United States

Department of the Interior

Geological Survey

Washington

Geological Investigations

Naval Petroleum Reserve No. 4

Alaska

PRELIMINARY GEOLOGIC REPORT OF SADLEROCHIT RIVER AREA.

November 1946

PRELIMINARY REPORT ON THE GEOLOGY OF THE SADLEROCHIT RIVER AREA, ALASKA

November 1948

By

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INTRODUCTION

"The Sadlerochit River area" is the name that has been applied for purposes of convenience to that portion of the eastern part of northern Alaska shown in Figure 1. The map covers an area of about 1400 square miles. The center of this map is a point approximately 55 miles southwest of Barter Island, 90 miles west of the International Boundary, and 130 miles east of Umiat.

During the summer of 1948, a U. S. Geological Survey party made a reconnaissance geologic survey of a portion of this area. The route followed by this party is indicated by the locations of field camps, beginning with Camp 1 on the Okpilak River and ending at the mouth of the Sadlerochit River beyond the north edge of the map. The survey was accomplished by traverses from the various field camps, the locations of stations and other data being plotted on aerial photographs in so far as possible. Except in a few rare instances, traverses did not extend to points more than five miles from the various field camps. Use of aerial photographs enabled the party to tie together data from various traverses and to extend their interpretations for considerable distances beyond points they were able to reach. The result has been a more detailed picture of the geology in this area than would have otherwise been possible in the time available.

During April and May 1948, caches of food and equipment were established at nine points in the area along the route proposed for the party to travel. On May 31 the senior author and Arthur H. Lachenbruch, field assistant, together with their equipment and supplies, were transported by ski plane to the site of Camp 1 on the Okpilak River. The junior author joined the party at this point

on June 12. From this place the party moved camp by back-packing, following the route indicated by camp locations, until they reached the eastern end of Lake Schrader on July 5. The various camp sites were selected at or near caches that had previously been set out, so that it was not necessary to transport any food while moving camp. A canvas boat with a small outboard motor, which had been cached previously, was used for transportation on Lake Peters and Lake Schrader. On July 7 George Gryc and Lloyd Spetzman joined the party at Lake Schrader. Mr. Gryc remained with the party until July 17, making material contributions to the geologic studies in the vicinity of Lake Schrader. Mr. Spetzman, a botanist working for the Arctic Research Laboratory, remained with the party for the balance of the field season and made a study of the flora of the area. From the western end of Lake Schrader the party continued moving of camp by back-packing until they reached Camp 12 on the Sadlerochit River at the mouth of Neruokpukkoonga Creek. From that point the party moved in boats down the Sadlerochit River, arriving at the Arctic coast on September 1. The following day they were transported to Barter Island in a Coast and Geodetic Survey launch.

The Sadlerochit River area is part of the Canning River region, of which the geography and geology were first described by Leffingwell 1/. During the several years that Leffingwell spent in northern Alaska, he made three trips, each of one to two months duration, from the Arctic coast into the Sadlerochit area. One of these trips was up the Okpilak River, another up the Hulahula River, and the third through the eastern part of the Sadlerochit Mountains to Lakes Schrader and Peters. The geologyof the western part of the Canning River region was restudied in 1947 2/.

1/ Leffingwell, E. de K., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, 1919.

2/ Gryc, George, and Mangus, M. D., Preliminary report on the stratigraphy and structure of the area of the Shaviovik and Canning Rivers, Alaska: U. S. Geol. Survey, 1947

CONTENTS

Page

Introduction.....1

Sedimentary rocks.....3

Neruokpuk formation (pre-Cambrian ?).....3

Noatak (?) formation (Mississippian).....4

Lisburne limestone (Mississippian).....6

Sadlerochit formation (Permian).....8

Shublik formation (Upper Triassic).....9

Kingak shale (Middle Jurassic).....11

Ignek formation (Upper Cretaceous).....13

Igneous rocks.....14

"Okpilak" gneissoid granite.....14

Basic igneous rocks.....16

Structure.....18

ILLUSTRATION

Figure 1. Preliminary geologic map of the Sadlerochit River area, Alaska. (Separate)

SEDIMENTARY ROCKS

Neruokpuk Formation (Pre-Cambrian ?)

The Neruokpuk formation is the oldest series of sedimentary rocks present in the Sadlerochit area. It unconformably underlies the Mississippian Noatak (?) formation. The formation makes up the bed rock of a large proportion of the country in the Franklin and Romanzof Mountains. However, the formation was studied in the Franklin Mountains only near the northern edge of its outcrop belt and in the Romanzof Mountains only above the forks of the Okpilak River where it was in contact with the granite. A small area west of the Sadlerochit River in Third Range and a considerably larger area west of Itkilyariak Creek in the Sadlerochit Mountains have exposures which probably belong with this formation.

The Neruokpuk formation consists largely of metamorphosd sediments. Carbonate rocks appear to be entirely absent. In the vicinity of Lake Peters quartzites make up about half of the total section. In color the quartzites range from light to dark gray and greenish gray, in grain size from fine to coarse. Some quartzites contain scattered granules and, occasionally, small pebbles, usually of quartz. The next most common rock types are phyllites of undetermined composition. The color ranges from light gray to black and, in addition, includes green and purple. The green and purple phyllites are occasionally interbanded. Less common rock types are black and white banded cherts (?), quartz mica schists and schistose quartzites, and dark gray massive argillite. At one place a rock was found that may be of igneous origin. It had a dark reddish color and a texture which appeared to be vesicular or amygdaloidal.

The rocks seen in this formation above the forks of the Okpilak were a quartz mica schist and a greenish chloritic schist. The outcrops in Third Range assigned to this formation consist of light greenish gray banded chert with associated greenish phyllites and a small amount of dark gray argillite. In the Sadlerochit Mountains the rocks seen which are referred to this formation include light gray quartzite, dark gray banded quartzite, light greenish gray chert, and greenish-yellow, black, and maroon phyllites.

The thickness of the formation is unknown but is believed to be at least several thousand feet. As seen from a distance along the mountain sides, the bedding appears to be simple; but detailed examination reveals much small folding and suggests the possibility of overturns and repetition of section. In outcrops bedding is often difficult to determine. It is easily confused with foliation which often lies parallel to it, or nearly so. In some instances the foliation seems to be folded.

The postulation of an unconformity between the Neruokpuk formation and younger formations is based mainly on a difference in degree of metamorphism. The Neruokpuk does not show a high degree of metamorphism, but the degree is considerably greater than in the younger formations. For instance,

the bedding may usually be discerned without much trouble in the overlying formations. In the Neruokpuk, on the other hand, it is usually difficult and often impossible to make out the bedding. In the Franklin Mountains considerable variation was noted in the lithologic types occuring immediately below the contact. At two localities where the basal beds of the Noatak (?) formation were conglomerate, the contact appeared to be an undulatory surface with several feet of relief. However, the exposures at these localities were not complete enough to eliminate the possibility that the apparent undulations resulted from faulting.

Although showing considerably less metamorphism, the Neruokpuk formation is lithologically similar to the Birch Creek schist as described from the Yukon-Tanana region 1/, and the correlation of the two formations is suggested. Correlation of the Neruokpuk with any of the pre-Carboniferous Paleozoics south of the Brooks Range appears doubtful, because sections of all these ages from Cambrian through Devonian, and also of the pre-Cambrian Tindir group, contain significant thicknesses of limestone and dolomite, whereas in the Neruokpuk formation carbonate rocks appear to be entirely absent.

Noatak (?) Formation (Mississippian)

The Noatak (?) formation overlies the pre-Cambrian (?) Neruokpuk formation unconformably and is overlain with gradational contact by the Mississippian Lisburne limestone. Leffingwell described this formation as consisting of "...black shales, slates, and possibly minor amounts of sandstones,...." and said that it was at least 700 feet thick on the Canning River and about 1000 feet thick where seen on the Hulahula River about 30 miles south of the mountain front, a point which would be about 10 miles beyond the south edge of Figure 1. Leffingwell found no fossils in the formation. He mapped it as black shale of Mississippian or Devonian age. Smith and Mertie 2/ suggested that this formation might be correlative with the Noatak. In their work on the Canning River in 1947, Gryc and Mangus found plant fossils in the formation which definitely establish a Mississippian age. In regard to lithology they state that "...these shales are interbedded with quartzite, calcareous ironstone, graphitic coal seams, and slates," and they further state that the maximum thickness exposed on the Canning River does not exceed 500 feet.

In the Sadlerochit River area the Noatak (?) formation was seen in the northern part of the Franklin Mountains at several points for a total distance of about 12 miles along the strike. The easternmost exposures were on a creek about five miles east of Lake Peters. The westernmost were

1/ Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872, pp. 47-59, 1937.

2/ Smith, P. S., and Mertie, J. B., Jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, p. 166, 1930.

in the area at the head of the Sadlerochit River about seven miles west of Lake Peters. Other exposures of rocks probably belonging to this formation were seen in Third Range on the Sadlerochit River and in the Sadlerochit Mountains in the drainage of Itkilyariak Creek. On the map (Figure 1) this formation is not differentiated from the Lisburne limestone.

Where best exposed in the Sadlerochit area, in the belt in the northern part of the Franklin Mountains, the Noatak (?) formation ranges in thickness from 150 to 300 feet, the variation being due chiefly to the varying thicknesses of conglomerates which occur mainly at the base of the formation. East of Lake Peters the conglomerates, when present at all, are not more than a few feet thick. One mile west of Lake Peters the conglomerates are about 75 feet thick, and at the head of the Sadlerochit River they are about 125 thick. The conglomerates range from rock composed entirely of cobbles and pebbles to quartzites containing scattered pebbles, and are interbedded with quartzites, the grain size of which ranges from fine to very coarse. The predominant rock type represented in the pebbles and cobbles is white quartz. Less common rock types represented in the pebbles (quartzites, cherts, and argillites) are very similar to the more resistant types of rock in the underlying Neruokpuk formation. About one mile east of Lake Peters, where the conglomerate was only a few feet thick, the lithology was more exotic, the rock at that place consisting of subangular white quartz pebbles, one to two inches in diameter, set in a dark green fine-grained apparently chloritic matrix. Gryc, upon examining boulders of the conglomerate in the stream west of Lake Peters, stated that the lithology of the conglomerate is very similar to that of conglomerates in the Noatak formation at Chandler Lake.

Aside from conglomerates and quartzites, lithologic types seen in this formation are black shales (in part metamorphosed to slate and phyllite) containing lenses and beds of ironstone, black bedded cherts, and dark gray argillite. Some of the black shale may occur interbedded with the conglomerates and quartzites, but in general the formation is characterized by decreasing grain size upward. In the area east of Lake Peters, where the best exposures occur, the contact with the overlying Lisburne limestone is gradational and is taken at that point where limestone becomes predominant in the section. Some limestone is found below this contact interbedded with shale and chert, and shale occurs interbedded with the limestone above the contact.

A few plant fossils were found in the black shales in the Sadlerochit area, but they do not appear to be sufficient to determine the age. However, there can be little doubt that these black shales are correlative with those on the Canning River in which Mississippian plant fossils were found. The correlation with the Noatak formation of these clastic beds underlying the Lisburne limestone in the Canning and Sadlerochit areas is suggested on the basis of similarities in lithology, stratigraphic relationships, and age. In this report, therefore, these beds have been designated the Noatak (?) formation.

Lisburne Limestone (Mississippian)

The Lisburne limestone overlies the Mississippian Noatak (?) formation with gradational contact and is overlain conformably by the Permian Sadlerochit formation. The formation, about 2000 feet thick, is, because of its distinctive light bluish gray weathering, the most easily recognized stratigraphic unit in the Sadlerochit area. It is widely distributed throughout the area, forming the cores of the Sadlerochit Mountains, the Shublik Mountains, Third Range, and Kikittut Mountain, and showing up prominently in the folds along the northern edge of the Franklin Mountains and in the northern part of the Romanzof Mountains.

The most common rock type is gray crystalline limestone, which to a considerable extent seems to be bioclastic. Other limestones range from dark gray to black, some being crystalline, some oolitic, and some sublithographic. Nodular chert is common at many places in the formation but is especially abundant in the upper third. Dark-weathering dark gray limestones comprise the basal part of the formation near Lake Peters, but this same lithology was seen near the top of the formation in the Sadlerochit Mountains.

On the Hulahula River in the vicinity of Kikittut Mountain the exposed limestone approaches a thickness of 2000 feet. The base of the formation was not definitely identified but may have been exposed. A bench on the slopes of the mountains in this vicinity coincides with a change in the general appearance of the limestone. The limestone below the bench makes more prominent and massive outcrops and weathers to a darker color than does the limestone above the bench. The lower limestone is about 1200 feet thick, the upper about 600 feet. Outcrops of oolitic limestone were found in the lower limestone. Observation of talus indicated that it contains little chert but is rather siliceous and shows considerable quartz veining. The bench marks the horizon of a clastic member, consisting of black shale and siltstone and light-colored quartzite and sandstone, which is probably not more than 50 feet thick.

On the Okpilak River estimates of the thickness of limestone exposed ranged from 500 to 800 feet. The limestone is overlain by the Sadlerochit formation and is underlain by a series of quartzites, quartz mica schists, and phyllites with which are associated minor amounts of plant-bearing black slate and graphitic schist. The clastic section is at least 200 feet thick. It, in turn, is underlain by green schist.

The data gathered during a hasty traverse up Ahngayukasrakuvik Creek are rather confusing. Underlying the Sadlerochit formation there is exposed about 400 feet of limestone, ranging in color from light gray to black and in texture from crystalline to sublithographic. Chert nodules are common. Their color ranges from medium gray to black and is generally somewhat darker than the containing limestone. For the next 1/4 mile upstream there are no

outcrops. At the junction of the stream with a major tributary from the east there is an outcrop of black slate. For 1/4 mile upstream from the junction there are outcrops of siliceous limestone, the first of these outcrops being banded highly siliceous limestone, in part considerably contorted and brecciated. For 1/2 mile beyond the limestone belt there occur outcrops of green, gray, and white quartzites and dark gray to black argillites and slates. Plant remains were seen in the slate. No reliable estimate could be made as to the thickness of this clastic section, but it may exceed 100 feet, possibly 200 feet. For 1/4 mile beyond and apparently underlying the clastic section green schists and phyllites outcrop along the stream. The clastic section and the green rocks underlying it appear quite similar to the rocks underlying the limestone on the Okpilak River. Upstream from the green rocks silicified limestone appears again, but the silicification appears to be less than in the preceding limestone belt.

The quartzite and slate sections exposed on the Okpilak River and on Ahgnayukasrakuvik Creek have been interpreted as correlative with the clastic section seen in the Lisburne limestone on the Hulahula River. The green schists and phyllites have been mapped as basalt. The thin limestone section seen on the Okpilak River is believed to represent only about the upper third of the formation, with the thicker lower limestone section not exposed.

The data obtained in the Okpilak-Hulahula area are rather sketchy and insufficient to completely substantiate the explanation given above, and it is possible to offer an alternate hypothesis. The clastic member of the Lisburne on the Hulahula could be only locally present and disappear to the east as well as to the west (No evidence for this member was seen west of the Hulahula River). The quartzite and slate sections to the east could belong in the Noatak (?) formation and the green schists and phyllites in the Neruokpuk. However, this hypothesis does not explain the anomalous eastward thinning of the limestone between the Hulahula and Okpilak Rivers.

It seems difficult to assess the degree of metamorphism which has affected the limestone. No evidence was found that would indicate any considerable amount of recrstallization. The greatest degree of metamorphism seemed to occur on the Okpilak River not far from the contact with the granite where foliation had developed in some of the limestone and where chert seemed to have been affected, some of it recrystallized to quartz and some changed so that it weathered to a white powder.

The Lisburne limestone, being more competent, has not been so severely affected by the folding in this area as some of the younger formations. In general it is seen in large simple overturned anticlines. Southward, however, these large-scale folds become modified more and more by the appearance of small scale folding. The most intense small folding observed was on the about five miles east of Lake Peters where part of the limestone section had been distorted into recumbent chevron folds.

Sadlerochit Formation (Permian)

The Sadlerochit formation overlies the Mississippian Lisburne limestone and underlies the Upper Triassic Shublik formation. Both contacts appear conformable. Leffingwell, in describing and naming the formation, did not specify a type locality, but presumably meant the southern slopes of the Sadlerochit Mountains.

The Sadlerochit formation is widely distributed throughout the area investigated. Its dark reddish brown weathering is conspicuous and easily recognized where it occurs on the flanks of the anticlinal ranges which have the Lisburne limestone at their cores. These ranges include the Sadlerochit Mountains, the Shublik Mountains, Third Range, and Kikittut Mountain. The formation is also conspicuous along the north front of the Franklin Mountains and over a large tract of country in the northern part of the Romanzof Mountains extending from the Hulahula River to beyond the Okpilak River.

The formation, about 500 feet thick, consists of shale, siltstone, sandstone, and conglomerate. To the south and also to a certain extent to the east these rocks show the effects of metamorphism so that the shales and siltstones are more accurately described by the terms slate, argillite, and siliceous argillite and the sandstones and conglomerates by quartzite, quartzitic sandstone, and quartzitic conglomerate. Metamorphism has gone only far enough in this formation to produce cleavage, and no foliation has developed.

In the Sadlerochit Mountains the lower two-thirds of the formation is largely sandstone, and at one place, Revelation Creek, includes 75 feet of conglomerate at the base. To the south the sandstone in the basal third of the formation largely disappears and is replaced by siltstone and shale. The sandstones in the middle third of the formation are somewhat more persistent, and although they are in part replaced by argillaceous rocks, they are everywhere conspicuous in this part of the formation. Wherever seen the upper third of the formation is largely siltstone and shale with only thin sandstone interbeds.

The conglomerate at the base of the formation on Revelation Creek seems to be local and to grade into sandstone to the east and west. This conglomerate and the sandstones into which it grades are believed to be, in part at least, time equivalents of the fossiliferous zone found at the base of the formation to the south and east. No fossils were found at the base of the formation in the Sadlerochit Mountains. Almost universally this fossiliferous zone was found in siltstone or argillite. However, on the Sadlerochit River at the east end of the Shublik Mountains these fossils occurred in a fine-grained quartzitic sandstone. Thus a facies change in the basal part of the section is suggested. The predominance of sandstone in the lower two-thirds of the formation in the Sadlerochit Mountains and its replacement by siltstone and shale at other places where the formation was seen suggests that during the time of deposition of this part of the formation the major source of sediments was to the north.

Except in the Sadlerochit Mountains the major part of the formation is composed of argillaceous rocks. Consequently it usually is more complexly folded than the underlying more uniform and more competent Lisburne limstone. However the structure of the Sadlerochit formation is generally less complex than that of the overlying less competent Shublik and Kingak formations.

Almost everywhere that the contact with the underlying Lisburne limestone was found exposed, or could be placed within a few feet, a fossiliferous zone was found in the basal 20 to 30 feet of the Sadlerochit formation, the first fossils usually occurring within one or two feet above the contact. This fauna consists of brachiopods and small horn corals, and the number of individuals is usually abundant. Usually the fossils are very poorly preserved as external molds. Fairly well preserved fossils were found only in the fine-grained quartzitic sandstone which occurs at the base of the formation on the Sadlerochit River at the east end of the Shublik Mountains. No fossils were found at the base of the formation in the Sadlerochit Mountains, but here the contact with the Lisburne limestone was not found exposed and usually there was a considerable covered interval at this horizon. The Permian age of the Sadlerochit formation is based on fossils collected from the basal part of the formation on the Canning River by Leffingwell and identified by G. H. Girty. Leffingwell assigned the formation to the Pennsylvanian as the result of Girty's original tentative correlation with this series. According to P. S. Smith 1/, "Originally, this fauna was referred to the Pennsylvanian, but with fuller insight into the general history of the Carboniferous gained through the added collections from that system throughout the territory, Girty is now convinced that it is more properly to be regarded as belonging to the Permian". At about the middle of the formation Leffingwell collected a pelecypod fauna which Girty found "...so meager and so ambiguous that I cannot positively claim it for the Paleozoic at all". Consequently, while the lower part of the Sadlerochit formation is of Permian age, the upper part may be Triassic.

Shublik Formation (Upper Triassic)

The Shublik formation, consisting of 200 to 300 feet of limestone, shale, siltstone, and sandstone, overlies the Permian Sadlerochit formation and underlies the Middle Jurassic Kingak shale, both contacts being apparently conformable.

The basal part of the formation is made up of from 25 to 65 feet of siltstone and sandstone. The siltstone is dark gray in color and generally noncalcareous. It is characterized by the presence of abundant black pebbles which seem to consist of argillaceous material. The abundance of these pebbles varies considerably from bed to bed. Some beds have very few pebbles.

1/ Smith, P. S., Areal geology of Alaska: U. S. Geol. Survey Prof. Paper 192, p. 32, 1939.

At the other extreme are beds up to two feet thick which consist almost entirely of pebbles. This silstone is rather similar in appearance to that in the Sadlerochit, but is differentiated by the abundant black pebbles and by a greenish color on weathered surfaces as opposed to a reddish or brownish weathering in the Sadlerochit. The sandstone is probably a coarser-grained facies of the siltstone. Its occurrence is sporadic. Its character varies from dark gray and highly argillaceous with shaly pebbles to light gray, clean, and quartzitic with siliceous pebbles. Grain size of the sandstone is fine to very fine.

The remainder of the formation, 175 to perhaps 250 feet, consists of interbedded limestone and shale. The lower part of this section is predominantly limestone and the upper part shale. The limestone is dark gray to black bituminous, finely crystalline to sublithographic, and at certain horizons abundantly pebbly and fossiliferous. The pebbles appear similar to those in the siltstone but seem to be made of limestone. The limestone weathers to a greenish color similar to that mentioned above for the siltstone. Some of the limestones are sandy. The shale is black, calcareous, and has an earthy appearance.

A number of excellent exposures of the Shublik formation occur on the Sadlerochit River. The only complete exposure of the formation, including the upper and lower contacts, is the one on the north side of the river near the mouth of Last Creek about one mile east of Camp 13. At this place the formation is about 200 feet thick, the basal 25 feet being siltstone and sandstone and the remaining 175 feet consisting of about 75 percent limestone interbedded with shale. In this exposure the siltstone-sandstone section appears to be considerably thinner than normal and the proportion of limestone to be considerably greater than normal. On the river above Camp 11 outcrops of the formation occur in four different belts. At a number of places in this area the lower contact was identified in outcrops. The northernmost of these four belts, occurring on the south limb of the Ignek synclinorium, is the least complicated structurally. The section, beginning at the exposed lower contact, consists of about 50 feet of siltstone and sandstone overlain by about 100 feet of limestone and shale, the limestone being predominant. The upper contact is in a covered interval which presumably is largely shale. The other three belts are structurally more complicated, the limestone and shale, especially, being compressed into small tight folds. However, the same stratigraphic succession is seen.

Exposures of the formation are present on several of the creeks draining the south slope of the Sadlerochit Mountains. Only one of these, that on Revalation Creek (the first stream east of Limit Creek), is noteworthy. Both the upper and lower contacts are exposed. The dip appears to be monoclinal. From the data gathered, the thickness was calculated to be about 1000 feet. The basal 65 feet is sandstone and siltstone and the remainder limestone and shale. A few small folds were noted but were disregarded in calculating the thickness. It seems apparent, however, that when this section is compared with others it is excessively thick. It is postulated that a large part of the measured thickness results from repetition of section by folding and, possibly, faulting.

Elsewhere in the area covered, the formation was seen in only a very few places, although its distribution may be considerably wider than indicated. Outcrops of sandstone, siltstone, and a little limestone occur on the Hulahula River at Camp 4. The only other known occurrence on this river is in an area four miles south of Camp 5. At this latter locality, the limestone was identified and was seen to occur in tight folds along with sandstones and siltstones of the Sadlerochit formation. The basal siltstones and sandstones of the Shublik formation were not seen and may be absent. The formation was not positively identified on the Okpilak River, but it may be present in a small area on top of the divide west of Camp 2.

Fossils are common in the formation, but seem to be confined mostly to the limestone. The Upper Triassic age is based on fossils collected by Leffingwell and identified by T. W. Stanton.

Kingak Shale (Middle Jurassic)

The Kingak shale overlies the Upper Triassic Shublik formation and underlies the Upper Cretaceous Ignek formation; both contacts appear conformable. The lower contact is exposed in the bluff one mile east of Camp 13 and in an exposure on Revelation Creek. The upper contact, which was taken as the base of the lowest sandstone in the shale and sandstone section overlying the formation, was seen on Neruokpukkoonga Creek.

Leffingwell's type locality for the Kingak shale, "...Kingak Cliff, near Camp 263, at the southeast end of Sadlerochit Mountains", could not be located. "Kingak", which means "nose", is applied by the natives of Barter Island to a high hill on the divide between the Hulahula and Sadlerochit Rivers southeast of Camp 13. The rocks in and around this hill belong in the Ignek formation. Leffingwell's map indicates that Kingak Cliff is in the vicinity of Camp 13, in which case the locality would be limited to two possibilities. One of these, the cliff or bluff on the southeast side of the river across from Camp 13, is an exposure of sandstones and shales which probably belong in the Sadlerochit formation. The other, the bluff one mile east of Camp 13, although it contains at the east end the basal 150 feet of the Kingak shale, nevertheless is made up largely of rocks of the Sadlerochit and Shublik formations. Moreover, it seems doubtful that Leffingwell ever reached the vicinity of Camp 13. Outcrops of the Kingak shale occur in cut banks along the Sadlerochit River from a point four miles above Camp 11 to a point about five miles below Camp 12. The data from which Leffingwell calculated the thickness of the formation were obtained from exposures on the Sadlerochit River, Camp 263 Creek, and a creek south of the river which almost certainly is Neruokpukkoonga Creek. It seems evident that these exposures are the type section and that "Kingak Cliff" is one of the cut banks along the Sadlerochit River in the vicinity of Camp 12.

The Kingak shale consists principally of black silt or mud shales. Ironstone, in the form of nodules, lenses and thin beds, is rather common throughout the formation. The basal 40 feet in the bluff one mile east of Camp 13 is a massive sandy and conglomeratic dark gray siltstone. The

The conglomeratic material consists of granules and pebbles of white quartz and green and black cherts. Throughout most of this basal siltstone unit the material is granule in size, pebbles being found only near the top of the unit. The basal siltstone was also seen on Edge Creek. At about the middle of the formation or higher, the shales are very dull and earthy and contain concretions ranging up to three feet in diameter. The shales in this part of the formation show a whitish effloescence. Probably higher in the formation small pyritic concretions are common. Near the top of the formation on Neruokpukkoonga, silstone beds six inches to two feet thick are interbedded with the shale. Except for the thin crinoid beds in the lower part of the formation, none of the rocks were found to be calcareous.

The Kingak shale, being relatively very incompetent, has been greatly affected by the forces which produced the structure in this area. From examination of outcrops, it appears that small-scale folding and faulting is widespread in these beds. In the direction normal to strike considerable variations in dip were noted, occasionally within just a few feet, and quite often within a few tens to hundreds of feet. For example, in one outcrop on Camp 263 Creek the dip changed from 20 degrees to 80 degrees in a horizontal distance of about 30 feet. In an outcrop on the Sadlerochit River, about four miles upstream from Camp 11, three small thrust faults were seen. At this place the bedding was nearly horizontal. The fault planes all had a steep south dip. Along each of the faults a distinctive ironstone bed in the shale was offset from two to three feet.

Leffingwell estimated the thickness of the Kingak shale as about 4000 feet. His estimation was based on observations of outcropping beds on Camp 263 Creek, Neruokpukkoonga Creek, and the Sadlerochit River. The general dip throughout this area is to the south, but the amount of dip is much more variable than Leffingwell reported. In addition, in two outcrops on Neruokpukkoonga Creek small folds were exposed, and in an outcrop near the mouth of Camp 263 Creek the beds were seen to dip north at an angle of about 50 degrees. While Leffingwell's estimate of the thickness of the formation may be fairly accurate, it is more likely to be high than to be low. In other words, the Kingak shale is a few thousand feet thick, but very probably not more than 4000 feet.

The Kingak shale was classified as Lower Jurassic by Leffingwell, but P. S. Smith 1/ placed it in the Middle Jurassic, and the revised classification is followed in the present paper. The formation contains two distinct faunas, both of which were first noted from the Canning district in collections made by Leffingwell. A crinoid fauna was found in a single locality on the Canning River, the stratigraphic position of which was obscure. However, during the season of 1948 the fauna was found in outcrops on the Sadlerochit River four miles above Camp 11. From the location of these outcrops, it is now evident that the fauna occurs not more than a few hundred feet above the base of the Kingak shale. Frank Springer classified the collection from Leffingwell's one locality as Lower Jurassic. Smith, in his report, had nothing to add except to mention that, on the Firth River, Maddren made a collection of crinoids which Springer also classified as

1/ Smith, P. S., Areal geology of Alaska: U. S. Geol. Survey Prof. Paper 192, p. 46, 1939.

Lower Jurassic and said were probably the same species as that in the collection from the Canning River. The other fauna, consisting of ammonites and pelecypods, was found, during the 1948 season, at several localities along the Sadlerochit River. The Leffingwell collections containing this fauna also came from the Sadlerochit River and probably from some of the same outcrops. From the locations of the outcrops where this ammonite-pelecypod fauna was found, it is evident that this fauna occurs considerably higher in the Kingak shale than does the crinoid fauna. In reporting on the collections made by Leffingwell, which contained the ammonite-pelecypod fauna, T. W. Stanton suggested a correlation with the ammonite-bearing beds at Kialagvik Bay on the Alaska Peninsula which at that time were considered to be Lower Jurassic. Smith, in his report, lists these beds as the Kialagvik formation and places them in the Middle Jurassic. In commenting on the ammonite-pelecypod fauna from the Kingak shale Smith states, "Identification of the fossils collected has led Stanton to correlate the beds with the Middle Jurassic series". Consequently, the Kingak shale is classified as Middle Jurassic, but with the provision that the basal part of the formation may be of Lower Jurassic age. Since there seems to be no lithologic difference between the shales near the top of the formation and those occurring with the sandstones of the younger Ignek formation, which is considered to be Upper Cretaceous, and since the top of the Kingak shale is defined in the present paper as the base of the lowest sandstone (Ignek) overlying the Kingak shale, it is possible that the upper part of the Kingak shale as here defined may, in age, be as young as Upper Cretaceous.

Ignek Formation (Upper Cretaceous)

The Ignek formation, as seen in the Sadlerochit River area, consists of about 1000 feet of shale, silstone, and sandstone overlying the Middle Jurassic Kingak shale with apparent conformity. The formation occurs in an area of roughly 30 square miles in the highlands south of the Sadlerochit River in the vicinity of Camp 12. In this area, the formation occupies the center of a synclinorium, the south flank of which is slightly overturned. An outcrop in the formation was also seen near Camp 14 beyond the north edge of the Sadlerochit Mountains.

The basal 400 feet of the formation is composed, in about equal proportions, of interbedded sandstones, siltstones, and black shales. The shales seem to be indistinguishable from those in the Kingak except for the apparent absence of ironstone. The sandstones vary in grain size from fine to medium and in color from medium gray to dark bluish gray. They are in part cross-bedded and occasionally calcareous. Porosities in the sandstones seemed to be uniformly low. The siltstones are dark gray in color.

Higher in the section sandstones and siltstones predominate, the shales decreasing in abundance and becoming more silty. One six inch bed of dark gray, finely crystalline limestone with organic fragments was observed. Upward in the section sandstones occur in thicker and more massive beds. They vary in grain size from fine to medium, in color from dark bluish gray to dark grayish brown, and in induration from friable to hard. Porosities

all appear to be low. Some are calcareous. Some of the hard grayish brown sandstones may, in isolated outcrops, be easily confused with sandstones in the Sadlerochit formation.

An isolated outcrop of rocks believed to be of Upper Cretaceous age occurs on the Sadlerochit River near Camp 14 about four miles north of Last Creek. The exposure consists of about 30 feet of black silt and clay shales with numerous lighter-colored interbeds. The interbeds seemed to be composed chiefly of bentonitic and tuffaceous material. They were commonly greenish in color and weathered to a pronounced reddish orange. The rocks at this place are probably younger than that part of the formation seen in the area south and east of Camp 12.

The Ignek formation here described corresponds to parts of Leffingwell's Ignek formation on the Canning River and to the lower part of the Upper Cretaceous sequence on the Shaviovik and Canning Rivers described by Gryc and Mangus. The sequence south and east of Camp 12 appears to be equivalent to the latter's subdivision UK-1, and the outcrop near Camp 14 seems to belong in UK-2. Fossils found in these rocks in the Sadlerochit area, as well as in the Canning and Shaviovik areas, are not definitely diagonostic of any certain age. Leffingwell called the Ignek formation Jurassic (?). However, Gryc and Mangus have shown that their subdivision UK-1 is traceable into known Upper Cretaceous rocks to the west.

IGNEOUS ROCKS

"Okpilak" Gneissoid Granite

The granite extends for about ten miles in a north-south direction on the Okpilak River, and was seen to extend to a point about three miles from the Hulahula River south of Kolotuk Creek. On aerial photographs the appearance of the granite is distinctive enough so that it has been possible to delineate the approximate outline of the mass.

Lithologically the mass seems to be made up of several different granites. The granite which is apparently most common is gray in color. In general the granites are composed of quartz, white feldspars, and minor amounts of dark minerals. Quartz probably averages 25 percent with feldspars contributing the bulk of the remainder. The feldspars are mostly white in color, but pink feldspar was seen in float. In a number of hand specimens two different white feldspars were tentatively differentiated. Although the dark minerals are generally a minor constituent, in a few cases they were found to comprise a considerable percentage, 30 to 50 percent, of the rock. The dark mineral or minerals have been mostly altered to chlorite. In a few cases biotite was found with a chlorite outline. Feldspar phenocrysts are present in some of the rock. Outcrops of granite containing phenocrysts were found near the north edge of the mass. Erratics bearing phenocrysts are common, and many of them must have come from other parts of the mass. In general, the phenocrysts are one to one and one-half inches long, but some have been seen up to six

inches in length. The phenocrysts are usually fractured, often showing two sets of fractures approximately at right angles.

Inclusions and segregations were seen only in outcrops along a creek which flows from the west into the Okpilak River near the north edge of the granite mass. The inclusions are generally angular, but the corners are rounded and the edges minutely scalloped, suggesting absorption of some of the rock by the including magma. Both light and dark colored inclusions were found. They are generally finer-grained than the including rock and are thought to be entirely igneous. One dark colored inclusion contained a light colored inclusion. Another dark inclusion contained feldspar phenocrysts. Segregations seen apparently consist of small masses of biotite which have been concentrated into layers.

In places the granite was seen to grade into schists and phyllites. The presence of these schists and phyllites in the mass is believed to be the result of an alteration or replacement.

A gneissoid structure is characteristic of the granite but is not universally present and varies considerably in degree of development. Where the granite was seen to grade into schist and phyllite the gneissoid structure becomes more intense and passes into foliation in the latter rocks.

The contact of the granite mass with the Neruokpuk formation on the south and with the Lisburne limestone on the north was investigated only briefly, and the contacts were not followed for any great distance. The contact with the Neruokpuk formation appears to be parallel to the foliation and possibly to the bedding in the latter, but the foliation is so intense that bedding was not definitely recognized. The contact with the Lisburne limestone where it was seen on the east side of the Okpilak River is definitely not parallel to the bedding. The actual contact is not exposed, but outcrops of granite and limestone within 100 feet of each other were studied. No inclusions of limestone in granite were seen, nor was there any evidence of intrusion or mineralization in the limestone.

The granite, which possibly has replaced or altered parts of the Neruokpuk formation, is also believed to have undergone metamorphism comparable to that affecting the Neruokpuk formation. Thus it is considered to be older than the Lisburne formation. The contact between the limestone and the granite is believed to be a fault. Available evidence is not sufficient to prove that the granite is intrusive into the Neruokpuk formation rather than being in contact with it along an erosional surface, but the former is thought to be the case.

In lithology, structure, and degree of metamorphism there appears to be a remarkable similarity between the granite on the Okpilak River and the Pelly gneiss as described from the Yukon-Tanana region 1/. The Pelly gneiss

1/ Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872, pp. 201-203, 1937.

is considered to be intrusive into the Birch Creek schist. The possibility of correlation of the Neruokpuk formation and the Birch Creek schist has been mentioned in a preceding section of the present report.

Basic Igneous Rocks

Basic igneous rocks were observed in two general localities in the Sadlerochit area. One locality is on the Hulahula Riveroon the east side of Kikittut Mountain, where the rock outcrops for a distance of about four miles along rhe river. At this place the exposures are mainly confined to the valley in an area about two miles wide. The other locality is in the Sadlerochit Mountains, mainly along Itkilyariak Creek and its tributaries.

The basalt on the Hulahula River is an aphanitic green rock, occasionally amgdaloidal. The amgdules rarely exceed one-eight of an inch in greatest dimensions. They are usually filled, either with quartz or with a black mineral. Macroscopic mica, probably biotite, is present as a constituent of the rock in a few instances.

On the Hulahula, the rock is in part massive and jointed, but everywhere toward the contacts it grades into green phyllites and slates. The exposed contacts are entirely with the Lisburne limestone. On the west side of the Hulahula for a distance of about two miles, the contact is about parallel to the bedding of the Lisburne at about the horizon to the middle member. South of this the contact becomes cross-cutting and the lower limestone member of the Lisburne appears. This general relationship seems to hold on that east side of the river also, but at that place it is not so clearly defined. Along the contact the limestone exhibits a pronounced reddish weathering and a foliation, parallel to that in the igneous mass, which are otherwise not present. The contracts between red weathering foliated limestone and green phyllite are sharp. However, inclusions of limestone, some several feet long, are present in the phyllite, and stringers of phyllite are present in the limestone parallel to bedding.

The base of the igneous mass on the Hulahula River was not seen. The mass is fairly large and seems to form the core of the Kikittut Mountain anticlinal structure. It seems possible that the mass may be a lacolith and that its intrusion may be the cause of the anticlinal structure.

The basalts in the Sadlerochit Mountains are largely dark gray, green, and reddish aphanitc rocks, partly amgdaloidal and vesicular. Also present is a macroscopically finely-crystalline greenish rock, without amygdules or vesicles, possibly a gabbro. Where present in these rocks, the amygdules are usually less than one-fourth of an inch in greatest dimension. They are filled with a variety of minerals of white, red, green, and greenish-blue color. The white mineral is calcite. Veins of calcite, quartz, and a light green mineral occur. A hasty examination of thin sections of some of these rocks indicated that some of the minerals present are basic plagioclase, augite(?), chlorite, and calcite. The chlorite and calcite are apparently secondary.

The basalts in the Sadlerochit Mountains occur in a tabular discontinuous mass which extends for about seven miles in a general east-west direction. The greatest thickness of this mass does not exceed 75 feet. Near the east end of the mass it appeared to be cutting across the bedding of the Lisburne limestone, but the exact relationships were obscured by talus, and the locality was only viewed from a distance. The mass appears to be a dike intrusive into the Lisburne limestone and the Neruokpuk formation.

Occurrences of green slates, phyllites, and schists on Ahngayukasrakuvik Creek and on the Okpilak River, both occurring in connection with the clastic middle member of the Lisburne limestone, have been tentatively mapped as basalt.

The basalts, both on the Hulahula River and in the Sadlerochit Mountains, appear to be intrusive into the Lisburne limestone. Thus they appear to be of post-Lisburne age and probably not older than the Mesozoic.

STRUCTURE

Folding, modified generally only by minor faulting, has produced the structural pattern in the Sadlerochit area. The folded structures are best exemplified in the outlying ranges (Sadlerochit Mountains, Shublik Mountains, and Third Range) and the intervening valleys, but the same pattern is seen in the post-Neruokpuk rocks through most of the rest of the area. The average trend of fold axes is about east-west. The three outlying ranges are all major anticlines, overturned to the north. The intervening valleys are synclinoria with numerous smaller anticlines and synclines. Each of these major anticlines plunges to the east and disappears in the Sadlerochit area.

Some faulting seems to be connected with the plunge of the major anticlines. Along the plunge of the Sadlerochit structure and roughly parallel to the axis is a fault with an indicated displacement at Itkilyariak Creek of about 1000 feet, north side down. The attitude of the fault plane is unknown. Near Camp 13 repetition of section indicates the presence of two faults with west side up which trend about at right angles to the first fault. At the east end of the Shublik Mountains a fault with a displacement of about 500 feet has the south side down.

Tear faults are suggested by three abrupt offsets of the Neruokpuk-Lisburne contact at and to the west of the Hulahula River. On aerial photographs numerous small offsets which are probably tear faults show up in the bedding traces in the Ignek formation east of Camp 12.

The only evidence of major overthrusting was seen on the Hulahula River upstream from Camp 5. Outcrops of folded rocks of the Sadlerochit and Shublik formations occur along the river for several miles. The folding becomes more intense to the south. The mountains to both the east and west, however, are made up largely of a thick, gently south-dipping Lisburne limestone section.

On the Okpilak River the contact between the limestone and the granite is believed to be a fault. The contact was seen to cut across the bedding and structure of the limestone. Yet the limestone is considered to be considerably younger than the granite. Consequently, faulting is postulated. The most highly metamorphosed phases of the limestone that were seen were near this contact on the east side of the Okpilak. Significantly, this metamorphism appears to be of a type that would result from stress and not from the contact action of an intrusive.