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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PRELIMINARY REPORT ON SEDIMENTARY AND METAMORPHIC ROCKS IN PART OF THE ROMANZOF MOUNTAINS, BROOKS RANGE, NORTHEASTERN ALASKA

by

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This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

1959

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ABSTRACT

The Romanzof Mountains comprise a high, rugged mountain group in the northeastern Brooks Range. A granite body of small batholith size, the "Okpilak" granite, occupies the central part of the Romanzofs, and is flanked by sedimentary and metasedimentary rocks which range from pre-Mississippian to Jurassic in age. Mafic dikes and extrusive(?) rocks are of minor occurrence. Cretaceous(?) rocks are exposed north of the area.

The Neruokpuk formation of pre-Mississippian age is here mapped to include several sedimentary and low grade metasedimentary rock units. These include a lower black limestone unit overlain by interbedded limestones, phyllite, argillite, slate, chert, and quartzite, in turn overlain by a thick section of quartzite and schistose quartzite. The total thickness of the Neruokpuk sequence is believed to be more than 4400 feet. A major angular unconformity separates these rocks from the overlying Mississippian rocks.

Mississippian rocks include the Kayak "shale", a unit of light to dark gray quartzite, carbonaceous shale, and conglomerate which is 0 to about 400 feet thick. The Lisburne group, of late Mississippian age, consists of gray limestone and dolomite, with minor amounts of chert, black shale, and sandstone, and is as much as 780 feet thick. The group is overlain at least disconformably by Permian rocks.

The Sadlerochit formation, of Permian-Triassic(?) age includes a lower Ferruginous sandstone member, about 200

feet thick, consisting of iron-stained, in part fossiliferous siltstone and sandstone interbedded with shale; a Shale member, about 400 feet thick east of the Okpilak River, consisting of dark gray, in part pyritic shale; and a Quartzite member, at least 500 feet thick, composed of grayish and light brown, evenly bedded sandy quartzite with minor amounts of interbedded shale and thin conglomerate beds.

The Upper Triassic Shublik formation consists of a basal phosphatic sandstone overlain by black phosphatic limestone and shale. Its thickness is about 700 feet.

The Jurassic Kingak formation includes a basal siltstone member, 75 to 150 feet thick, composed of gray, in part conglomeratic silty quartzite with thin conglomeratic lenses and beds. Above this, a shale member, consisting of black clay and silty shale with scattered ironstone nodules, is probably more than 1000 feet thick.

Rocks considered to be correlative with the Ignek formation of Cretaceous age crop out several miles north of the mountain front. They include interbedded carbonaceous sandstone, siltstone and shale, and coaly beds. The thickness of the Ignek formation is unknown.

Pleistocene and Recent glacial, glaciofluvial, alluvial and colluvial deposits are confined mostly to stream valleys within the mountains, but glacial drift covers large areas to the north.

The structure of the area consists of a "central core", the "Okpilak" granite mass, around which beds in general dip outward. Overturned folds and thrust faults reflect northward tangential movement. Transverse normal and reverse faults, and transverse faults with apparent lateral movement include many which are aligned in a north-northwest pattern. South dipping cleavage, a strong roughly north-striking vertical joint set, and schistose rocks interpreted to lie along zones of shear are also prominent features.

INTRODUCTION

The Romanzof Mountains represent an area which is geologically unique in northern Alaska; they contain the only known granitic body on the northern side of the Brooks Range. In addition, a variety of sedimentary and metamorphic rocks are present, and Pleistocene to Recent valley glaciation features are abundant. Geologic field investigations were undertaken during the summers of 1957 and 1958 to study the granite and its relationships to adjoining rocks and to compare the sedimentary and metamorphic rock sequence with those in better known areas of the Brooks Range.

Location, Size, and Accessibility of Area

The Romanzof Mountains lie within the Mount Michelson and Demarcation Point Quadrangles, Alaska, and cover about 600 square miles. They are approximately bounded on the east and west by the Jago and Hulahula Rivers, respectively, and lie between latitudes 69°05' and 69°27' N (Figure 1).

Airline distances to the nearest Alaskan settlements of Barter Island, Bettles, and Barrow are 60, 130, and 320 miles respectively. No roads or established trails are present into or within the area, and access is most easily accomplished by use of small float- or ski-equipped aircraft.

Within the area, travel can best be accomplished on foot. Although tracked vehicle travel is possible along the Jago, Okpilak, and Hulahula Rivers nearly to their headwaters, such travel would be difficult within the mountains. Shallow draft boats might be used on the major rivers, particularly on the Hulahula, the largest and deepest stream in the area.

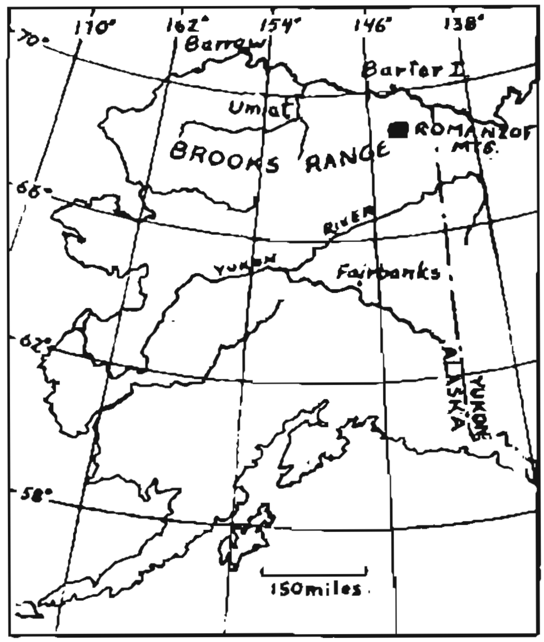

Figure 1. Index map of Alaska, showing location of Romanzof Mountains.

Previous Investigations

The Romanzof Mountains were first named by Sir John Franklin (1828, p. 145-147), who saw their snow-clad peaks from the Arctic Coast. The name was later restricted to that portion of the mountains between the Hulahula and Jago Rivers by Ernest de K. Leffingwell (1919, p. 50), who, during his extended stays on the Arctic Coast, made two trips into the area. Geology accomplished on these trips was of a reconnaissance nature, and served to outline some of the main stratigraphic units and gross structural features of the northwestern Romanzofs.

In June 1948, a U. S. Geological Survey party consisting of Charles L. Whittington, geologist and party chief, E. G. Sable and Arthur H. Lachenbruch, geologists, conducted a geologic reconnaissance along the Okpilak and Hulahula Rivers and along the front of the mountains between these rivers. The 1948 work in the area resulted in relatively few refinements on Leffingwell's earlier observations. At this writing, preliminary results of this work are on open file in the offices of the U. S. Geological Survey in Washington, D. C.

Nature and Scope of the Investigation

Field studies undertaken during the summers of 1957 and 1958 were parts of a project visualized by the author in 1956. The purpose of the overall project is to produce a relatively detailed geologic map of the area, to determine the age and relationships of the various rock units, and to evaluate the structural features and economic mineral potential. The significance of the area in relation to the overall tectonic framework of the Brooks Range is perhaps the most important conclusion which is hoped to be ultimately gained from the studies.

The present paper is in large part descriptive, and is concerned mainly with the sedimentary and metasedimentary rocks exposed in the eastern part of the area, east of the Okpilak River. Much of the sedimentary sequence in this area has not been previously mapped, or was described only briefly (Leffingwell, 1919; Whittington and Sable, 1948).

The sedimentary rocks exposed in the northwestern part of the area, between the Okpilak and Hulahula Rivers, are described by Bunnell (1959, in preparation). Studies of glaciation along the Jago and Okpilak Rivers have been reported on by Kunkle (1957).

It is planned that the preliminary descriptive data presented herein shall be reevaluated in light of further laboratory studies, and the results incorporated in a comprehensive report covering both the descriptive and interpretive aspects of all rocks in the area.

Field Operations, 1957 - 1958

On June 10, 1957, the writer and George R. Kunkle, field assistant, were landed on Jago Lake, a small lake along the Jago River, by single-engine ski-equipped airplane. Work was begun on the glacial and bedrock geology along the Jago River and its tributaries, and extended upstream. Mapping was also done along the north side of the mountains between the Jago and Okpilak Rivers, and along the east side of the Okpilak within several miles of Okpilak Lake. Temporary camps were established by backpacking and air-dropping of food and equipment; rock specimens were back-packed to locations for aircraft pick up. The party left the field from Okpilak Lake on August 25, via Umiat to Barrow, the base of operations.

On June 10, 1958, Sable and Ralph S. Bunnell, field assistant, were landed on McCall Glacier and immediately backpacked 17 miles to Okpilak Lake. All work was done on foot from 14 temporary camp locations, and covered ground along the upper Okpilak River, between the Okpilak and Hulahula Rivers, and on the Jago River. Professor William C. Kelly of the University of Michigan visited the party in early August for consultation purposes. The party was flown to Barter Island and Barrow on September 2 and 3.

During field work, the geology was mapped directly on high altitude Tri-metrogon, vertical, and transverse aerial photographs, and low angle oblique photographs, flown by the Army, Navy, and a private contractor for the U. S. Government. Data was transferred from aerial photos to unpublished inch-to-the-mile topographic maps with contour intervals of 100 and 200 feet, prepared by the U. S. Geological Survey.

Acknowledgments

The field work in 1957 and 1958 was made possible in part by a grant from the Office of Naval Research, U. S. Department of the Navy, as administered through the Arctic Institute of North America. Support by the U. S. Geological Survey and the Arctic Research Laboratory at Point Barrow, is also gratefully acknowledged. In addition, the author wishes to acknowledge the aid given him by other scientific investigators in the area: Mr. Charles Keeler of the McCall Glacier I.G.Y. Glacialogical project, and Dr. John E. Cantlon of Michigan State University.

The writer much appreciated the active interest evinced and consulting aid given by Professor Kelly during his visit to the area, as well as his helpful suggestions during preparation of this report. Thanks is also due to Professor Edwin N. Goddard of the University of Michigan for his constructive comments.

GEOGRAPHY

Topography and Drainage

The highest and most rugged mountain mass in the northern Brooks Range, the Romanzof Mountains reach altitudes of 9000 feet, with relief as much as 7000 feet. They are nevertheless a relatively small group of mountains compared to other components of the Brooks Range; the Franklins, Endicotts, and DeLongs. The Romanzofs rise rather abruptly from low hills to the north. Their northern parts consist of high, mostly rubble-covered uplands with terrace-like erosional surfaces at several altitudes, linear ridges, and massive, irregularly-shaped mountains. These rise gradually towards the central part of the Romanzofs where massive, precipitous mountains with jagged peaks and ridges are the dominant topographic features. Many valley glaciers as much as 6 miles long head in the higher parts of the area, and a small ice cap covers the vicinity of Mount Michelson, one of the highest peaks in the Brooks Range.

Three major north-flowing rivers, the Jago, Okpilak, and Hulahula, drain the Romanzofs. Their valleys have been heavily glaciated and, except in their headwaters, are wide and U-shaped. Gradients are relatively steep, but at present, lateral cutting appears to be an important erosional process of these rivers. Tributary streams such as Okpirourak and Ahngayakasrakuvik Creeks are deeply incised within the mountains. Although previously glaciated, the tributaries are not as well graded as the major streams, and downward cutting since glaciation has been the dominant process. Valley profiles of the tributaries are generally V-shaped and steep-sided.

Over-graded and unstable slopes are common in the area and, as a result, numerous examples of soil creep, soil flow, and other evidences of surface material instability are present in the area. Rock falls and small avalanches are a common occurrence in the higher mountains. As far as is known, the entire area is underlain by permafrost and there is little doubt that in these high latitudes and altitudes, mechanical disintegration is, at present, of prime importance as a weathering agent.

GENERAL GEOLOGY

Both in areal extent and in topographic expression, the large granitic mass which constitutes the bulk of the Romanzof Mountains is the most striking bedrock feature of this area. First reported by Leffingwell (1919, p. 126-128), the granite was briefly re-examined and tentatively named by the 1948 U. S. Geological Survey party. The "Okpilak" granite covers about 150 square miles and is elongate northeast-southwest, generally parallel to the strike of the structural grain in the area. It consists mostly of light to medium-gray, fine- to very coarse-grained biotite granite ranging from equigranular to highly porphyritic, and holocrystalline to strongly gneissoid, with numerous zones of cataclastic texture, shear, and alteration. At least two granitic facies are present. Contacts with pre-Mississippian rocks, which the granite post-dates, are sharply discordant, and are in part bordered by zones of contact metamorphism. Xenoliths are common features near the margins of the granite mass. Contacts with Mississippian and younger rocks, however, either lie along faults or their nature is uncertain. The age of the "Okpilak" granite is as yet undetermined.

The sedimentary and low grade metamorphic rocks discussed in this report generally dip away from the granite on all sides except within about a quarter of a mile of the contact along the north and west limits of the granite. Here the granite locally overlies the adjoining rocks.

The sedimentary and metasedimentary rocks include several units of clastic, carbonate, and cherty rocks of pre-Mississippian age, carbonate and coarse- to fine-grained clastic rocks of Mississippian and Permian age, Upper Triassic phosphatic limestone and shale, and clastic rocks of probable Jurassic and Cretaceous age. All of these, except for the Cretaceous(?) rocks, are silicified, cut by quartz and calcite veins, and at least those of pre-Mississippian age are locally altered to a higher grade of metamorphism by contact action associated with emplacement of the granite. The structure ranges from extremely complex within the mountains to relatively simple near their north and west limits.

Aphanitic mafic igneous rocks occur in dikes cutting the "Okpilak" granite, in a roughly elliptical body which covers about five square miles along the Hulahula River, and in several dike-like bodies of small dimensions which intrude Mississippian and older rocks. The age of the mafic rocks is thought to be Jurassic or younger.

Pleistocene and Recent glacial deposits of at least two widely different ages occur within and along the north front of the mountains to beyond the north limit of the area. Major stream valleys have been heavily glaciated, and it is almost certain that at least local piedmont-type glaciation occurred during Pleistocene time, as inferred from widespread till and erratics north of the mountains. The area also contains many present glaciers and spectacular examples of recently glaciated topography, including hanging valleys, evacuated cirques, arête ridges, and both fresh and stabilized morainal material. Although glaciation has resulted in excellent bedrock exposures in the central Romanzofs, the widespread drift cover at the mountain front and the relatively fresh unstable debris within the mountains makes geological investigation on foot an extremely arduous and exhausting task.

STRATIGRAPHY

Sedimentary and low-grade metasedimentary rocks exposed in and north of the Romanzof Mountains encompass units of widely different rock types ranging from pre-Mississippian to Recent age. The succession of stratigraphic units is tabulated in Table 1.

The terminology used in the rock descriptions of this report includes the terms bed, sets of beds, unit, sequence, and section. The terms carry only relative thickness connotations. Bed is used to denote a layer of rock that is separated from the adjoining layers by a difference in lithology, a physical break, or both, similar to Payne's (1942) definition of lamina and stratum. Sets of beds denotes a succession of beds of similar lithologic character, as shale, which lie between rocks of visually different character, as sandstone. Unit is used in a general sense for any of the above terms. The term sequence carries an inferred genetic or time connotation. Section denotes a specifically located measured or estimated stratigraphic interval.

Terms designating clastic sedimentary rock types are based on the Wentworth scale, and the adjective prefixes "clay" and "silty" refer to grain size. The term shale essentially follows the usage of Pettijohn (1949, p. 269-270). The color designations conform insofar as possible to the color names of the National Research Council Rock Color Chart (Goddard and others, 1948).

AGE	NAME OF UNIT	APPROXIMATE THICKNESS	GENERALIZED DESCRIPTION
Pleistocene-Recent	---	0-200?	Glaciofluvial and alluvial silt, sand and gravel; mostly granitic constituents. Ice and ice-contact deposits; till, coarse morainal deposits.
Cretaceous	Ignek formation	?	Dark gray shale, sandstone, siltstone, coaly beds.
Jurassic	Kingak formation	1000+	Predominantly dark gray clay and silty shale underlain by basal silty quartzite with minor conglomerate beds.
Upper Triassic	Shublik formation	700	Black phosphatic limestone and limy shale. Basal phosphatic sandstone.
Permian-Triassic(?)	Sadlerochit formation		
	Quartzite member	700±	Medium-gray massive quartzite with interbedded slate, limy sandstone, and minor conglomerate.
	Shale member	420+	Predominantly medium dark-gray slate, laminated to uniform. Minor thin quartzite beds.
	Ferruginous Sandstone member	200±	Ferruginous quartzite with minor conglomerate lenses, interbedded with slate and ferruginous sandstone.
Upper Mississippian	Lisburne group	600-800	Carbonate rocks. Limestone, biostromal limestone, sandy dolomite; lower part silty and sandy limestone, minor slate beds.
Mississippian	Kayak shale	0-420	Light- to dark-gray silt to granule-size quartzite interbedded with variable amounts of carbonaceous shale and slate. Local pebble to boulder conglomerate.
Pre-Mississippian (Precambrian?-Devonian?)	Neruokpuk formation	4350+	Several facies. Dominantly gray and brownish or greenish quartzite and schistose quartzite with interbedded slate and minor siliceous rocks. Limestone and silicified carbonate rocks, light gray to black, finely crystalline to sandy, in part probably phosphatic.

Table 1. Summary of sedimentary rocks and surficial deposits, Romanzof Mountains, Northeastern Alaska.

Section thicknesses were obtained by several methods, including pace-and-compass traverse, altimeter traverse, direct measurement, and estimation. The resulting thicknesses are approximate; the nature of the terrain and the necessity of covering a relatively large area in a limited time period were factors which precluded a higher degree of measurement accuracy and descriptive detail.

Pre-Mississippian Rocks

Neruokpuk formation

Name and Definition.- The name Neruokpuk schist was first used by Leffingwell (1919, p. 103-105) to denote pre-Carboniferous metasedimentary rocks in northeastern Alaska, which consist predominantly of quartz mica schists and quartzite schists. Leffingwell examined these rocks mostly west of the Romanzof Mountains, but correctly inferred that they extended farther east beyond the Okpilak River. Later studies by the U. S. Geological Survey (Brosge *et al*, 1952; Mangus, 1953) both west and east of the Romanzof Mountains have shown that several pre-Mississippian lithologic units are present in those areas. Likewise, the present studies show that several mappable units lie below Mississippian rocks in the Romanzof Mountains, and include or are included in the Neruokpuk schist as defined by Leffingwell. The author believes that, in light of the relatively recent work, the term Neruokpuk is ambiguous and should perhaps be redefined. In this report, however, the pre-Mississippian rock units described below are given informal unit designations and are mapped as units in the Neruokpuk formation (Plate 1).

Distribution and Outcrop.- Neruokpuk formation rocks are exposed around the periphery of the "Okpilak" granite body to the south, east, and west, where their outcrops cover at least several hundred square miles. A few small erosional remnants of the formation also lie within and overlying the granite, particularly along its southern margin. The third type of occurrence consists of isolated areas north of the granite along the Hulahula River, and between the Hulahula and Okpilak Rivers.

The various rock facies in the Neruokpuk formation are mostly resistant units and are best exposed in the high mountains adjoining the granite. Although carbonate and shaly rocks are poorly resistant, and commonly occur as high rubble-covered hills, they are well exposed in north-facing mountain slopes along the west side of the Jago River between Boulder and Met Creeks. Quartzitic and schistose units form cliffs and nearly entire mountains along the Jago River valley and excellent, but of difficult access, mountain exposures are present in the headwaters of the Okpilak River. East of the Romanzof Mountains, units of the Neruokpuk formation can be mapped beyond the Canadian boundary, and west of the area, they extend beyond the Canning River.

Character and Thickness.- The rocks of the Neruokpuk formation in the Romanzofs consist of several types of low grade metasediments. They are equivalent to or less in rank than the chlorite zone of the greenschist facies, except locally, where they lie along mineralized shear zones or in contact metamorphic aureoles. Original argillaceous sandstones are commonly represented by chlorite schist and schistose quartzites (Figure 2), carbonate rocks range from almost unaltered types to calcareous schists and hornfels (Figure 3), and many rock types are highly silicified. Because of metamorphism, the complex structures of the orogenic belt type, and the fact that Mississippian rocks overlie various units of the Neruokpuk formation, it is difficult to ascertain the relative positions and abundance of the various rock units in the total sequence. It is believed, however, that although the thicknesses given are approximate and may be subject to change, the following units are represented in correct order of age, from youngest to oldest.

Map unit symbols (Plate 1)	Units	Approximate thickness in feet
Nk_4	1. Green quartzite and schistose quartzite.	750+
	2. Upper brown quartzite..................	850±
Nk_3	3. Limestone, argillite, chert.............	350±
	4. Upper black limestone..................	300±
Nk_2	5. Lower brown quartzite..................	400±
Nk_1	6. Limestone and phyllite.................	700±
	7. Lower black limestone..................	1000+
		4350±

Figure 2. Quartzite beds of the Neruokpuk formation exposed along tributary on west side of Jago River, 11 miles south of Jago Lake. (Bedding dips to left; height of outcrop about 20 feet).

Figure 3. Tightly folded and silicified beds of Neruokpuk formation lower limestone unit near granite contact along tributary creek, west side of Jago River.

The above units are well exposed along the Jago River and can be traced for at least several miles east. Westward, the units are partly cut out by the "Okpilak" granite, but along tributaries of the east fork of Okpilak River a section containing rocks similar to the upper four units shown above is exposed. Most of the mountains south of the granite which are composed of Neruokpuk formation appear to be mainly quartzite and green schistose quartzite; these represent the thickest units in the known Neruokpuk section.

The following is a generalized description of the Neruokpuk formation exposed along the Jago River.

Section 1. Generalized section of Neruokpuk formation, along west side of Jago River between Boulder and Met Creeks. Examined by E. G. Sable, July-August, 1957.

Unit	Thickness in feet
1. Quartzite, with interbedded schist and slate. Quartzite and schist grayish green, chloritic, banded, evenly bedded, fine- to coarse-grained with scattered subround quartz granules. Beds generally 6 inches to 2 feet thick, but locally as much as 5 feet thick. Interbedded medium to medium dark gray quartzite, argillaceous to sandy; grayish-green chloritic schist; dark gray slate. Minor gray calcareous sandstone, very fine grained, in platy 2-inch beds. Resistant unit; quartzite about 75 percent of section..........	750+

2. Quartzite, with interbedded dark gray slate and siliceous shale. Quartzite medium to medium dark gray and olive gray, fine to coarse grained, with scattered granules of quartz and chert; evenly bedded, massive beds 6 inches to 7 feet thick, weathers flaggy, blocky, and massive. Interbedded thin quartzite and shale beds less than 6 inches thick weather pale yellowish brown, olive gray, and greenish gray, ironstained, banded to uniform. Massive resistant unit, quartzite about 80 percent of section... 850

3. Poorly exposed. Argillite, siliceous shale, and slate estimated to be 80 percent of unit; interbedded chert about 20 percent. Argillaceous rocks greenish gray, pale olive, and light gray, with platy parting mostly less than 1 inch thick, in part oolitic(?). Upper part of unit contains higher percentage of chert and cherty argillite, light gray to grayish red, in evenly bedded to wavy beds 1/8 to 1 inch thick alternating with slate and argillite. Milky quartz veins common in upper part of section. Moderately resistant unit; outcrops on steep mountain slope.................... 350±

4. Very poorly exposed. Limestone, medium dark gray to dark gray, weathers light olive gray,

sandy, with platy to fissile parting less than 1 inch thick. Contains few 1/8-inch ironstained spherical concretions(?). White calcite and pinkish quartz veins seen in rubble. Poorly resistant unit, crops out on moderately sloping mountain sides.................................... 300±

5. Quartzite, medium gray, weathers moderate yellowish brown, fine to coarse grained with few granules of quartz and dark gray chert; in part salt and pepper texture, in part argillaceous to silty; some interbedded calcareous sandstone. Beds as much as 5 feet thick, evenly bedded, in part banded, mostly massive to blocky, cut by white quartz veins. Very resistant unit but less massive in upper 100 feet; cliff-former.............................. 400±

6. Interbedded limestone, phyllite, quartzite, and slate. Mostly limestone, dark gray to medium gray, very finely crystalline, shaly, and sandy, soft to well indurated, in part phosphatic(?) and carbonaceous, blocky to fissile. Quartzite mostly greenish gray, weathers light to moderate brown, in tabular to lenticular beds 1 to 3 feet thick, commonly interbedded with dark gray slate in sets of beds as much as 2 feet thick. Micaceous and calcareous phyllite appears to be commonly interbedded with limestone and slate, gray to

greenish gray, in sets of beds as much as 5 feet thick. Interbedded schist commonly greenish gray to pale olive, in part calcareous. Poorly resistant unit, contains few ironstained zones perhaps along faults........................... 700±

7. Limestone, with minor interbedded slate, phyllite, siltstone and quartzite similar to those in above units. Limestone medium gray to black, in part graphitic, weathers medium light gray to moderate yellowish brown, sandy to shaly with grain size increasing upwards in unit. Some finely crystalline beds in lower part of unit. Tabular beds with blocky, platy, and fissile fracture; some beds finely laminated or are alternating fine and coarse grained. Several zones of shear and mineralization parallel to bedding and as much as 30 feet thick which include veins and lenses of milky quartz and calcite, disseminated pyrite, and greenish asbestiform amphibole(?). Moderately resistant unit; includes some massive cliff-forming limestone sets of beds as much as 90 feet thick.................................... 1000+

Two carbonate units of pre-Mississippian age, in part different from those described above, are exposed in the western part of the Romanzof Mountains. Their total thicknesses and stratigraphic correlation with other units are not known; they are mapped as undifferentiated Neruokpuk formation on Plate 1. One unit, exposed in several localities between the Okpilak and Hulahula Rivers (Bunnell, 1959, in preparation), consists of at least 400 feet of largely silicified light to dark gray, very fine-grained limestone, in part laminated, and containing intraformational breccia, pisolitic and oolitic beds, and limestone pebble- to boulder-conglomerate. The second unit, exposed in the southwestern part of the area, is composed of yellowish brown weathering, platy, ferruginous sandy limestone and is at least 500 feet thick. Both of these units appear to normally overlie schistose quartzites and quartz-mica schists of unknown thickness.

Stratigraphic Relationships.- The base of the Neruokpuk formation is not exposed in the area. A major angular unconformity of regional significance lies between Neruokpuk and overlying Mississippian rocks. No major breaks were recognized with certainty within the Neruokpuk formation, although locally, contacts between quartzite and underlying limestone or shaly units are irregular, and intraformational conglomerate and breccia are present in some exposures of carbonate rocks. Studies of a more regional nature are necessary to determine whether major depositional breaks exist within the Neruokpuk. Such studies are being undertaken in northeastern Alaska; Brosge and Reiser of the U. S. Geological Survey (1958, personal communication) report that at least one major unconformity probably is present within pre-Mississippian rocks of the northeastern Brooks Range.

Age and Correlation.- Except for scattered crinoid columnals found in silicified limestones near Ahngayakasrakuvik Creek, no identifiable fossil remains have been found in pre-Mississippian rocks of this area. Questionable fossils in the lower limestone unit of the Neruokpuk formation of the Jago River consist of highly deformed ellipsoidal "blebs" of white calcite which lie along bedding planes.

Payne and others (1951) considered the Neruokpuk formation, as defined by Leffingwell, to be of possible Precambrian age. Other units of pre-Mississippian age in the Brooks Range include Devonian rocks (Bowsher and Dutro, 1957, p. 4-5), and older metamorphics, perhaps in part of Silurian age (Smith and Mertie, 1930, p. 115-151) or older. To date, the evidence in the Romanzof area does not permit clear-cut correlations with these other units. Studies by the U. S. Geological Survey now underway elsewhere in the northeastern Brooks Range show that at least some pre-Mississippian units are similar to those in the Romanzofs (Brosge, 1958, personal communication). It is probable that when these studies are completed, correlations with the Romanzof stratigraphy will enable the establishment of a nomenclature suitable for the entire eastern Brooks Range.

Mississippian System

Kayak shale

Name and Definition.- Rocks of Mississippian and probable Mississippian age include a unit of clastic rocks tentatively correlated with the Kayak shale of more western areas of northern Alaska (Bowsher and Dutro, 1957, p. 13-16). This unit is in whole or in part the same as Leffingwell's "black shale and slate" formation which he recognized to conformably underlie "Lisburne limestone" west and southwest of the Romanzof Mountains (Leffingwell, 1919, p. 105-108).

Distribution and Outcrop.- Although it is widely distributed on the eastern, northern, and western fringes of the Romanzof Mountains, the Kayak shale is a relatively thin unit and covers little exposure area. Where well developed, the Kayak forms a distinctive marker unit between rocks of the Lisburne group and Neruokpuk formation, and differs from the adjoining rocks in color, weathering effects, and topographic expression. Where quartzite, sandstone, and conglomerate constitute a major part of the formation it outcrops as precipitous cliffs, such as in the exposures along the east side of the Okpilak valley 1.7 miles south of Okpilak Lake, at higher altitudes 4 miles south of the lake (Figure 4) and on the east side of the Jago River 15 miles southeast of Jago Lake. The Kayak is also exposed mostly as rubble in the hills along the east side of the "Okpilak" granite, in the hills on the east side of the Jago River, and along Okpirourak Creek and other tributaries of the Hulahula River. A higher proportion of shale and conglomerate appears to constitute the exposures west of the Okpilak River (Bunnell, 1959, in preparation), and the formation commonly weathers to rubble-covered benches or swales between the more resistant Lisburne and Neruokpuk rocks. On aerial photographs, neither the texture nor the outcrop appearance are particularly distinctive, except for the color contrast between the Kayak and the lighter Lisburne group rocks.

Character and Thickness.- The Kayak formation consists of epiclastic rock types ranging from boulder conglomerates to clay shale. East of the Okpilak River, however, the sections examined consist of about 50 to 80 percent sandstone and quartzite with lesser amounts of silty and clay shale. A few thin conglomerate beds in which pebble-size constituents are present were seen, but these are relatively rare.

Sandstone, granule conglomerate, and quartzite range from very light gray to dark gray, are commonly medium- to coarse-grained, weather yellowish gray to medium gray, are generally well sorted with respect to size, and are nearly monomineralic, consisting almost entirely of mostly well packed, subround to subangular quartz grains with a few heavy resistate and chert grains. The matrix which comprises roughly 10 to 30 percent of these rocks is mostly quartz and calcite, and carbonaceous material is present in the darker varieties. Blocky to massive beds average about 4 feet and are as much as 15 feet thick, and resistant sets of beds are as much as 80 feet thick. The rock is evenly bedded, uniform to banded, and cross-bedding is rare or absent. Few sharp contacts were observed between beds.

Very fine-grained sandstone and siltstone are relatively rare, but occur as transitional units between sandstone and shale. Silty and clay shale is medium gray to black, commonly carbonaceous, and occurs in sets of beds averaging 1 to 2 feet, but as much as 15 feet thick. Macerated coaly plant fragments are locally abundant in shale from the lower part of the formation. Some shale grades to argillaceous sandstone in which medium- to coarse-grained quartz is poorly packed.

In general, dark-colored quartzites and slates are dominant in the lower part of the formation, but the light, colored rocks are the most abundant east of the Okpilak River where they make up about 80 percent of the Kayak exposures.

Nearly all rocks of Kayak formation have been metamorphosed to some degree. Relatively clean sandstones have been altered to quartzite and schistose quartzite whereas more argillaceous varieties range to quartz muscovite- and quartz-sericite schist. Shales have been metamorphosed to slate or phyllite with south-dipping cleavage. In addition, pyrite and iron oxides are locally common.

The following section is typical of the Kayak formation east of the Okpilak River.

Section 2. Kayak formation, east valley wall of Okpilak River about 1.7 miles south of Okpilak Lake; measured by E. G. Sable and R. S. Bunnell, June 14, 1958.

Unit	Thickness in feet
Top of section. Rubble of Lisburne group limestone.	
1. Covered. Scattered rubble and talus of Lisburne	

group limestone and Kayak formation(?) shale......... 10±

2. Quartzite, medium light-gray to medium-gray, medium- to coarse-grained with some granule-size grains. Quartz grains subangular, clear, moderately well sorted in quartzose, micaceous, and partly carbonate matrix. Banded to uniform in appearance. Massive unit.......................... 15

3. Poorly exposed. Interbedded quartzite and slate; quartzite 70 percent of unit. Quartzite similar to unit 2; slate medium-gray, in part finely laminated, contains few quartz granules....... 22

4. Schistose quartzite and quartzitic conglomerate, medium light-gray, granules and small pebbles of quartz and chert(?) as much as 3/4 inch in diameter about 40 to 60 percent of unit. Matrix quartzose, micaceous, in part iron-stained.. 7

5. Quartzite and phyllitic slate, interbedded. Slate, medium light-gray to light grayish-green, about 30 percent of unit in beds less than 3 feet thick; contains quartz granules. Quartzite beds less than 6 feet thick, micaceous. Grades downward into unit 6.............. 20

6. Phyllite and slate, medium-gray, soft, in part finely laminated, interbedded with few 1 to 1½ foot beds of schistose quartzite.................. 15±

7. Schistose quartzitic granule conglomerate

medium light-gray, massive, highly micaceous, contains about 30 percent quartz granules.......................... 12

8. Phyllitic slate, medium gray.......................... 2

9. Schistose quartzose sandstone and quartzite interbedded and intergraded with gray to greenish-gray phyllitic slate. Quartzite light medium-gray, contains subround to subangular granules and pebbles as much as 3/8 inch in diameter of clear and milky quartz concentrated in beds as much as 3 feet thick. Low porosity.......................... 25±

10. Covered. Talus of quartzite and slate.......................... 65±

11. Quartzite, light to very light-gray, evenly bedded, fine-grained to granule-size quartz grains, well sorted, subround to subangular. Varying admixture of light micaceous matrix. Outcrop weathers light brown to grayish orange....... 12

12. Rubble covered. Quartzite, slate, small amount of gray, very finely-crystalline limestone.......................... 127±

13. Sandstone and granule conglomerate, medium dark-gray, fine- to coarse-grained with few granules, quartzose grains subround to round, well sorted, micaceous matrix, massive unit.......................... 12

14. Slate, dark gray, micaceous, silty.......................... 1

15.	Sandstone, medium dark-gray, fine- to coarse-grained, carbonaceous, quartzose, with thin lenses of granule conglomerate. Massive unit........	4
16.	Sandstone and slate as in units 14 and 15, interbedded..	3
17.	Slate, black, carbonaceous, with macerated plant fragments................	2
18.	Sandstone, medium-gray, massive, ironstained.........	3
19.	Interbedded sandstone and slate as in units 13 and 14. Sandstone beds and lenses to 3 feet thick 60 percent of unit. Slate contains micaceous flattened and distorted plant impressions. Some concentrations of hematite along slate bedding................................	16
20.	Covered. Estimated................................	50
	Schist and schistose mafic igneous rock.	
	Total	421 ±

The Kayak formation is highly variable in thickness, ranging from 0 to about 400 feet. In some parts of the area the formation appears to be locally absent and Lisburne group rocks rest on pre-Mississippian units. Thicknesses of the easternmost exposures along the Jago River range from 40 to 200 feet, but here the Kayak rests on granite and the thickness variations may be the result of intrusion. Likewise, along the north front of the granite mass between the Jago and Okpilak Rivers, highly schistose rocks thought to be metamorphosed Kayak formation vary from a few feet to more than 100 feet in thickness.

Stratigraphic Relationships and Mode of Deposition.- The Kayak formation overlies pre-Mississippian metasedimentary rocks with angular unconformity. This relationship is best exposed on a small scale west of the Okpilak River along Ahngayakasruvik Creek (Bunnell, 1959, in preparation). The actual contact at the base of the Kayak was not seen east of the Okpilak River, except where it overlies granite. Here the contact appears to be gradational. Throughout the general area, however, Kayak rocks rest on several different units of older metasediments, and aerial photograph studies east of the area (Reiser, 1957, oral communication) show distinct angular relationships between Mississippian and pre-Mississippian rock units.

Bedding relationships within the Kayak formation suggest essentially continuous deposition during Kayak time with a gradual change in sedimentation to the dominantly carbonate deposition of the Lisburne group rocks.

Kayak rocks are interpreted to represent initial deposits of a shoreline type during transgression of the Mississippian seas. Some were probably deposited in beach, deltaic and lagoonal environments, and in part, the Kayak sands were probably reworked pre-Mississippian sandstones.

Age and Correlation.- On the basis of lithology and stratigraphic relationships, it is felt that this unit can be correlated with the Kayak shale of the Shainin Lake area (Bowsher and Dutro, 1957, p. 13-16) with a fair degree of confidence. Rocks of similar character and stratigraphic position have been reported in many areas of northeastern Alaska including the Kongakut - Firth River area (Mangus, 1953), the Shaviovik - Canning Rivers area (Gryc and Mangus, 1947), and others (Brosge, et al, 1952), where they are referred to as the Kayak formation or the Noatak formation, a name now restricted to rocks farther west than any of the above areas (Bowsher and Dutro, 1957, p. 3). Although thicknesses of the unit are variable in these areas, they are consistently greater than those in the Romanzofs, ranging from about 500 feet along the Canning River to 900 or 1000 feet along the Canadian border. It would appear that the Romanzof Mountains may have been a structural high during deposition of Kayak sediments.

No definitive fossils have been found in the Kayak formation of the Romanzof area, and no direct indication of the age of this unit is forthcoming. The locally abundant plant fragments are in a poor state of preservation and indeterminate. Mississippian plant fossils were, however, found in this sequence on the Canning River (Gryc and Mangus, 1947). At its type locality, the Kayak shale is about 960 feet thick, and contains marine invertebrates of early Mississippian age and is disconformably overlain by the Lisburne group Wachsmuth limestone of early Mississippian age (Bowsher and Dutro, 1957, p. 6). In the Romanzof area, the Kayak grades upward into the Lisburne group, of probable upper Mississippian age. It would therefore appear that, if the Kayak was a continuous sedimentation unit ranging from early to late Mississippian in age, it represents deposition along the shores of an eastward or northward transgressing sea.

Lisburne group

Name and Definition.- Lisburne formation was a name given by Schrader (1906, p. 62-67) to a sequence of light-gray limestone with subordinate shale and dark limestone exposed along the Anaktuvuk River, 190 miles southwest of the Romanzof Mountains. Leffingwell (1919, p. 105-108) referred to similar rocks in northeastern Alaska as the Lisburne limestone. Subsequently, detailed studies in the Shainin Lake area, 170 miles southwest of the Romanzof Mountains have resulted in this carbonate sequence being raised in rank to the Lisburne group, which consists of two formations (Bowsher and Dutro, 1957, p. 6). The lower formation is termed the Wachsmuth limestone of early Mississippian age and consists of 1230 feet of mostly limestone, dolomite, and chert. The upper formation, of probable late Mississippian age, is termed the Alapah limestone, and at its type locality is 970 feet thick and contains zones of shale, chert, clastic limestone, silicified limestone, and oolitic limestone. The Alapah is disconformably or unconformably overlain by Permian(?) or Upper Triassic rocks in some areas of northern Alaska. Mississippian carbonate rocks of the Romanzof

Mountains are here compared to rocks in the type area of Lisburne group exposures.

Distribution and Outcrop.- Lisburne group rocks are exposed in essentially the same belts as those of the Kayak. East of the Okpilak River, the group crops out along the north front of the "Okpilak" granite and locally rests on mountains made up principally of the granite. This general belt appears to extend across the Jago River and continue eastward as a series of east-striking ridges along the front of the mountains. In addition, a north-striking belt lies along the west side of the Jago River, and the southernmost known exposures lie in a roughly east-striking belt east of the Jago. The northernmost exposures east of the Okpilak River are those in the dome-like structure along Okpirourak Creek.

The Lisburne group is a resistant and structurally competent unit in the Romanzof Mountains. Good exposures are common in cliffs along steep mountainsides or as massive ledges projecting through rubble. The light-gray weathering colors of the unit make it the most distinctive and easily recognized unit in the area, both as seen on the ground and on photographs (Figure 5). It can be confused only with the pre-Mississippian silicified limestone unit (p. 25) whose outcrops, however, are lighter in color and weather to resistant pinnacles along the mountainsides.

Character and Thickness.- Carbonate rocks make up about 90 percent of the Lisburne group in the Romanzof Mountains and

Figure 4. Horizontal beds of Kayak quartzite exposed on mountain ridge, east side of Okpilak River, 4 miles south of Okpilak Lake. (Cliff in foreground about 50 feet high).

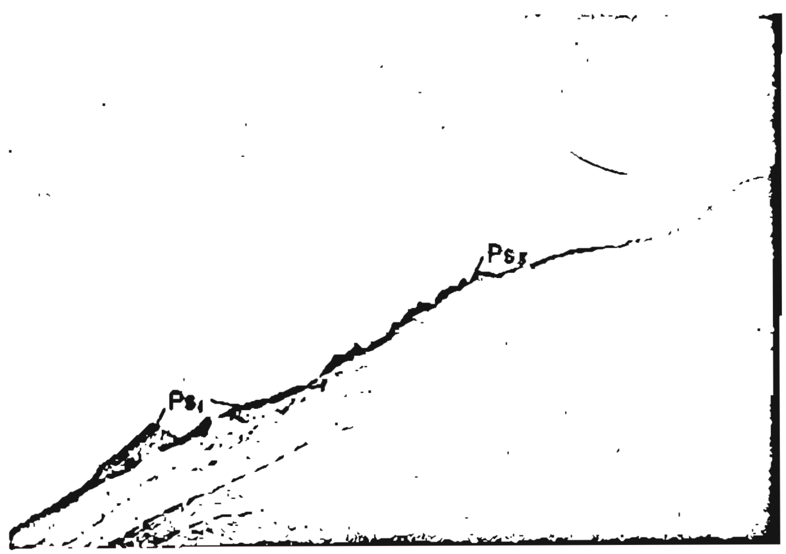

Figure 5. Kayak formation (Mk), Lisburne group (Ml), and Ferruginous Sandstone member of the Sadlerochit formation (Ps_1) exposed 1.7 miles south of Okpilak Lake. Highest ridges composed of Quartzite member of Sadlerochit (Ps_3). (Looking northeast).

include clastic limestone, crystalline limestone, silicified limestone, crinoidal limestone, and colomite. Chert, shale, and limy sandstone and quartzite are less common.

In general, the lower third of the Lisburne consists of arenaceous silty to medium-grained limestone interbedded in some sections with minor amounts of dark-gray shale, quartzite and sandstone, and thin granule to pebble conglomerate similar to those types in the upper part of the Kayak formation. Limestone is commonly medium to medium dark-gray, blocky to massive, well consolidated to friable, and contains scattered dark- and light-gray chert nodules. Some beds contain abundant crinoidal debris and some sandy limestone is crossbedded. One or more zones of spheroidal sandy chert concretions occur in the upper part of this unit. The middle third of the sequence contains perhaps 30 to 40 percent dolomite and dolomitic limestone interbedded with limestone. The dolomite is light- to dark-gray, weathers in characteristic grayish-orange and yellowish-orange or dark-gray colors, is sandy to very finely saccharoidal in texture and occurs in blocky-fracturing beds, commonly less than 1 foot, but as much as 5 feet thick. Interbedded limestone is commonly darker than the dolomite and generally less sandy than limestones in the lower third of the group, and includes calcilutite and minor phosphatic(?) types. Minor dark-gray shale beds and nodules, lenses, and thin beds of chert in limestone units are subordinate but characteristic features of this part of the Lisburne. Some units are very thick and massive (Figure 6).

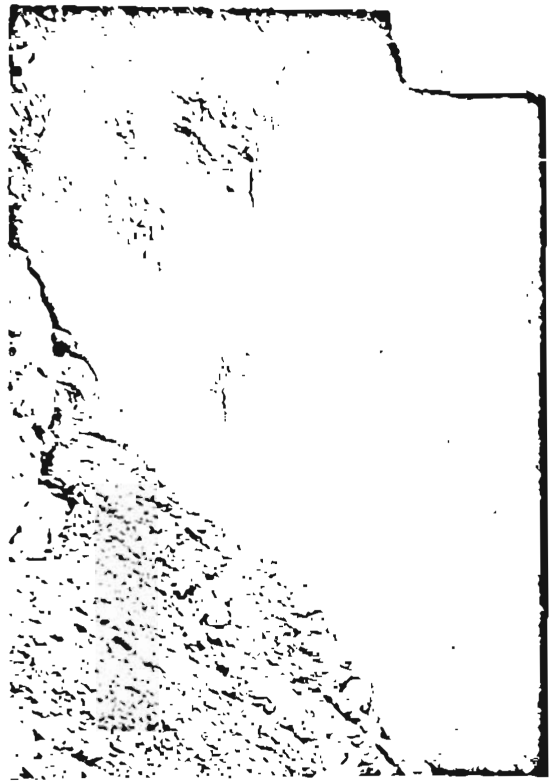

Figure 6. Massive limestone in middle part of Lisburne group exposed in east valley wall of Okpilak River. Beds dip about 15° away from observer, cut by closely spaced, nearly vertical joint pattern. (Looking southeast).

Thick massive beds of bioclastic crinoidal limestone, in part biostromal, form distinctive units in part of the upper third of the Lisburne sequence. They are light- to medium-gray, weather whitish to light gray, and are well consolidated to friable. These beds form massive units more than 100 feet thick in some sections. Medium-gray silty to very finely-crystalline platy to blocky limestone and minor amounts of dolomite are also present in the upper part of the sequence, but the sandy beds which characterize the lower part of the formation are relatively rare. At least one zone of septarian concretions and sedimentary chert breccia is associated with biostromal limestone. Scattered chert nodules and lenses are not abundant.

The following section of Lisburne group, exposed on the east wall of the Okpilak River valley, overlies and may in part be faulted against Kayak formation, and is overlain by the Ferruginous Sandstone member of the Sadlerochit formation. Thicknesses are approximate.

Section 3. Lisburne group exposed on mountainside, east wall Okpilak valley, 1.7 miles south of Okpilak Lake. Measured by E. G. Sable and George R. Kunkle, August 12, 1957.

Unit	Thickness in feet
1. Rubble and cover. Limestone, medium-gray, very fine-grained to silty, platy to small blocky fragments	10?

2. Limestone as in unit 1, blocky, weathers in small fragments.................................... 10
3. Limestone, light- to medium-gray, weathers light gray to white, medium- to coarse-grained, crinoidal biohermal bed. Crinoid rings and columnals about 40 percent of unit, cemented by very fine-grained calcite. Beds well consolidated to very friable, weather in small fragments, contain crinoid impressions and some subround fragments of light weathering dolomite(?) in uppermost part which is mainly calcilutite type.................................... 90
4. Limestone, medium-gray, very fine to very coarse calcarenite. Local concentrations of crinoidal debris along bedding. Massive unit but weathers to relatively small fragments........... 105±
5. Dolomite, olive-gray to medium light-gray, weathers grayish orange, with fine-grained, saccharoidal texture, beds 2 to 3 inches thick....... 10
6. Limestone and dolomite or silicified limestone; medium dark-gray to dark-gray, very finely-crystalline to calcilutite type, fractures in small platy fragments.................................. 60±
7. Limestone, dark-gray, very finely-crystalline, contains 3-inch to 1-foot thick lenses of white to light-gray chert parallel to bedding. Limestone about 70 percent of unit.................... 7

8. Limestone, dark-gray, very finely-crystalline to lithographic, in part probably silicified. 4-inch thick nodular black chert lense within unit.. 3.5

9. Dolomite and limestone interbedded, dolomite about 60 percent of unit, light- to medium-gray, fine-grained; limestone medium-dark to dark-gray, very finely-crystalline, dense, breaks with conchoidal fracture. Grades downward into unit 10............................ 75±

10. Limestone, dark gray, very finely-crystalline....... 3

11. Limestone, light-gray to white, weathers light yellowish gray, sandy, with dark-gray argillaceous appearing grains to 1/16 inch diameter........ 3.5

12. Limestone with minor chert interbeds. Limestone medium-dark to dark-gray, sandy, very fine- to medium-grained, to finely-crystalline. Chert dark-gray, in lenses less than 1 foot in thickness, about 5 percent of unit. Calcite lenses and earthy hematitic zones about 1/8 inch thick, roughly parallel to bedding but irregular. Estimated thickness..................... 70±

13. Slate, dark-gray, micaceous, fissile, contains numerous calcite veins at various attitudes......... 2.5

14. Dolomite and limestone interbedded as in unit 7 but weathers dark orangish color; limestone calcilutite type. Resistant unit with beds as

much as 5 feet thick. Estimated thickness......... 55±

15. Limestone, dark-gray, very finely-crystalline to silty, soft, emits strong organic odor from fresh fracture surfaces, contains some fissile parting. Few scattered crinoid rings and scattered round to subround pebbles of light-gray sandy limestone. Whitish efflorescence on some surfaces. Grades downward into unit 16.............................. 10

16. Dolomite, medium-gray, fine-grained, saccharoidal texture................................ 9

17. Limestone, medium-gray, finely-crystalline to sandy, dense, massive. Contains about 25 percent medium dark-gray chert nodules and lenses as much as 4 inches thick. Earthy hematite associated with some chert lenses. Irregular contact with unit 18.................... 3.5

18. Dolomite, medium- to medium dark-gray, weathers dark orange, sandy, fine- to very fine-grained..... 4±

Note: Units 19 - 21 form massive resistant section.

19. Limestone, medium dark-gray, finely-crystalline, contains about 5 percent crinoid rings and bryozoan(?) fragments. Minor lenses of light- to dark-gray, white-weathering chert............... 5

20. Limestone, and interbedded beds and nodules of white chert. Limestone medium- to light-gray, weathers white to light gray, sandy, massive,

in part friable, in beds 1 to 10 feet thick. Chert lenses as much as 4 inches thick, about 5 percent of unit.. $48\pm$

21. Limestone and chert as in unit 18, with about 40 percent bioclastic limestone containing abundant crinoidal debris and granule size calcite grains. Contains less than 10 percent white chert in beds and lenses to 6 inches thick and spheroidal cherty concretion-like bodies as much as 3 inches in diameter aligned along bedding planes......................... 12

22. Sandstone, light-gray, weathers medium dark-gray, highly calcareous, platy to blocky, parting 2 to 4 inches, evenly bedded. Upper 20 feet poorly exposed, contains about 5 percent ellipsoidal white chert nodules or concretions 2 to 3 inches in diameter........................... 30

23. Mostly talus covered. Limestone, light to medium-gray, sandy, fine-grained, blocky........... 30

24. Limestone as in unit 23, but well exposed. Contains a few lenses of sandy white limestone..... 25

25. Rubble of limestone, light- to medium dark-gray, fine- to medium-grained and including some lithographic types............................ 50

26. Limestone, white to medium-gray, sandy, very fine-grained, friable to well consolidated, weathers medium gray, platy to blocky.............. 5

27.	Limestone similar to unit 26, but in part yellowish gray, and contains irregular 2 to 6 inch white chert nodules at top of unit..........	5
28.	Limestone, white to medium-gray, sandy, very fine-grained, clean, friable........................	1.5
29.	Limestone, medium-gray, sandy, fine-grained, weathers dark yellowish orange, blocky to massive, beds 4 inches to 4 feet thick; emits organic odor from freshly fractured surfaces, contains scattered crinoid rings, small calcite crystals, and travertine on surfaces. Estimated thickness................................	28
30.	Covered...	10±
	(Overlies Kayak formation, section 2.)	
	Total	780±

The Lisburne group appears to vary considerably in thickness throughout the area, and has its greatest apparent thickness of 700 to 800 feet east of the Okpilak River. However, sections of 600 to 700 feet are reported between the Okpilak and Hulahula Rivers (Bunnell, 1959, in preparation), and some apparently unfaulted sections overlying granite are less than 100 feet thick. Possible reasons for the thickness variations include (1) unrecognized faulting, (2) the equivalence of Kayak formation in parts of the area to basal Lisburne rocks exposed elsewhere, (3) erosion prior to deposition of Sadlerochit formation rocks, and (4) assimilation or replacement by granite.

Stratigraphic Relationships and Mode of Deposition.- Contacts between the Lisburne group and Kayak formation are gradational. In one such exposure along the south side of Contact Creek, quartzitic sandstone of the Kayak grades into massive sandy limestone of the Lisburne group within 2 stratigraphic feet. Several feet above the contact, beds of sandy limestone are interbedded with massive finely-crystalline to silty limestone. Higher in the section, sandy beds are relatively scarce.

No significant stratigraphic breaks were recognized within the Lisburne group sequence in the Romanzof Mountains. Some irregular bedding contacts and relatively rare intraformational conglomerates are present, but their significance is not as yet known.

The Sadlerochit formation overlies the Lisburne group with apparent disconformity to perhaps a low degree of angular unconformity (p. 57). The amount of Lisburne removed by pre-Sadlerochit erosion is not known, but the crinoidal limestones in the upper part of the Lisburne are present in most sections, and lie as much as 30 feet and as little as 5 feet below basal Sadlerochit beds. In some sections, moreover, the crinoidal beds are absent. Although some warping between the Mississippian and Permian periods may have occurred, severe diastrophism did not affect the area.

Age and Correlation.- Fossils in the Lisburne group of the Romanzof Mountains are locally abundant but distorted, fractured, and so completely replaced by quartz or calcite that for the most part not even genera can be identified. Crinoid fragments are the most abundant forms, consisting almost entirely of columnal segments. Brachiopods, including spiriferoid and productid types, are poorly preserved, as are questionable pelecypod shells. Corals including colonial lithostrotionoid and syringiporoid types and solitary zaphrentid types are best preserved, being commonly completely silicified, although much distorted. Fossil collections from the area have not yet been thoroughly studied.

At this writing, Lisburne group rocks in the Romanzof Mountains cannot be correlated with certainty with the two formations in the Lisburne group type sections. Lithologically, the Lisburne group rocks in the Romanzofs appear to most closely resemble those of the Wachsmuth limestone. The fossils, however, resemble those types in the Alapah limestone. Lithostrotionoid corals which occur within 10 feet or less of the base of the group on the Jago River and within 50 feet of the top of a few Lisburne sections farther west, and the brachiopod Gigantoproductus sp. seen in both the upper and lower parts of the formation along the Jago and Okpilak Rivers, are characteristic forms. Bowsher and Dutro (1957, p. 6) state that these fossils, occurring in the Alapah limestone, indicate a probable late Mississippian age.

It would appear from the fossil evidence, stratigraphic relationships, and known distribution of Lisburne group rocks in northeastern Alaska, that the Lisburne group rocks in the

Romanzof Mountains represent the gradual stabilization of the Mississippian seas which, encroaching from the west or south, reached this area during late Mississippian time. The Lisburne group here then represents sedimentation conditions similar to those for the Wachsmuth limestone in its type area but occurring at a later date. A generalized interpretation of these relationships is shown in Figure 7.

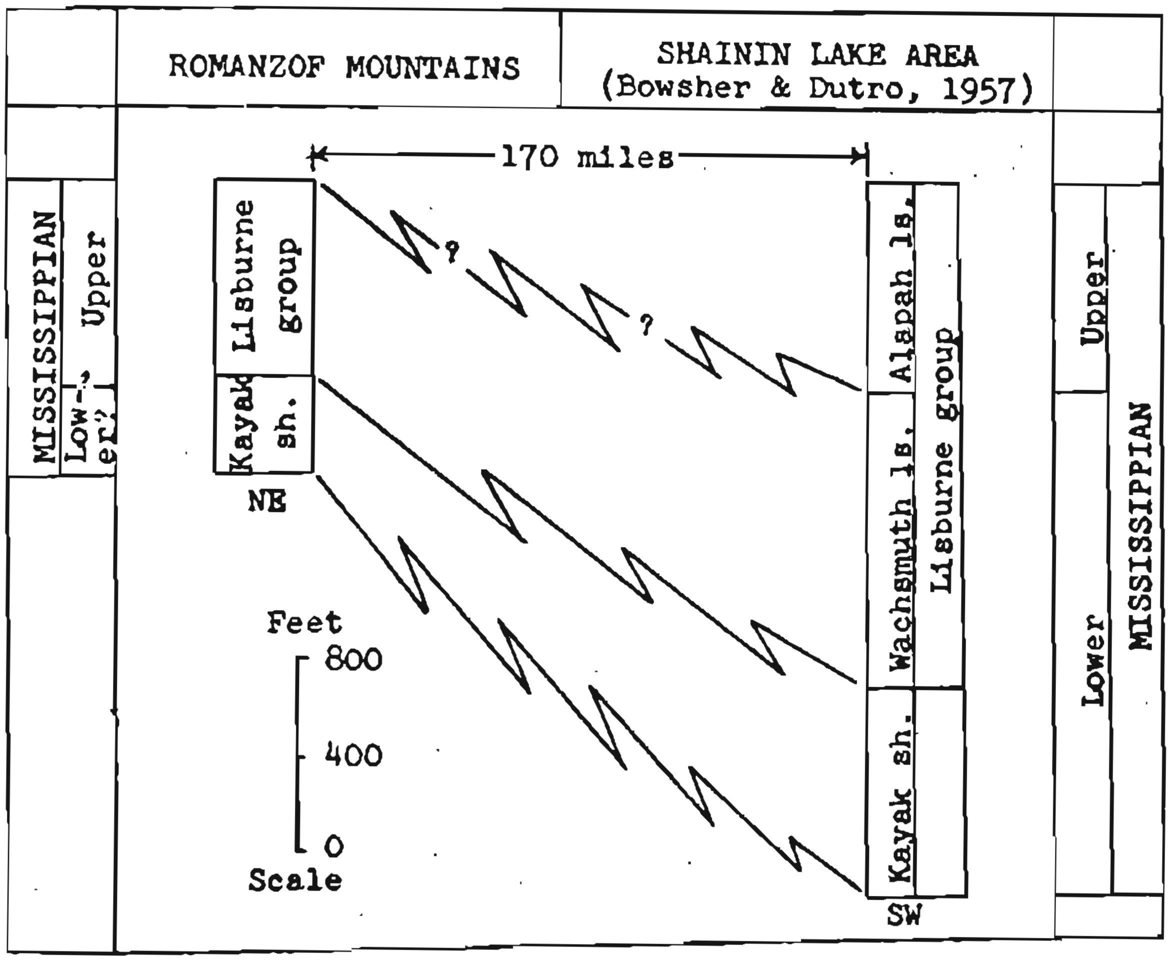

Figure 7. Diagrammatic sections showing suggested relationships of Mississippian rocks in Romanzof Mountains and Shainin Lake area.

Pennsylvanian System

No rocks of Pennsylvanian age have been recognized in the Romanzof Mountains, although Pennsylvanian limestones have recently been identified south of this area (Dutro, J. T. Jr., 1957, oral communication), and may be present along the Alaska-Canada boundary. Fossils collected by Maddren in 1912 from rocks overlying Lisburne rocks along the boundary were originally identified as Pennsylvanian in age. Later, the fossils were referred to the Permian (Smith, 1932) Sadlerochit formation. However, Maddren, in his 1912 field notes, states that the rocks overlying the Lisburne limestone consist of sandstone in some localities and limestone in others.

Permian and Triassic(?) Systems

Sadlerochit formation

Name and Definition.- Sadlerochit sandstone or Sadlerochit formation was first named and described by Leffingwell (1919, p. 113-115) after the Sadlerochit Mountains, 15 miles northwest of the Romanzof Mountains. According to Leffingwell, the formation lies between Lisburne limestone and rocks of the Upper Triassic Shublik formation, is about 300 feet thick in the Sadlerochit Mountains, and is composed of ferruginous sandstone with a few conglomeratic layers. He describes the formation as consisting elsewhere mostly of dark ferruginous quartzite. Sadlerochit formation was mapped on the east side of the Okpilak River by Leffingwell, and Whittington and Sable (1948, pl. 1) reported the formation along the north front of the mountains west of the Okpilak River.

In addition to extending the known exposure belts of this formation in the Romanzof Mountains, the 1957-1958 work has divided the Sadlerochit formation into three members, which are differentiated on the basis of lithology. From younger to older, they are: Quartzite member

Shale member

Ferruginous Sandstone member.

Although Leffingwell defined the Sadlerochit formation as the sequence lying between the Lisburne group and Shublik formation, both of which are well defined units, he apparently mapped only the unit here called Ferruginous Sandstone member as Sadlerochit formation. The overlying Shale and Quartzite members, as well as younger units, were mapped as undifferentiated Mesozoic rocks in the Romanzof area. In this report, the writer retains the stratigraphic boundaries of the Sadlerochit formation as defined by Leffingwell, but extends the Sadlerochit to include units younger than that which Leffingwell described as the Sadlerochit.

Distribution and Outcrop.- Surface rocks of the Sadlerochit formation comprise the most extensive exposures of sedimentary rocks along the north front of the Romanzofs. Here they occur in an east-trending belt which narrows eastward. The Quartzite and Shale members are exposed throughout most of the outcrop belt; outcrops of the Ferruginous Sandstone member are restricted to localities near Lisburne group surface exposures and occupy a smaller area.

Owing to the presence of poorly resistant shaly rocks and because many of the hills comprised of Sadlerochit formation have not been recently glaciated, the exposures are mostly covered by residual rubble and talus. Perhaps the best exposures of the Ferruginous Sandstone member lie on the mountainsides adjoining the Okpirourak and east side of the Okpilak Rivers, and fair to good exposures are also found along Ahngayakasrakuvik Creek and its tributaries. In outcrop, the Ferruginous Sandstone member is recognized by its pronounced ironstained appearance in weathered exposures. The Quartzite member weathers to grayish hues and stabilized rubble is largely covered by black lichens. On aerial photographs the formation has a blotchy "two-toned" appearance due to the lichen cover and the amount of light-appearing shale in the rubble.

Character and Thickness.- The lithologic characteristics of each member of the Sadlerochit formation are described below. The author wishes to emphasize that nearly all of these rocks have been subject to dynamic and low grade regional metamorphism and, in part, silicification. The present rocks are almost entirely quartzites and slates which, however, are not so severely altered that the original features have been lost. Even in the most severely deformed parts of the area, the Sadlerochit formation retains most of its primary characteristics. Two formations which it might be mistaken for, however, are parts of the Kayak and Kingak formations.

Ferruginous Sandstone member.- Quartzite, quartzitic sandstone and siltstone, limy sandstone and siltstone, and minor thin conglomeratic beds occur in two fairly uniform, massive cliff-forming units separated by a unit composed dominantly of shale and slate (Figure 8). The lowest quartzitic unit is argillaceous and ferruginous, due to numerous limonite grains and oxidized pyrite; the rocks are generally medium dark-gray, fine-grained to silty, and occur in even beds 6 inches to 5 feet thick. Thin pebble conglomerates consisting of about 70 percent well-rounded gray chert and argillite, rounded siliceous nodules, and clay ironstone nodules are conspicuous in the lower few feet. Abundant but poorly-preserved fossil molds and casts range throughout most of this unit, and the fossils include horn corals, productid and spiriferoid brachiopods, and crinoid debris which are commonly associated with siliceous chert nodules. The middle shaly unit consists of medium- to medium-dark gray shale and slate. This is poorly resistant and unfossiliferous. The third and uppermost unit is similar to the lowest unit, but fossils are rare to absent, and massive beds are as much as 9 feet thick. Shaly interbeds less than 1 foot thick are present. This unit probably contains a variable clay size content, as it is not everywhere well expressed. Pyritic concretions occur in all three units.

The thickness of the Ferruginous Sandstone member is 175 to 200 feet east of the Okpilak River.

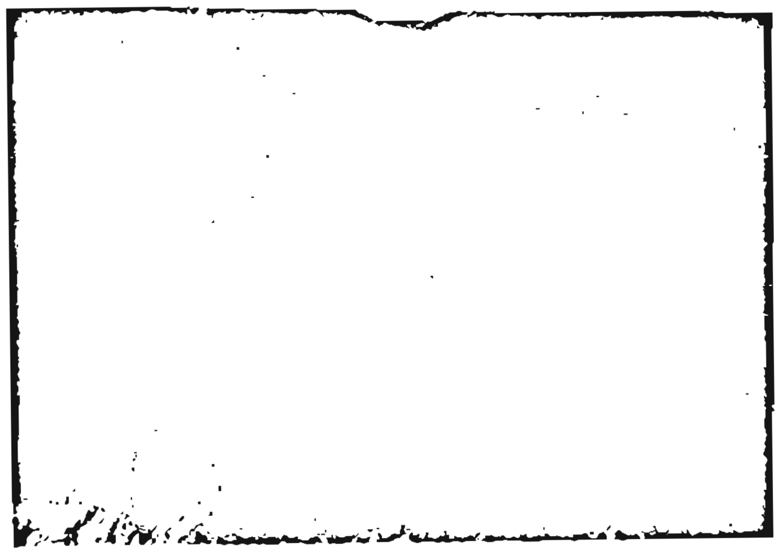

Figure 8. Ferruginous Sandstone member of the Sadlerochit formation (Ps_1) overlying Lisburne group limestone (Ml). Shale (Ps_2) and Quartzite (Ps_3) members of Sadlerochit formation in distant hills. (Photo looking east up tributary of Okpilak River, lower dark cliffs about 40 feet high).

Shale member.- Medium dark-gray to black silty and clay shale with about 10 to 20 percent thin interbedded quartzite comprise the Shale member of the Sadlerochit formation. The shale is uniform, laminated and banded, with beds a fraction to 1½ inches thick, and sets of beds as much as 30 feet thick (Figure 9). A few 1- to 2-inch beds of nodular clay ironstone are interbedded with the shales, and disseminated pyrite crystals are relatively common, particularly in the black sooty shales. Quartzites are medium-gray, in part laminated, evenly bedded, less than 1 foot thick and weather pale yellowish-brown. The quartzites resemble those in the overlying Quartzite member.

Thickness measurements of the Shale member are approximate. The member is relatively incompetent, and has yielded to orogenic forces mainly by flowage; as a result, apparent thicknesses of the section vary considerably. In addition the Shale member grades upward into the Quartzite member so that the contact between the two members in one part of the area has probably not been drawn at the same horizon elsewhere. The average thickness of the Shale member between the Okpilak and Jago Rivers is believed to be about 420 feet. Farther southwest, in the southernmost exposures at the head of Ahngayakasrakuvik Creek, the member is several hundred feet thicker (Bunnell, 1959, in preparation). The apparent southward increase in thickness is probably in part due to southward decrease in grain size of the upper part of the Ferruginous Sandstone member.

Figure 9. Shale member of Sadlerochit formation exposed on east valley wall of Okpilak River. Note beds dipping away from observer cut by cleavage dipping 40 degrees to right. (Looking north; falcon's nest about 1½ feet high).

Quartzite member.- Quartzite, lesser amounts of shale and limy sandstone, and minor amounts of granule to pebble conglomerate, granule to pebble breccia, and clay ironstone constitute the uppermost member of the Sadlerochit formation. Consisting largely of resistant beds which uphold high ridges and hills, quartzite makes up about 80 percent of the member. The quartzite is medium- to medium dark-gray, fine- to very fine-grained, dense, apparently well sorted and clean, and weathers pale yellowish-brown, grayish, and reddish-brown. Beds are evenly bedded, average about 2 feet and are as much as 10 feet in thickness, and weather to massive, blocky, or platy fragments. Resistant sets of beds are as much as 50 feet thick. Texture is uniform to laminated, and beds locally contain symmetrical but irregular ripple marks of small amplitude and scattered pelecypod molds on their surfaces. Gray to black shale and slate, similar to that in the Shale member, are interbedded with quartzite and occur in thin sets of beds commonly less than 1 foot thick. Pale brown fine-grained limy sandstone occurs in 6-inch to 2-foot beds. The upper 100(?) feet of the unit is flaggy, ripple-marked, and contains a few pelecypod molds. Quartzitic conglomerate occurs as beds and lenses less than 1 foot thick, and is apparently restricted to the upper part of the member. Conglomerate constituents, which are well rounded to subround, fairly well sorted, but poorly packed, consist of gray and black chert, milky quartz and other siliceous rock fragments, and minor clay ironstone nodules. Dark reddish-brown weathering clay ironstone occurs as scattered nodules or in nodular beds less than 2 inches thick. Spheroidal pyrite(?) concretions, now weathered to iron oxides, are of scattered occurrence.

The total maximum thickness of the Quartzite member is estimated to be about 700 feet. No complete uncomplicated section of this member was found east of the Okpilak River. West of the river, Bunnell (1959, in preparation) reports a possible maximum thickness of 800 feet for the Quartzite member.

Stratigraphic Relationships and Mode of Deposition.- The Sadlerochit formation overlies the Lisburne group with at least slight angular unconformity in the Romanzof Mountains and is in turn overlain by the Shublik formation with possible disconformity. No stratigraphic breaks have been recognized within the Sadlerochit formation in this area.

The base of the Sadlerochit is exposed in a few cliffs on the east valley wall of the Okpilak River, 2 miles south of Okpilak Lake. The contact is abrupt. Basal Sadlerochit beds are locally conglomeratic, contain chert possibly derived from the Lisburne group, and overlie more than one horizon in the upper unit of the Lisburne. Where accessible, the Sadlerochit beds were seen to overlie the Lisburne conformably or with slight discordance not exceeding 5°, although apparent discordance of as much as 20° was seen in one inaccessible exposure of the contact in this vicinity. Faults cut this part of the area, however, and the discordance may be in fact due to faulting.

Contacts between members of the Sadlerochit formation are poorly exposed due to the shaly character of the contact rocks. Relationships between the Ferruginous Sandstone and Shale members appears to be gradational, and the contact is placed at the top of the upper quartzite unit of the lower member. The Shale and Quartzite members are almost certainly gradational, with thin quartzite beds appearing in the upper 100 feet or so of the Shale member and culminating in thick massive quartzite beds.

The contact between beds mapped as Sadlerochit formation Quartzite member and Shublik formation is poorly exposed high on the Okpilak valley wall three-fourths of a mile east of Okpilak Lake. The highest Sadlerochit beds are slates, in part ironstained. These are overlain with apparent conformity by basal phosphate-pebble sandstone of the Shublik, but the exact contact relationships are masked by rubble.

The Sadlerochit formation is believed to be entirely a product of marine deposition. The lower member is interpreted to represent deposition in a shallow shelf-type environment during a relatively rapid but fluctuating marine transgression. Source areas for the formation may have been to the north, as inferred from the apparent northward thinning of the formation to 300 feet and the presence of local coarse conglomerates in the Sadlerochit Mountains (Leffingwell, 1919, p. 113; Whittington and Sable, 1948). Mississippian(?) and older crystalline rocks probably contributed to the sediments. The Shale member was deposited below wave base, and may represent deposition in a euxinic environment. The Quartzite member was deposited under shallow shelf conditions, at least in part above wave base, and represents a progressively shallower and more marginal environment upward in the section.

Age and Correlation.- Fossils found in the Sadlerochit formation include abundant but poorly preserved spiriferoid, productid, and chonetid(?) brachiopods in the lower part of the Ferruginous Sandstone member, one possible pelecypod impression in slate of the Shale member, and scattered pelecypod molds and one partial ammonoid cast in quartzites and limy sandstones of the Quartzite member.

The fossils in the Ferruginous Sandstone member are similar to those reported by Leffingwell (1919, p. 114-115) and other workers in northeastern Alaska. Fossils from the lower part of the formation had previously been identified by Girty (Leffingwell, 1919, p. 114-115) who referred them to the Pennsylvanian (Uralian). Later, according to P. S. Smith (1932, p. 32), "...Girty is now convinced that it (the lower Sadlerochit fauna) is more properly to be regarded as belonging to the Permian." Dutro (1956, oral communication), after examination of many Sadlerochit formation collections, believes that the lower Sadlerochit fossils have an early Permian aspect.

The poorly preserved pelecypod molds and ammonoid fragment from the upper part of the formation have not as yet been studied, but may be Triassic forms. Pelecypods and ammonites, collected from the upper part of a unit mapped as Sadlerochit formation near the Shaviovik River, 70 miles east of the Romanzof Mountains (Keller and Morris, 1952), are reported to be of early and middle(?) Triassic age. Should the fossils found in the middle and upper part of the unit mapped as Sadlerochit formation on the Okpilak River have similar age affinities, the formation then represents an age range from early Permian through possibly middle Triassic.

Triassic System

Shublik formation

Name and Definition.- Defined by Leffingwell (1919, p. 116-118) as the sequence which overlies the Sadlerochit formation and underlies the Jurassic Kingak formation, the Shublik formation has not been redefined during more recent investigations. Its lithologic character and contained fossils make it a distinctive unit in northeastern Alaska and its equivalents in northwestern Alaska, although in part lithologically different, bear a similar fauna (Smith and Mertie, 1930, p. 185-194; Payne, 1951).

Distribution and Outcrop.- Exposures of the Shublik formation, although of small areal extent, are widespread along the northern front of the Brooks Range. In the Romanzof Mountains the formation crops out in a relatively narrow belt north of Sadlerochit formation exposures, occurs in a few places as erosional remnants, or is sharply infolded with Sadlerochit rocks.

Good outcrops of the Shublik formation are scarce because of its poorly resistant nature. One good exposure of part of the formation lies in a cut bank of a small stream along the east wall of the Okpilak valley, 1 mile northeast of Okpilak Lake. Elsewhere, except for a few small cut banks and steep hillsides, mostly west of the Okpilak River, the formation can be traced only by recognition of rock types in scattered frost heavings and on rubble covered slopes.

Weathered outcrops of Shublik formation have a characteristic bluish-white phosphatic efflorescence on otherwise black sooty-appearing exposures. The basal sandstone, however, often weathers pale-brown and is slightly iron-stained, similar to parts of the Sadlerochit formation. On aerial photographs, the formation is not distinctive in appearance, but occupies belts of low relief.

Character and Thickness.- The Shublik formation is dominantly dark-gray to black limestone and limy shale, in large part phosphatic. A dark sandstone, about 40 feet thick, is a persistent marker zone at the base of the formation. On this basis Leffingwell divided the formation into an upper limestone member and a lower sandstone member.

The basal sandstone member is medium- to dark-gray, weathers pale- to moderate yellowish-brown, fine- to medium-grained, and ranges from calcareous and well indurated to quartzitic. Beds are 1 to 2 feet thick, evenly bedded, and weather to irregular blocky to massive fragments. Black irregular phosphatic, pebbly nodules as much as 1 inch in diameter make up perhaps 10 percent of the member.

The limestone member consists of dark gray to black, argillaceous to sandy limestone interbedded with black, sooty, calcareous shale and fissile black limestones. Sandy limestone beds are blocky to platy, average less than 1 foot in thickness but as much as 4 feet thick, and sets of beds are as much as 20 feet thick. Shale and fissile limestone occur in sets of beds as much as 30 feet thick. Blocky and platy limestone is dominant in the lower half of the limestone member, making up about 60 percent of those rocks. Shale and fissile limestone increase in abundance upward and constitute about 70 percent of the upper half of the member.

Scattered limonitic (pyritic?) spherical and ovoid nodules as much as 4 inches in diameter, and scattered clay ironstone nodules are relatively rare. Much of the limestone and shale is phosphatic as evidenced by bluish and white efflorescence on weathered surfaces (Figure 10). A dark yellowish-orange weathering laminated silty limestone is present in rubble at or near the top of the Shublik sequence in some exposures.

Grayish-black phosphatic nodules ranging in size from 1/32 to more than 2 inches in diameter are most abundant in the lower part of the limestone member and are estimated to constitute about 15 percent of the lower half. The nodules

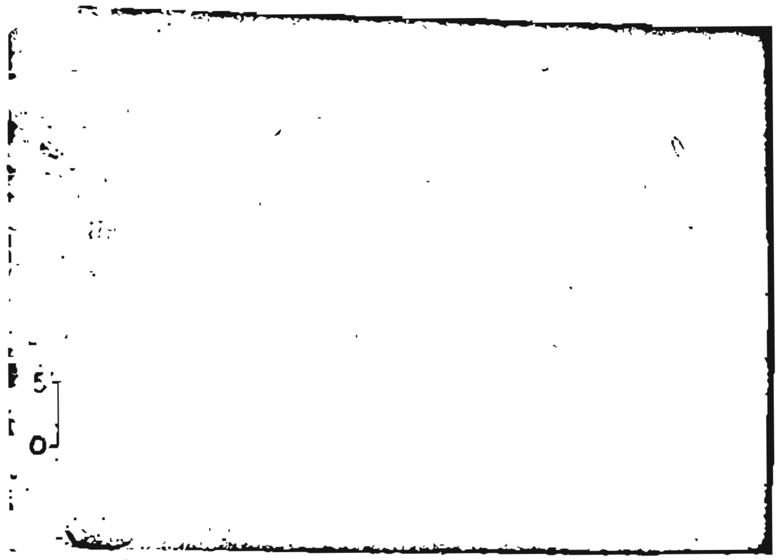

Figure 10. Phosphatic shale and limestone of the Shublik formation exposed on east valley wall of Okpilak River, 1 mile northeast of Okpilak Lake. Beds dip to left; cleavage dips to right. (Looking northeast. Photograph by John E. Cantlon).

Figure 11. Basal siltstone member of the Kingak formation exposed in hills northeast of Okpilak Lake. (Beds dip about 20° away from observer; cliff about 40 feet high).

are spheroidal to highly irregular, rounded in shape, aphanitic, and hard. Some are distinctly concretionary; others are without visible structure and appear to grade into and replace limestone. Locally, beds as much as 2 feet thick consist of as much as 80 percent phosphatic nodules.

The Shublik is locally fossiliferous. Fossils appear to be abundant near the middle and at the top of the limestone member and scattered throughout the upper half. No fossils were found in the lower half of the member or in the sandstone member. Fossils consist of monotid-type pelecypods, rhynconellid and terebratuloid brachiopods, belemnoid and nautiloid(?) fragments, and gastropods. Shell material appears to be either phosphatic or calcareous.

The Shublik formation is believed to be about 700 feet thick on the east side of the Okpilak River. A section, which is not completely exposed and may be faulted, is given below.

Section 4. Shublik formation, east valley wall of Okpilak River, 1 mile northeast of Okpilak Lake; measured by E. G. Sable and G. R. Kunkle, August 13 and 15, 1957.

Unit	Thickness in feet
Overlain by Jurassic Kingak formation.	
1. Tundra covered. Scattered heavings of grayish-black to dark-gray limestone; black calcareous shale or shaly limestone, soft, sooty, phosphatic; and dark yellowish-	

orange, very fine-grained to silty laminated limestone. Few fossil fragments of monotid pelecypods, rhynconellid brachiopods, belemnoids(?)........................ 50?

2. Interbedded li·estone and limy shale in alternating sets of beds about 10 to 30 feet thick. Black, fissile, "sooty" limestone and black "sooty", silty to sandy calcareous shale containing black phosphatic nodules, about 70 percent of unit. Dark-gray fine-grained sandy to silty, blocky limestone, weathers grayish-black and containing fewer phosphatic nodules. Phosphatic nodules average perhaps 15 percent of unit, as much as 40 percent in uppermost 10 feet of unit. Phosphate nodules, grayish-black, hard, round to subround to highly irregular shape, 1/32 inch to 2 inches in diameter. Some distinctly concretionary, others apparently structureless, noticeably compressed and aligned with secondary cleavage. Unit weakly resistant. Scattered ironstained pyritic(?) concretions and nodules as much as 2 inches by 4 inches, spherical to oblong; few scattered clay ironstone nodules....... 250?

3. Interbedded limestone types as in unit 2, but blocky sandy limestone about 65 percent of unit and most abundant in lower 20 feet

of unit. Blocky limestone beds average 6 inches to 1 foot, as much as 4 feet thick. Black shaly limestone, fissile, in beds less than 1 foot thick, with whitish efflorescence on surfaces. Phosphate nodules not abundant.......	63
4. Calcareous sandstone and sandy limestone, dark-gray, weathers dark yellowish-brown 10YR 4/2, blocky, beds 1 to 3 feet thick, contain about 20 to 30 percent black phosphatic nodules; whitish efflorescence prominent on surfaces of limestone and nodules...	20
5. Sandy limestone, dark-gray to black, weathers dark yellowish brown with 60 to 80 percent phosphatic nodules.....................	0.6 to 2
6. Same as unit 4. About 30 percent phosphatic nodules averaging ½ to 1 inch diameter.............	16
7. Partly covered. Limestone, dark-gray to black, with white phosphatic efflorescence and nodules, sandy, fine- to medium-grained, blocky to fissile, mostly poorly indurated. Fossil fragments within 10 feet of top. Phosphate nodules about 5 percent of unit at base to about 15-20 percent near top, appears to roughly correlate with grain size which coarsens upward in unit......................	200?
8. Interbedded black shaly limestone and medium-	

gray sandy limestone. Sandy limestone about 70 percent of unit, blocky, ½- to 2-foot thick beds, weathers yellowish brown, contains about 20 percent black phosphatic nodules, 1/8 to 1½ inches in diameter, with few thin beds composed of about 90 percent nodules. Shaly limestone weathers medium to light gray............ 15

9. Poorly exposed. Limestone, black, shaly in part, weathers pale yellowish brown............. 50

10. Sandstone, medium- to dark-gray, weathers pale to moderate yellowish brown, fine- to medium-grained, in part calcareous, blocky, beds 1 to 1½ feet thick, contains black phosphatic nodules less than 1 inch in diameter; unit in part with bluish-white efflorescence, resistant............................. 43±

Sadlerochit formation slate and quartzite.

Total 709±

<u>Stratigraphic Relationships and Mode of Deposition</u>.- Neither the top nor the bottom of the Shublik formation is well exposed in the area. The relatively abrupt change in rock character between the sandstone member and the Sadlerochit formation, despite their apparent structural conformity, implies a corresponding change in sedimentary conditions if the phosphatic material is considered to be syngenetic. The quartzite beds of the overlying Jurassic Kingak formation

also represent an abrupt change back to dominantly clastic-type deposition. The Shublik formation itself reflects relatively constant conditions of sedimentation, but a discussion of the environment of this type of phosphatic deposit is beyond the scope of this report.

Age and Correlation.- Tentative identification of fossils collected from the Shublik formation in the Romanzof Mountains were made by the author as follows:

Monotis subcircularis Gabb

Halobia cf. *H. cordillerana* Smith

belemnoids and nautiloids undet.

rhynconellid brachiopods

terebratuloid brachiopods

Species of *Monotis* and *Halobia* are considered to be Late Triassic index fossils on the North American continent. These forms are present in Upper Triassic rocks throughout northern Alaska (Payne, 1951), and the Shublik formation remains one of the best-established age units in the region. The remaining fossils are similar to some of those in the large collections reported by Leffingwell (1919, p. 117-118), and at least the upper half of the Shublik formation in the Romanzof area is considered to be of Late Triassic age. The sections examined are almost identical to those reported by other workers in northeastern Alaska.

Jurassic System

Kingak formation

Name and Definition.- Named by Leffingwell (1919, p. 119-120) after Kingak Cliff at the southeast end of the Sadlerochit Mountains, the Kingak shale was defined to include about 4000 feet of black concretion-bearing shale in its type area. According to Leffingwell, the Kingak shale overlies the Shublik formation with apparent conformity and probably directly underlies the Ignek formation. Subsequent to Leffingwell's work, the outcrop belts of Kingak have been extended both east and west of the type area (Gryc and Mangus, 1947; Keller and Morris, 1952; Mangus, 1953). Some of the exposures reported by Leffingwell have been re-examined (Gryc and Mangus, 1947; Whittington and Sable, 1948), and megafossil and microfossil information from the formation have been published (Imlay, 1955; Tappan, 1955).

In addition to the predominance of shale in the Kingak section, Whittington and Sable also mapped a massive sandy siltstone and conglomeratic siltstone unit as much as 120 feet thick as constituting the basal beds of the formation along the Sadlerochit River, 16 miles northwest of the Romanzof Mountains. During the 1957-58 studies in the Romanzof area, a similar siltstone and sandstone was recognized to overlie the Shublik formation. The Kingak shale, as defined in the Romanzofs, then, includes the basal siltstone and sandstone overlying the Shublik and an undetermined thickness of clay and silty shale above this.

The basal unit is here informally termed the siltstone member, and the remainder of the formation is called the black shale member.

Distribution and Outcrop.- The Kingak shale is poorly exposed, and crops out sporadically along the north front of the Romanzof Mountains. Between the Okpilak and Jago Rivers a linear belt of exposures strikes east northeast. Between the Okpilak and Hulahula Rivers, the belt strikes generally northwest; in addition, one erosional remnant of the Kingak lies south of these exposures and makes up a high prominent butte 2 miles west of Okpilak Lake.

Good but sporadic exposures of the siltstone member of the formation lie in the belts of exposure mentioned above. Resistant sandstone and siltstone, metamorphosed to quartzite, form largely rubble-covered ridges as much as 300 feet in relief. North of these ridges the poorly resistant shale beds of the Kingak crop out in a few stream cutbanks and low hills, but are otherwise covered by tundra or glacially-derived deposits.

Character and Thickness.- The Kingak consists mostly of dark-gray to black shale, as inferred from scattered rubble and frost heavings far to the north of basal Kingak beds, although little of this rock type is exposed in the vicinity of the Romanzof Mountains. A few cutbank exposures of the black shale member were examined along tributaries of the Okpirourak River. Here the rocks consist mostly of dark-gray to grayish-black fissile silty shale with interbedded dark-gray platy to blocky siltstone beds less than 2 inches thick. Shale constitutes about 85 percent of the exposures, and both shale and siltstone weather dark yellowish orange and commonly exhibit a whitish to moderate yellow efflorescence. The shale is in part pyritic. A few clay ironstone lenses and nodules which weather dark reddish brown were seen in rubble of this member. The thickness of the black shale member in the Romanzof Mountains is unknown, but is probably more than 1000 feet.

The siltstone member, about 75 feet thick 1¼ miles northeast of Okpilak Lake, consists of 20 feet of quartzitic siltstone to fine-grained sandstone and 40 feet of limy sandstone, separated by approximately 15 feet of dark-gray shale. Siltstone is medium to medium dark gray and olive gray, weathers light brown, is evenly bedded, massive, and resistant, with beds ranging from 1½ to 6 feet and averaging 4 feet in thickness (Figure 11). The upper 40 feet of the siltstone member consists mostly of medium dark gray calcareous fine-grained sandstone weathering a distinctive pale yellowish brown and light brown (5Y/R6/4). The unit is evenly bedded, with beds ranging from 6 inches to 2½ feet thick. Scattered subround to irregular phosphatic(?) dark-gray nodules or pebbles as much as 2½ inches in diameter, and medium-gray argillaceous pellets are scattered along bedding planes. A few calcareous shell fragments (pelecypods?) are present in the sandstone.

Although the probable maximum thickness of the siltstone member is about 75 feet along the Okpilak River, exposures of this unit along Okpirourak River drainages appear to be at least 150 feet thick and some individual quartzitic siltstone beds reach a thickness of 20 feet. The unit probably varies in thickness along the mountain front.

Stratigraphic Relationships, Age, and Correlation.- The rocks of the Kingak formation are too poorly exposed in the Romanzof area to permit an interpretation of their relationships with older and younger rocks or between rocks within the Kingak sequence. In addition, the apparent lack of identifiable fossil remains precludes statements regarding the age of the Kingak beds in the area. The abrupt change from the phosphatic organic shale and limestone of the Shublik formation to the variable thicknesses of clastic rocks of the basal part of the Kingak may indicate an erosional or nondepositional break before deposition of Kingak beds. Likewise, the presence of rounded phosphatic "pebbles" in parts of the siltstone member of the Kingak suggests that these may, in fact, be pebbles derived from older Shublik beds. In general, basal Kingak deposition was probably more rapid than that during Shublik time, as shown by the larger proportion of coarser clastic material and absence or scarcity of primary phosphatic material. Deposition was also probably below wave base; cross bedding, ripple marks, and other bedding features of a shallow water environment were not seen. The widespread distribution of the shales and presence of marine fossils elsewhere in northeastern Alaska points to a marine origin, perhaps in a deep restricted basin, or in a sinking basin adjacent to a slowly rising source area of relatively low relief. Source areas for these rocks is unknown; farther west, source rocks for Jurassic sediments of graywacke-type are known to have lain to the south, and an interpretation by Keller and Morris (1952) is that the Kingak shale represents an offshore equivalent of the graywackes. According to this interpretation, any diastrophic episode between the Triassic and Jurassic in the source area may not be reflected in these offshore sediments. However, if the phosphatic pebbles in the siltstone member are Triassic in age, it would seem that this plus the marked change in sedimentation may provide evidence for an erosional break. The siltstone member of the Kingak might be interpreted to represent the early shoreline stages of a Jurassic marine transgression.

First classified as Lower Jurassic by Leffingwell (1919, p. 119-120), the Kingak shale and probable equivalents were later placed in the Middle and provisionally Lower Jurassic by P. S. Smith (1939, p. 46). Fossils from the Kingak shale elsewhere in northeastern Alaska, have been more recently reported by Imlay (1955) to represent parts of the Pliensbachian and Toarcian stages of the Lower Jurassic, the Bajocian and Callovian of the Middle Jurassic, and the Oxfordian and Kimmeridgian of the Upper Jurassic. Several breaks during the Middle and Upper Jurassic time are suggested by Imlay.

The few shell fragments found in the siltstone member of the Kingak formation represent the only fossils found in this unit, and these are too fragmental to yield age information. The basal Kingak beds reported by Whittington and Sable on the Sadlerochit River (1948), with which the siltstone member is correlated, contain pelecypods, including Gryphea cf. G. cymbium Lamarck, of probable early Jurassic (Pliensbachian?) age (Imlay, 1955, p. 73).

Cretaceous(?) System

Ignek(?) formation

A poorly-exposed sequence consisting of sandstone, shale, and coaly beds tentatively correlated with the Ignek formation, crops out in low whaleback ridges along Okpirourak Creek about 3 miles northwest of Jago Lake, and along the Jago River, 9 miles downstream from Jago Lake. These lie north of the mapped area and are not shown on Plate 1. The Ignek formation, named by Leffingwell (1919, p. 120-125) contains similar lithologies as well as a marine or transitional fossil fauna in part of the formation. Although Leffingwell provisionally placed the sequence in the Jurassic system, more recent studies of the Ignek formation and its traceable equivalents in areas northwest of the Romanzof Mountains place the Ignek in the Cretaceous. The exposures in the area here described, however, are unfossiliferous except for small carbonized wood fragments. In addition, neither the thickness of the sequence nor its relationships to other rocks are known except that the Ignek rocks are unconformably overlain by Pleistocene glacial and glaciofluvial deposits.

The exposures on Okpirourak Creek consist of at least several hundred feet of poorly-exposed interbedded sandstone and shale. The sandstone, which makes up about 50 percent of the exposures, is medium-dark gray to medium gray, weathers grayish red (10R 4/2) and brownish gray (5YR 4/1) and in part with "gun metal blue" stain and ironstain. It is very fine- to medium-grained, platy to flaggy beds are two inches to 2½ feet thick with 1/8- to 6-inch parting, and contain scattered carbonized wood fragments. Small ripple marks and scour markings were observed on some sandstone surfaces in rubble. Clay and silty shale is dark gray to black, hackly to fissile, and contains scattered clay ironstone nodules.

Carbonaceous sandstone, thin coal beds, and black carbonaceous shale crop out on a ridge west of the Jago River, 9 miles north of Jago Lake, according to John E. Cantlon, who procured specimens of these rocks. These exposures lie along the same general strike as the Okpirourak Creek exposures, and are considered to be roughly equivalent to the latter.

Quaternary System

Pleistocene and Recent deposits

Unconsolidated deposits in the Romanzof area include glacial and glaciofluvial material of probable Pleistocene to Recent age, and Recent alluvial, aeolian, and colluvial deposits. All deposits consist of material derived from the Romanzof Mountains; they are not differentiated on the geologic map (Plate 1).

Lateral, terminal, recessional, and ground moraines along the major rivers extend many miles north of the mountain front, and may represent six major ice advances (Kunkle, 1957, p. 16). Unstratified drift and erratics form a thin cover in interstream areas north of the mountains, thus providing evidence that a coalescence of valley glaciers formed at least local piedmont glaciers during more extensive past glaciation(s). Glaciofluvial material is confined mostly to present valleys, but is probably more extensive north of the area. Present alluvial deposits include boulder- to glacial flour-size constituents. Windblown silt and sand forms a local thin cover along the major river valleys. Large talus cones, terrace-like slump features, and other evidences of creep and flow phenomena are common in the higher mountains.

STRUCTURE

The Romanzof Mountains comprise a structurally positive area, and contain structural elements resulting from both uplift and northward tangential forces. The structural grain strikes northeast and, with the exception of the north side of the mountains, the average dip is south.

The "Okpilak" granite body constitutes the major structural element in the area. In general, other rock units dip away from the body except near some granite contacts, where beds are either overturned or are discordantly cut by granite. Thus, north of the granite, overturning within half a mile of the granite contacts gives way to asymmetrical and normal folds successively farther north, and normal north dips characterize the structure at the mountain front. Two relatively small dome-shaped structures, along Ahngayakasrakuvik and Okpirourak Creeks, are present north of the granite body. South of the granite, dips are predominantly south for many miles into the Brooks Range.

Except for the pre-Mississippian shaly limestone units, the Sadlerochit formation Shale member, and the shaly rocks of the Shublik and Kingak formations, the rock sequence is made up of structurally competent units, which have yielded mainly by large scale folding or by faulting. The relatively incompetent units, particularly the Shale member of the Sadlerochit formation appear to have yielded mainly by flowage and tight folding, which has in part affected units such as the Quartzite member of the Sadlerochit formation.

South-dipping rock cleavage and local schistosity which strikes N 60-80° E, are strongly developed north of the granite mass between the Jago and Okpilak Rivers. Farther northwest, cleavage, where well developed, appears to be more variable. In addition to the cleavage, a strong joint set which strikes N 20° E to N 20° W and dips steeply west to vertical, is strongly developed throughout much of the area. This and other less conspicuous joint sets cut all consolidated rocks in the area.

Faults include normal and reverse transverse faults, transverse faults with apparent lateral movement, and thrust faults. Transverse faults are steeply dipping and have apparent displacements of not more than a few hundred feet, and commonly less than one hundred. A set of these faults, striking about N 30° W forms a prominent subparallel pattern between the Okpilak and Jago Rivers. Thrust faults in the southeastern part of the area and along the mountain front east of Okpilak Lake dip south at relatively low angles, probably not exceeding 30°. The displacement of the thrust fault near Okpilak Lake is probably not more than several hundred feet, but that east of the Jago River may be as much as several thousand feet. The east-northeast strikes of these thrusts are roughly parallel to shear zones along the north front of the granite.

The following tentative statements on the structural development of the Romanzof Mountains are based on the assumptions that (1) the "Okpilak" granite was emplaced during late Mesozoic or Tertiary time, and (2) emplacement was contemporaneous with an orogenic maximum. The tentative age assignment is supported by the presence of widespread silicification in sedimentary rocks as young as Jurassic, the apparent absence of feldspathic constituents in the clastic rocks, and the fact that rocks as young as the Cretaceous(?) Ignek formation are deformed. Except for possible Quaternary uplift, the major structural elements are therefore interpreted to have resulted from deformation contemporaneous with granite emplacement.

The structural grain of the Neruokpuk formation, despite the fact that Mississippian rocks overlie it with angular unconformity, is approximately parallel to that of younger sedimentary units. It would appear that pre-Mississippian diastrophism was either mild or that its directional elements roughly coincided with those of later deformation.

Northward tangential stresses resulting in folds, thrust faults, shear zones, and south-dipping cleavage are interpreted to have occurred during the orogenic maximum in the northeastern Brooks Range. Differential uplift, possibly concurrent with shear, has resulted in the dome-like structures north of the granite mass.

The north-striking and steeply dipping joint set cuts the above structural elements. It is interpreted to represent tensional planes of weakness developed during the northward compression and opened during relief of stresses subsequent to the orogenic maximum. Shear effects, retrograde metamorphism, and hydrothermal alteration are present along some of these joints within the granite, and quartz veins fill some joints in sedimentary rocks.

The north-northwest trending transverse faults which displace tangential stress features (Plate 1) are believed to have resulted mainly from differential uplift subsequent to granite emplacement. Quartz and calcite veins, which are prominent along these faults, may indicate hydrothermal action genetically related to late stages of plutonic activity. More recent uplift and deep erosion has resulted in locally developed sheeting which is parallel to mountain slopes.

CONCLUSIONS

Most of the sedimentary and metasedimentary rocks in the Romanzof Mountains are similar to those elsewhere in the northeastern Brooks Range. However, the recent work has resulted in refinements in mapping of known stratigraphic units in this area, delineation of some previously undescribed rock units, and new information concerning age and relationships within the stratigraphic sequence. The results include the recognition of several clastic and carbonate units collectively ascribed to the Neruokpuk formation of pre-Mississippian age, good evidence that all of the Lisburne group and perhaps the Kayak formation are of late Mississippian age, and the recognition of three distinct stratigraphic units in the Permian-Triassic(?) rocks of the Sadlerochit formation. Other stratigraphic units, including the phosphatic rocks of the Triassic Shublik formation and the Jurassic Kingak formation are, in lithology and in thickness, much like these two formations where exposed elsewhere in northeastern Alaska.

The "Okpilak" granite body is in contact with rocks as young as Permian, but the age of granite emplacement is not certain. However, most of the structural features in the bedded rocks, which include northward overturned folds, normal folds, and thrust and transverse faults, could have developed contemporaneously with emplacement of the granite body. This, as well as the presence of post-Jurassic silicification, may suggest that the granite is late Cretaceous or Tertiary in age.

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