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Naval Petroleum Reserve No. 4

Alaska

Report No. 6

STRATIGRAPHY AND STRUCTURE OF THE AREA OF THE MEADE AND KUK RIVERS AND POINT BARROW, ALASKA

1947

Previous reports on investigations by the Geological Survey in Naval Petroleum Reserve No. 4, Alaska

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No. 1 Stratigraphy and structure of the area of the Killik, Chandler, Anaktuvuk, and Colville Rivers. (1946)

No. 2 Magnetic survey of part of Naval Petroleum Reserve No. 4 by airborne magnetometer. (1946)

No. 3 Stratigraphy and structure of the Umiat anticline. (1947)

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No. 5 Stratigraphy and structure of the area of the Kurupa, Oolamnagavik, Killik, and Colville Rivers. (1947)

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by

Edward J. Webber

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STRATIGRAPHY AND STRUCTURE OF THE AREA OF THE MEADE AND KUK RIVERS AND POINT BARROW, ALASKA

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INTRODUCTION

This report incorporates the results of field and laboratory studies, from June 1946 through March 1947, of the stratigraphy and structure of the area of the Meade and Kuk Rivers and Point Barrow, Alaska. The investigations were made by the Geological Survey as part of the Navy Department's program of petroleum exploration in northern Alaska.

Paige, Foran, and Gilluly 1/ made the only previous geological investigations in parts of the area described in this report. In 1946 Geological Survey Party 4 made a geologic traverse by boat down the Meade River, from the headwaters to the mouth, along the west shore of Admiralty Bay and south shore of Elson Lagoon to Point Barrow, along the Arctic coast southwest from Point Barrow to Peard Bay, up the Kukroak River for about 10 miles, along the coast to Wainwright, and 25 miles up the Kuk River. Aerial reconnaissance flights were made along the Esoktok and Nigisaktovik Rivers and upper part of the Topagoruk River; no outcroppings were seen along these rivers and plans for boat traverses were abandoned.

Most of the area traversed lies within the Arctic coastal plain (fig. 1), where a blanket of unconsolidated sediments covers the bedrock. So far as known, outcrops here are limited to banks of streams and to sea cliffs along the Arctic coast. Exposures are also limited to the banks of streams in that part of the traverse that lies within the Arctic Plateau province, with the exception of the headwaters area of the Meade River. Outcrops and structural traces believed indicative of the attitude of the underlying rocks (topographic features, lines of vegetation, and lines of rubble) were not seen in the interstream areas. Only limited data can be obtained at the many localities along the streams where only piles of rock rubble are found. Along parts of the traverse the distance between outcrops was 5 to 10 miles, and the stratigraphic thickness exposed at individual outcrops was rarely more than 10 feet.

1/ Paige, Sidney, Foran, W. T., Gilluly, James, A Reconnaissance of the Point Barrow Region, Alaska: U. S. Geol. Survey Bull. 772, 1925.

A preliminary report based largely on the field work was prepared in October 1946. The present report contains the descriptive data of the preliminary report and also incorporates the results of heavy mineral analysis of sandstones, megafossil identification, laboratory tests of rock samples, and other work. Stratigraphic and micropaleontologic data from Skull Cliff Core Test No. 1 up to March 9, 1947, have also been included. These studies have resulted in a major revision of the stratigraphy as presented in the preliminary report. Adequate data are not available for correlation of all of the Upper Cretaceous rocks in the area traversed with the formation sequence of the Upper Cretaceous rocks recognized to the south and east. The outcrop areas have been divided into "areal rock units" which are believed to be stratigraphic units, and their equivalent formation or formations are suggested.

STRATIGRAPHY OF UPPER CRETACEOUS ROCKS

General lithology

Rocks of Upper Cretaceous age crop out in the area here discussed. Sandstone, silt shale, and clay shale comprise the bulk of the stratigraphic section. Coal, lignite, impure limestone, conglomeratic sandstone, and bentonite occur as interbeds.

Shales are probably the preponderant rock type, but they tend not to crop out. The Upper Cretaceous sandstones are mostly light colored and rather well sorted as to size. The predominant grain size is very fine to fine but some of the standstones are medium grained and a few coarse grained. The cementing material is mostly calcareous, but locally, as in the area of the Meade River coal mine and lower Meade River, much of the cementing material is siliceous and forms a very dense, well indurated rock. Porosities of the sandstones were roughly estimated and designated as low, medium, and high by determining the time necessary for and the relative amount of absorption of drops of water on 51 hand specimens. Most of the sandstones exposed at or near Skull Cliff have relatively high porosities. Few of the sandstones exposed throughout the rest of the area and none in the headwaters of the Meade River have high porosities. Many of the sandstones are ripple marked. Fewer are crossbedded. Thin very local lenses of pebble conglomerate in sandstone are present in minor amount throughout most of the area. The pebbles consist of quartz, black and green chert, ironstone, and shale in order of abundance.

Beds of impure, sublithographic limestone, as much as six feet thick, are widely distributed along the Meade River and locally, as in the area of the Meade River coal mine and lower Meade River, appear to comprise an important part of the section. Beds of coal and lignite, from less than one foot to as much as 14.5 feet thick, are abundant and widely distributed in the area, except in the section disclosed by Skull Cliff Core Test No. 1. Boghead cannel coal is found with some of the coal and lignite along the Meade River. Beds of bentonite are believed to be more abundant than indicated by surface exposures of this material, which are limited to the area of the Meade River coal mine, Skull Cliff, and the Kuk River.

Carbonized plant remains and wood and ironstone as nodules, bands, and lenses are found in many of the sandstones, shales and limestones.

The character of the Upper Cretaceous rocks exposed throughout the area traversed is shown in the columnar sections of figure 2.

Paleontology

A few megafossils were found in the rocks exposed along the Meade River south of the mouth of Shaningarok Creek. These specimens have been examined by George Gryc and reported on as follows:

46AWb8. (20491). South bank of Meade River, 16 miles S. 74° W. of the mouth of Shaningarok Creek.

Tellina sp., internal mold of one individual.

Ammonite, undescribed.

Ammonite compared with other ammonites from Faunal Zone 1 and with undescribed ammonites collected by J. B. Reeside, Jr., from lower Cenomanian (Thermopolis and Mowry formations). This collection quite probably represents Faunal Zone 1.

46AWb29. (20490). South bank of Shaningarok Creek about 200 feet above mouth.

Inoceramus, two fragments showing concentric ridges.

Evidence inconclusive but suggests an affinity to Faunal Zones 1 or 2, more likely Faunal Zone 2.

Two microfossil zones have been found in Skull Cliff Core Test No. 1. Preliminary comparison by Mrs. Helen Loeblich of these microfossils with those recovered from the core tests at Cape Simpson indicates that the microfaunal assemblages from these two sections are similar.

Subdivision of Upper Cretaceous rocks into "areal rock units"

At the time the preliminary report on the Meade River was written it was believed that all of the Upper Cretaceous rocks throughout the area traversed represented formations lower than Formation E, largely Formation D. Paleontologic evidence now indicates that part of Formations A, B, and C (undifferentiated) are exposed in the headwaters area of the Meade River and that Formation I is exposed to the north in the Skull Cliff area. Between these two areas lies a wide belt of rocks in which no fossils have been found.

The Upper Cretaceous rocks are divided in this report into "areal rock units" instead of formations. An "areal rock unit" comprises a group of rocks having certain characteristics, within a certain area, which set it apart from rocks exposed in adjoining areas. This rather unorthodox treatment of the stratigraphy is made in order to surmount logically the difficulties posed by the lack of paleontologic evidence and adequate structural data in correlating rocks lithologically dissimilar but equivalent in time to known formational units in the area south of Umiat. These "areal rock units" probably are equivalent to parts of the Upper Cretaceous section (Formations A-I) exposed in and south of the Umiat area. The thickness and stratigraphic position, relative to Formations A-I, of the units are described in a tentative way.

Each "areal rock unit" is delineated by certain features: fauna, lithology, and heavy mineral content of the sandstones, one or more of which distinguishes the unit from other units. For a description of the faunal criteria see heading of Paleontology. The lithologic criteria used are the presence and abundance of limestone, coal and lignite, and bentonite, and the degree of induration of the standstones. A qualitative and quantitative study of heavy mineral separations from 73 sandstone samples showed a number of heavy mineral zones. Two of the zones used as heavy mineral criteria are: (1) the percentage of fractured garnet grains of the total garnet content of the heavy mineral separations from standstones, and (2) the percentage of rutile grains to the total number of grains except the opaques. The garnet study was done by Ernest H. Lathram. The extent of the individual "areal rock units" is based largely on the garnet study. This study has been compared with a similar study by Fellows and Lathram 2/ in and south of the Umiat area which showed the percentage of fractured garnet grains in the various formations. Not enough of the regional heavy mineral picture is known to make use of the other zones in the Meade River area. The paleontologic, lithologic, and heavy mineral character of the "areal rock units" are compared in table 1.

2/ Lathram, Ernest H., Revision of the report by Robert E. Fellows on the significance and preliminary results of heavy mineral studies in northern Alaska: U. S. Geol. Survey mimeographed rpt. (for limited distribution), table I, p. 2, November, 1946.

	Headwaters of Meade River to near mouth of Shaningarok Creek	Meade River from near mouth of Shaningarok Creek to near edge of Arctic Plateaus	Middle Meade River	Meade River coal mine and lower Meade River	Arctic coast from Sina shelter cabin to Peard Bay	Kuk and Kukroak Rivers
Exposures, quality of	Good to fair	Fair to poor	Fair to poor	Fair to poor	Good to poor	Good to poor
number of	Numerous	Several	Few	Few	Very few	Very few
Fossils	Ammonite, cf. Faunal Zone 1; Tellina	Inoceramus fragment	None	None	Microfauna, Skull Cliff Core Test, cf. Cape Simpson microfauna	None
Heavy minerals Ave. pct. fractured garnets	94	56	78	39		
Percentage of rutiles	2-14; average, 4				1-2; average, 1 plus	
Limestone, no. of beds	4	3	2	12	None	1
Coal and lignite Number of beds	17	6	7	6	2 ? (thin)	4
Boghead cannel	Absent (?)	Present			Absent	
Bentonite	Absent			Present		
Sandstones Grain size	Dominantly very fine to fine; several medium; few coarse					
Wood, plant remains	Abundant throughout					
Ironstone	Abundant throughout					
Cementing material	Mostly calcareous			Calcareous, Siliceous	Mostly calcareous	
Induration	Mostly moderate			Moderate to hard	Friable to moderate	
Porosity, estimated	Mostly low to medium	Mostly low, few medium and high			Several high	Low to high
Ripple marks	Present locally					
Cross bedding	Present locally					
Conglomerates	Thin, lenticular, and local; composed of pebbles of quartz, black and green chert, ironstone, and shale					Absent (?)

Table 1 - Summary of paleontologic, heavy mineral, and lithologic characteristics of "areal rock units".

Area of the headwaters of the Meade River to near mouth of Shaningarok Creek.--Contains a few fossils probably from Faunal Zone 1. Percentage of fractured garnets in heavy mineral separations averages 94%. Topographic expression similar to topographic expression of resistant beds of Formations A, B, and C. Belt of outcrop believed traceable across and along limbs of folds toward south and east into known areas of Formations A, B, and C. Correlated with part of Formations A, B, and C (undifferentiated). Thickness at least 2,000 feet. Base of Upper Cretaceous section not seen. Topography at southernmost point reached on traverse indicates that top beds of Formations A, B, and C are present.

Area of the Meade River from near mouth of Shaningarok Creek to near edge of Arctic Plateaus.-- Percentage of fractured garnets in heavy mineral separations averages 56%. Inconclusive faunal evidence suggests affinity to Faunal Zones 1 or 2. Lies immediately north of the area of rocks correlated with part of Formations A, B, and C (undifferentiated). Change in topographic expression on entering this area from the south is similar to that in passing from Formations A, B, and C to Formations D and E on the Kurupa River to the southeast. Thickness uncertain but probably in the order of 2,000 feet. Correlative with the lower or middle parts of the Upper Cretaceous sequence, not higher than Formation E. Probably correlative with all or part of Formation D and E (undifferentiated).

Area of the middle Meade River.-- Percentage of fractured garnets in heavy mineral separations averages 78%. Thickness unknown but probably not more than a few thousands of feet. Correlative with the lower or middle parts of the Upper Cretaceous sequence, not higher than Formation E, probably all or part of Formations D and E (undifferentiated).

Area of the Meade River coal mine and the lower Meade River.-- Included in zone of 39% fractured garnets. Limestones form an important part of the sequence. Section contains bentonite. Some of the sandstones are cemented with silica and are noticeably denser and better indurated than other sandstones of the region. Thickness unknown but probably at least several hundreds of feet, possibly more. Correlative with the upper part of the Upper Cretaceous sequence, not lower than Formation F, probably all or part of Formations F, G, and H (undifferentiated).

Area of the Arctic coast from Sina shelter cabin to Peard Bay.-- Included in zone of 39% fractured garnets. Microfossils from Skull Cliff Core Test No. 1 similar to microfossils from Cape Simpson core tests 1 through 10. Contains bentonite. Limestones not seen. Coal almost entirely absent, in contrast with the other "areal rock units." Sandstones distinctly less well indurated than in other areas. Probably correlative with Formation I. Core test indicates thickness is over 400 feet.

Area of the Kuk and Kukpuk Rivers.-- Included in zone of 39% fractured garnets. Contains bentonite. Only one bed of limestone seen. Correlative with the upper part of the Upper Cretaceous sequence, not lower than Formation F. Affinity with Formation I is favored. Thickness unknown but probably at least several hundreds of feet.

Conditions of deposition

Upper Cretaceous rocks in the area here described are believed to have been deposited in what is structurally an area of platform or gentle basin and arch conditions, in contrast with the probably much thicker, east-west trending deltaic geosynclinal section to the south in the area of the Colville River. This "platform" facies of Upper Cretaceous sedimentation probably extends northward from near the latitude of the headwaters of the Meade River to the Arctic Ocean and to the east and west of the Meade River for an undetermined distance. Northward the Upper Cretaceous section probably thins from the order of 15,000 to 20,000 feet in the geosynclinal belt to a fraction of this figure in the "platform" area. The section may be as little as a few thousands of feet thick in the latitude of the lower Meade River.

There is evidence that in Upper Cretaceous time the "platform" area was undergoing broad and possibly differential epeirogenic subsidence and probably was never more than a few tens of feet above or below sea level. Very slight vertical movements caused shifts of the strand line for great distances. During times of inundation it was a vast expanse of impounded brackish or fresh water or marsh land. Environmental conditions such as these probably account for the unfossiliferous nature of most of the rocks. The sublithographic limestones, which contain ironstone and the remains of carbonized plants and wood, seem to represent calcareous oozes deposited, as were the coals, under more stagnating conditions. During times of emergence the platform region was an alluvial plain only slightly above sea level containing bodies of ponded water and crossed by sluggish rivers which deposited the thin conglomerates and many of the sandstones. Thick and numerous coal beds attest to the recurrence of swamp conditions throughout most of Upper Cretaceous time. In the area of the headwaters of the Meade River the platform facies of sedimentation probably interfingers southward with the more active deltaic geosynclinal facies of sedimentation.

In the geosynclinal belt of sedimentation vertical and lateral facies change and variation in proportions and associations of rock types are marked. In the platform area, in contrast, little facies change and variation in the proportions and associations of rock types are indicated, and five of the six "areal rock units" represented by the columnar sections (fig. 2) are similar in aggregate aspect. Thus it would seem that throughout most of Upper Cretaceous time the conditions under which sedimentation took place in the platform area were more uniform and less diastrophic in nature. Environmental conditions changed in time possibly with a cyclic repetition of rock types. The greater uniformity of grain size in the sandstone beds suggests that the currents in the rivers and impounded water bodies were better able to handle the volume of sediments contributed than were those in the more active geosynclinal area of sedimentation to the south. The rate at which sedimentation took place must have been relatively slower than in the geosynclinal belt. A few hundreds of feet of strata in the platform area may be equivalent in time to a few thousands of feet of strata in the geosynclinal belt.

Skull Cliff Core Test No. 1 has penetrated a series of rocks, which, except for one possible bed of coal, is entirely clastic in origin. Paleontologic evidence points to correlation with Upper Cretaceous rocks encountered in Simpson core holes 1 through 10, believed to be part of Formation I. Except for this section drilled at Skull Cliff rocks correlated with Formation I contain numerous thick beds of coal. The sequence at Skull Cliff may represent a new formation or a different facies of Formation I than that encountered in drilling at Cape Simpson and exposed along the Colville River below Umiat.

STRUCTURE

The structural data are shown on the accompanying map (fig. 1). South of about latitude 69° 55' N. the strata are in gentle, open, east-west trending folds. To the north they approach horizontality and structures presumably are low and broad.

Three anticlines were recognized in and immediately north of the headwaters of the Meade River. They trend east-west, and their axes are about 10 miles apart. Most of the dips measured on the limbs are less than five degrees; a few as much as 15 degrees or more were measured. The steepest dips are near the crests on the two southernmost anticlines. A plunge of 1½ degrees to the east was measured on a bed at the axis of the southernmost anticline. A plunge to the west on the middle anticline is indicated by structural data obtained from outcrops along the banks of the Meade River. Structural traces were not discernible on available aerial photographs that show the interstream areas or on the ground, except

locally. Aerial reconnaissance along the middle anticline later disclosed structural traces not seen from the ground. Some of these suggest an eastward plunge about four miles east of the Meade River. Structural data obtained in the area 6 to 18 miles north of the axis of the northernmost anticline suggest the presence of other folds, but here dip readings are few, questionable, and not adequate to delineate the structural axes.

In the Arctic coastal plain Cretaceous bedrock is believed to be nearer the surface west of the Meade River than it is to the east. Between the Meade and Kuk Rivers, the Avalik River and Nigisaktovik River flow on or near bedrock, whereas east of the Meade River the Esoktok and Topagoruk Rivers are separated from bedrock by probably a considerable thickness of post-Cretaceous unconsolidated sediments, except in their headwaters in the Arctic Plateaus. That this bedrock "high" may possibly reflect the regional structure to some extent is suggested by very gentle dips to the northwest in the vicinity of the Kuk River and Peard Bay, mostly horizontal attitudes between Point Barrow and Peard Bay, and gentle dips to the southeast at the Meade River coal mine and for about 25 miles south (fig. 1).

POST-CRETACEOUS SEDIMENTS

Tertiary (?) deposits

The uppermost sandstones, shales, and bentonites exposed at Skull Cliff totalling 8 feet in thickness, previously designated as Tertiary (?), have been referred to the Upper Cretaceous sequence in this report.

At numerous places along the Kuk River, middle and lower parts of the Meade River, and along the Arctic coast a stiff blue clay, having a greasy feel, was seen in thicknesses of less than a foot to as much as about six feet. This clay overlies Upper Cretaceous rocks and underlies unconsolidated sands. Similar clay is described as occurring on the Inaru River by James Gilluly 3/. At several localities along the Meade River it appears to grade downward into the Upper Cretaceous bedrock. The blue clay is thought to represent a post-Upper Cretaceous soil, possibly of Tertiary age, formed by long-continued weathering at or near sea level. Although it was not everywhere seen to overlie the Upper Cretaceous rocks, its presence may be considered an indication of the presence of Upper Cretaceous bedrock within about six feet.

3/ Smith, P. S., Mertie, J. B., Jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, p. 241, 1930.

Undifferentiated Quaternary and Tertiary deposits

Throughout the Arctic coastal plain bedrock is overlain by a cover of unconsolidated sediments, except locally along some of the stream courses where this cover has been removed. About eight miles north of the approximate boundary between the Arctic Plateaus and the Arctic coastal plain a thickness of 55 feet of unconsolidated sediments was measured in a cut bank along the Meade River. The contact with underlying bedrock was not seen. The difference in elevation of the top of the cut bank and the top of the adjacent hill suggests that an additional 30 feet of these beds overlies the cut bank section. East of the Meade River these deposits probably thicken, as described under the heading of Structure. The thickness of the unconsolidated deposits has been modified by erosion at many places near the southern margin of the coastal plain. Unconsolidated sand is their principal constituent. Locally, clay, silt, coaly debris, quartz, and chert pebbles, and exotic boulders, of different igneous and metamorphic rocks are admixed with the sand. Beds of peat as much as six feet thick overlie the sands at many localities. Shells similar to those of species now living in the Arctic Ocean are found at many places in these deposits. Presumably the sediments are mostly marine.

In general, the present land forms and surface of the Arctic coastal plain are aggradational rather than degradational. The flatness of the surface, markedly emphasized toward the north, and abundant lakes suggest an upraised slightly uneven sea floor. Other topographic features, best shown to the south, are believed to represent offshore bars, spits, wave terraces, and ancient beaches, only slightly modified by erosion.

Permafrost conditions as related to terrain features and character of sediments are being made by the Permafrost Unit of the U. S. Geological Survey and preliminary reports are to be available shortly 4/.

That part of the Meade River area that lies within the Arctic Plateaus contains no thick or widespread unconsolidated deposits. Fluviatile deposits, probably not more than 30 feet thick, are found in the valley of the Meade River. These are composed of sand and minor amounts of plant debris, and clay and silt. Some mammalian remains are found in these deposits.

4/ Black, R. F., and Barksdale, W. L., Permafrost and related phenomena of northern Alaska: U. S. Geol. Survey report (for limited distribution only). In preparation.

Black, R. F., and Barksdale, W. L., Oriented lakes in northern Alaska: U. S. Geol. Survey report (for limited distribution only). In preparation.

Terrain conditions

The surface of the Arctic coastal plain is almost flat. In the southern part, however, unconnected escarpments in the unconsolidated sands have gentle to steep faces as much as about 60 feet high. The ground is permanently frozen below a depth of about two feet. The small creeks are usually as deep or deeper than they are wide; their underwater profile is generally that of a "U". The Topagoruk, Meade, Esoktok, and Nigisaktovik Rivers have gentle banks and channel profiles at many places. Deep ponded stretches are separated by braided areas and riffles where the water is a few inches to a few feet in depth. Below the mouth of the Nigisaktovik River, however, the Meade River has few braided areas or riffles where the water is less than a few feet deep.

In the Arctic Plateau province the terrain is gently rolling, and the maximum relief is generally in the order of several hundred feet. In the headwaters of the Meade River, however, the hill slopes are as much as 15 to 20 degrees and the maximum relief as much as 1,500 feet. The small creeks generally are not more than a few feet deep and have gentle banks, although many are incised for short distances above the points at which they empty into the Meade River. The banks of the Meade River are steep in most places, especially in the eastward-flowing part near the headwaters. The river is mostly less than three or four feet deep.

PETROLEUM POSSIBILITIES

Oil seepages

At the base of Skull Cliff a light petroleum drips slowly from an area a few inches across in a bed of fine-grained sandstone. The thickness of sandstone exposed is eight feet; the bottom of the bed was not seen. Porosity determinations were made on samples thought to represent the same sandstone bed collected at four localities along the coast and in the vicinity of Skull Cliff. Results are as follows:

Specimen	Porosity (%)	Location
46AWb97	13.6	Two miles N.E. of Skull Cliff.
46AWb98	24.4	Three quarters of a mile N.E. of Skull Cliff.
46AWb100	9.3	Quarter of a mile N.E. of Sina shelter cabin.
46AWb118	25.	Skull Cliff.

Another oil seep has been reported about 1½ miles northeast of the Sina shelter cabin near the head of one of the gullies emptying into the ocean. This latter seep is said to be readily visible in the wintertime.

Gas bubbling from the bed of a lake near the headwaters of the Meade River has been reported to be coal gas, according to an analysis made for the U. S. Navy.

Natives have reported "lakes of oil" in the vicinity of Wainwright. Investigations at Wainwright and along the Kuk River indicate that these reports probably refer to the deposits of peat that have a strong organic odor.

Petroliferous material

Two float specimens of oil shale from the Meade River were given to Philip S. Smith, of the U. S. Geological Survey, in 1926. Microthermal studies of the two specimens and of other oil shales from Alaska have been made by Stadnichenko 5/. One specimen is designated as rich boghead or algal coal, and the other as spore shale. Stadnichenko's experiments indicate that both types are rich potential sources of petroleum and capable of yielding large quantities of oil and gas.

Several beds of boghead cannel coal, ranging in thickness from 0.1 to 1.2 feet, are found associated with beds of coal and lignite in each of the three "areal rock units" between the mouth of Shaningarok Creek and the mouth of the Meade River. They crop out over a north-south distance of about 75 miles along the Meade River. Thin slivers can be ignited readily with a match and burn with a petroliferous odor. Beds of the spore shale were not seen along the Meade River.

Material that may be pitch is said to have been found by natives near the head of the Ivisauruk River and also between the Ivisauruk and Kaolak Rivers.

Stratigraphic conditions

In the headwaters area of the Meade River underlain by part of Formations A, B, and C (undifferentiated), the structural conditions are similar to those of the folded area of Upper Cretaceous rocks to the south and east. Porosity determinations have not as yet been made on sandstone samples from the area, but rough tests by the

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5/ Stadnichenko, Taisia, Microthermal studies of some "mother rocks" of petroleum from Alaska, Bull. Am. Assoc. Petroleum Geol., Vol. 13, No. 7, pp. 823-840, 1929.

water-drop method indicate that porosities are, in general, very low; none of the samples appear to have high porosity. Immediately beneath this series lie, probably unconformably, the Lower Cretaceous rocks. In the nearest exposures of these rocks to the southward where they have been seen by Survey geologists they are reported to consist almost entirely of shale.

North of the headwaters area of the Meade River the Upper Cretaceous section appears more favorable in regard to porosity. The bed of sandstone, at least eight feet thick, exposed along the Arctic coast at Skull Cliff is, for the most part, of fairly high porosity. Skull Cliff Core Test No. 1 has penetrated several thick porous sands to a depth of 426 feet. Of the sandstone samples from the three northernmost "areal rock units" along the Meade River 5 of 29 tested by the water-drop method have relatively high porosity. The rather well sorted character of these sands suggests winnowing action of waves and currents, which probably removed much of the argillaceous material.

The stratigraphic characteristics of the coastal plain part of the area traversed suggest a platform or shallow basin-and-arch facies of sedimentation with the possibility of bed-for-bed correlation over considerable distances. This is in contrast to the deltaic geosynclinal facies of sedimentation in the area south of Umiat. Field observations along the Arctic coast and Kuk River seem to bear out this inference. There are scattered outcrops of sandstone along the Arctic coast from near the Sina shelter cabin to near Peard Bay, a distance of about 25 miles; these outcrops are believed to represent the same bed of sandstone. A thick bed of coal can be traced for a distance of 15 miles along the Kuk River and is seen to split into two beds, separated by six feet of siltstone, which have nearly the same aggregate thickness as the single bed. Scattered outcrops near the mouth of the Kuk River and coal float from the beach at Wainwright suggest the continuance of the same coal for a total distance of roughly 22 miles. It is possible that some of the sands likewise are of a blanket nature, in contrast with those in and south of the Umiat area.

The boundary between the "areal rock unit" of the middle Meade River, probably about equivalent to Formations D and E (undifferentiated), and the "areal rock unit" of the Meade River coal mine and lower Meade River, believed to be approximately equivalent to Formations F, G and H (undifferentiated), is at about latitude 70° 15' N. Structural data indicate that the section equivalent to Formations F, G, and H (?) dips gently beneath or into the section equivalent to Formations D and E (?). This structural anomaly may possibly be due to southward overlap of the F, G, and H section on to the D and E section, followed by northward upwarping and beveling of the former section.

The bedrock "high" along and west of the Meade River discussed under the heading of "Structure" and the probable bedrock "low" east of the Meade River indicate broad regional warpings in post-Cretaceous time. Possibly such areas were more or less positive or negative during Upper Cretaceous time as well.