arctic Foothills and the Brooks Range physiographic provinces; it can be roughly divided into three physiographic belts. Four north-flowing major streams drain this area: Driftwood Creek, a tributary to the Utukok River; and the Colville, Nuka, and Utukok Rivers. South of the divide, tributaries of the Kugururok and Nimiuktuk Rivers head against the above streams.

South of the Colville River, which in this area marks the boundary between the Northern and Southern Foothills sections, are lowlands which are underlain by relatively nonresistant shale, siltstone, and sandstone of the Torok formation. In this lowland belt, 10 to 12 miles in width, bedrock crops out in cutbanks of the Colville and Nuka Rivers. A few mud heavings occur along bedding traces, but interstream areas are for the most part tundra-covered. Maximum relief of this belt is approximately 50 feet.

Twelve miles south of the Colville River, a belt approximately 8 to 11 miles wide extends to the mountain front. This belt trends approximately N. 70° E. to east and consists of rubble-covered whaleback and hogback ridges, irregularly shaped hills, and cone-shaped knobs. Interstream areas are approximately 60 percent tundra-covered. These topographic features are characteristic of areas underlain by infolded and faulted Mesozoic and Paleozoic rocks. Maximum relief of this area is approximately 1,500 feet.

The De Long Mountains of the Brooks Range province at the head of Driftwood Creek are topographically expressed as a group of high mountains and high rubble-covered hills exposing Devonian to Lower Cretaceous rocks. The Range generally trends N. 80° E. to E. Altitudes are as high as 5,000 feet; the maximum relief is approximately 2,300 feet. Major north-flowing streams are usually moderately to strongly incised, with tundra and gravel-covered flood-plains. South-flowing tributaries of the Kugururok and Nimiuktuk Rivers are deeply incised with high canyon walls that provide good exposures of Paleozoic and Mesozoic rocks. Passes across the mountains at the heads of Driftwood Creek and Storm Creek (upper Colville) can be traversed by vehicles only with extreme difficulty; passes between the

Nuka and Nimiuktuk drainages are "weaselable" if routes are carefully picked. No suitable landing places for wheel planes are present in the area; float landings can be made on Lake Noluk and a small float plane could put down on the Colville River 12 miles north of Lake Noluk.

STRATIGRAPHY

Sedimentary rocks identified in the Driftwood-Noluk area include Upper Devonian rocks, Mississippian Lisburne limestone, upper Paleozoic chert, Triassic Shublik formation, Jurassic Kingak formation, and the Okpikruak and Torok formations of Cretaceous age. Poor exposures of the Lower Cretaceous Nanushuk group were examined north of the Colville River.

A geologic map at a scale of 1:96,000 (pl. 1), correlated and composite columnar sections (pls. 2 and 3), and generalized structure sections (pl. 4) accompany this report. Sections in plate 2 are arranged roughly according to their geographic location. For correlative purposes, sections of Lisburne limestone, wherever measured, have been placed along the lower half of the plate. The sections illustrate interesting relationships, especially those of the Okpikruak formation with older rocks. The geologic map includes surface geology mapped in 1950 by Sable and Mangus, and in 1947 by Thompson and Barksdale; it also shows locations of sections measured in 1951. Because the area is one of extreme structural complexity, the scale of the map does not permit designation of all the small isolated exposures.

Measurement of thicknesses and stratigraphic relationships of pre-Nanushuk group rocks were emphasized in the field study, as were faunal and lithologic data. Thicknesses given are approximate and some are estimated, based on incomplete section measurements in various parts of the area, general structure, gross lithologic features, and occurrence of fossils. Because of structural complexity, scarcity of good exposures, facies changes, and erosional breaks, it was not possible to obtain completely reliable thickness measurements throughout the area. Subsurface rocks north of the Driftwood-Noluk area, especially Jurassic and Cretaceous rocks, are believed to vary considerably in lithology and thickness from those exposed 15 to 20 miles farther south.

Appendices A and B contain notes on the eastward extension of the Driftwood anticline and on the Cape Thompson region.

Some fossils of Paleozoic age have been examined and tentatively identified by J. Thomas Dutro, Jr.; those of Mesozoic age have been studied by Ralph W. Imlay. No microfossil determinations have been made.

Devonian rocks

Rocks of Upper Devonian age were found in two localities, one 2 miles south of the Kugururok River and another in the headwaters area of the west fork of the Nuka River.

The former sequence is well exposed in a prominent mesalike mountain (Mont Bastille) and consists of approximately 1,135 feet of shale, sandstone, conglomerate, limestone, and dolomite. Both upper and lower contacts were obscured by rubble. The Devonian sequence underlies unfossiliferous shale believed to be a part of the Okpikruak formation and is faulted over dark-gray to black, sheared silt shale and clay shale that contain lenses of gray calcareous siltstone.

The basal 200 feet of this Devonian section consists of 60 percent gray-black fissile to hackly clay shale and silt shale interbedded with medium-dark to dark-gray, medium- to coarse-grained sandstone, granular conglomerate, and silty limestone, which exhibit graded bedding and weather red brown to grayish red. A few elongate pebbles of ferruginous claystone occur in the coarser phases. The limestone contains fragmental brachiopods, pelecypods, and a tetracoral.

Thirty feet of dark- to medium-gray, sublithographic massive limestone, weathering yellow orange, overlies the lower unit. This is succeeded by 350 feet of massive, cliff-forming, light-brown to gray-blue, gray-weathering sandy limestone that contains limestone pebbles and calcareous, very fine grained sandstone that weathers yellow brown. Near its base, this limestone contains brachiopods (Atrypa sp.), pelecypods, gastropods, cephalopods, and corals of Upper (?) Devonian age.

Four hundred feet of sandy, creamy-weathering dolomite caps the section. The dolomite is light gray to light-brownish gray, has a sugary texture, and is in part conspicuously cross-bedded and laminated.

The structure of the section is relatively simple; carbonate units appear to grade into one another. The dolomite of the upper part is believed to be correlative with dolomite in a section measured in 1950 by Dutro on the lower Kugururok River west of camp 15. Correlation of these sections would indicate a minimum thickness of 1,800 feet of Upper Devonian rocks in the Kugururok River area.

The Devonian section overlies rocks of upper Paleozoic and Triassic age in low-angle fault relationship. Shale believed to be of the Okpikruak formation unconformably overlies the Devonian rocks.

In the upper Nuka River area exposures of known Upper Devonian rocks are limited to a few feet of section in two outcrops. Dense, medium olive gray coquinoid limestone containing brachiopods, pelecypods, an ammonite, and crinoid fragments is interbedded with dark-gray calcareous shale. The exposures are in a complex area of major thrust faults where rubble obscures relationships with younger rocks. They are structurally and lithologically similar to Devonian outcrops examined in 1950 in the Kokolik-Utukok area.6/

6/ Sable, E. G., and Mangus, M. D., op. cit., p. 3, 1951.

Mississippian rocks

Lisburne limestone

In 1950 the Lisburne limestone exposed in extreme western areas of NPR-4 was divided into three mappable lithologic units: lower, middle, and upper.[7] In 1951 these units were recognized and tentatively designated as first, second, and third; a fourth unit of quartzose sandstone, conglomerate, and sandy limestone was encountered, similar to strata examined in the Killigwa-Etivluk area by Tailleur in 1950.[8] The fourth unit is believed to be near the top of the Lisburne limestone, but in none of the exposures studied is the relationship to underlying units clear-cut.

The Lisburne limestone sequence in the Driftwood-Noluk area has not been divided into the Alapah and Wachsmuth members as it has in areas to the east. A brief discussion of tentative correlations is given on pages 7 and

Lisburne limestone is sparsely and sporadically exposed in the Driftwood-Noluk area; no thick sequences comparable to those in the Kokolik-Utukok area occur. Sequences a few feet to a few hundred feet thick are faulted over younger rocks, and are overlain by Mesozoic clastics. The two distinct bands of Lisburne limestone examined in the Kokolik-Utukok area in 1950 are crossed by the Utukok River near its headwaters. They trend eastward into south-flowing drainages and are thinned by reverse faults as they do so. These bands are comprised of the lower (first) and middle (second) lithologic units.

North of these bands, all units of Lisburne limestone are exposed sporadically as rubble hills or low north-facing escarpments associated with both younger and older rocks in complex thrust and high-angle fault relationships. The northern limit of Lisburne limestone exposures trends northward from west to east; east of the Nuka River small crops of faulted Lisburne are exposed as far north as lat. 68° 47' N.

First (lower) unit.--A maximum of 800 feet of the first unit of the Lisburne is exposed on Chertchip Creek, 2 miles south of camp 12. This consists mainly (80 percent) of dark-gray, silty to argillaceous, limestone (calcarenite), that is platy to blocky, and occurs in beds 1 to 12 inches thick; it weathers a dark-yellow brown. The limestone is nonfossiliferous to abundantly fossiliferous and contains an assemblage of brachiopods, pelecypods, gastropods, crinoid columnals, cephalopods, and a few trilobites. Fauna are listed on the columnar section (pl. 2). Quartzite, quartzitic siltstone, calcareous siltstone, calcareous, very fine grained sandstone, and silty shale comprise approximately 20 percent of this unit. These are medium dark gray to blue gray, occur in resistant, massive to blocky beds as much as 20 feet (?) thick.

7/ Sable, E. G., and Mangus, M. D., idem, pp. 3-7, 1951.

8/ Tailleur, I. L., and Kent, B. H., Stratigraphy and structure of the Southern Foothills between the Etivluk and Killigwa Rivers: U. S. Geol. Survey Navy Oil Unit Rept. 43, p. 11, 1951.

The first unit differs from other units in (1) the silty and argillaceous character of the limestone; (2) presence of quartzitic siltstone and other clastics; (3) the absence of chert; and (4) the characteristic dark yellow-brown weathered color. The first unit grades upward into the second unit; its upper contact has been placed at the first occurrence of massive chert-bearing "blue-gray" limestone of the second unit.

The first unit has been recognized as far east as the Etivluk River[9] and as far south as the lower Nimiuktuk River, where it was mapped in 1950 as a pre-Lisburne sequence.[10] This distinct unit is easily mappable, and because of its faunal and structural relationships to limestone and chert of the second lithologic unit, it is here included in the Lisburne limestone.

Second (middle) unit.--The maximum exposed section of this unit was examined northwest of camp 7 where it is 170 feet thick. The lower contact was exposed and is conformable and gradational with the first lithologic unit. The upper contact was not seen; on the basis of previous field work, however, the unit is believed to grade upward into the third unit.

Approximately 60 to 80 percent of this unit consists of light- to medium-gray ("blue-gray"), massive to blocky, and in part fossiliferous limestone that occurs in resistant units as much as 20 feet thick. Most of the limestone is dense and fine- to medium-grained, but some is coarse-grained to granular, containing beds of crinoidal "gravelly" limestone that may be 20 feet thick. A bituminous odor on fresh fracture surfaces is common. No dolomite was recognized in exposures of this unit in the Driftwood-Noluk area. However, in a 1,500-foot section exposed at Cape Thompson, and believed to be the second unit, 50 percent of the rock consisted of dolomite.

Medium dark gray to black chert, occurring as irregular nodules and lenses 2 to 8 inches thick constitutes 20 to 40 percent of this unit. Some fossils are in the chert; the major part of which is believed to be of secondary origin. Fractures cemented by silica were observed in the limestone at several localities.

The second unit of the Driftwood-Noluk area contains a sparse fauna of crinoidal remains, brachiopods, horn corals, and lithostrotionid corals.

Several thinner sections of this unit were measured in outcrops in the Utukok River headwaters area, and it is widely distributed as fault klippen in the Southern Foothills section.

Third (upper) unit.--A minimum of 100 feet and a maximum of 500 feet are suggested for the thickness of the third unit of the Driftwood-Noluk area. The entire sequence was not found in any one locality, and contacts are not exposed in the area. The third unit is believed to vary considerably in thickness and probably intertongues with the second and fourth units.

9/ Mangus, M. D., and others, Stratigraphy and structure of the Etivluk-Kuna Rivers area, Alaska: U. S. Geol. Survey Navy Oil Unit Rept. 35, p. 5, 1950.

10/ Dutro, J. T., Jr., and others, op. cit., p. 6, 1951.

Dark-gray to sooty black, thick-bedded chert and dark-gray, very fine grained thin-bedded limestone constitute the major part of the section. Minor amounts of black sooty shale were observed in some outcrops. In good outcrops, a distinctive banded appearance was noted. No phosphatic zones were recognized. Black chert approximates 50 to 75 percent of the section and limestone comprises less than 5 percent of the upper part. Chert occurs in fairly regular beds from 3 inches to 1½ feet thick and in the lower portion of the unit as lensing beds between thin limestone units. The limestone ranges from thin, platy, unfossiliferous "musical" limestone to partly silicified limestone with fragmental faunal remains. The limestone beds are mostly less than 1 foot thick, but some are 10 feet thick. Both limestone and chert generally have a bituminous odor when freshly broken.

The third unit is similar in lithology to the Kuruktagiak facies of the Lisburne limestone exposed in other areas of northern Alaska. Faunal identifications have not been completed.

The abundance of chert serves to distinguish the third unit from lower units in the Driftwood-Noluk area. The lower contact is believed conformable and gradational with the second lithologic unit; it appears to grade upward into Siksikpuk-type shale and chert 2 miles southeast of camp 7. Relationships between third and fourth units are not clear.

Fourth unit.--One hundred eighty five feet of the fourth unit were measured 1½ miles east of camp 6, and a 300-foot section is present 2 miles southeast of camp 12. The unit occurs in massive resistant ridges throughout the area. The fourth unit was recognized in areas to the east of the Driftwood-Noluk area in 1950.[11] To the west it was seen in 1950 only as a small rubble patch near the Utukok-Kugururok divide.

In general the unit consists of 60 to 70 percent of light-gray to dark-gray, moderately clean, very fine to coarse-grained sandstone and conglomeratic calcareous sandstone. At places 80 percent of the rock is round to subangular, clear to milky quartz sand, with minor amounts of black chert grains. The sandstone weathers yellow brown to white, is interbedded with bright gray-green sandstone, limy siltstone, and silty limestone, and is capped by fossiliferous limestone. With the exception of the green sandstone, all lithologic types contain scarce to common faunas: crinoid fragments, brachiopods, and bryozoa. These appear to be correlative with fossils of the seventh to ninth zones of the Alapah member of the Lisburne Limestone in the Kanayut Lake vicinity.[12]

Correlation.--The first unit is equivalent to the pre-Lisburne formation as mapped by Dutro and others in the Niniuktuk-Kugururok area in 1950. It is considered correlative with a part of the Wachsmuth member of the central Brooks Range but may also be partly equivalent to the Kayak formation.

11/ Tailleur, and others, op. cit., p. 11, 1951.
12/ Dutro, J. T., Jr., personal communication.

The second unit is probably correlative to parts of the Wachsmuth and Alapah members of the Kanayut-Anaktuvuk region. In the Driftwood-Noluk area it was impossible to map the Wachsmuth and Alapah members separately on the basis of lithology.

The third unit is thought to be equivalent to the Kiruktagiak member as it has been mapped farther east.

The fourth unit is the same as that mapped by Tailleur in the Etivluk-Killigwa area immediately to the east. This sandy facies has been demonstrated to intertongue with upper beds of the second unit (high Alapah equivalents).

Pennsylvanian (?)-Permian (?) rocks

Siksikpuk group

Rocks herein designated as Siksikpuk group include those rocks overlying the Lisburne limestone and underlying known Triassic rocks. No complete sequence is exposed in the Driftwood-Noluk area and the almost unfossiliferous and monotonous lithologic character of the strata make correlations of structurally complex isolated sections difficult. Several sections from 100 to 800 feet in thickness were measured, and a maximum thickness of 1,300 feet is postulated.

Chert comprises approximately 80 percent of the Siksikpuk group in the Driftwood-Noluk area. The chert occurs in units as much as 150 feet thick; it is dull to glassy, ranges from black to green gray, gray, blue gray, and maroon in color, and is usually thick-bedded (up to 2 feet), although thin, abruptly lensing beds are also common. Dark-gray to green-gray argillite, dark-gray siliceous shale, and dark-gray limestone occur in lesser amounts. Minor amounts of chert conglomerate with angular constituents appear to be near the base of the group. Maroon and green shale was encountered as rubble in a few localities, but its exact stratigraphic position is unknown.

A strikingly different 230-foot sequence of sooty shale and cross-bedded siltstone was examined along Trail Creek, a tributary of the Kugururok River, 2 miles east of camp 7 (see pl. 1) where the thickest known section of this unit occurs. The micaceous, platy to hackly, laminated and slightly cross bedded, dark gray sooty shale weathers yellow brown to yellow orange, and has a slight bituminous odor on fresh fracture surfaces. Interbedded with it is a hard, medium dark gray, noncalcareous to moderately calcareous, laminated and cross-bedded siltstone that weathers yellow brown. The siltstone beds range from 1/8 inch thick to large lenses 20 feet thick; they comprise 20 percent of the unit and increase in amount upward in the section. The bottom of the section is not exposed; the top is overlain by blue-gray, green-gray, and maroon chert and argillite with interbedded, dark-gray siliceous shale of the Siksikpuk group. This is unconformably overlain by sandstone, conglomerate, and shale of the Okpikruak formation.

The shale and limestone sequences of the Siksikpuk group are underlain by limestone, chert, conglomeratic shale, and limestone-matrix conglomerate that contains boulders of limestone. These rocks resemble the limestone and chert of the Kiruktagiak member, and are believed to be a facies of the Lisburne limestone. In the southernmost exposures, the Siksikpuk group is normally overlain by the Okpikruak formation with varying angular discordance (0° to 45°) (see pl. 3). This condition infers deep erosion of older rocks prior to Cretaceous deposition, or Cretaceous deposition on a faulted complex.

A few leiorhynchid brachiopods were found associated with these rocks, but exact age determinations are not possible.

Triassic rocks

Shublik formation

The majority of exposures of the Shublik formation in the Driftwood-Noluk area are in an anticlinal area 2 miles south of camp 3. The anticlinal area is exposed as scattered outcrops to the east fork of the Nuka River. The Shublik formation also crops out in discontinuous rubble bands and poor outcrops east and west of camp 8. South of these localities, fossiliferous Triassic rocks are scarce, but farther south on the main Kugururok and Utukok Rivers Triassic rocks are fairly well exposed.

The Triassic Shublik formation is herein restricted to the rocks that contain Triassic fossils and those sequences associated with and showing no depositional break with the fossiliferous sequences. The thickest section (102 feet) of such rocks is exposed on Thunder Creek, 5 miles west of camp 8; a strikingly different section of 200 feet thick crops out on the Kugururok River drainage just north of Mont Bastille. The former section is in fault contact with the conglomerate unit of the Torok formation. Neither top nor bottom is exposed. Twenty-three feet of medium-gray, olive-gray, and black, very thin bedded chert with thin shaly interbeds underlies half a foot of black chert and shale that contains Daonella (?) sp. of middle (?) Triassic age. This is overlain by 19½ feet of black chert and shale and olive-gray banded chert with a small amount of olive-gray siltstone. Fifty-seven feet of unfossiliferous black shale and black, olive-gray, and blue chert occurs near the top of the section and is capped by 13 feet of thin-bedded medium-gray cherty limestone containing abundant Monotis shells of Upper Triassic (Noric) age. This Monotis zone is persistent throughout the Driftwood-Noluk area, and in areas to the west, such as Cape Thompson, it constitutes a good horizon, and varies in thickness from 10 to 30 feet.

Two hundred feet of chert, limestone, and Monotis-bearing conglomerate is well exposed on the north side of Mont Bastille, 5 miles southwest of camp 7. This unusual sequence was seen in place only in this locality, but stream gravel of the Utukok River contains similar rocks. Neither top nor bottom is exposed, but the section appears to overlie conformably Paleozoic cherts and limestone, chert and shale of the third unit of the Lisburne limestone. This Triassic sequence consists of 95 feet of blue-gray,

gray, and green-gray chert and thin-bedded, medium-gray limestone, overlain by 85 feet of gray-green, gray, and grayish-red (maroon), banded, thin-bedded chert and limestone. In the upper 70 feet of the chert and limestone are thin beds of siltstone and sandstone that show graded bedding. Two conglomerate beds, each 1 foot thick, occur 130 feet and 145 feet above the base of the section. These are medium gray to maroon, contain elongate granules of varicolored chert and closely packed fragmental shells of Monotis. The section is capped by 20 feet of chert similar to that in the lower 85 feet. Rubble of unfossiliferous black silt shale overlies these known Triassic rocks.

Jurassic (?) rocks

Kingak (?) formation

A predominantly clastic sequence overlying Paleozoic and Triassic rocks and underlying fossiliferous Cretaceous rocks is sporadically exposed in the Southern Foothills section in the Driftwood-Noluk area. It was recognized in a few places in the Brooks Range province but for the most part is absent there. Except for conglomeratic and cherty members, it is relatively nonresistant and is topographically expressed as low rolling hills and discontinuous ridges. Because fossils are scarce or absent and structures in this unit are extremely complex, thickness measurements and age determinations are uncertain. No complete section was encountered in the area, but 1,200 feet is believed to be the maximum thickness. Because of angular discordance with overlying and underlying rocks, it is tentatively assigned a Jurassic age.

Varied rock types indicating rapidly changing sedimentary conditions both laterally and upward in the sequence are characteristic of this unit. Local basal conglomerates from 5 to 250 feet thick are interbedded with shale and fine-grained sandstone, but lense laterally into conglomeratic siltstone, sandstone, and shale. Conglomerate constituents range from granule to boulder size (up to 5 feet in diameter), and are poorly sorted and chaotically arranged, implying rapid deposition, in part from a nearby source. They consist of varicolored chert, mafic and salic igneous rocks, small amounts of limestone, white quartz, green-gray sandstone, shale, quartzite, and schistose rocks. Most of the pebbles and boulders are angular, with the exception of the igneous rock detritus which is generally round to subround. Some phases of the conglomerate consist entirely of igneous constituents, others are predominantly chert, and one "igneous" conglomerate was found that grades laterally into a "chert" conglomerate. The matrix of these massive, resistant conglomerates generally consists of a green-gray to dark-gray, silty, slightly calcareous to noncalcareous sandstone which comprises 20 to 50 percent of the rock. Dark-gray, conglomeratic siltstone and shale equivalents of these conglomerates contain scattered pebbles and some boulders as much as 10 feet in diameter. Two hundred fifty feet, the thickest measured sequence of these conglomerates in the Driftwood-Noluk area, crops out on Thunder Mountain 3 miles northeast of camp 4.

A few sharpstone chert conglomerates from 2 to 50 feet thick are also believed to be in the lower part of the Kingak formation, but are thin and discontinuous and are poor key beds. No fossils are present in the conglomerate units.

Above and partly equivalent to the Jurassic conglomeratic sequences, a clastic sequence of interbedded shale, sandstone, conglomeratic sandstone, and limy siltstone with minor chert locally underlies known Cretaceous rocks with pronounced angular discordance. Thickness of this unit varies, and it is entirely absent in some localities where Cretaceous rocks overlie older units. This infers an orogenic and erosional hiatus between the Jurassic and overlying Okpikruak formation. Sandstone of this unit is gray green to medium dark gray subgraywacke; it is noncalcareous to moderately calcareous, very fine to medium-grained, well-indurated, weathers olive gray to brown, and locally contains numerous "cannonball" concretions from $\frac{1}{2}$ inch to 3 feet in diameter. The sandstone beds have a sharply lensing character, are massive to blocky, and occur in units to 25 feet thick. They are interbedded with dark-gray, platy to hackly silt shale that contains pebbles of chert and igneous rocks, and with gray-green, olive, black, and blue-gray, thin-bedded, banded lensing chert units as much as 40 feet thick.

Isolated sections of dark-gray silt shale and clay shale containing scattered medium-gray, cream to red-brown-weathering silty limestone lenses and nodules and sections of red and green shale were examined in the upper Colville and Nuka Rivers drainages. No definite relationships with other sedimentary sequences could be determined, but these shale sequences are believed to cap the Jurassic units. The shale is not everywhere present and for the most part appears to have been eroded prior to deposition of the Okpikruak formation. Maximum thickness of this unit is believed to be 400 feet. Some of the limestone lenses contain aucelloid pelecypods of possible Jurassic age. Further laboratory work is necessary for precise identification of these pelecypods. No other fossils were found in the Jurassic rocks.

Locally, Jurassic rocks in major thrust-fault zones have been metamorphosed to quartzite and slate. Metamorphism is probably the result of compressional stresses of post-Jurassic diastrophism. Extrusive and intrusive mafic rocks are also associated with the Jurassic units, and in some places clastics near igneous contacts are partially mineralized and altered.

Jurassic rocks almost certainly overlie older rocks with angular unconformity. In various localities Jurassic units overlie Lisburne limestone, Siksikpuk group chert, and the Shublik formation. Deposition on an erosional surface of folded and faulted rocks is postulated.

Source areas for the Jurassic rocks vary. Highlands to the south contributed most of the sediments; some coarse clastics were deposited close to their source; in others, igneous constituents imply a source area a considerable distance south of present Jurassic exposures, possibly in the present Baird Mountain region, 75 to 100 miles south of the Driftwood-Noluk area.

Exposures of Jurassic rocks invariably are structurally complex, and are sharply folded and faulted with older sequences and with Okpikruak and Torok formations.

No Jurassic rocks were recognized with certainty in the upper Utukok and Kokolik Rivers area during the summer of 1950; however, some cherty units and red and green shales were tentatively assigned to the Jurassic because of their stratigraphic relationships with younger rocks.13/

Lower Cretaceous rocks

The thick sequences of Lower Cretaceous rocks exposed in the western part of NPR-4 have been previously divided into three major units; the Okpikruak formation, the Torok formation, and the Nanushuk group,14/ as has been done in more easterly areas of NPR-4.15/ Work in the Driftwood-Noluk area in the summer of 1951 has confirmed the previous investigation and provided additional information as to lateral extent and persistence of these Lower Cretaceous units.

Relationships between the Okpikruak formation (Neocomian) and older rocks show good evidence of a major erosional break and angular unconformity. The Okpikruak formation is approximately 1,500 to 2,000 feet thick in the area, and underlies the Torok formation. The nature of the contact between the Okpikruak and Torok formations is obscure, but angular breaks between the two appear to be present at least locally. The stratigraphy and structure of these formations were examined in detail. The almost unfossiliferous Torok formation (post-Neocomian) is the thickest sedimentary unit in the Southern Foothills section and is approximately 9,000 to 9,500 feet thick in the Driftwood-Noluk area. The contact between the Torok formation and overlying basal Nanushuk group, zones B-C undifferentiated, was examined briefly.

Okpikruak formation

In the western part of the Driftwood-Noluk area exposures of the Okpikruak formation are confined to the De Long Mountains, but near the eastern margin swing northward to within 3 miles south of Lake Noluk. At the mountain front the Okpikruak formation is topographically expressed as rubble-covered mountains with as much as 2,300 feet of relief. In the foothills belt it occurs in discontinuous ridges, knobs, and tundra-covered flats. No complete section of the Okpikruak formation is exposed in the Driftwood-Noluk area; partial sections as thick as 1,650 feet were measured.

The Okpikruak formation is restricted to a fairly distinctive sequence of rocks bearing Aucella crassicollis Keyserling and related aucelloid pelecypods, and to unfossiliferous rocks which in their lithologic character and stratigraphic position are indistinguishable from the fossiliferous sequences. It can be divided into two general facies which appear to intertongue, no one unit having a constant position within the formation.

13/ Sable, E. G., and Mangus, M. D., Report 45, 1951.
14/ Sable, E. G., and Mangus, M. D., op. cit., 1951.
15/ Patton, W. W., Jr., and Tailleur, I. L., Report 34, 1950.

However, the basal part is generally finer than the upper. The facies in the De Long Mountains is coarser-grained than the northernmost exposures which contain a high percent of shale. In general the Okpikruak formation shales northward.

The basal unit, 0 to 500 feet thick, generally consists of sandstone, siltstone, and shale with thin conglomeratic lenses within 100 feet of the base. Thicker conglomerate lenses occur locally. This basal unit is characterized by well-developed cyclic bedding, with rhythmic alternations of fine- and coarse-grained rocks. Graded bedding is common. Subgraywacke sandstone and siltstone in beds up to 2 feet thick vary from dark-gray green and green gray to medium gray and are fine- to coarse-grained with scattered pebbles of chert; they are laminated to finely cross bedded, blocky to massive, weather light brown to dark-yellow orange, and make up 20 to 50 percent of the unit. Some contain scattered to abundant shells of Aucella crassicollis and Aucella okensis (?) (within 50 feet of the base) but many are unfossiliferous. Interbedded silt shale and lesser amounts of clay shale are medium dark to dark gray, with small amounts of green-gray shale near the base. The shale increases upward in the unit and comprises 90 percent of the strata in the upper part. Lenses of dark-gray limestone as much as 3 inches thick are common and some contain abundant Aucella crassicollis.

Near-basal graywacke-type conglomerate occurs as lenses in southerly exposures of the Okpikruak formation. The matrix is a green-gray to medium dark gray, hard, fine-grained sandstone and siltstone, noncalcareous to moderately calcareous. Constituents are igneous rock, varicolored chert, quartzite, Triassic and Mississippian limestone, shale, sandstone, white quartz, and schistose rocks, with percentages widely varying in different localities. These are generally angular to subround ranging from granules to 4-inch cobbles, with occasional boulders 3 feet in diameter. The conglomerates are massive, ledge-forming members and are unfossiliferous in the Driftwood-Noluk area.

The upper unit of massive to flaggy, micaceous, calcareous, moderately to well-indurated conglomeratic sandstone and conglomerate caps the section. It is gray green in color and weathers light brown. Shale in thin interbeds makes up less than 20 percent of the section. Coarser clastics are of graywacke type and constituents are predominantly angular to subangular chert granules and pebbles. Pebbles of limestone containing Monotis sp. (Upper Triassic), Lisburne limestone, and a few igneous pebbles occur as minor constituents. The unit coarsens upward, and coarsens appreciably southward. Aucella crassicollis and other shell fragments are scattered through this unit, though absent in some localities.

The upper unit is extremely variable in thickness and apparently is equivalent in part to the lower, cyclically bedded unit. The thickest measured section, on Trail Creek drainage 2 miles east of camp 7, is 1,150 feet.

The Okpikruak formation unconformably overlies various older formations and a major orogenic and erosional break occurred prior to Okpikruak

deposition, possibly in Upper Jurassic time. Sharp angular contacts of the Okpikruak formation with older Mesozoic and Paleozoic rocks are best exposed north of the mountain front on Driftwood Creek, Storm Creek, and the Nuka River. The discordance varies from 0° to 90°. These relationships are strikingly evident as shown in the correlated columnar sections (pl. 2). In southernmost exposures the Okpikruak formation directly overlies Devonian rocks, Lisburne limestone, Siksikpuk group chert, and thin remnants of Kingak formation. Eight to 10 miles farther north it overlies the Kingak formation. Contact relationships of the Okpikruak formation with these older rocks are angular to conformable. Okpikruak sediments may have been deposited on an irregular surface, on a surface containing complexly folded and faulted rocks, or on both. Field evidence points toward deposition on an old complex.

In a band extending roughly N. 70° E. from Elbow Fork of Driftwood Creek to the Nuka River, the Okpikruak formation was not recognized. Here the sequence designated as the lower shale-siltstone unit of the Torok formation directly overlies Triassic rocks. No fossils were found; this unit may actually be equivalent to the Okpikruak formation or to the Jurassic Kingak formation.

Upper contacts with unfossiliferous Torok formation rocks were nowhere recognized with certainty. Three miles west of camp 8, steeply dipping shale of the Okpikruak formation that contains fossiliferous limestone lenses is overlain by nearly horizontal beds of unfossiliferous sandstone and conglomerate. If these rocks are basal Torok formation, then a strong angular unconformity between the Torok and Okpikruak formations is present in this vicinity.

Okpikruak rocks show good evidence of a southerly source area. The lower unit was in part deposited in relatively quiet water, with periodic flooding from the southerly landmass. Local nearby source areas contributed part of the sediments of some beds of the formation, but it is believed that the major highlands lay south of the present crest of the Brooks Range.

The structure of the Okpikruak formation, although complex, is considerably less complicated than that of older rocks. Tight isoclinal folds are common, reverse faults are present, and Okpikruak rocks are in many places thrust over older formations. However, in mappable large-scale synclinal structures, the relatively broad folds overlie a complex of older formations. These relationships are exhibited south of Thunder Mountain and west of camp 9 on the Nuka River.

Torok formation

Four subdivisions of the Torok formation were recognized in the upper Utukok-Kokolik Rivers area in 1950.16/ They are, in ascending order, the lower shale-siltstone unit, the conglomerate unit, the upper siltstone-shale unit, and the zone A shale unit. These mappable units were again recognized in the Driftwood-Noluk area during the summer of 1951, and new information relative to structure and stratigraphy was obtained.

16/ Sable, E. G., and Mangus, M. D., op. cit. 1951.

Lower shale-siltstone unit.--The lowest Torok formation sequence, the lower shale-siltstone unit, crops out in a generally N. 70° E.-trending band of low hills and tundra-covered flats from the major forks of Driftwood Creek to the Nuka River. East of the Nuka River it is not exposed but may underlie overthrust sheets of complexly folded and faulted early Mesozoic and Paleozoic rocks (see pl. 1). The belt has been recognized as far west as Iligluruk Creek. The lower shale-siltstone unit conformably underlies the conglomerate unit, apparently with gradational contact. It directly overlies Triassic rocks. It is in fault contact with various Paleozoic and early Mesozoic rocks in southerly exposures. Structurally it is on the south limb of a major syncline in the Torok formation and contains numerous small intricate folds. As the unit is unfossiliferous, it may not be part of the Torok formation, but may possibly be correlative with part of the Okpikruak formation or the Jurassic Kingak formation. The only evidence relating to the age of the unit is its relationship with overlying and underlying rocks. If it is equivalent to the Okpikruak, Okpikruak and Torok sedimentation must have been essentially continuous. If it is younger than the Okpikruak formation, either erosion between Okpikruak and Torok time removed the Okpikruak formation in this part of the southern foothills, or the Okpikruak formation was never deposited there.

Eight hundred feet of the lower shale-siltstone unit was measured on Cirque Fork of Driftwood Creek 1 mile east of camp 3; the section consists of a fairly rhythmic alternation of medium-gray to black, thin-bedded (commonly less than 1 foot thick), well-indurated, micaceous, noncalcareous siltstone that weathers rusty brown, olive gray, and purplish, and contains scattered pyrite nodules. Ripple marks, mudflow markings, concentrations of woody fragments, worm trails, and fucoidal markings are common on the undersides of the siltstone beds. A few more massive fine-grained sandstone beds of similar character occur in the upper part of the unit, and range in thickness from 2 to 20 feet. Six-inch to 15-foot interbeds of dark-gray fissile silt shale constitute 40 to 60 percent of the unit. The unit appears to coarsen southward; massive sandstone and sharpstone conglomerates in southerly exposures are believed to be equivalent to the fine clastics described above. This coarse facies is mapped as undifferentiated Jurassic-Cretaceous on plate 1.

The cyclic bedding of much of this unit, combined with the dark color and dense character of the siltstone, is characteristic and distinctive. No complete sections were exposed in the Driftwood-Noluk area; however, two 800-foot sections measured on Driftwood Creek in 1950[17/] were reexamined. Computation of thickness east of Driftwood Creek give a maximum of 900 feet.

Conglomerate unit.--In the Driftwood-Noluk area the best exposures of the resistant conglomerate unit occur 8 miles west of camp 8 on Thunder Creek. No complete section is exposed, but from structural computation, 2,200 feet of this unit is believed to be present. The unit is commonly expressed as high hogback ridges and hills of 1,000 feet of relief in the Driftwood Creek vicinity. Eastward the conglomerate unit trends south of

17/ Sable, E. G., and Mangus, M. D., op. cit., 1951.

Lake Noluk and appears to "pinch-out"; 3 miles west of the Nuka River only low scattered rubble hills mark this general horizon. As a mappable unit, it is probably no more than 2,000 feet thick in the eastern part of the area.

North of Cirque Fork of Driftwood Creek a 5-mile-wide belt of the conglomerate unit extends N. 80° E.; in the vicinity of Lake Noluk it narrows to approximately 3 miles and strikes east. It is believed to consist of two major structures, a normal anticlinorium on the north and a northward-overturned synclinorium in the south part of the belt (see cross sections, pl. 4). It is infaulted with rocks of the Shublik formation and infolded with other units of the Torok formation.

The conglomerate unit consists of approximately 40 to 70 percent green-gray to medium dark gray, moderately calcareous, graywacke sandstone, conglomeratic sandstone, and granule to pebble conglomerate; and 30 to 60 percent of interbedded silt shale with small amounts of dark-gray platy to nodular clay shale. Sandstone and conglomerate occur as massive, moderately to well-indurated, lensing beds as much as 30 feet thick; they exhibit graded bedding, cross bedding, fucoidal markings, and contain mud lumps, shale pebbles, wood fragments, and a few sandy "cannonball" concretions. Their constituents are subround to subangular varicolored chert, white quartz, and a few pyrite nodules. The sandstone and conglomerate weather olive gray to light brown. Medium dark gray silty limestone that weathers light brown and cream-colored occurs as minor lenses up to 4 inches thick; some of the lenses contain wood fragments and chert granules.

The conglomerate unit appears to overlie the lower shale-siltstone unit conformably and gradationally. At the northern edge of conglomerate outcrop, the conglomerate unit underlies a sequence of shale, siltstone, and sandstone that is believed to be a slightly coarser southern equivalent of the zone A shale unit of the Torok formation. One to 3 miles north of the conglomerate unit this zone A sequence occurs in a synclinorium and appears to be underlain by the upper siltstone-shale unit. It therefore appears that the conglomerate unit is equivalent to the basal part of the upper siltstone-shale unit (see pl. 4).

The conglomerate unit occurs as a series of relatively simple normal folds. Axial areas, however, are more complex, with numerous minor folds and small-scale reverse and normal faults.

No fossils were found in the conglomerate unit.

Upper siltstone-shale unit.--The upper siltstone-shale unit of the Torok formation in the Driftwood-Noluk area is exposed in anticlines in approximately east-trending bands; it extends from 2½ miles north of camp 2 on Driftwood Creek to an area north of Lake Noluk, east across the main Nuka River. Poor traces and river-cut exposures of this unit are also present north of these bands in a major anticline whose axis appears to strike into the Driftwood anticline 8 miles west of the Colville River. Recent gravels cover the area between the anticline and the Colville River.

The unit is expressed in whaleback ridges 800 feet high immediately north of Lake Noluk, and as low linear ridges farther north. Tundra covers flats east of the Nuka River, where these rocks would be expected to crop out. No complete section was exposed in any one locality, the best outcrops being on the Colville River east of the Driftwood anticline. Overall structural measurements give approximately 2,600 feet as the total thickness. The unit appears to "shale-out" eastward and northward and resembles the zone A shale unit exposed near camp 11 on the Nuka River. Here the upper siltstone-shale unit as a mappable unit probably is not more than 1,800 feet thick. Northerly exposures of the unit also contain a greater percent of shale and appear to be gradational with the overlying zone A shale unit.

The upper siltstone-shale unit was first mapped on Iligluruk Creek and the Utukok River in 1950 where 4,000+ feet was measured.18/ It comprises the exposed core of the Driftwood anticline.

Siltstone, sandstone, thin conglomeratic lenses, clay shale, and silt shale constitute this unit. The coarser phases comprise approximately 40 to 70 percent of the unit on the Colville River; beds range in thickness from a few inches to 75 feet. On the Nuka River, 12 miles east of the Colville River exposures, the coarser clastics comprise from 20 to 50 percent of the sequence; the beds are thin, ranging from a few inches to 3 feet in thickness. They are very fine grained to medium-grained, medium gray to olive gray, moderately micaceous, calcareous, moderately to well-indurated, platy to massive, and weather light-olive gray to dark-yellow brown. Worm trails, prominent fucoidal markings, mudflow phenomena, carbonaceous material, shale pebbles, and pyrite nodules are common. A very finely cross bedded to laminated appearance is characteristic of the siltstone. Lenses of green-gray chert-granule and pebble conglomerate and conglomeratic sandstone less than 3 feet thick occur near the base and in the lower part of the unit. Constituents are round to subround varicolored chert granules and pebbles. The coarser clastics are interbedded with varying amounts of silt shale and clay shale in units commonly 1 to 5 feet thick but with some as thick as 75 feet. These are medium- to dark-gray, calcareous, blocky, platy, or nodular, and of varying degrees of hardness; they are indistinguishable from the zone A shales. Lenses of coaly material are interbedded, and a small amount of bentonitic clay is believed to lie near the top of the unit. One Lower Cretaceous ammonite, not yet identified, was collected from santstone of the upper siltstone-shale unit. No other megafossils were found.

From structural observations, it is now believed that most of this unit is equivalent to the conglomerate unit, but without faunal evidence it is difficult to state this absolutely. However, in the vicinities of the Colville River, Lake Noluk, and the Nuka River, the conglomerate unit and upper siltstone-shale unit, both occurring in anticlinorial structures, are separated by a synclinorium of the zone A shale unit which directly overlies both the older units. Precise correlation of the conglomerate and siltstone-shale units could not be made. The gross

---

18/ Sable, E. G., and Mangus, M. D., op. cit., 1951.

lenslike character and similar easterly "shaling out" of these units is added evidence of their correlation.

Zone A shale unit.--This widely distributed sequence has been recognized as underlying the basal Nanushuk group rocks in most areas of the Arctic Slope. In the Utukok-Kokolik Rivers area a total thickness of 5,700 feet was estimated in the Driftwood anticline vicinity.19/ The unit overlies and is gradational with the upper siltstone-shale unit of the Torok formation, and also conformably and gradationally underlies zones B-C undifferentiated, Nanushuk group.

In the Driftwood-Noluk area, the poorly resistant zone A shale unit is exposed only in stream cuts in tundra-covered flats. An east-trending valley from Driftwood Creek across Lake Noluk to the Nuka River reflects a synclinorium in this unit. The valley widens eastward from 1 mile on Driftwood Creek to approximately 3 miles on the Colville River. Whaleback ridges of the upper siltstone-shale unit separate this valley from a lowland belt to the north which extends 7 miles to the Nanushuk group hills north of the Colville River. These nearly featureless lowlands are underlain by infolded zone A shale and upper siltstone-shale unit.

North of Lake Noluk approximately 1,500 feet of zone A shale unit was measured in a 90-percent exposed section on the Colville River. The section is gently dipping and underlies Nanushuk group rocks with a steadily decreasing north dip. Structural measurements based on scattered exposures north of the 1,500-foot section give a thickness of approximately 6,000 feet for the zone A shale unit.

The zone A shale unit, a monotonous sequence of dominantly clay shale and silt shale, contains thin interbeds of medium-gray calcareous siltstone and very fine grained sandstone in beds averaging 4 inches to 1 foot in thickness. Carbonaceous fragments are common, and a few coaly lenses are present; in the lower and upper parts of the unit sandy lenses and beds are thicker. The shale, which constitutes 70 to 90 percent of the unit, is medium gray, dark gray, and olive gray, moderately calcareous, with occasional pyrite nodules; it is nodular to blocky, with partings 1/8 inch to 1 inch thick, and occurs in units up to several hundred feet thick.

In the upper 1,000 feet of this unit, sandstone lenses and beds increase in thickness (maximum 75 feet). These fine-grained sandstone beds in general are cleaner than those in older units of the Torok formation, and strongly resemble Nanushuk group sandstones. They offer further evidence that the zone A shale and Nanushuk group zones B-C undifferentiated were deposited as an essentially unbroken sequence.

A precise lower contact between the zone A shale unit and the upper siltstone-shale unit was not recognized in the Driftwood-Noluk area. However, poorly exposed rocks in a cut on the Colville River are believed to be basal zone A. This distinctive sequence, approximately 800 feet thick,

19/ Sable, E. G., and Magus, M. D., op. cit., 1951.

contains dark-gray and green shale interbedded with minor siltstone, sandstone, lenses of medium- to dark-gray ironstone, buff-colored claystone, and silty limestone exhibiting cone-in-cone structure. Bentonitic clay mudflows are associated with maroon and green shale. These rocks closely resemble the basal part of zone A shale unit exposed on the north side of the Driftwood anticline. 20/ In stratigraphic position and lithology they also appear to be similar to an unusual sequence of rocks examined in 1949 21/ on the Kukpowruk River 75 miles west of the Colville River. The Kukpowruk River exposures contain Aucellina sp. and Inoceramus sp., and are therefore believed to be of Albian (?) age (upper Lower Cretaceous).

In the vicinity of Lake Noluk, a predominantly shale sequence, but containing more siltstone and sandstone than the zone A shale outcrops 3 to 6 miles north, apparently overlies both the conglomerate and upper siltstone-shale units of the Torok formation. This is believed to be a slightly coarser southerly equivalent of the zone A shale unit. Thickness of this poorly exposed sequence could not be measured.

Dark-gray silt shale and clay shale comprise 60 to 80 percent of the southerly sequence, and are interbedded with medium-dark to dark-gray and blue-gray dense siltstone and medium-gray to olive-gray, very fine to fine-grained, platy to blocky, micaceous, dense to friable sandstone. Siltstone and sandstone beds are commonly less than 1 foot thick, but some are 15 feet thick. They weather grayish to yellowish brown and orange, and contain mud markings and small ripple marks.

On Driftwood Creek (1½ miles north of 1951 camp 2), 80 feet of an unusual sequence of shale, coquinoid limestone, and chert lenses was examined in 1950 and reexamined and measured in 1951. The section is believed to be basal zone A; it crops out in the center of a syncline, where it directly overlies the conglomerate unit. The contact is apparently conformable but sharp; the top of the sequence was not exposed. The section consists of 85 percent dark-gray, black, and gray-green clay shale that contains wood fragments and is interbedded with thin (maximum 1 inch) lenses and beds of dark-gray dull chert. Twenty-eight and 39 feet above the base, two limestone beds, respectively 5 and 8 feet thick, contain numerous pelecypods, identified in the field as Aucellina sp., and one Cretaceous (?) belemnite. Other scattered limestone lenses are also present. The limestone is green gray to light gray, weathers grayish red to pale brown, and locally contains well-rounded chert granules. This horizon was also seen in the hills east of Driftwood Creek and east of the Colville River.

20/ Sable, E. G., and Mangus, M. D., Stratigraphy and structure of the Driftwood anticline: U. S. Geol. Survey Navy Oil Unit Rept. 44, 1951.

21/ Chapman, R. M., and Sable, E. G., Stratigraphy and structure of the Kokolik and Kukpowruk Rivers area: U. S. Geol. Survey Navy Oil Unit Rept. 33, p. 8, 1950.

Zones B-C undifferentiated.--No exposures of the Nanushuk group are present in the Driftwood-Noluk area. The southernmost outcrops of this group occur 2 miles north of the Colville River in the Folsom Ridge syncline. Party 4 did not attempt detailed description or measurement of sections of the Nanushuk group. One traverse was made north of the Colville River to observe the nature and position of the Torok formation-Nanushuk group contact.

These southernmost exposures of basal zones B-C undifferentiated form prominent cuestas and mesalike bluffs in broad synclines separated by anticlines breached to the zone A shale unit of the Torok formation. In Folsom Ridge syncline, roughly 1,000 feet of zones B-C undifferentiated is exposed; only the basal 200 feet was examined by party 4.

Basal zones B-C undifferentiated include thick resistant units of medium-gray, fine-grained yellow-brown weathering sandstone, interbedded with dark-gray calcareous clay shale and silt shale. The sandstone is massively cross bedded, moderately indurated, flaggy to blocky, and contains impressions of Unio-type and Protocardium-type pelecypods. A few rounded pebbles of gray and black chert are concentrated in sandstone "pockets."

The Torok formation-Nanushuk group contact has been placed at the lowermost ledge-forming sandstone of zones B-C. Below these ledges a few outcrops and heavings suggest a predominantly shale sequence with scattered thick lenses of sandstone and siltstone. The contact appears to be conformable and gradational; this is a lithologic contact and should not be considered as a time boundary.

IGNEOUS ROCKS

Small bodies of igneous rocks in the Driftwood-Noluk area are exposed sporadically in the southern foothills along the entire mountain front. They crop out as very resistant spires and jagged knobs. Larger sill-like bodies, present in the De Long Mountains south and east of the Utukok River headwaters, form rugged mountains 1/2 to 2 miles wide with approximately 2,000 feet of relief.

Both intrusive and extrusive rocks were recognized. However, all appear to be mafic in composition; coarser-grained samples were identified as doleritic or dioritic with granular to diabasic texture. They are dark green to gray green and vary from finely aphanitic to coarsely crystalline with crystals to 1/4 inch long.

Intrusive igneous rocks form tabular to pluglike bodies, are finely to coarsely crystalline, and weather dark-red brown. Many of these were identified as sills, from 5 to 50 feet thick. Others suggest dikes which cross bedding at low angles. A granular to flinty chilled border phase ranging from a few inches to 2 feet in thickness was often noted. Intruded rocks are silicified; in general mineralization was restricted to quartz veining and pyritization. Intrusive rocks almost invariably occur in

major reverse and thrust fault zones and in anticlines of Paleozoic rocks, extending along these zones for great distances. Time of intrusion in relation to major faulting is uncertain. Intrusion probably took place during or immediately following major orogenic movements--possibly in early Jurassic time. No large-scale batholiths or laccoliths were seen.

Extrusive rocks were examined in several localities. These are fine-grained, gray green, and contain well-developed to almost unidentifiable pillow structures as large as 2 feet long and 8 inches thick. The pillows are commonly enclosed by a thin layer of shaly material, and are concavo-convex to doubly convex in shape. Black to dark-green amygdaloidal basalt was also examined. Amygdule fillings generally consist of carbonate material. The exact age of the extrusive rocks is unknown. Most igneous exposures are complexly faulted and folded with sedimentary sequences, and a true age determination with present information is not possible. However, the extrusive rocks appear to be consistently associated with exposures of the Jurassic (?) Kingak formation and are probably of this age. A few sandstone beds in this unit appear to have been metamorphosed.

There is some evidence that at least two periods of igneous activity occurred in the Driftwood-Noluk area. Lisburne limestone, Siksikpuk group, and Triassic rocks have been intruded. Jurassic conglomerates contain a high percent of igneous rock pebbles of composition similar to these intrusives. Jurassic clastic rocks appear to be interbedded with extrusive rocks and possibly with intrusive sills. No evidence of igneous activity in the Okpikruak formation or in younger sequences was seen, with the exception of small amounts of bentonite in the zone A shale unit (Torok). Major igneous activity thus appears to have been restricted to pre-Jurassic and Jurassic time.

STRUCTURE

Regional structural trends of pre-Namushuk group rocks in the Southern Foothills section and Brooks Range province parallel the southward swing of the Brooks Range along its western part. In the western part of the Driftwood-Noluk area, a strong N. 70° E. trend is common. This trend continues west to the Kukpowruk River, where a N. 50° E. alinement is pronounced. In the eastern part of the Driftwood-Noluk area, regional structure swings to a general east trend and continues this trend east of the Nuka River.

In the area mapped, the general regional dip is south; progressively older rocks and more complex structure are encountered from north to south. The area can roughly be divided into two structural belts: (1) a northern folded belt, extending from the Colville River south to approximately 3 miles south of Lake Noluk; it is characterized by relatively broad folds at its northern limit, with increasingly complex isoclinal and imbricate folds and minor reverse faults to the south; and (2) a belt of major low-angle thrust and high-angle reverse faults extending south from the folded belt beyond the southern limit of the area.

Belt 1.--North of the Colville River, Nanushuk group rocks are exposed in the gently folded Folsom Ridge syncline. Southward from the Nanushuk group, the zone A shale unit and upper siltstone-shale unit (Torok formation) crop out in normal fold relationships from the Colville River to Lake Noluk. Two major anticlinal and two synclinal structures were mapped north and west of Lake Noluk along the Colville River.

A major synclinorium of zone A shale unit forms an east-trending valley from the Nuka River across Lake Noluk to Driftwood Creek. South of this, the conglomerate unit (Torok formation) occurs in an area of high-angle folds with associated reverse faults. A major normal anticlinorium in the conglomerate unit is succeeded to the south by a northward-overturned synclinorium. Near the western margin of the area in the vicinity of Driftwood Creek, vertical dips are dominant; east of here, folds are broader. One belt of Triassic Shublik formation crops out in reverse-fault relationship with the conglomerate unit.

The conglomerate unit is underlain southward by a complex anticlinorium in the Torok formation lower shale-siltstone unit. Triassic rocks are sporadically exposed along the axis from Driftwood Creek to the Nuka River. These are so sharply folded and faulted that in most exposures structural details could not be delineated.

Belt 2.--At the mountain front and within the Range, reverse and thrust faults of considerable displacement involve both Mesozoic and Paleozoic sequences. With the exception of some large exposures of the Okpikruak formation, extremely complex structure occurs south of the mountain front. Several major thrust- and reverse-fault zones extend from the south limit of the area north to 4 miles south of Lake Noluk.

Associated with and extending along these major thrust zones, highly deformed and locally metamorphosed rocks occur in belts from 1/2 to 2 miles in width. Jurassic and Cretaceous (Okpikruak) clastics are altered to quartzite and slate, and cherts are occasionally mineralized; sheared zones are common. Igneous intrusives are concentrated in these zones and imbricate faults are pronounced. Because of this type of structure and lack of exposures, and because many outcrops are exceedingly small, detailed structures in these zones are not shown on the geologic map accompanying the report. The northernmost of the major thrust- and reverse-fault zones involves late Paleozoic rocks faulted over Mesozoic rocks. These appear to be high-angle reverse faults; however, in many places it is certain that the faulted rocks were later folded into the present apparent high-angle relationships. At camp 7, on the upper Utukok River, this is certainly the case. Siksikpuk group cherts and Lisburne limestone have been thrust at low angles over Okpikruak and Kingak formations, and subsequently folded into a broad syncline and tight anticlinal structure (see pl. 4). Other thrust faults in this vicinity dip as little as 7°. Klippen and fensters are common and it is believed that many of the small exposures of Lisburne limestone and Siksikpuk group 6 miles north of camp 7 are klippe remnants which have been subsequently folded with younger rocks. Near the eastern limit of the area, the fourth unit of the Lisburne limestone has similar relationships; it was thrust over younger sequences and then folded. At least two periods of major thrust faulting are thought to have

occurred: one in early Jurassic time, with Okpikruak and Kingak formations being deposited on thrust sheets in the southern part of the area and on complexly folded rocks to the north; the second period in post-Cretaceous time.

Because of relationships of the Okpikruak and Kingak formations, it is inferred that four periods of orogeny occurred in the southern part of the Driftwood-Noluk area: (1) preceding deposition of the Kingak formation, possibly in early Jurassic time; (2) preceding Okpikruak deposition; (3) after Okpikruak deposition; and (4) late or post-Cretaceous.

PETROLEUM POSSIBILITIES

1. A major anticline believed to be an easterly extension of the Driftwood anticline has been mapped on the Colville River, 8 miles east of the Driftwood anticline. No east plunge is present in this locality. (See Appendix A.)

2. Sandstone and siltstone of the Torok formation are usually well indurated and calcareous. Conglomerates are poorly sorted.

3. Okpikruak formation sandstone and conglomerate are poorly sorted, hard, and of low porosity.

4. Kingak formation sandstone, shale, conglomerate, and chert show no reservoir possibilities.

5. No oil shale was seen in the Shublik formation, most of which consists of impervious rocks. However, the chert and limestone are highly fractured.

6. Siksikpuk group rocks are composed mainly of dense, impervious but highly fractured cherts. A small percent of the rock consists of bituminous limestone.

7. The Lisburne limestone appears to be of low porosity throughout. No dolomite was seen in the Lisburne limestone in this area; secondary (?) chert is common in the second and third units. The Lisburne is highly fractured, but some recementing by silica has taken place. A bituminous odor was noticed from fresh fracture surfaces of limestone in the second and third units, and in fractured chert of the third unit. Quartzose sandstone of the fourth unit varies considerably in its apparent reservoir capacity. Some beds are quartzitic and impervious; others appear to show favorable indications. No porosity-permeability tests have been as yet made. The fourth unit is apparently most favorable as a reservoir prospect.

8. Surface structures in the folded belt in general are normal anticlinal and synclinal folds, becoming more complex and overturned southward. In the faulted belt at the mountain front, surface structure includes remnants of low-angle thrusts (klippen, fensters). No one simple large structure is exposed here. High-angle reverse faults and intricate drag folds occur along the entire mountain front.

9. No oil or gas seeps, asphaltic residue, or other direct indication of petroleum were found.

10. If subsurface rock units in the northern part of the area (along the Driftwood anticlinal trend) are essentially equivalent in thickness to the units exposed farther south, Lisburne limestone would be expected to occur at a depth of 6,700 to 7,100 feet. If the conglomerate and upper siltstone-shale units are partly equivalent, as indicated on page 17, the Torok formation is less than previously supposed, and erosional breaks may further decrease the estimate of depth to Lisburne limestone. Possible subsurface thicknesses on the Driftwood "trend" at the Colville River are:

Surface	Estimated thickness (feet)
(Torok) siltstone-shale unit	1,300
(Torok) lower shale-siltstone unit	900-1,000
POSSIBLE UNCONFORMITY	
Okpikruak formation	1,700-2,000?
UNCONFORMITY	
Kingak formation	1,200
UNCONFORMITY	
Shublik formation	300
Siksikpuk group	1,300
Total depth to Lisburne limestone	6,700-7,100

However, it is doubtful that surface structures of Cretaceous rocks accurate reflect subsurface structures in the Driftwood-Noluk area. A further deterrent to drilling in this area is the great thickness of resistant cherty units in the upper Paleozoic and Triassic sequences. It is not known how far northward these cherty facies extend in the subsurface.

SUMMARY

1. One thousand one hundred thirty five feet of Devonian limestone, dolomite, sandstone, shale, and conglomerate is exposed on the Kugururok River. Smaller exposures of Devonian limestone and shale occur on the upper Nuka River. The total Devonian section thickness is unknown but is believed to be in excess of 1,800 feet.

2. Lisburne limestone crops out in small exposures in the Brooks Range province and foothills belt in the Driftwood-Noluk area. No thick sections are present. The Lisburne limestone in this area is divided into four lithologic units. The first and oldest unit consists of silty limestone and quartzite with thin shaly interbeds; a partial section of 800 feet was examined. Massive "blue-gray"-weathering limestone and gray to black chert comprise the second unit; a partial section of 170 feet was measured. The third unit contains black bedded chert, black limestone, and black shale. It is believed to be 100 to 500 feet thick. Limy quartzose sandstone and conglomerate with interbeds of green sandstone and sandy limestone make up the fourth unit. Three hundred feet were measured.

3. Rocks of Pennsylvanian (?)-Permian (?) age may be as much as 1,300 feet thick. Black, red, green-gray, and gray chert, argillite, and shale are most abundant; minor amounts of bituminous limestone and siltstone are also present.

4. The Triassic Shublik formation is believed to be approximately 300 feet thick. Varicolored chert, cherty limestone, black shale, and minor amounts of olive-green argillite and siltstone are present. Some chert and limestone are fossiliferous.

5. Rocks of possible Jurassic age (Kingak formation) include green-gray graywacke-type conglomerate, sandstone, siltstone, shale, and chert; maximum thickness of known sections is 1,200 feet. An angular unconformity is believed present at the base of this sequence. Some extrusive and intrusive igneous rocks are associated with the formation.

6. Pre-Nanushuk Lower Cretaceous rocks are divided into the Okpikruak formation and the Torok formation. The Okpikruak formation is 1,700+ feet thick and consists of conglomerate, argillaceous sandstone, siltstone, and shale, in part cyclically bedded. The pelecypod Aucella crassicollis and associated types are abundant to absent. A strong erosional and angular break is believed to occur at the base of the Okpikruak formation.

The Torok formation is subdivided into four mappable units: lower shale-siltstone unit, conglomerate unit, upper siltstone-shale unit, and zone A shale unit. The lower unit, which in reality may be a northern facies of the Okpikruak or Kingak formations, consists of approximately 900+ feet of dark-gray shale, dense siltstone and sandstone. The conglomerate unit, similar in part to the coarse clastics of the Okpikruak formation, is at least 2,200 feet thick, thins eastward, and is correlative to part of the upper siltstone-shale unit. This latter unit, a sequence of gray calcareous siltstone, sandstone, and shale, is believed to be 1,800 to 2,600 feet thick, but thins and shales out pronouncedly to the east. A predominantly calcareous shale sequence with thin interbeds of siltstone constitutes zone A shale unit, and is about 6,000 feet thick. No unconformities were recognized within the Torok formation.

7. Zone A shale unit of the Torok formation appears to conformably underlie and grade upward into the Nanushuk group.

8. Large structures in the Torok formation north of Lake Noluk are present, but lack of exposure limits detailed mapping. South of Lake Noluk in the Southern Foothills section, extremely tight folds and reverse faults are common. Folded low-angle and high-angle faults are pronounced in the Brooks Range.

9. Porosity and permeability of rocks in all sequences are low. Fractures in rocks are abundant, but are commonly filled with secondary calcite and quartz. Oil shale does not crop out in the area, and no seeps or asphaltic residues were seen. In general, the area is one of great structural complexity.

APPENDIX A. NOTES ON THE EASTERLY EXTENSION OF THE DRIFTWOOD ANTICLINAL TREND

A possible easterly extension of the Driftwood anticline is believed to be present at long. 160° 20' W. between lat. 68° 49' and 68° 59' N., 8 airmiles east of the Driftwood anticline. At this locality cut banks of the Colville River expose the Torok formation. At long. 160° 20' W. and lat. 68° 52' N. (see pl. 1) a major anticlinal area, exposing the upper siltstone-shale unit flanked by the zone A shale unit, strikes approximately N. 80° E.

This possible easterly extension of the Driftwood anticline is an anticlinorium approximately 7½ miles wide. The south "limb" contains many normal minor folds with associated reverse faults near its south limit. Dips average 55° and range from 40° to 90°. The north limb also has minor normal folds, but dips decrease rapidly northward from 50°-70° to 12°-30°. Minor folds in this anticlinorium plunge west; no east plunge of the major structure was observed. A structure cross section of this area is included with the report (pl. 4).

North of this anticlinal area, a major syncline exposing zone A shale unit strikes west toward Meat Mountain syncline, which is north of the Driftwood anticline. South of the anticlinal area, a synclinorium of zone A shales is encountered. No exposures occur between the Colville River outcrops and those in the vicinity of the Driftwood anticline, as the area is covered by terrace gravel and tundra. If the Driftwood anticline proper plunges east, the plunge is reversed within this covered interval.

APPENDIX B. NOTES ON THE CAPE THOMPSON REGION

The Cape Thompson region (68° 08' N., 166° W., about 135 miles west of the Driftwood-Noluk area) was examined by J. T. Dutro, Jr., and E. H. Lathram from August 11-24, 1951. The main purpose of this investigation was detailed measurement of the section of Paleozoic and Mesozoic rocks previously reported by E. M. Kindle,1/ and collection of fossils from all horizons.

Rocks cropping out in the immediate vicinity of the Cape range from possible Upper Devonian to probable Jurassic age. The most complete unfaulted sequence is exposed in a broad syncline about 2 miles southeast of the Cape proper.

The uppermost beds are a series of alternating siltstone and clay shale which overlies Triassic Monotis-bearing chert and limestone and is at least 650 feet thick. No megafossils were found; and microfossil samples from these strata have not yet been studied. Stratigraphic position suggests a Jurassic age.

Triassic rocks are mainly brownish-gray calcilutite, black, gray, and gray-green chert and black clay shale. Monotis sp. ranges through 30 feet of strata near the top of this sequence, which totals about 170 feet. Both the upper and lower contacts appear to be gradational. The lower gray chert grades downward through a few feet of green and red chert into 15 feet of red and green argillite, then into dark-gray argillite. This sequence, apparently unfossiliferous, is considered correlative with the Siksikpuk group and is known to be at least 240 feet thick.

Mississippian rocks underlie the argillite, but the two units are in fault contact. There are several faults in the Mississippian section, but unfossiliferous dark-gray, fine-grained limestone and black chert of Kiruktagiak type are at least 500 feet thick. This is considered correlative with the third unit of the Lisburne limestone as mapped in the Driftwood-Noluk area. Partial sections of coarse, brownish-gray calcarenite and light brownish-gray dolomite indicate a thickness of at least 1,500 feet. Fossils in this unit resemble those reported from the Alapah member in the central Brooks Range2/ and include lithostrotionid and caninoid corals and spiriferoid brachiopods. These are probably equivalent to the second unit of the Lisburne limestone of the Driftwood-Noluk area.

A diagrammatic columnar section showing probable correlation with rocks exposed in the Driftwood-Noluk area is included on plate 2.

Older strata crop out just northwest of Cape Thompson. These include at least 1,500 feet of plant fossil-bearing fine-grained red-brown quartzite and dark-gray slaty shale which may be uppermost Devonian or lowermost Carboniferous.

1/ Kindle, E. M., The section at Cape Thompson, Alaska: Am. Jour. Sci. (4th sec.) vol. 28, pp. 520-528, 1909.

2/ Bowsher, A. L., Sr., and Dutro, J. T., Jr., A handbook of some Mississippian fossils from the central part of the Brooks Range, Alaska: U. S. Geol. Survey Navy Oil Unit Handbook (not for distribution, 1950).

Lying above these beds and below the more massive Mississippian limestone is an undetermined thickness of black shale and argillaceous limestone which contains a marine invertebrate fauna of probable lower Mississippian age. This sequence, at least 200 feet thick, may be partly equivalent to the Kayak formation of the Kaneyut-Anaktuvuk Rivers area.

SUMMARY

1. Rocks of Upper Devonian (?) to Jurassic (?) age crop out in the vicinity of Cape Thompson. Recognizable equivalents of the Lisburne, Siksikpuk, and Shublik units are present.

2. A considerable thickness of dolomite and dolomitic limestone (at least 700 feet) is included in the Mississippian sequence. Porosity may range from 5 to 10 percent; laboratory determinations have not yet been made. These rocks might well underlie the Lower Cretaceous (?) strata which cross the Lisburne Peninsula in a north-south belt 10 to 40 miles east of Cape Thompson.

3. Rocks considered Siksikpuk equivalents and known to directly underlie Triassic rocks are strikingly similar to "basement" rocks in Simpson Test Well No. 1.

4. Structurally, the region is characterized by high-angle faults and thrust faults which suggest tectonic forces acting from the southwest, as contrasted to the generally southerly forces assumed to have been active over most of the Brooks Range to the east. Folded thrust-fault planes are cut by the high-angle faults, indicating that folding followed thrusting and was in turn succeeded by high-angle faulting. This could have been accomplished in a single period of diastrophism, or in two or perhaps three separate periods.