# Geology of the Lake Peters Area Northeastern Brooks Range, Alaska

GEOLOGICAL SURVEY BULLETIN 1236

U.S. DEPARTMENT OF THE INTERIOR

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View looking south across Lake Schrader in foreground, and Lake Peters lying in U-shaped glacial valley. Snow covered Mount Chamberlin on left rises to over 9,000 feet in this spectacularly scenic area. The higher mountains in background are composed of Neruokpuk Formation and the foothills north of Lake Peters are composed of Mississippian and younger sedimentary rocks. Photograph by John Hobbie.

# Geology of the Lake Peters Area Northeastern Brooks Range, Alaska

*By* BRUCE L. REED

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*The stratigraphy, petrology, structural geology, and glacial history of the sedimentary and low-grade metamorphic rock sequence in the Lake Peters area*

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# GEOLOGY OF THE LAKE PETERS AREA NORTHEASTERN BROOKS RANGE, ALASKA

By Bruce L. Reed


## ABSTRACT

The Lake Peters area lies in a remote, topographically rugged part of the Franklin Mountains in the northeastern Brooks Range, Alaska. The area is at approximately lat 69°N. and long 145°W.; Mount Chamberlin is in the southern part. Rocks exposed in the map area include seven formations ranging in age from Devonian or older to Jurassic. Quaternary surficial deposits overlie Jurassic rocks and six glacial advances are recognized.

The Neruokpuk Formation, of Devonian or older age, is mapped largely as undivided. It consists of more than 6,000 feet of interbedded quartz wacke, quartz semischist, and phyllite with subordinate amounts of metachert and quartzite. Underlying, and gradational with, the Neruokpuk Formation undivided is an informally named calcareous sandstone member that consists chiefly of dolomitic and calcareous quartz wacke with subordinate amounts of phyllite, metaconglomerate, and metachert. Rocks of the Neruokpuk Formation have a well-developed metamorphic fabric and generally one, and in places two, foliations are present. A marked angular unconformity at the base of the overlying Kekiktuk Conglomerate indicates that more than 6,000 feet of Neruokput rocks have been removed by erosion prior to deposition of younger rocks.

The Kekiktuk Conglomerate of Late(?) Devonian or Mississippian age ranges in thicknes from 0 to 350 feet and consists of quartzite, pebble and cobble conglomerate, and minor siltstone. The presence of pyrophyllite as a matrix mineral in the quartzite is believed to be the first such occurrence described.

The Kayak(?) Shale of Early(?) and Late Mississippian age is 85–400 feet thick. The lower part is predominantly argillite, siltstone, and quartzite. The upper part consists of chert, sandy and argillaceous limestone, and limestone.

The Lisburne Group is composed of 1,300–1,500 feet of predominantly carbonate rocks. The Alapah Limestone (Upper Mississippian) includes silty and shaly limestone, light- to medium-gray coarse-grained limestone, dolomitic limestone, and dolomite. Nodules and lenses of chert are common. The lower contact is gradational with the Kayak(?) Shale. The Wahoo(?) Limestone (Pennsylvanian(?) and Permian) consists of light-gray to gray medium- to coarse-grained limestone with local calcirudites.

The Sadlerochit Formation of Permian and Early Triassic age disconformably overlies rocks of the Lisburne Group. It is about 1,400 feet thick and consists of three informally designated units; a lower 190–240-foot-thick siliceous sandstone—siliceous siltstone unit; a middle 400–500-foot-thick siltstone-shale unit; and an upper 600–700-foot-thick interbedded siltstone-sandstone unit.

The Shublik Formation of Late Triassic age is in thrust-fault contact with the Sadlerochit Formation. About 100 feet of the upper part of the Shublik Formation is exposed; it consists of dark-gray phosphatic limestone and calcareous shale.

The Kingak Formation of Jurassic age is more than 1,000 feet thick. It consists of 70–100 feet of basal quartzitic siltstone overlain by an unknown thickness of shale and slaty shale that contains a few interbeds of siltstone and sandstone. The sharp lithologic contrast of the basal quartzitic siltstone with the underlying Shublik Formation indicates a possible unconformity.

Six glacial advances (pre-Wisconsin to Recent), including one advance previously unrecognized in this area (Alapah Mountain), correlate with glacial advances recognized elsewhere in the Brooks Range.

The Lake Peters area is divided into two structural provinces. The southern (Peters) structural province consists chiefly of rocks of the Neruokpuk Formation. The northern (Schrader) province is composed of post-Neruokpuk rocks. Three generations of structural features are recognized. The first two generations affected rocks of the Neruokpuk Formation in the Peters structural province and probably resulted from one more or less continuous period of Late Devonian(?) deformation that involved south-southwestward–north-northeastward compressive stresses. The first generation is represented by broad, open east-southeastward-trending folds (first folds) with nearly vertical axial planes. Second generation structural features consist of east-southeastward-trending minor folds (second folds) and south-dipping thrust faults. Second folds are superimposed on first folds; their axial planes dip steeply south on both the northern and southern limbs of the first folds and are thus incongruous with the first folds.

Third generation structural features of late Mesozoic (Laramide) age formed contemporaneously in the Peters and Schrader structural provinces. Compressive stresses were in an approximately north-south direction. Third generation structural features in the Peters province consist of east-west-trending open folds (third folds) and high-angle faults that strike east-west. The third folds formed at the same time that the Kekiktuk Conglomerate was folded. Regional basement folds have a wavelength of about 15 miles. Third generation structural features in the Schrader province consist of east-trending en echelon folds and south-dipping thrust faults. Axial planes of the folds dip to the south; folds are locally overturned with vertical to steep south-dipping northern limbs.

Rocks of the Neruokpuk Formation are regionally metamorphosed and belong to the quartz-albite-muscovite-chlorite subfacies of the greenschist facies. Post-Neruokpuk rocks also belong to the greenschist facies, but do not have a well-developed metamorphic fabric.

## INTRODUCTION

This report describes the structural geology and stratigraphy of the Lake Peters area in the northeastern Brooks Range. Bedrock units consist of low-grade metamorphic and sedimentary rocks that range in age from Devonian or older to Jurassic. Two major unconformities are recorded in the bedrock geology. Previous reconnaissance work in the area provided only a field description of the rocks; thus a brief petrographic and stratigraphic description is given, and the metamorphic grade of the rocks is described. A previously unreported glacial advance in the Lake Peters area can be correlated with glacial advances elsewhere in the Brooks range. The age of pre-Mississippian folding, the orientation of structural features involved, and the manner in which the pre-Mississippian basement yielded during Mesozoic and Laramide deformations are suggested.

The Lake Peters area lies in the northern part of the Franklin Mountains, and includes Mount Chamberlin (fig. 1). The area mapped (pl. 1) covers about 145 square miles in the southern part of the Mount Michelson B–2 quadrangle (scale 1: 63,360). The area is remote, without trails or roads, and the only effective method of reaching it is by ski- or float-equipped aircraft. Travel within the area is best accomplished on foot. Tracked-vehicle travel is possible in the major valleys in the winter and early spring, but in other seasons is restricted to areas north of the mountain front. The nearest permanent settlement is at Barter Island, a military Dew-Line station 65 miles northeast of Lake Peters. Air-line distances to the other "near-by" Alaskan settlements at Fort Yukon, Bettles, Barrow, and Fairbanks are 190, 240, 310, and 320 miles, respectively.

Early work in the eastern Brooks Range was done by the U.S. Geological Survey and consisted of boundary surveys and reconnaissance mapping along the major rivers (Schrader, 1900; Mendenhall, 1902; Maddren, 1912; Mertie, 1925, 1930). Between 1906 and 1914, Leffingwell (1919) investigated the Canning River region and also parts of the Franklin and Romanzof Mountains. He established the stratigraphic nomenclature for the northeastern Brooks Range and named many of the prominent geographic features. From 1944 to 1953 the U.S. Geological Survey, in cooperation with the Department of the Navy, made a geologic reconnaissance of the Arctic Coastal Plain and the Brooks Range. At the time of the writer's field investigations results of this work were available as Preliminary Reports on the Naval Petroleum Reserve No. 4. Reports pertinent to the mapped area which have been published are: Keller, Morris, and Detterman (1961); Brosgé, Dutro, Mangus, and Reiser (1962); Holmes and Lewis (1961, 1965). Sable's reports (1959, 1965) on an area in the Romanzof Mountains were of considerable value in the present investigation.

Fieldwork for the present investigation was carried out during the months of June, July, and August of 1960 and 1961. The field party was transported between Point Barrow and Lake Peters by ski- and float-equipped aircraft. The Arctic Research Laboratory has erected permanent buildings at Lake Peters which serve as a base camp for scientific personnel during the summer months. In the spring, prior to the first field season, tracked vehicles were used to set out food caches on

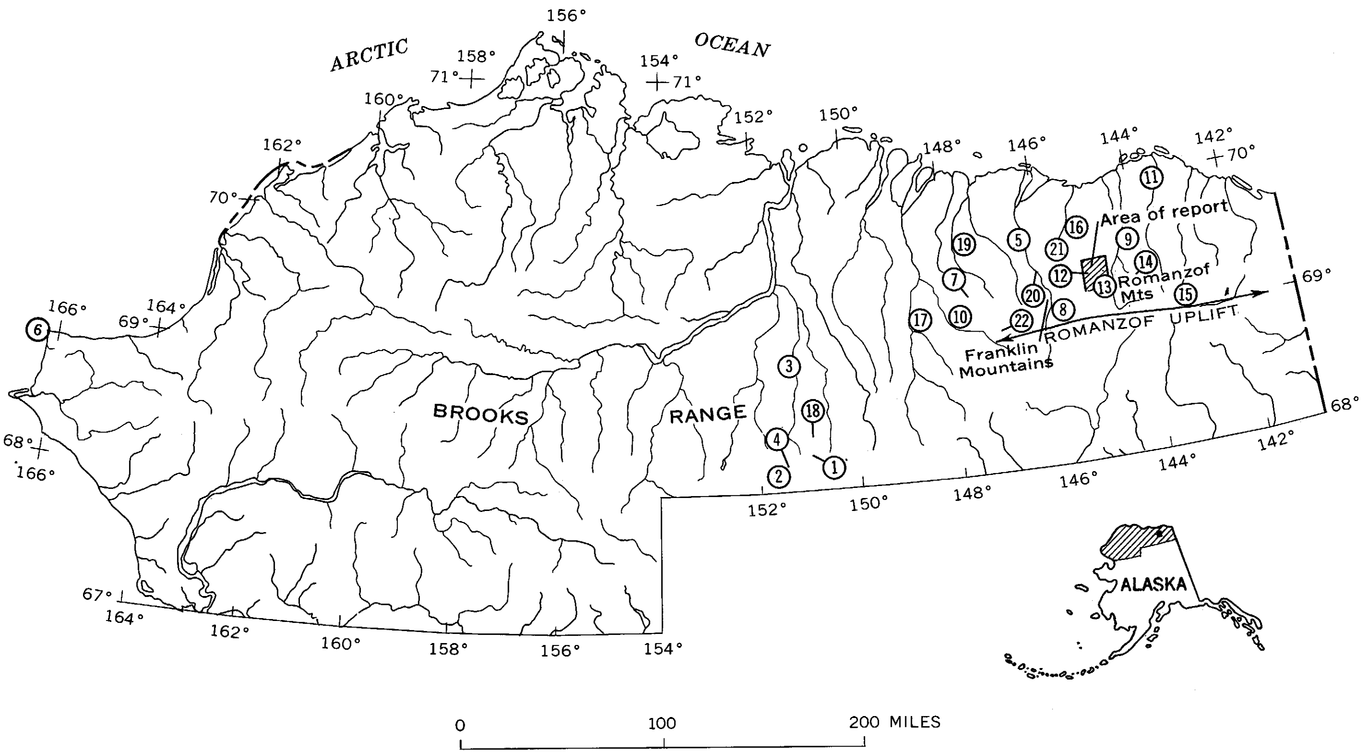


**FIGURE 1.—Arctic Alaska showing area of report and locations of various geographic features mentioned in text.**

LOCALITIES SHOWN ON FIGURE 1

1. Alapah Mountain
2. Anaktuvuk Pass
3. Anaktuvuk River
4. Anivik Lake
5. Canning River
6. Cape Lisburne
7. Echooka River
8. Franklin Mountains
9. Hulahula River
10. Ivishak River
11. Jago River
12. Lake Peters
13. Mount Chamberlin
14. Mount Michelson
15. Romanzof Mountains
16. Sadlerochit Mountains
17. Sagavanirktok River
18. Shainin Lake
19. Shaviovik River
20. Shublik Island
21. Shublik Mountains
22. Wahoo Lake

Carnivore, Coke, and Whistler Creeks. Field equipment was backpacked to these caches which served as temporary field camps. Later, temporary camps were made by backpacking and airdropping of food and equipment.

During fieldwork, geology was mapped on vertical aerial photographs (scale 1:25,000) flown by the U.S. Army and Navy. Data were transferred from aerial photographs to a U.S. Geological Survey topographic map (scale 1:63,360, contous interval 100 ft) that was enlarged to 1:40,000.

The fieldwork was supported by the Arctic Institute of North America under contract with the Office of Naval Research (O.N.R. contracts 266, 289, 310). Special thanks for field support are due to Max C. Brewer, Director of the Arctic Research Laboratory at Point Barrow, and to his staff.

The encouragement and counsel given by Professor Marland P. Billings of Harvard University, advisor for this project, are acknowledged with particular gratitude. Thanks are also due to Professors John Haller, Alan V. Jopling, and Harry B. Whittington of Harvard University for valuable criticisms on parts of the manuscript.

Able assistance in the field was provided by Peter Workum during the summer of 1960 and by Robert Fisher during the summer of 1961. Edward G. Sable of the U.S. Geological Survey graciously made data available prior to publication. The writer benefited considerably from conferences with William P. Brosgé, Robert L. Detterman, G. Donald Eberlein, George Gryc, Ernest H. Lathram, Hillard N. Reiser, and Norman J. Silberling of the U.S. Geological Survey on various aspects of Brooks Range geology.

Frank Riddell and Vincent Peabody, communications and logistics supervisors for the Arctic Research Laboratory camp at Lake Peters, helped to facilitate the fieldwork. John Hobbie collected the meteorological data and allowed the writer to use his laboratory at Lake Peters camp.

## GEOGRAPHY

### TOPOGRAPHY AND DRAINAGE

The Brooks Range forms the Alaskan counterpart of the Rocky Mountain System of Canada and the United States. This glaciated mountain system across arctic Alaska extends about 600 miles from Cape Lisburne eastward to the Canadian border. The range consists of a number of mountain groups to which specific names have been applied (Gryc, 1958). Generally the relief increases from west to east. In the western part of the range few peaks are higher than 5,000 feet. In the east the highest and most rugged peaks, the Franklin and

Romanzof Mountains (fig. 1), rise to over 9,000 feet. The Franklin Mountains rise rather abruptly from the low northern foothills and are characterized by jagged peaks, cirques, arêtes, and small valley glaciers. Mount Chamberlin, one of the Franklin Mountains, is southeast of Lake Peters (pl. 1); it is the second highest peak in the Brooks Range and has an altitude of 9,020 feet (frontispiece). From Lake Peters it rises over 6,000 feet in 3 miles. The low relief of the gently rolling linear hills north of the mountain front contrasts sharply with the high relief of the mountains.

The Lake Peters area is drained by north-flowing streams that occupy U-shaped glacial valleys. Although these streams are locally braided, downcutting seems to be the most important erosional process. Tributaries to these streams have V-shaped profiles with steep gradients. Carnivore Creek, with headwaters to the south in the Franklin Mountains, drains north into Lake Peters. Lake Peters, a moraine-dammed lake lying within a glacial valley, has a drainage area of 62 square miles. Whistler Creek and Coke Creek, in the western and central parts of the mapped area, respectively, drain northward into Lake Schrader. Lake Schrader lies north of the mountain front and immediately north of the valley of Lake Peters. It is also dammed by a moraine and has a drainage area of 55 square miles, exclusive of Lake Peters. The Kekiktuk River drains Lake Schrader and is a tributary of the Sadlerochit River, which flows northward to the Arctic Ocean. Katak Creek drains the eastern part of the mapped area and is a tributary of the Hulahula River, which also flows into the Arctic Ocean.

## CLIMATE

The weather at Lake Peters varies from moderately warm days with only a few cloudy periods to cold overcast days with light rain or snow. In general, during the summer months the days are moderately warm and the nights cool. Maximum and minimum temperatures during the months of June, July, and August are shown in figure 2. As a general rule, snow melts from the area by early June and begins to accumulate again in mid-September. Lake Peters generally becomes ice free during the first 2 weeks in July but by mid-September again shows a thin skim of ice along the shores of the lake. From mid-June through mid-July fieldwork can be carried out at any time during a 24-hour period. Fog drifting in from the Arctic Ocean can restrict visibility to less than 100 feet.

Rainfall is not great, but few days pass without at least a trace of precipitation. Snow may fall at any time of the year. Precipitation during the 1960–1961 field seasons is shown in figure 3. Although precipitation is low, the region is not dry. North of the mountain front the

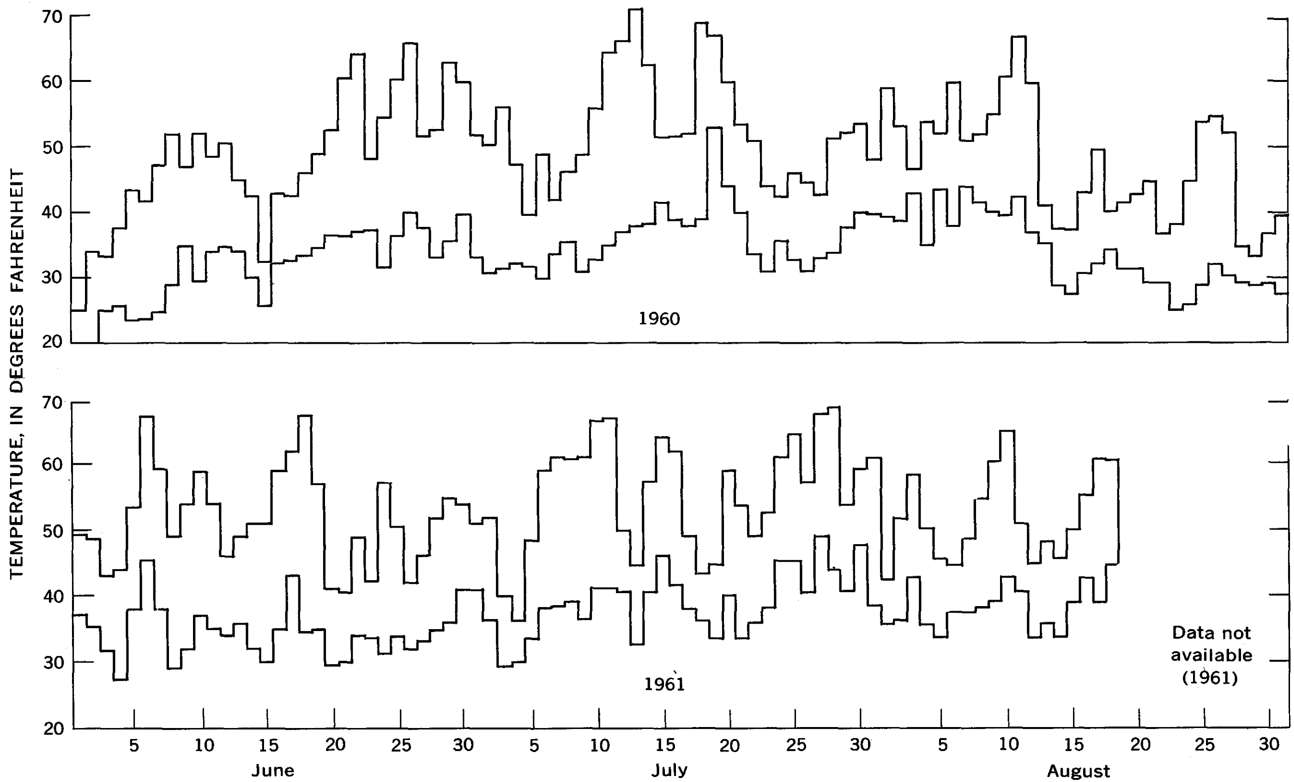


**FIGURE 2.—Maximum and minimum temperatures at Lake Peters for June, July, and August in 1960 and 1961. Data collected by John Hobbie.**

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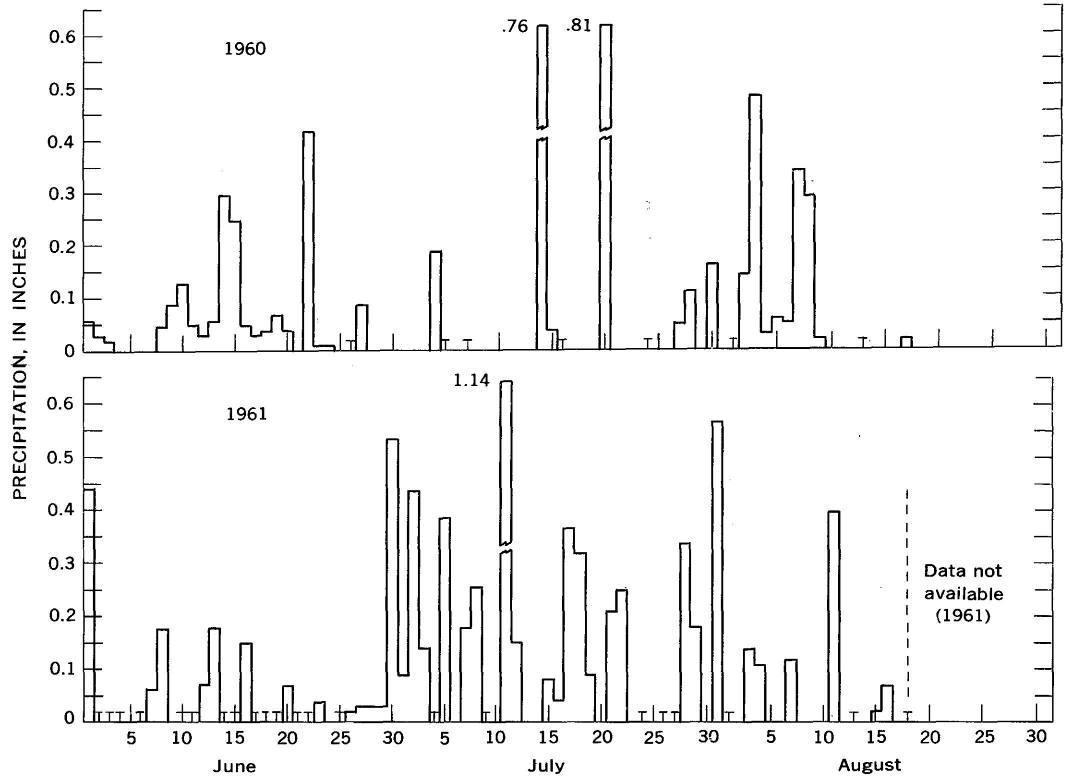


**FIGURE 3.—Precipitation at Lake Peters for June, July, and August in 1960 and 1961.**

land is covered with tundra, and water stands in many small ponds. Metorological conditions in the Lake Peters–Schrader area are discussed in some detail by Larsson (1960).

## STRATIGRAPHY

The metamorphic and sedimentary rocks exposed in the Lake Peters area (table 1) range in age from Devonian or older to Jurassic. The oldest formation, the Neruokpuk Formation, consists of low-grade, regionally metamorphosed rocks of the quartz-albite-muscovite-chlorite subfacies of the greenschist facies (Turner and Verhoogen, 1960, p. 534). The overlying six formations range in age from Late (?) Devonian through Jurassic. They are metamorphosed to some extent, and cleavage is locally developed. Quaternary surficial deposits overlie Jurassic rocks.

### TERMINOLOGY AND METHODS

In the following description, the terminology includes bed, set of beds, unit, and section. A bed is a layer of rock separated from overlying and underlying layers by a physical break, a change in lithology, or both. A set of beds is a succession of beds of similar lithology. Unit is a term applied informally to any stratigraphic interval and may include any of the above terms. A section is a specific measured stratigraphic interval. Sections were measured either directly or by tape-and-compass traverse. A general lithologic description of a formation is given under the heading "Character." More detailed descriptions are given under the heading "Measured Sections;" these consist of both field stratigraphic observations and brief petrographic descriptions of the different rocks.

Color names conform as nearly as possible to the National Research Council "Rock Color Chart" (Goddard and others, 1948). Stratification terms and parting properties generally follow those of McKee and Weir (1953) as modified by Ingram (1954). Clastic is the term used to denote argillaceous and arenaceous rocks as distinguished from dominantly carbonate rocks, regardless of the latter's mode of deposition. The grain size and textural terminology of clastic rocks are those of the Wentworth scale. Limestones and dolomites are classified in the measured sections according to the system and nomenclature proposed by Folk (1959). The terminology used in the description of metamorphic rocks and sandstone follows that of Williams, Turner, and Gilbert (1955).

TABLE 1.—*Summary of metamorphic and sedimentary rocks, and surficial deposits, Lake Peters area, northeastern Alaska*

| Age | Unit Name | Character | Approximate thickness (feet) |
|---|---|---|---|
| Recent and Pleistocene | | Flood-plain alluvium; sand, pebbles, cobbles, boulders; talus cones; alluvial fans, cones; debris from frost processes; outwash sand, gravel. Ice and ice-contact features; coarse morainal deposits, till | 0–200(?) |
| Jurassic | Kingak Shale | Shale, slaty shale, siltstone, sandstone; basal quartzitic siltstone containing phosphatic nodules | 1, 000+ |
| Upper Triassic | Shublik Formation | Dark-gray phosphatic limestone and calcareous shale | 100+ |
| Lower Triassic and Permian | Sadlerochit Formation | Lower siliceous sandstone-siliceous siltstone, minor chert unit; middle siltstone, shale, minor sandstone unit; upper interbedded siltstone-sandstone unit | 1, 400± |
| Permian, Pennsylvanian(?) and Upper Mississippian | Lisburne Group [Alapah Limestone and Wahoo(?) Limestone] | Carbonate rocks. Fine- to coarse-grained limestone, dolomitic limestone, dolomite; chert nodules and lenses common; lower part silty and shaly | 1,300–1, 600 |
| Upper and Lower(?) Mississippian | Kayak(?) Shale | Argillite, siltstone, chert, quartzite. Chert and limestone in upper part | 85–400 |
| Mississippian or Upper(?) Devonian | Kekiktuk Conglomerate | Quartzite, pebble to cobble conglomerate, minor siltstone | 0–350 |
| Upper(?) Devonian or older | Neruokpuk Formation | Neruokpuk Formation undivided: quartz wacke, quartz semischist, phyllite; subordinate amounts of metachert, and quartzite<br>Calcareous sandstone member: dolomitic and calcareous quartz wacke; subordinate amounts of phyllite, metachert, and metaconglomerate | 6, 000+ |

## DEVONIAN OR OLDER

### NERUOKPUK FORMATION

#### NAME AND DEFINITION

Leffingwell (1919, p. 103–105) gave the name Neruokpuk Schist to pre-Carboniferous "quartzite schists and quartz mica schists" that are typically exposed in the Lake Peters area and near the forks of the Canning River. Gryc and Mangus (1947, p. 4) in a traverse down the Canning River also reported the Neruokpuk Schist as pre-Carboniferous quartz-mica schist. Whittington and Sable (1948) and Payne and others (1951) referred to this sequence of rocks in northeastern Alaska as the Neruokpuk Formation. Brosgé, Dutro, Mangus, and Reiser (1952, p. 2), in their study of some selected localities in the eastern Brooks Range, referred to the "great thickness of predominantly metasedimentary rock" as the Neruokpuk Schist of pre-Carboniferous age. Where exposed along the Kongakut and Firth Rivers about 100 miles east of Lake Peters, the older metasedimentary rocks were referred to as the Neruokpuk Schist by Mangus (1953, p. 12). Sable (1959, 1965), in the Mount Michelson area, mapped a varied sequence of pre-Mississippian quartzites, slates, and limestones which he designated the Neruokpuk Formation. Norris, Price, and Mountjoy (1963) mapped the continuation of these rocks east of the International Boundary as Neruokpuk Formation and tentatively assigned them a Precambrian or Cambrian(?) age. Brosgé, Dutro, Mangus, and Reiser (1960; 1962, p. 2182–2185) formally defined the Neruokpuk Formation and tentatively divided it into four informal members. Two of these members, the quartzite-schist member and overlying phyllite-chert member, are in the Lake Peters area.

In this report the major part of the Neruokpuk Formation is not subdivided (Dn, pl. 1). One lithologically distinctive unit that comprises the lowest beds of the exposed Neruokpuk Formation and is characterized by dolomitic and calcareous quartz wacke with subordinate amounts of phyllite, metachert, and metaconglomerate is separately mapped and informally designated the calcareous sandstone member (Dnc, pl. 1).

#### OCCURRENCE

The rocks of the Neruokpuk Formation form nearly all of the mountains in the southern half of the Lake Peters area, including Mount Chamberlin, which rises over 6,000 feet above Lake Peters (frontispiece). Typically the Neroukpuk rocks show well-defined bedding that generally dips to the south. From a distance the rocks are a monotonous gray to brownish gray, but a few purple, green, or black phyllite units break the uniformity of color.

### NERUOKPUK UNDIVIDED

Rocks of the Neruokpuk Formation undivided (Dn, pl. 1) are predominantly low-grade, regionally metamorphosed, interbedded quartz wacke, quartz semischist, and phyllite with subordinate amounts of metachert and quartzite. Generally one foliation is present in the rocks, though in a few places two foliations are present.

#### QUARTZ WACKE

In this report the term "quartz wacke" designates a poorly sorted sandstone in which the detrital grains are predominantly subangular to angular quartz in a matrix of varying amounts of quartz, albite, sericite, and chlorite (fig. 4).[1] The proportion of matrix to detrital components ranges from 10 to 70 percent. This usage of the term "quartz wacke" follows that of Williams, Turner, and Gilbert (1955, p. 289–301). The term "wacke" is used in preference to "graywacke"

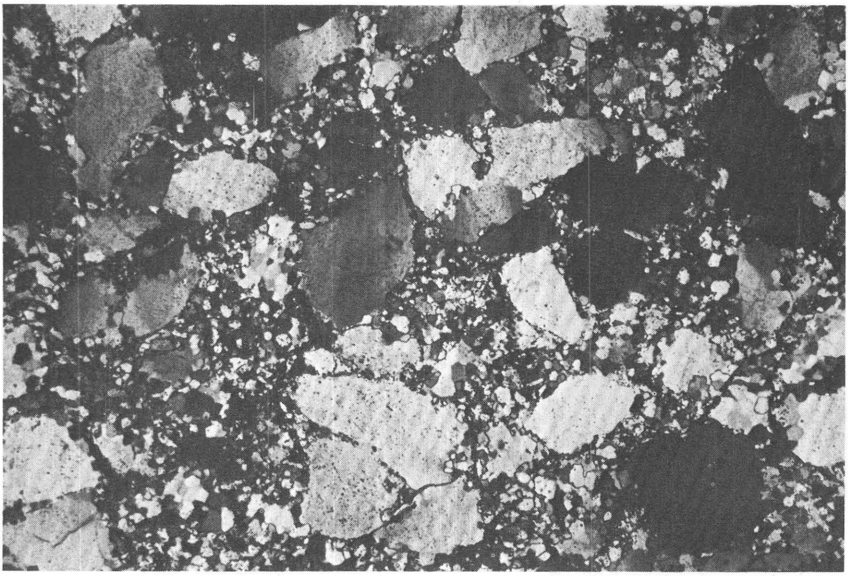

FIGURE 4.—Quartz wacke showing detrital quartz grains in a fine matrix of intergrown quartz and albite with minor muscovite and chlorite (crossed nicols, × 68).

[1] All the rocks of the Neruokpuk Formation have been subjected to low-grade metamorphism and contain in varying amounts quartz, albite, sericite and chlorite. It could be argued that a metamorphic prefix should be added to the name quartz wacke, which is basically a textural rock term. The term "metaquartz wacke," however, seems awkward; for this reason the term "quartz wacke" will be used in this report to denote the low-grade metamorphic equivalent of this rock type.

because graywacke usually implies a dark-colored rock (Williams and others, 1955, p. 293, 294, 298; Carozzi, 1960, p. 67; Pettijohn, 1957, p. 303). Detrital feldspar and rock fragments are each less than 10 percent of the total rock. Clast size ranges from pebble to fine silt. Fragments less than 0.03 mm in diameter are included in the matrix.

The quartz wacke is interbedded with quartz semischist and phyllite. greenish gray, with a few medium-gray to light-olive-gray beds. Modal analyses of three typical quartz wackes are given in table 2. The analyses are based on a series of traverses made at 1-mm intervals across an entire standard thin section on a Leitz integrating stage.

The quartz wacke is interbedded with quartz semischist and phyllite. It is thickly laminated to very thick bedded, but individual beds lack uniform thickness and are generally lenticular. Partings are flaggy to massive. Graded bedding is a common feature and is evident both in outcrop and in thin section. Crossbedding and ripple marks are uncommon. Slump structures and contemporaneous folding were noted in the finer grained, laminated beds. Intraformational breccias are thin and of limited extent.

The most abundant detrital mineral in the quartz wackes is quartz. The angular to subangular quartz grains range in size from very fine silt to small pebbles. In thin section they characteristically are seen as angular slivers that lie parallel to the plane of stratification. The margins of the quartz grains are partly replaced and embayed by chlorite and sericite. In many places this marginal replacement makes the boundaries of the quartz ill defined and hazy. Inclusions of small flakes

TABLE 2.—*Modal analyses, in percent, of quartz wacke and quartz semischist of the Neruokpuk Formation*

| Mineral | Quartz wacke | | | Quartz semischist | |
|---|---|---|---|---|---|
| | Unit 11 | Unit 27 | Unit 45 | Unit 5 | Unit 19 |
| Larger grains: | | | | | |
| Detrital quartz | 40. 7 | 29. 5 | 36. 9 | 25. 0 | 27. 0 |
| Detrital plagioclase | 2. 7 | . 6 | . 4 | . 7 | <1. 0 |
| Detrital accessories [1] | <1. 0 | <1. 0 | <1. 0 | <1. 0 | <1. 0 |
| Matrix: | | | | | |
| Sericite-chlorite | 9. 5 | 19. 5 | 6. 6 | 29. 0 | 37. 8 |
| Quartz-albite | 45. 9 | 49. 8 | 55. 4 | 42. 5 | 33. 1 |
| Carbonate | . 7 | ----- | ----- | ----- | 1. 2 |
| Other [2] | <1. 0 | <1. 0 | <1. 0 | <2. 0 | <1. 0 |
| Total | 99. 5 | 99. 4 | 99. 3 | 99. 2 | 99. 1 |

[1] Mainly tourmaline, zircon, rutile.
[2] Includes iron oxides, other opaques, and rock fragments.

Sample locations above the base of section 4, plate 2:
Unit 11. 202 ft.
Unit 27. 544 ft.
Unit 45. 1,055 ft.
Unit 5. 67 ft.
Unit 19. 278 ft.

of muscovite and tourmaline, as well as minor rutile, plagioclase, biotite, chlorite, and zircon, are seen in the quartz grains. Deformation lamellae are also present in some of the grains. In all the thin sections examined, single grains showing varying degrees of undulose extinction were the most abundant, although large, nonundulose grains were common; composite, semicomposite, and strongly undulose composite grains were generally subordinate to single quartz grains.

Detrital quartz in the Neruokpuk Formation could have had more than one source. Grain counts were made in eight thin sections (table 3) to tabulate the several types of quartz grains. Table 3 also serves as a basis for tentative interpretation concerning the more probable source of the quartz grains (p. 25). In table 3, detrital quartz was limited to grains greater than 0.03 mm in diameter. The columns "undulose" and "nonundulose" are for single grains; "undulose" contains grains showing all degrees of undulose extinction. A "semicomposite" grain is one one made up of two or more subindividuals which have close optical orientation but a distinct contact between subindividuals. The subindividuals may have straight to slightly undulose extinction (<10°). "Composite" grains have two or more subindividuals with widely differing orientation. The subindividuals may have straight to slightly undulose extinction. "Strongly undulose composite" grains have two or more subindividuals with or without crenulated boundaries and with strongly undulose extinction (>10°). Where possible, 300 grains were counted and classified in each section. Three thin sections from unit 6 and one thin section from unit 7 are from the conglomerate and metachert in section 3, plate 2. In these thin sections all the quartz

TABLE 3.—*Classification of detrital quartz grains in Neruokpuk Formation*

[See text for explanation of quartz types]

| Sample | Undulose extinction | | | Nonundulose extinction | | | Semicomposite | | | Composite | | | Strongly undulose composite | | | Abraded overgrowths | Number of grains counted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | | |
| Unit 20 | 116 | 24 | 9 | 90 | 19 | 9 | 6 | 4 | 3 | 6 | 6 | -- | 6 | 2 | -- | ------- | 300 |
| Unit 22 | 134 | 34 | 3 | 79 | 19 | 4 | 10 | 3 | -- | 5 | 1 | -- | 6 | 1 | -- | 1 | 300 |
| Unit 27 | 141 | 15 | 2 | 87 | 21 | 3 | 2 | -- | 2 | 18 | 2 | -- | 3 | 3 | -- | 1 | 300 |
| Unit 47 | 180 | 21 | -- | 57 | 5 | -- | 7 | 2 | -- | 8 | 1 | -- | 15 | 4 | -- | ------- | 300 |
| Unit 6 | 5 | -- | -- | 10 | -- | -- | 6 | -- | -- | 12 | -- | -- | 13 | 1 | -- | ------- | 47 |
| Unit 6 | 4 | -- | -- | 4 | -- | -- | 4 | -- | -- | 7 | -- | -- | 8 | 1 | -- | ------- | 28 |
| Unit 6 | 2 | -- | -- | 4 | -- | -- | 1 | -- | -- | 8 | -- | -- | 12 | -- | -- | ------- | 27 |
| Unit 7 | 8 | -- | -- | 4 | -- | -- | 6 | -- | -- | 12 | -- | -- | 15 | 1 | -- | ------- | 46 |

A Few vacuoles.
B Mineral inclusions; includes tourmaline, rutile, muscovite, biotite, zircon, and feldspar.
C Abundant vacuoles.

Sample locations above the base of sections 3 and 4, plate 2:
Unit 20. 288 ft, section 4.
Unit 22. 356 ft, section 4.
Unit 27. 544 ft, section 4.
Unit 47. 1,080 ft, section 4.
Unit 6. 34–68 ft, section 3.
Unit 7. 68–83 ft, section 3.

grains were counted. The varied data given in table 3 are direct evidence of the great divergence of detrital quartz types in the Neruokpuk Formation. This divergence of types indicates that metamorphism has not been sufficient to bring about homogeneity in the detrital quartz.

Detrital feldspar is a minor constituent in most of the rocks. No potassium feldspar was definitely identified, although clots of unoriented sericite flakes could represent completely sericitized potassium feldspar. Detrital grains of plagioclase are slightly to strongly sericitized and show polysynthetic twinning; the average grain size is 0.1–0.7 mm. This plagioclase is less than 10 percent anorthite and may represent altered, more calcic varities of plagioclase. Several composite grains of plagioclase and quartz were noted. In two instances the plagioclase was myrmekitic. Metamorphic albite ranges from $An_2$ to $An_7$, is fine grained and untwinned, and is difficult to distinguish from the fine-grained quartz matrix.

Detrital muscovite is present in most of the rocks. Generally the relatively fresh bent and broken flakes are up to 2 mm long and are oriented subparallel to the stratification. Carbonates are relatively rare in rocks mapped as Neruokpuk Formation undivided. Where present they are distributed irregularly and replace the matrix. Dolomite and siderite tend to be idiomorphic and are generally stained with iron oxides.

Tourmaline, zircon, rutile, magnetite, leucoxene, chloritoid, and epidote are accessory minerals in the quartz wackes. Tourmaline, zircon, and rutile are present as rounded small crystals or as broken and fractured subangular grains which rarely exceed 0.5 mm in diameter. Tourmaline is the most abundant. It is typically blue to bluish green with $N_o = 1.646 \pm .003$, $N_e = 1.624 \pm .003$. Some crystals have deep-blue and yellowish-green colors at opposite ends of the vertical axis; others are brown to moderately deep brown, and a few are very light pink. No overgrowths on the tourmaline were seen. Zircon is light gray to colorless with $N_o = 1.92 \pm .01$, $N_e = 1.96 \pm .01$. Rutile is deep red to reddish brown and is found as small broken subangular fragments. Pyrophyllite is found locally near the contact with the overlying Kekiktuk Conglomerate. Chloritoid and epidote are present only as very minor accessories. Chloritoid generally occurs as very small pale- to yellowish-green crystal aggregates in which individual crystals are from 0.01 to 0.05 mm long. In one thin section (unit 16, sec. 1*A*, pl. 2) porphyroblasts of chloritoid (altered to iron oxide) up to 0.5 mm long were observed. These porphyroblasts are restricted to pelitic laminae in a calcareous quartz wacke. Chloritoid never composes more than 1 percent of the total rock. Epidote occurs as rare small crystals. Because of their small size (generally less than 0.5 mm in diameter) optical determinations were not made. Epidote could not be identified on whole-rock X-ray diffraction charts.

### QUARTZ SEMISCHIST

Quartz semischist is a rock in which the predominant detrital component, quartz, is slightly granulated and the fabric has poorly developed schistosity defined by slip planes that cross bedding-plane schistosity. The quartz semischist is less resistant than the quartz wacke throughout the Neruokpuk Formation. It is generally thickly laminated to thin bedded and is slightly darker greenish gray than the quartz wacke. Phyllite beds range from 2 inches to 3 feet in thickness and grade vertically into the semischist.

The mineral assemblage of the quartz semischist is similar to that of the quartz wacke. Sliverlike detrital quartz and minor plagioclase lie in a poorly developed schistose aggregate of fine quartz, albite, sericite, and chlorite, with calcite and dolomite or siderite present as subordinate minerals (fig. 5). Pyrite and opaque iron oxides are scattered throughout. Accessory minerals present are tourmaline, graphite, zircon, and in places, magnetite, leucoxene, and rutile. The matrix ex-

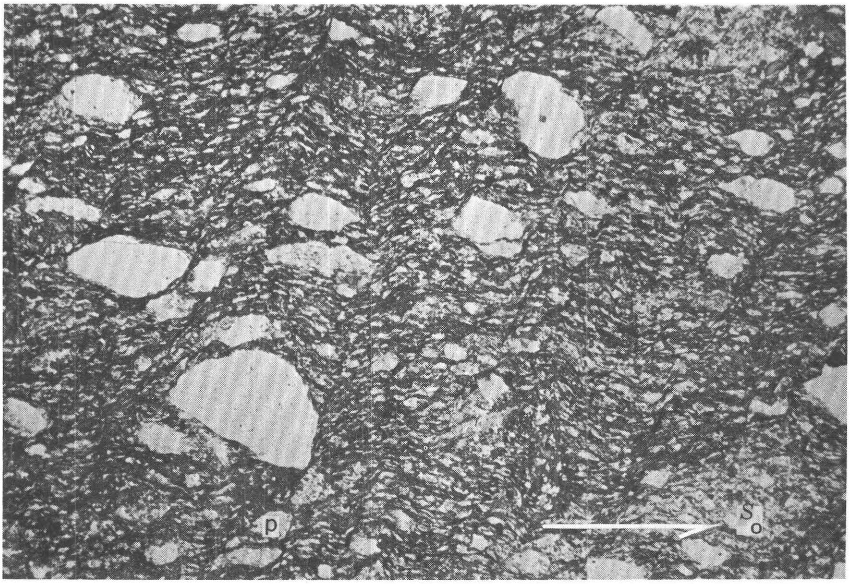


FIGURE 5.—Quartz semischist showing detrital quartz grains and one detrital plagioclase (p) grain in a matrix of quartz, muscovite, albite, and chlorite. Main schistosity ($S_0$, parallel to bedding) defined by a preferred orientation of chlorite and muscovite and shape of quartz grains. Bedding is crossed by later strain-slip and fracture cleavage (plane light, × 68).

ceeds detrital constituents (table 2), and sericite and chlorite are more abundant than in the quartz wacke. Schistosity and lineation are locally well developed. The main schistosity is parallel to the bedding surfaces where sericite and chlorite show preferred orientation of (001) parallel to this schistosity. A later strain-slip cleavage due to microfolding crosses relict bedding and the earlier formed schistosity.

###### PHYLLITE

Phyllite is the least resistant rock in the Neruokpuk Formation. It commonly occurs in units from 1 inch to 80 feet thick, and is intercalated with the quartz wacke and quartz semischist. The phyllite is commonly less competent than the surrounding rocks and has many small crenulate folds and a well-developed cleavage. The contacts of the phyllite with the quartz wacke and quartz semischist are sharp or graduational. Where the phyllite is associated with the metachert, the contacts are gradational from phyllite to cherty phyllite to metachert. The color of the phyllite is grayish black, medium to light gray, greenish gray, grayish green, or grayish red purple. Alternating beds of green and purple phyllite are common. The purple color can be attributed to the finely disseminated hematite.

The lithology of any one phyllite is relatively uniform; thin sections show varying amounts of very fine grained quartz, sericite, chlorite, albite, and a small amount of carbonate. Accessories are graphite, pyrite, tourmaline, magnetite, leucoxene, reddish-brown to opaque iron oxides, very minor chloritoid, and possibly a few small grains of epidote. The main schistosity of the phyllite results from alined flakes of sericite and chlorite which have crystallized parallel to the plane of stratification. This schistosity is locally realined by postcrystalline strain-slip and fracture cleavage.

Chlorite was separated from two samples of phyllite in section 4 (pl. 2) which are designated *A* (782 ft above the base of sec. 4, unit 37) and *B* (1,073 ft above the base of sec. 4, unit 46). The chlorite is optically negative and has positive elongation, low birefringence, and very light blue to gray interference colors. The $N_y$ indices are:

Sample *A* $N_y=1.638\pm0.003$

Sample *B* $N_y=1.637\pm0.003$

The chlorite was also analyzed by the semiquantitative X-ray diffraction methods described by Schoen (1962). The chlorite has 3.30 and 3.25 atoms (or equivalent diffracting cations) per six octahedral positions for samples *A* and *B*, respectively. The aluminum content was estimated from the basal spacing *d* (001) (Brindley, 1961, p. 269).

Using quartz as an internal standard, $d(001)$ was determined from the $d(004)$ and $d(005)$ spacings to be:

Sample *A* $d(001) = 14.17\text{A}$
Sample *B* $d(001) = 14.18\text{A}$

The general formula for chlorite and the linear relation between basal spacing and aluminum content given by Brindley (1961, p. 268, 269) are:

(1) $Mg_{6-x-y}(Fe^{+2}Fe^{+3})_y\ Al_x\ (Si_{4-x}Al_x)O_{10}(OH)_8$
(2) $d(001) = 14.55 \times 0.29.$

where $x$, the layer charge per unit cell, is equal to the amount of Al replacing Si in the above formula $(Si_{4-x}Al_x)$, and $y$ is the total number of Fe atoms per six octahedral positions as determined by the X-ray method of Schoen (1962). By solving the linear relation (2) for $x$ and by substituting $x$ into the general formula (1) the following approximate chlorite compositions were calculated:

Sample *A* $(Mg_{1.39}Fe_{3.3}Al_{1.31})\ (Si_{2.69}Al_{1.31})\ O_{10}(OH)_8$
Sample *B* $(Mg_{1.47}Fe_{3.25}Al_{1.28})\ (Si_{2.72}Al_{1.28})\ O_{10}(OH)_8$

Schoen (1962, p. 1389), comparing the results of the X-ray diffraction methods with the results of the chemical analysis of seven chlorites, gave a percentage of error that ranged from 0.67 to 13 percent. However, the determinations made above at least show the chlorites to be iron rich.

Using the methods described by Albee (1962) the Fe/Fe+Mg ratios indicated by the indices given above are:

$$\frac{Fe}{Fe+Mg}$$

Sample *A* $0.64 \pm 0.03$
Sample *B* $0.63 \pm 0.03$

The variation of $\pm 0.03$ is that given by Albee (1962, p. 866).

The same ratio, obtained from the compositions determined by X-ray diffraction methods as given above, is:

$$\frac{Fe}{Fe+Mg}$$

Sample *A* 0.70
Sample *B* 0.69

A comparison of the ratios obtained by optical methods with those obtained by X-ray diffraction shows that the ratios are in moderately close agreement.

### METACHERT

The metachert is very hard, dense, subvitreous, and well jointed. It is resistant and forms prominent bluffs. The color is generally dark gray, but varies from light gray to grayish black, with local light-gray and dark-gray banding (fig. 6). The metachert is thickly laminated to thin bedded, and individual units are up to 50 feet thick. The units are lenticular; laminae may pinch and swell, bifurcate, and pinch out. The layers are commonly separated by thin (0.005–0.05 mm) discontinuous partings of sericite and finely divided opaque (possibly graphitic) material. These partings give a phyllitic sheen to the rocks on bedding surfaces. With an increasing content of sericite and chlorite (which was originally argillaceous material), the metachert grades into cherty phyllite and phyllite.

Where fractured across the bedding planes, the metachert has a typical chert or porcellanitelike appearance. In thin section the metachert is seen to be a colorless microcrystalline aggregate of granular quartz ranging in size from 0.002 to 0.1 mm. The rock has been recrystallized. The grain size, although always microcrystalline, is not entirely uniform. In some thin sections the quartz grains are preferentially elongated with their long axes lying in the plane of the bedding. In other thin sections equidimensional interlocking grains

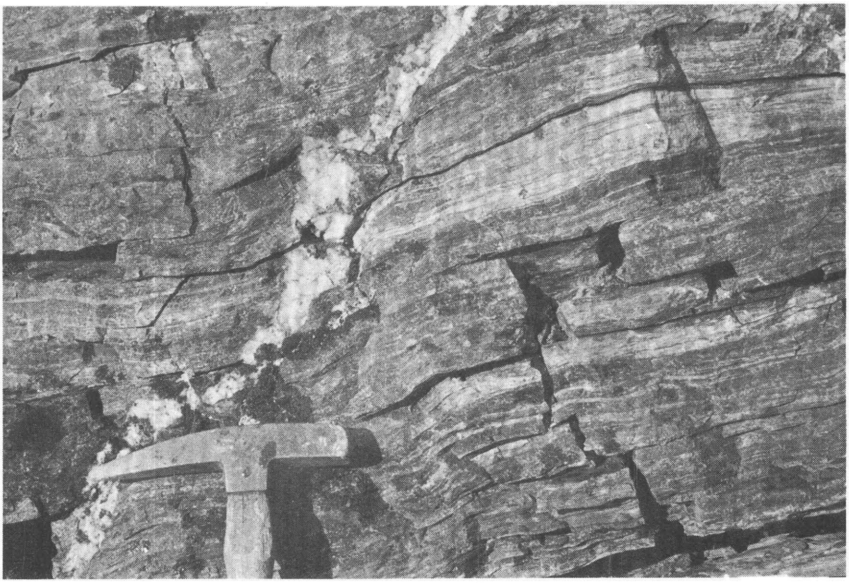

FIGURE 6.—Thinly laminated to very thin bedded light- and dark-gray banded metachert. Thin irregular quartz vein transects metachert on left side of photograph. Note well-developed jointing.

have slightly undulose extinction. Individual grains uncommonly have minute inclusions of dark organic or iron oxide material and small cavities that show negative relief. The dark color of the metachert is the result of thin, discontinuous, stretched, and flattened lenses and streaks of black opaque material which, in many places is present as stylolitic seams. Some of this opaque material is magnetite, but most could not be identified.

Impurities of argillaceous material originally deposited with the chert are now converted to small (0.01–0.05 mm) flakes of sericite and chlorite. These are scattered throughout the rock approximately parallel to the bedding. Carbonates are rarely found in the metachert. Calcite locally forms small crystal aggregates in quartz veins. In one thin section (unit 50, sec. 4, pl. 2) a few small (0.02–0.06 mm) rhombs of dolomite are present. The dolomite rhombs have a thin film of opaque to reddish-brown iron oxide material. Thin, discontinuous veinlets of coarser grained quartz transect the metachert. They commonly form a crisscrossing pattern; some are ptygmatic.

One of the most interesting features of the metachert are the small, elongated, ovate quartz aggregates with individual crystals 3–10 times larger than the surrounding microcrystalline quartz. These aggregates were seen in only a few of the thin sections, and show no well-defined pattern of crystallinity. They range in size from 0.1 to 0.4 mm. Their long axes are generally parallel to the bedding. These isolated quartz aggregates could represent either sand grains incorporated into the original sediment or radiolarian tests that have been stretched and flattened. Any organic remains would be difficult to recognize after recrystallization.

#### CALCAREOUS SANDSTONE MEMBER

The calcareous sandstone member (Dnc, pl. 1) consists chiefly of calcareous and dolomitic quartz wacke and quartz semischist with lesser amounts of phyllite, metachert, and metaconglomerate (secs. 1*A*, 2, and 3, pl. 2). With the exception of the carbonates, the quartz wacke and quartz semischist are identical to the wacke and semischist of the Neruokpuk Formation undivided. The phyllite and metachert are also similar to these previously described lithologies.

Irregular crystal aggregates of calcite replace both matrix and margins of detrital quartz. Calcite replaces the margins of detrital plagioclase, and small crystals are also found within the plagioclase. Dolomite replaces both detrital grains and matrix, preferentially forming small rhombs which commonly show brownish oxidation streaks along cleavage planes and a thin film of iron oxide around the rhombs. Siderite is less common than dolomite and is partly altered to a dark-reddish-brown iron oxide.

Metaconglomerate is locally interbedded with metachert (sec. 3, p. 107). The beds of metaconglomerate are very hard, resistant to erosion, light brown weathering, medium to thick, and lenticular. Clasts in the conglomerate range in size from pebble to cobble. Locally matrix greatly exceeds the amount of clasts, and pebbles and cobbles are scattered throughout the matrix. The metaconglomerate is composed of 40–70 percent angular to subangular white to medium-gray quartz and subordinate dark-gray chert. Plutonic and volcanic clasts are absent. The matrix is dark-gray microcrystalline metachert similar to the associated metachert beds.

## MEASURED SECTIONS

Four incomplete stratigraphic sections totaling about 2,200 feet were measured in the Neruokpuk Formation. The sections are illustrated on plate 2, and their location is shown on inset map *A*, plate 1. All the sections are described in descending stratigraphic order and are presented in the same succession on plate 2.

Section 1*A* (p. 99), an incomplete section of the calcareous sandstone member, was measured on the east side of Coke Creek. The contact between unit 16 of the Neruokpuk Formation and the overlying siltstone of the Kayak Shale is shown in figure 7. Because the beds on

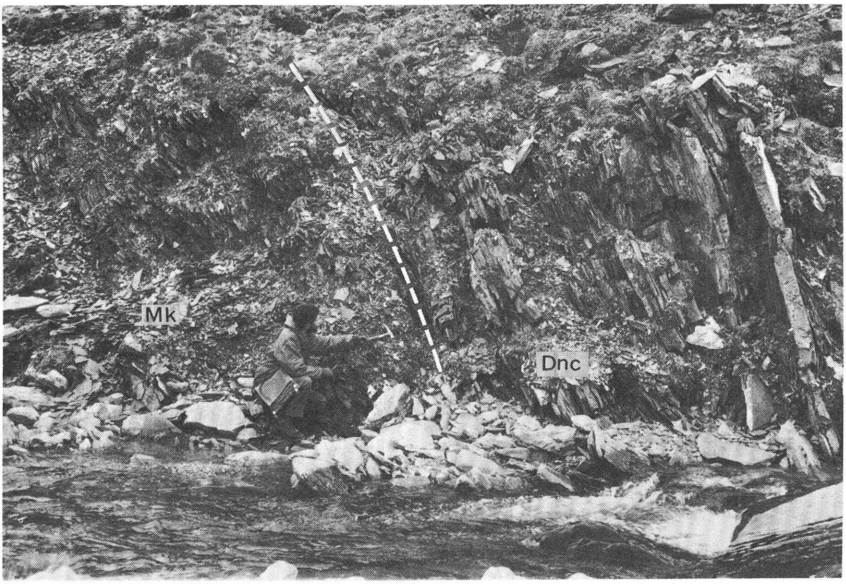


FIGURE 7.—Contact between calcareous sandstone member of the Neruokpuk Formation (Dnc, unit 16, section 1*A*, pl. 2) and Kayak(?) Shale (Mk, unit 17, section 1*B*, pl. 3). View looking east across Coke Creek. Beds are overturned and dip to the south.

either side of the contact show no appreciable difference in attitude, the contact is believed to be a disconformity. The beds, however, may be faulted.

Section 2 (p. 105) is an incomplete section of the calcareous sandstone member. Exposed in this section is the typical calcareous quartz wacke which is lithologically similar to the rocks mapped on Coke Creek and described in the lower part of Section 1*A*. The base of the section is covered by an alluvial fan and the top is covered by slope rubble. A total of 438 feet was measured.

Section 3 (p. 107) is also an incomplete section of the calcareous sandstone member. Most of the rocks in this section are metachert and metaconglomerate. The base and top of the section are covered by slope rubble. The contact with the overlying Kekiktuk Conglomerate is not exposed but is believed to be an angular unconformity. The overlying Kekiktuk Conglomerate and Kayak Shale (?) are described in section 6*A* and 6*B*.

Section 4 (p. 109) is an incomplete section that is characteristic of the undifferentiated Neruokpuk Formation (Dn on pl. 1). The rocks in this section are part of the quartzite-schist member described by Brosgé, Dutro, Mangus, and Reiser (1962, p. 2184). The base of the section is covered by an alluvial fan. The top of the section lies at an altitude of 4,050±20 feet, which is about 100 feet below a thrust fault.

### THICKNESS AND STRATIGRAPHIC RELATIONS

The base of the Neruokpuk Formation is not exposed in the mapped area. No accurate thickness for the formation in the Lake Peters area can be given because of the variable and discontinuous character of lithologic units within the formation, the absence of good marker units, and the presence of faults, which in many places are nearly bedding-plane faults. Lenticular intraformational breccia and conglomerate are present (sec. 2, unit 7, p. 106; sec. 3, units 5, 6, and 7, p. 108), but such breccia and conglomerate are of local extent. Major depositional breaks within the formation were not recognized. The upper contact of the calcareous sandstone member appears to be conformable with the overlying Neruokpuk Formation undivided.

Examination of cross section *B–B′* (pl. 1) indicates that a minimum thickness of 6,000 feet is exposed. If the two low-angle thrusts (believed to be of pre-Kekiktuk age, 83) shown on section *A–A′* (pl. 1) have little or no stratigraphic displacement, as indicated by the small amount of crosscutting in exposed parts, and if the dips of these thrusts do not increase with depth more than projected, then more than 10,000 feet of Neruokpuk Formation have been removed by erosion prior to deposition of younger rocks. However, this figure is speculative as the amount of stratigraphic displacement on these thrusts is unknown.

The Neruokpuk Formation is overlain by both the Upper Devonian(?) or Mississippian Kekiktuk Conglomerate and the Upper Mississippian Kayak(?) Shale. In most places the contact with the overlying rocks is an angular unconformity which is well exposed on the ridge immediately west of Lake Peters (fig. 8). Here a channel approximately 15 feet across and 3 feet deep has been cut into the Neruokpuk Formation. On Coke Creek the Kayak(?) Shale overlies the Neruokpuk Formation disconformably (fig. 7). Brosgé, Dutro, Mangus, and Reiser (1962, p. 2183–2184) and Sable (1965, p. 35) also reported the contact of the Neruokpuk Formation with younger rocks as an angular unconformity.

#### SOURCE AND MODE OF DEPOSITION

The rocks of the Neruokpuk Formation probably were derived from earlier sedimentary and metamorphic rocks. Quartz is by far the most abundant detrital constituent of the rocks. A predominance of detrital

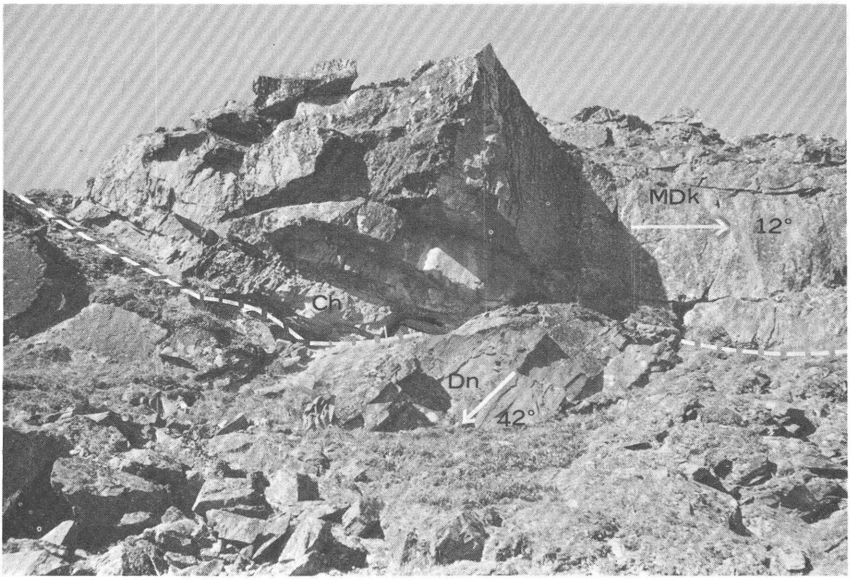


FIGURE 8.—Kekiktuk Conglomerate (MDk) overlying the Neruokpuk Formation (Dn) with angular unconformity on ridge immediately west of Lake Peters. The Kekiktuk Conglomerate strikes N. 75°W. and dips 12°NE. The Neruokpuk Formation strikes N. 75°E. and dips 42°SE. Note channel (Ch) cut into Neruokpuk Formation. Pack in foreground (lower left corner of outcrop labeled Dn) for scale. View is toward the west.

undulatory quartz, especially strongly undulose composite quartz grains, is viewed by some workers (Folk, 1961) as evidence of an original metamorphic terrane, although agreement on this is by no means universal (Blatt and Christie, 1963). Table 3 indicates that in section 4 (pl. 2) single undulose grains are the most common and single nonundulose grains are common. Composite grains are most abundant in the conglomerate of section 3 (pl. 2) but are present in all the thin sections examined. Plutonic or volcanic clasts are absent in the conglomerate. The absence of volcanic rock fragments precludes an immediate volcanic source. An immediate mafic plutonic source is also unlikely because of the rarity of pyroxene, hornblende, and biotite.

Conclusions regarding the source of the Neruokpuk Formation are necessarily tenuous for indeed these are the oldest rocks exposed in the Brooks Range or northwestern Yukon. Single and composite nonundulose grains, composite grains of quartz and plagioclase, detrital plagioclase, zircon, rutile, and varicolored tourmaline all may have an original igneous source. Two cycles of erosion, or one intense weathering cycle, would have eliminated the less stable mafic minerals. Tourmaline, zircon, and rutile, now found in the Neruokpuk Formation, are considered detrital constituents; however, these minerals could have formed authigenically in an earlier sediment (Pettijohn 1957, p. 669–670). The presence of composite stretched metamorphic quartz grains with inclusions of muscovite, and the abundance of undulose quartz grains, many of which have deformation lamellae, suggest that a metamorphic rock, perhaps a quartzite, was also available as a source. The only definite conclusion drawn regarding the source of the Neruokpuk Formation is that the provenance was sedimentary and perhaps metamorphic in nature.

Rocks of the Neruokpuk Formation in the mapped area are poorly sorted angular quartz wacke and phyllite, which are interbedded with intraformational breccia and conglomerate and metachert. Slump structures, graded bedding, and the general absence of clean quartzite, crossbedding, and ripple marks are typical of a graywacke environment and indicate rapid deposition in an unstable basin. Furthermore, the close association of metachert and local conglomerate (unit 6 in sec. 3, pl. 2) (whose matrix is virtually the same composition as the overlying and underlying metachert) suggests turbidity current transport of the clastic material into the depositional environment of the chert. Thus, the rocks of the Neruokpuk Formation seem to record transportation and deposition by turbidity flows in a subaqueous environment. The presence of phyllite up to 80 feet thick indicates that periods of quiescence must have prevailed intermittently.

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### AGE AND CORRELATION

The relative age of the Neruokpuk Formation is not known, since no fossils were found.[2] Previous authors have suggested the formation may be Precambrian (Norris and others, 1963; Payne and others, 1951) or pre-Carboniferous (Leffingwell, 1919). Brosgé, Dutro, Mangus, and Reiser (1962, p. 2184) tentatively correlated their phyllite-chert member of the Neruokpuk Formation with similar rocks in the southern Brooks Range that contain Late Devonian fossils. They correlated a limestone member in the Neruokpuk Formation with the Skajit Limestone in the southern Brooks Range; the Skajit contains Middle(?) and Late Devonian fossils. The oldest quartzite-schist member "may represent different stratigraphic intervals at different localities" (Brosgé and others, 1962, p. 2184–2185), but these authors considered it to be Devonian or pre-Devonian(?) in age. Since no fossils were found in the mapped area, the writer follows Brosgé, Dutro, Mangus, and Reiser (1962) in assigning the Neruokpuk Formation a Devonian or older age. However, the writer feels it noteworthy to mention that the hiatus, represented by the unconformity at the base of the Kekiktuk Conglomerate, implies folding, uplift, and erosion of at least 6,000 feet of Neruokpuk rocks prior to Kekiktuk deposition. If this is so, the Neruokpuk Formation in the Lake Peters area may be considerably older than Devonian and could represent lower Paleozoic sediments.

A tentative correlation of the Neruokpuk Formation in the Lake Peters area with other units of the Neruokpuk Formation in other areas in northeastern Alaska is shown in figure 9. This correlation is based solely on gross lithologic similarities and is included here with scepticism. The writer feel that a valid correlation of pre-Kekiktuk rocks in the eastern Brooks Range can be made only when detailed stratigraphic, petrographic, and structural analyses have been completed in more areas.

Rocks mapped as the phyllite-chert member of Brosgé, Dutro, Mangus, and Reiser (1960, 1962) were not mapped as a separate unit in the Lake Peters area by the writer. Most of that member in the Lake Peters area is included in the Neruokpuk Formation undivided; part of it is included in the calcareous sandstone member. The 1,200-foot section of the phyllite-chert member 3 miles west of Lake Peters, de-

[2] Two concretions, resembling a pelecypod, were found in the Neruokpuk Formation. These specimens were sent to J. T. Dutro, Jr., who reported: "A number of us have examined the two specimens from the Neruokpuk Formation (R–335) and have concluded that there is no demonstrable organic material present. Although one of the objects crudely resembles a large clam, it, like the other, is probably a deformed concretion" (written commun., 1964). He further stated that he also had found similar concretionary objects in the Neruokpuk Formation which at first were thought to be fossils but "they were not and neither are these specimens."

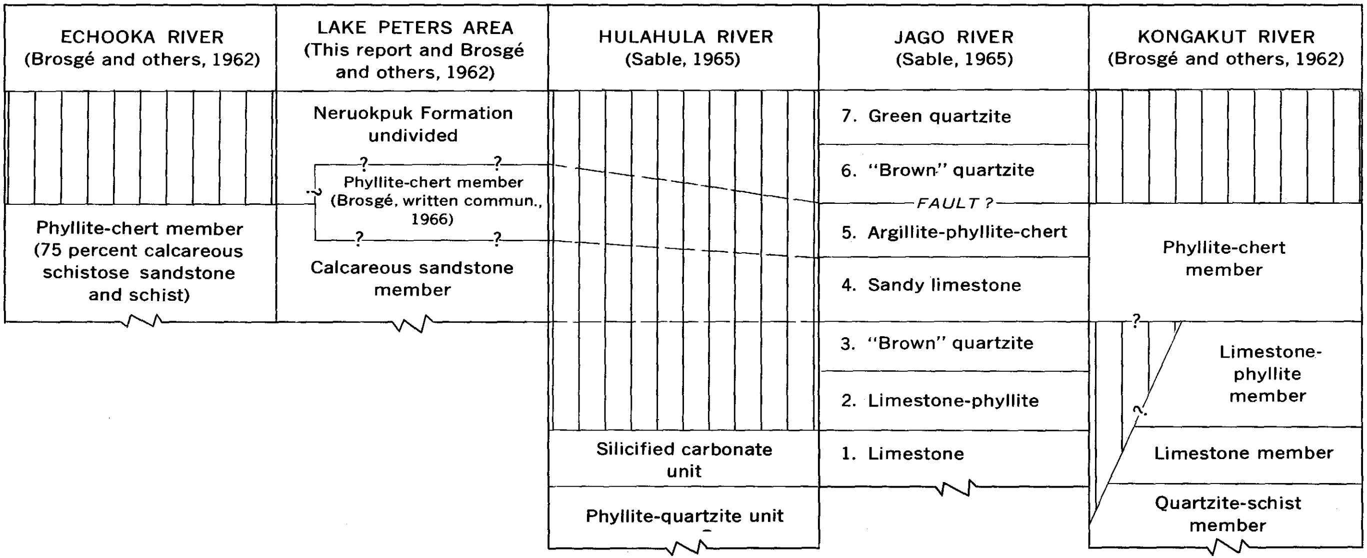


FIGURE 9.—Tentative lithologic correlation of units within the Neruokpuk Formation in northeastern Alaska.

scribed by Brosgé, Dutro, Mangus, and Reiser (1962, p. 2184), as well as most of the rocks that they (1960) observed in the field and mapped as the phyllite-chert member in the Lake Peters area lie within a stratigraphic interval 1,000–2,000 feet thick directly above the calcareous sandstone member (W. P. Brosgé, written commun., 1966). The "limestone and calcareous siltstone" east of Lake Peters (Coke Creek) that was assigned to the phyllite-chert member (Brosgé and others, 1962, p. 2184), as well as the rocks in the lower part of the section west of Lake Peters that were mapped as phyllite-chert member but not described, are included here in the calcareous sandstone member. Consequently the rocks that Brosgé, Dutro, Mangus, and Reiser (1962) assigned to the phyllite-chert member in the Lake Peters area, although locally truncated by the pre-Kekiktuk unconformity, do not lie at the stratigraphic top of the Neruokpuk Formation as they indicated (1962, p. 2177, fig. 2); instead, they underlie the upper few thousand feet of the Neruokpuk Formation undivided (pl. 1).

Rocks previously assigned to the phyllite-chert member in the Lake Peters area are similar to those of Sable's unit 5 (argillite-phyllite-chert) on the Jago River, whereas the underlying calcareous sandstone member is similar to Sable's unit 4 (sandy limestone) (Sable, 1965, p. 17–20). The phyllite-chert member is the only member mapped on the Echooka River (Brosgé and others, 1960). It contains 75 percent moderately calcareous schistose sandstone and schist (Brosgé and others, 1962, p. 2184) and, therefore, is lithologically similar to the calcareous sandstone member at Lake Peters. The base of the phyllite-chert member is believed by Brosgé, Dutro, Mangus, and Reiser (1962, p. 2182) to represent a regional unconformity in the eastern Brooks Range. This stratigraphic relation cannot be verified in the Lake Peters area because the base of the calcareous sandstone member is not exposed there. Rocks mapped as Neruokpuk Formation undivided on plate 1 are equivalent, at least in part, to the quartzite schist member of Brosgé, Dutro, Mangus, and Reiser (1962, p. 2177, fig. 2), and also to the green and brown quartzite of Sable (1965, p. 17–19). Thus the Neruokpuk Formation undivided in the Lake Peters area belongs to the upper part of the Neruokpuk section in the northeastern Brooks Range.

## DEVONIAN(?) AND MISSISSIPPIAN

### KEKIKTUK CONGLOMERATE

#### NAME AND DEFINITION

Brosgé, Dutro, Mangus, and Reiser (1962, p. 2186) gave the name Kekiktuk Conglomerate to a quartzitic chert-pebble conglomerate that unconformably overlies the Neruokpuk Formation and underlies the Kayak(?) Shale in the northeastern Brooks Range.[3] The type section was measured on the west side of Whistler Creek at lat 69°19′ N., long 145°09′ W. (Brosgé and others, 1962, p. 2195).

The conglomerate was mapped by Whittington and Sable (1948, p. 4–5) as the basal part of the Noatak(?) Formation, a name now restricted to the western part of the Brooks Range (Bowsher and Dutro, 1957, p. 3). Brosgé, Dutro, Mangus, and Reiser (1952, p. 8) included the conglomerate in the basal part of the Kayak Formation, but in a paper published in 1960 they separated the conglomerate from the Kayak Shale as an "unnamed conglomerate." In the Romanzof Mountains, Sable (1965, p. 31, 32) mapped the Kekiktuk Conglomerate and Kayak(?) Shale as one unit; however, the coarse clastic rocks with interbedded shale that underlie the Kayak(?) Shale were referred to the Kekiktuk Conglomerate.

#### OCCURRENCE

The Kekiktuk Conglomerate is prominently exposed as a ridge-capping conglomerate on the east and west sides of Lake Peters and west of Carnivore Creek in the southwestern part of the mapped area (pl. 1). West of Whistler Creek it forms a resistant bluff along the northwest valley wall. It is covered by glacial and alluvial deposits where it is crossed by Whistler Creek, but crops out on a ridge between Whistler Creek and Lake Peters. East of Lake Peters the Kekiktuk Conglomerate is thin, and locally absent, and it extends southeast of Lake Peters to Katak Creek.

Brosgé, Dutro, Mangus, and Reiser (1962, p. 2185) stated that the conglomerate is widespread on the north side of the Brooks Range east of the Canning River.

#### CHARACTER

The Kekiktuk Conglomerate is composed of resistant, generally massive quartzite interbedded with beds and lenses of pebble-and-cobble conglomerate. Thin lenses of dark-gray siltstone are locally present. The Kekiktuk Conglomerate is light to dark gray and weathers light gray and pale yellowish brown to reddish brown. The pebble-and-cobble conglomerate beds are found most commonly at the base of the formation, although festoon(?) crossbeds and discontinuous beds of conglomerate are generally present throughout. In the southernmost exposures, west of Carnivore Creek, no conglomerate is

[3] The Kekiktuk Conglomerate was named for the stream that drains Lake Peters. The most recent map (Mount Michelson, Alaska, scale 1 : 250,000, 1956) does not show a name for the stream that drains Lake Peters. The Kekiktuk River drains Lake Schrader (pl. 1).

present. Exposures are not sufficiently extensive to indicate any lateral change in grain size in the mapped area.

The conglomerate pebbles and cobbles are predominantly white vein quartz with subordinate pebbles of medium- and dark-gray metachert similar to that of the Neruokpuk Formation. Phyllite pebbles are rare. Pebbles of quartzite and quartz-tourmaline rock are present. The quartzite pebbles are of a cleaner variety than the quartz wacke of the Neruokpuk Formation and include only minor amounts of sericite and chlorite. The fabric of the pebbles is unidirectional and is similar to that of the pebbles in the cleaner quartz wacke in the Neruokpuk Formation. The matrix of the conglomerate is similar to that of the associated quartzite beds.

The quartzite of the Kekiktuk Conglomerate consists of angular to subangular quartz grains and some dark-gray chert grains, in a matrix of quartz and pyrophyllite. The quartzite fractures across the grains, although as pyrophyllite increases as a cementing matrix, the quartzite becomes less cohesive. Sericite is present locally as a minor constituent. The grain size of the quartzite ranges from medium sand to granule size, and the finer grained quartzite tends to occur in the upper part of a single bed. The quartz grains are predominantly single grains with both undulose and nonundulose extinction, although composite grains are not uncommon. Vacuoles are common in the quartz grains and show fluid inclusions with enclosed bubbles of gas. Many of the inclusions are localized along curved or straight fractures within grains. Mineral inclusions found most commonly include muscovite and tourmaline. Zircon and rutile inclusions are rare. All quartzite specimens collected from the Kekiktuk Conglomerate were stained to determine whether potassium feldspar and plagioclase were present, and many were examined in thin section. Plagioclase is rare, and potassium feldspar is not present in any of these specimens.

The quartz matrix consists of quartz silt and varying amounts of secondary quartz occurring as overgrowths on detrital grains and as anhedral interstitial fillings. Quantitative determinations of the cement were not made, but examination of thin sections shows an obvious increase of secondary quartz as overgrowths, along with less interpenetration of grain boundaries, in nonfolded, virtually flat-lying ridge-capping beds than in the thin discontinuous band of quartzite and conglomerate that crops out east and southeast of Lake Peters. Strained quartz grains show more interpenetration than unstrained quartz grains.

Pyrophyllite forms thin yellowish-gray films filling the interstices between the quartzite grains. It is present as fine compact feltlike aggregates of small clear crystals that range from 0.02 to 0.1 mm in length. Some of the larger crystals form poorly developed rosettes. The fine-grained nature of the mineral prevented precise optical determinations. The pyrophyllite occurs in platy crystals slightly broader than crystals of the less common sericite.

The pyrophyllite content ranges from 0 to slightly more than 40 percent (by weight) of a particular sample, but in general the content is less than 20 percent of the rock. The finer grained dark-gray siltstone lenses contain more pyrophyllite than does the coarser grained cleaner quartzite. Pyrophyllite replaces the original matrix, quartz overgrowths, and detrital quartz grains; the replacement is so complete in places that it is difficult to identify textures of the original matrix. In a few places small irregular patches of unreplaced quartz grains remain within the pyrophyllite. In extreme cases of pyrophyllitization there are no original detrital quartz outlines, and only isolated fragments of the original quartz grains remain. Strained quartz grains show a greater tendency to be replaced than do unstrained grains. Pyrophyllite is present in minor amounts in the underlying Neruokpuk Formation and in the overlying Kayak(?) Shale, but only near the contacts of those formations with the Kekiktuk Conglomerate.

Heavy minerals in the Kekiktuk Conglomerate include tourmaline, cassiterite, ilmenite, sphene, and zircon. Of these, only tourmaline is abundant. The grains are generally less than 1 mm in maximum diameter, are angular, and show little evidence of abrasion. A few small granules and pebbles of quartz-and-tourmaline rock are present. Both tourmaline and cassiterite increase noticeably toward the east. One thin section of the conglomerate near Katak Creek shows several grains of tourmaline, cassiterite, sphene, magnetite, and ilmenite. Cassiterite is small (0.1–0.8 mm) and angular; the color varies from brownish orange to wine red with well-developed zones. Sphene is generally elongate, is of similar size, and is yellowish green to light brown. Ilmenite occurs as slightly larger grains (0.6–1 mm) and is opaque and whitish gray in reflected light.

A glacial erratic found on Katak Creek is similar in composition to the Kekiktuk Conglomerate. It is composed of rounded pebbles and cobbles of white vein quartz, gray chert, quartzite, and quartz-tourmaline rock; some of the pebbles and cobbles are as large as 14 inches in diameter. The matrix of the conglomerate contains pyrophyllite. The quartz-tourmaline rock is filled with microscopic liquid inclusions. Many liquid inclusions, microscopic in size, can be seen in thin sections of the quartz-tourmaline rock. The optical properties of the tourmaline are as follows:

$$N_o = 1.667 \pm 0.003$$
$$N_e = 1.645 \pm 0.003$$

Pleochroic formulae in sections 0.03 mm thick

$$O(Z) = \text{light-greenish-blue}$$
$$E(X) = \text{very pale yellowish green}$$

Using the data given by Winchell and Winchell (1951, p. 465–467) the tourmaline would be classified as schorlite. These optical properties are similar to those of the small-grained tourmaline found throughout the Kekiktuk Conglomerate. Moreover, the indices are nearly the same as those given by Sable (1965, p. 161) for tourmaline from veinlets and replacement bands in the granitic rocks of the Romanzof Mountains.

### MEASURED SECTIONS

Two stratigraphic sections (secs. 5 and 6) were measured in the Kekiktuk Conglomerate. These sections are illustrated on plate 3, and their location is shown on inset map *A*, plate 1. The sections are described in descending stratigraphic order and are presented in the same succession as on plate 3.

Section 5 (p. 116) is an incomplete section of the ridge-capping conglomerate on the west side of Lake Peters. Here 98 feet of the Kekiktuk Conglomerate overlies the Neruokpuk Formation with an angular unconformity. The overlying Kayak(?) Shale and an unknown amount of the Kekiktuk Conglomerate have been removed by erosion.

Section 6*A* (p. 118) was measured on the west side of the ridge between Whistler Creek and Lake Peters. The contact with the underlying Neruokpuk Formation is covered, but it is believed to be an angular unconformity. This section was measured only 0.3 mile northwest of section 5. A total of 40 feet was measured in section 6*A* as compared to a minimum thickness of 98 feet measured in section 5. This abrupt change in thickness is characteristic of the formation.

### THICKNESS AND STRATIGRAPHIC RELATIONS

The thickness of the Kekiktuk Conglomerate in the Lake Peters area ranges from 0 to about 350 feet, but is generally less than 150 feet. On the west side of Whistler Creek, Brosgé, Dutro, Mangus, and Reiser (1962, p. 2195) measured 295 feet of Kekiktuk Conglomerate. On the ridge west of Carnivore Creek about 350 feet is exposed. An incomplete section of 98 feet was measured (sec. 5) on the ridge west of Lake Peters. On the ridge east of Lake Peters about 130 feet is exposed. Immediately east of Lake Peters and on Coke Creek the conglomerate is a thin discontinuous unit and does not exceed 70 feet in thickness.

Between the conglomerate and the underlying Neruokpuk Formation is a profound angular unconformity (fig. 8). The contact with the overlying Kayak(?) Shale is generally covered with slope rubble, but where the contact is exposed, the bedding planes are parallel. The quartzite and conglomerate of the Kekiktuk Conglomerate contrast sharply with the overlying argillite of the Kayak(?) Shale and indicate a major change in depositional environment. This abrupt change in lithology suggests a hiatus, but not necessarily one of great magnitude. The upper part of the Kayak(?) Shale contains marine fossils and this indicates the beginning of Mississippian sea transgression in the area. No evidence is available in the Lake Peters area that proves or disproves the presence of a disconformity between these two formations, and lack of fossil evidence impedes further clarification.

#### SOURCE AND MODE OF DEPOSITION

The Kekiktuk Conglomerate contains quartz-tourmaline pebbles and a heavy mineral suite of tourmaline, cassiterite, sphene, and ilmenite. Plagioclase is rare and potassium-feldspar is absent in the samples collected. The angularity of the heavy minerals and quartz grains suggests that if feldspar were present in the source area it would not have been destroyed by transportation and would be present in Kekiktuk rocks. An eastward increase of tourmaline and cassiterite suggests a source to the east.

About 20 miles southeast of Lake Peters, intrusive rocks of Late Devonian(?) age (Sable, 1965, p. 111, 174) exposed in the Romanzof Mountains are chiefly granitic in composition. If the source of the Kekiktuk Conglomerate was to the southeast in the Romanzof Mountains, then the general absence of feldspar in the Kekiktuk Conglomerate suggests that this igneous mass was not unroofed during Kekiktuk deposition; however, quartz-tourmaline veins and anomalously high percentages of tin in stream sediment samples from some drainages in the Romanzof Mountains, as reported by Sable (1965, p. 208), do support the theory of a source to the east. Thus the quartz-tourmaline pebbles and the cassiterite in the Kekiktuk Conglomerate may be genetically related to intrusive rocks in the Romanzof Mountains.

Light- and dark-gray chert pebbles in the Kekiktuk Conglomerate are identical in hand specimen and thin section to the cherts found in the Neruokpuk Formation. Phyllitic pebbles were noted in the field, but are relatively rare. Quartzite pebbles are similar to the cleaner quartz wacke of the Neruokpuk Formation.

In conclusion it seems that the source of the Kekiktuk Conglomerate was to the east or southeast in an area near the present-day Romanzof Mountains. Pebbles and cobbles in the Kekiktuk Conglomerate were largely derived from the Neruokpuk Formation. The main granitic mass in the Romanzof Mountains was probably not unroofed during Kekiktuk time, but offshoots of the granitic body were available as a source.

The general appearance of the Kekiktuk Conglomerate suggests deposition as sheets or channels, most probably as a fluvial deposit of a piedmont or flood-plain type in which streams were shifting back and forth and spreading their load over a relatively broad area. Local lenses of dark-gray siltstone may represent concentrations of clayey silt which accumulated in swales.

### AGE AND CORRELATION

The difficulties in dating and correlating the Kekiktuk Conglomerate are due to lack of paleontologic evidence and to complex stratigraphic relationships. The writer found no fossils in the Kekiktuk Conglomerate, and Brosgé, Dutro, Mangus, and Reiser (1962, p. 2185) reported that they found only indeterminate plant fragments in it. On the basis of stratigraphic position, Brosgé, Dutro, Mangus, and Reiser assigned it a Late(?) Devonian or Mississippian age. The underlying Neruokpuk Formation so far has been found to be unfossiliferous. Some of its beds seem to be lithologically similar to other beds in the southern Brooks Range that contain Middle(?) and Late Devonian fossils. The overlying Kayak(?) Shale contains Late Mississippian fossils in the Lake Peters area.

The base of the Kekiktuk Conglomerate represents a major unconformity. The Kekiktuk Conglomerate is lithologically similar to the Late Devonian Kanayut Conglomerate exposed in the central and southeastern parts of the Brooks Range (Bowsher and Dutro, 1957, p. 5; Brosgé and others, 1962, p. 2182). The Kanayut Conglomerate is over 5,000 feet thick in the central Brooks Range and rests conformably on rocks of Late Devonian age. It thins eastward into the eastern Brooks Range, where it is locally absent. It is possible that the Kekiktuk Conglomerate is a lateral equivalent of the Kanayut. If the two conglomerates are equivalent, this fact suggests a northeastward overlap on an Upper Devonian erosional surface.

Another similar thick sequence of Upper Devonian Conglomerate and sandstone has been mapped in northwestern Canada (Martin, 1959, p. 2421). This conglomerate and sandstone may be equivalent to or at least contemporaneous with the Kanayut Conglomerate in the central Brooks Range.

Part of the eastern Brooks Range must have stood above sea level in Late Devonian time and been the source of the Late Devonian clastics to which the Kekiktuk Conglomerate may be equivalent. The thin discontinuous nature of the Kekiktuk Conglomerate, plus the fact that the base represents a major unconformity, suggests that it was marginal to or within an area of uplift during the Late Devonian.

## KAKAK(?) SHALE

### NAME AND DEFINITION

Bowsher and Dutro (1957, p. 6) gave the name Kayak Shale to 960 feet of early Mississippian black shale, argillaceous limestone, and sandstone in the central Brooks Range near Shainin Lake. The formation lies disconformably above the Kanayut Conglomerate and disconformably below the Wachsmuth Limestone of the Lisburne Group. In the type area, the Kayak Shale consists of a basal sandstone member, a lower shale member, an argillaceous limestone member, an upper shale member, and a red limestone member. Eastward a similar sequence of late Mississippian rocks grades from a basal sandstone through shale to interbedded shale and limestone at the top. This sequence has been called Kayak (?) Shale by Brosgé, Dutro, Mangus, and Reiser (1962, p. 2185). Continuity with the type Kayak has not been established.

In the Lake Peters area the Kayak(?) Shale overlies both the Neruokpuk Formation and the Kekiktuk Conglomerate and underlies the Lisburne Group.

### OCCURRENCE

The Kayak(?) Shale is exposed as a thin east-west-trending unit across the central part of the mapped area. The formation lies between the more resistant Kekiktuk Conglomerate or Neruokpuk Formation and rocks of the Lisburne Group (fig. 10). It is poorly exposed; generally talus from the Lisburne Group covers it. On aerial photographs the Kayak(?) Shale can be traced as a thin relatively nonresistant dark-colored unit below the lighter colored carbonate rocks of the Lisburne Group.

### CHARACTER

The lower and most widely exposed part of the Kayak(?) Shale consists of argillite, slate, siltstone, and quartzite. The upper part of the formation characteristically contains bedded chert, cherty, sandy and argillaceous limestone, limestone, and minor thin shale beds. Basal argillite and siltstone are dark-gray to grayish-black and are carbonaceous; the rocks are commonly nonresistant and locally weather to small chips. The argillite and siltstone occur in sets of beds ranging from 3 to more than 100 feet in thickness. Essential minerals are quartz, sericite, and minor chlorite; pyrophyllite is found locally in argillite beds within a few feet of the underlying Kekiktuk Conglomerate. Quartzite beds, similar to those of the Kekiktuk Conglomerate, are present locally near the base of the formation, but do not contain pyrophyllite. These quartzite beds have been mapped as part of the Kayak(?) Shale where they occur above the basal dark-gray siltstone

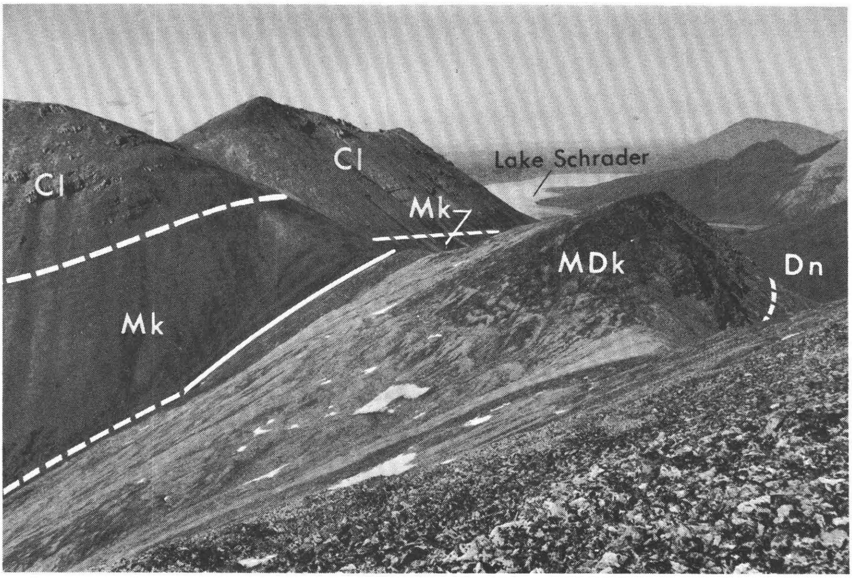


FIGURE 10.—Looking northeast from ridge west of Whistler Creek at Kayak(?) Shale (Mk) lying below Lisburne Group (Cl) and above resistant Kekiktuk Conglomerate (MDk). Kekiktuk Conglomerate overlies the Neruokpuk Formation (Dn) with angular unconformity.

or argillite unit. The upper chert, cherty and argillaceous limestone, and limestone beds are thin to medium in thickness, irregularly bedded, and contain varying amounts of dolomite and fine silt-size detrital quartz. The units range from 3 to 40 feet in thickness. Thin intercalated shale occurs throughout the upper part of the formation. One shale unit (unit 29, sec. 1*B*, pl. 3) near the top of the formation is similar in hand specimen to the lower argillite, but is less resistant and does not contain chlorite as the lower unit does.

#### MEASURED SECTIONS

Two stratigraphic sections in the Kayak(?) Shale indicate the character of the formation in the Lake Peters area. These sections are shown on plate 3, and their location is given on inset map *A*, plate 1. The sections are described in descending stratigraphic order in the same succession as on plate 3.

Section 1*B* (p. 101) is a continuation of section 1*A* measured on the east side of Coke Creek. Here a disconformity separates the Kayak(?) Shale from the underlying Neruokpuk Formation (fig. 7), and the contact with the overlying Lisburne Group is gradational. The section was measured at the only locality in the mapped area where the contact between the Kayak(?) Shale and the Lisburne Group is well exposed. The lower argillite unit (unit 17) is probably equivalent to the argillite (unit 4) measured in section 6*B*.

Section 6*B* (p. 118) is a continuation of section 6*A* (pl. 3). Bedding planes of the Kayak(?) Shale and the underlying Kekiktuk Conglomerate are parallel. The top of the formation is not exposed. Rubble of limestone and cherty limestone, similar to the upper part of the formation in section 1*B*, are present in talus below the Lisburne Group approximately 1,000 feet northeast of this section. This evidence indicates that the covered part of the formation here is similar to the section measured on Coke Creek.

#### THICKNESS, DEPOSITIONAL CHARACTER, AND STRATIGRAPHIC RELATIONS

The thickness of the Kayak(?) Shale ranges from 85 to 400 feet in the Lake Peters area. One complete section (sec. 1*B* on Coke Creek) is 237 feet thick, but this does not represent the maximum thickness in the mapped area. Brosgé, Dutro, Mangus, and Reiser (1962, p. 2195) measured 85 feet of Kayak(?) Shale west of Whistler Creek. East of Whistler Creek (sec. 6*B*) a measured 101-foot section of the lower siltstone and argillite is overlain by an estimated 250 feet of covered limestone and cherty limestone. The headwaters of Karen Creek expose slightly more than 300 feet of Kayak(?) Shale. From Coke Creek to Katak Creek, the formation ranges from 300 to 400 feet in thickness. In the Romanzof Mountains the thickness of the Kayak(?) Shale ranges from 0 to 400 feet (Sable, 1965, p. 35). This includes, however, sandstone and conglomerate that are lithologic equivalents to the Kekiktuk Conglomerate.

Fossils are present both in the lower and upper beds of the Kayak(?) Shale. Plant fossils have been found in the lower part of the Kayak(?) Shale a few miles west of Lake Peters (S. Schindler, oral commun., 1961). On the Canning River about 25 miles west of Lake Peters, Gryc and Mangus (1947, p. 5) found Carboniferous fossil plants in black shale overlying the Neruokpuk Formation. George Gyrc (oral commun., 1965) stated that coaly stringers consisting of macerated plant fragments are present and that delicate fossile leaves, well preserved in shales, could not have been transported far before burial. Lithostrotionoid corals are found in the upper part of the Kayak(?) Shale on Coke Creek.

The following environmental succession may be inferred from the sequence of lithologic and fossil types. After fluvial deposition of the Kekiktuk Conglomerate, transgressing Mississippian seas deposited black mud and silt in a paralic swamp or lagoonal environment where vegetation was abundant. The cleaner quartzite in the lower part of the Kayak(?) Shale may represent reworked clastics from the Kekiktuk Conglomerate washed in by streams or sheet floods. Later, the environment changed and the deposition of the Kayak(?) carbonate deposits with minor inflows of sand gradually changed to the deposition of dominantly carbonate deposits of the younger Lisburne Group.

The contact with the Lisburne Group is well exposed only at Coke Creek (sec. 1*B*). Here the contact seems to be gradational. The contact was placed at the top of a prominent reddish-brown limestone (unit 30, sec. 1*B*) which is similar to the red limestone described in the type area of the Kayak Shale (Bowsher and Dutro, 1957). Sable (1965, p. 49) also suggested that the contact between the Kayak(?) Shale and the Lisburne Group is gradational. Brosgé, Dutro, Mangus, and Reiser (1962, p. 2190) stated that at Lake Peters the rocks of the Lisburne Group rest with apparent conformity on the Kayak(?) Shale. The recognition of the upper limit of the Kayak(?) Shale is complicated because the contact with the overlying Lisburne is covered in most places and is gradational where exposed. Fossils found in both the Kayak(?) Shale and the lower part of the Lisburne Group at Lake Peters are of Late Mississippian age; therefore any hiatus between these formations cannot have been great.

The variable thickness of the Kayak(?) Shale may be due to (1) local unequal rates of deposition, (2) deposition on irregular terrain, (3) inclusion of basal Lisburne units with the Kayak(?) Shale, (4) some erosion prior to Lisburne deposition, and (5) unrecognized folding or faulting. The first three of these possibilities seem to the writer to be the most valid.

#### AGE AND CORRELATION

Both the upper part of the Kayak(?) Shale and the Alapah Limestone at Lake Peters contain marine fossils of Late Mississippian age. The Kayak(?) Shale in the eastern Brooks Range was reported to be Late Mississippian in age by Brosgé, Dutro, Mangus, and Reiser (1962, p. 2186). In contrast, in the central Brooks Range, at the type locality, the Kayak Shale contains a marine fauna of Early Mississippian age (Bowsher and Dutro, 1957, p. 6), and the Wachsmuth Limestone, which it underlies disconformably, also contains marine fossils of Early Mississippian age. Thus in the type area both the lower Lisburne Group and the Kayak Shale are of Early Mississippian age, whereas in the eastern Brooks Range, they both are of Late Mississippian age.

The Kayak Shale cannot be continuously traced from the type locality to the Lake Peters area, but the Kayak(?) Shale in the eastern Brooks Range is of similar lithology and also underlies the Lisburne Group. The similar position and lithology suggest relationships. The contact in the type area is a disconformity; in the Lake Peters area the contact is gradational although a disconformity may exist.

The areal and time relationship of the two formations and the contact between them suggest that the Kayak(?) Shale was deposited by a northeasterly or easterly transgressing sea and is a rock unit which crosses time boundaries. When detailed mapping has been completed, it may be found that the Kayak Shale is simply a facies representing marginal deposition during the gradual transgression of a Mississippian sea.

## MISSISSIPPIAN AND PENNSYLVANIAN(?)

### LISBURNE GROUP

#### NAME AND DEFINITION

In his exploration of the upper Anaktuvuk River valley in the central Brooks Range, Schrader (1902, p. 241–243) gave the name Lisburne Formation to a dominantly light-gray limestone that resembled a limestone and shale sequence at Cape Lisburne. Leffingwell (1919, p. 108–113) referred to a similar sequence of dominantly carbonate rocks in the Canning River region as the Lisburne Limestone. In the Shainin Lake area, 165 miles southwest of Lake Peters, Bowsher and Dutro (1957, p. 4–6) defined the Lisburne Group as a sequence of carbonate rocks and divided it into two formations. The lower formation, the Wachsmuth Limestone (Lower Mississippian), consists of 1,230 feet of shaly limestone, crinoidal limestone, dolomite, and banded chert-limestone. The upper formation, the Alapah Limestone (Upper Mississippian), is 970 feet thick and is divided into nine members. The lower four members, generally dark colored, are separated from the four upper light-colored members by a black chert-slate member that pinches out east of Shainin Lake. The Alapah Limestone disconformably overlies the Wachsmuth Limestone in the type area.

Subsequent to the completion of the fieldwork of this report, Brosgé, Dutro, Mangus, and Reiser (1962, p. 2187–2192) extended the name Lisburne Group into the eastern Brooks Range and recognized the Wachsmuth Limestone and the Alapah Limestone of Late Mississippian age and a new unit, the Wahoo Limestone of Pennsylvanian(?) and Permian age. The Wahoo Limestone overlies the Alapah and is present throughout the eastern Brooks Range.[4]

[4] Concerning separation of the Lisburne Group in the eastern Brooks Range, Brosgé, Dutro, Mangus, and Reiser (1962, p. 2187) stated:

The Lisburne is a relatively unvaried sequence of carbonate rocks with few marker beds. Terrigenous clastics are rare. Lithologic units in the eastern Brooks Range have been differentiated on the color value (shades of gray) of the carbonates, the presence of dolomite and disseminated silica, and the abundance of shaly thin-bedded limestone and clay shale * * *. Because most of the distinctive features are not restricted to any one unit, the formations and members are based on gross lithologic aspect.

The Wachsmuth Limestone thins eastward; consequently it is absent at Lake Peters. On the other hand, the Alapah Limestone thickens eastward until it is more than 1,300 feet thick in the eastern Brooks Range; here it is informally divided into two members (Brosgé and others, 1962). The lower member is a dark, somewhat shaly limestone, tentatively considered to be equivalent to the lower four members of the Alapah Limestone in the type area. The upper member is a silicified, dolomitic, lighter colored limestone equivalent to the upper four members of the Alapah Limestone in the type area. The Wahoo Limestone is also divided into two informal members. The lower member is characterized by the lack of dark-gray limestone and by an abundance of medium- and light-gray coarse-grained limestone and lithographic limestone. The upper member, not recognized at Lake Peters, consists of coarse-grained crinoidal limestone interbedded with shale and shaly limestone.

In the Peters Lake area the writer mapped the dominantly carbonate sequence above the Kayak (?) Shale and below the Sadlerochit Formation collectively as the Lisburne Group (pl. 1). From the stratigraphic work of Brosgé, Dutro, Mangus, and Reiser (1962), it has been possible to rework the field data and to recognize the lithologic equivalents of the Alapah and Wahoo Limestones. Rocks similar to the lower member of the Alapah Limestone are referred to as the Alapah Limestone in the stratigraphic sections. The complex folding and the presence of light- to dark-gray fine- and coarse-grained limestone throughout the entire carbonate sequence made the contact between the Alapah and Wahoo Limestones difficult to determine. A section of limestone measured at the top of the Lisburne Group is referred to as Wahoo (?) Limestone.

#### OCCURRENCE

The carbonate sequence of the Lisburne Group is the most extensive unit in the folded and faulted mountain system north of the Brooks Range. In the Lake Peters area it is distinguished from all other formations by its gray to light-gray weathered surfaces and its resistance to erosion. The southern exposures (pl. 1) form resistant ridges and cliffs north of and parallel to the less resistant and darker weathering Kayak (?) Shale (fig. 10). At the north end of Lake Peters, the Lisburne Group crops out as a resistant belt about half a mile wide that broadens to the east and southeast in a series of rounded ridges. Streams flowing north through these ridges expose the Lisburne Group overlain by the darker colored Sadlerochit Formation (fig. 11) in anticlines and synclines. West of Lake Peters the Lisburne Group forms a belt 1–1½ miles wide.

#### CHARACTER

The Lisburne Group consists of light- to dark-gray limestone, dolomitic limestone, siliceous limestone, argillaceous limestone, chert, and dolomite with a lower silty and shaly part. The limestone ranges from thin bedded to massive. The massive limestone is generally lighter in color than the bedded limestone. Fossils are locally abundant, and many rocks emit a fetid odor on fracturing.

The lower 100–200 feet of the Lisburne Group (Alapah Limestone) is characterized by medium- to dark-gray thin-bedded argillaceous limestone that weathers grayish orange pink to light brown. Fine-grained generally thin-bedded locally sandy limestone and dolomitic limestone are also present. The rocks contain rare nodules and lenses of chert. Locally abundant fossils are mainly crinoid debris and lithostrotionoid corals.

The middle and thickest part of the Lisburne Group consists largely of light-, medium-, and dark-gray fine- to medium-grained medium-bedded to massive limestone, silicified limestone, and 20–40 percent

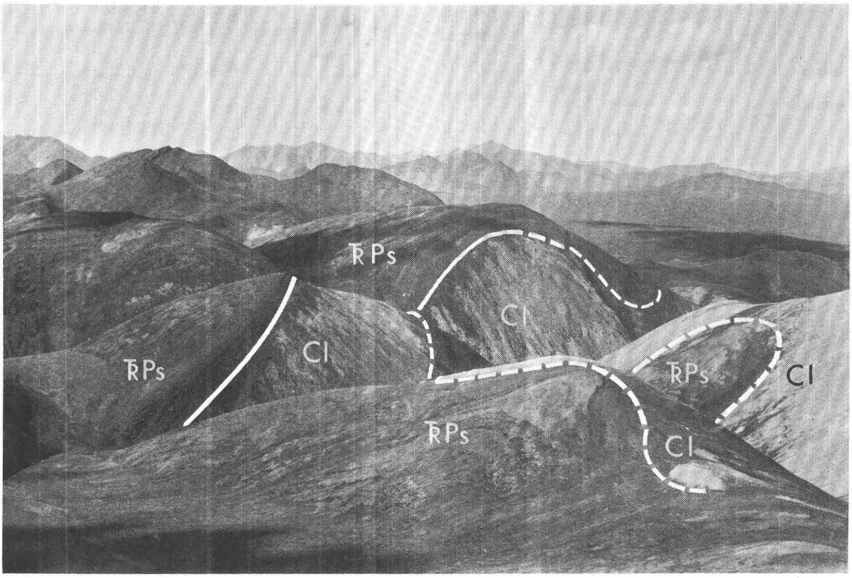


**FIGURE 11.—Lisburne Group (Cl) east of Lake Peters forming cores of anticlinal ridges and overlain by dark-colored Sadlerochit Formation (₮Ps). View is west-northwest.**

dolomite. The dolomite is dark to medium gray, commonly silicified, thin to medium bedded, and sublithographic to finely crystalline. Dolomitic limestone is generally medium to fine grained with local coarse-grained beds. Dolomite crystals are distributed throughout the dolomitic limestone as small, locally zoned, brownish gray euhedral rhombs. In some specimens the dolomite is restricted to discontinuous dark laminae which alternate with lighter calcite laminae. Light- and dark-gray chert occurs in thin irregular lenses, which locally coalesce and are parallel to the bedding, and in elliptical or spherical nodules with concentric structure in the thick-bedded to massive limestone (fig. 12). Thin sections show that the chert is relatively impure and that it contains varying amounts of anhedral calcite, euhedral dolomite, silicified fossils, and disseminated opaque material. Margins of the nodules are indistinct and contain many irregular aggregates of calcite.

The upper 200–300 feet of the Lisburne Group (Wahoo(?) Limestone) is characterized by thin-to-medium-bedded medium-to coarse-grained light-gray to gray limestone with local rudities. Dolomite is absent, and dolomitic limestone is less common than in the middle part of the Lisburne Group in this area. Chert is light to medium gray and is less abundant near the top of the Lisburne Group. Because the Sadlerochit Formation overlies the Lisburne Group disconformably,

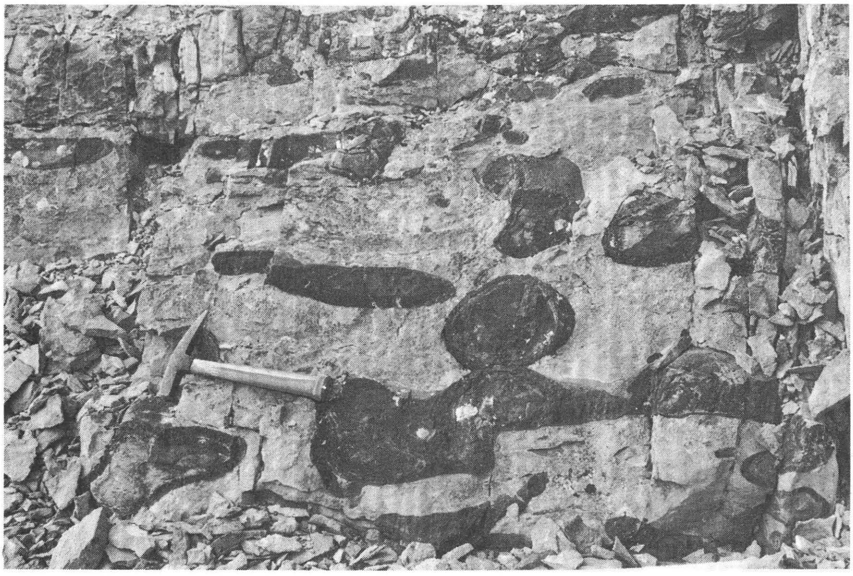

FIGURE 12. Dark-gray chert nodules in thick-bedded limestone of Lisburne Group. Note concentric structures in chert nodules.

it contacts different lithologic units of the Lisburne in different places. East of Lake Peters, a medium- to dark-gray, partly dolomitic lithographic limestone 10 feet thick lies at the contact or as much as 17 feet below it. The dark weathered surfaces of this limestone are uncolored by pyrite oxidation. West of Lake Peters, pyrite oxidation in the limestone at the contact gives grayish-orange-pink to reddish-brown weathered surfaces.

#### MEASURED SECTIONS

Two incomplete sections were measured, one across each contact of the Lisburne Group. Owing to complex folding with structural thickening and thinning and owing to the lack of distinctive correlative units, a complete section could not be measured. The two sections are illustrated on plate 3, and their location is shown on inset map *A*, plate 1. The sections are described in descending stratigraphic order and are presented in the same succession as on plate 3.

Section 1*C* (p. 104), a continuation of section 1*B*, was measured on the east side of Coke Creek. It is the stratigraphic equivalent of the lower member of the Alapah Limestone of the Lisburne Group. The lower contact appears to be gradational with the underlying Kayak(?) Shale (sec. 1*B*, pl. 3). The 212-foot section was taped in nearly continuously exposed overturned strata with an average dip of about 55°S. The upper part of the section ends at a 150-foot covered interval.

Section 7*A* (p. 119) represents the upper part of the Lisburne Group as exposed on Karen Creek. This section probably represents part of the lower member of the Wahoo(?) Limestone. The section was measured in overturned strata that dip 75°–80°S. The lower 85 feet of the measured section, taped on the west side of the stream, begins at a large rubble-covered area. The upper 87 feet was taped on the east side of the stream. The contact with the overlying Sadlerochit Formation was masked by a 12-foot covered interval (fig. 13).

#### STRATIGRAPHIC RELATIONS AND THICKNESS

The contact of the Lisburne Group with the underlying Kayak(?) Shale appears to be gradational. No significant stratigraphic breaks were recognized within the Lisburne Group. A few irregular bedding contacts, sparse calcirudite, and at least one thin intraformational limestone breccia with clasts ranging from ½ inch to 1½ inches in diameter are present. These probably are local depositional features.

Brosgé, Dutro, Mangus, and Reiser (1962, p. 2194) stated that the contact between the Lisburne Group and the Sadlerochit Formation represents an unconformity at most places. In the Romanzof Moun-

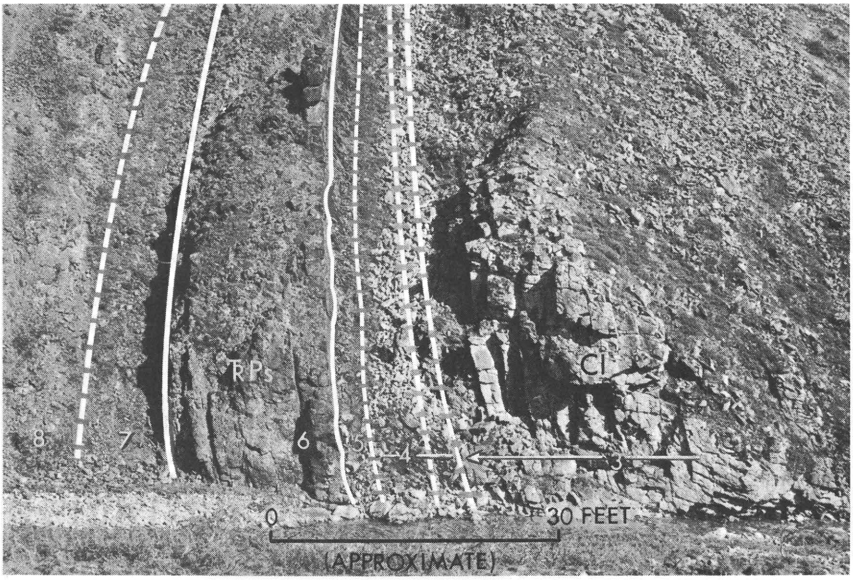


FIGURE. 13.—View east at contact (covered, short dashed line) between Lisburne Group (Cl) and Sadlerochit Formation (TRPs). Numbers on photograph refer to units described in measured sections (units 3 and 4, section 7*A*; units 4, 5, 6, 7 and 8, section 7*B*). Photograph taken on Karen Creek.

tains, 15 miles east of Lake Peters, the Sadlerochit Formation overlies the Lisburne Group with disconformity to slight angular unconformity (Sable, 1965, p. 66). In the Lake Peters area the Sadlerochit Formation overlies different beds of the Lisburne Group, and an erosional relief of at least 15 feet is present with no apparent angular discordance. The presence of intrasparite and intrasparrudite (Folk, 1959, p. 15) near and at the top of the Lisburne Group may indicate a lowering of wave base and possible tectonic uplift near the end of Lisburne time.

The thickness of the Lisburne Group is not uniform in northeastern Alaska. At Wahoo Lake, 50 miles southwest of Lake Peters, an incomplete section of the Lisburne Group is 3,314 feet thick (Brosgé and others, 1962, fig. 6, p. 2189). At Lake Peters, Alapah Limestone is reported to be 1,378 feet thick and the Wahoo Limestone 447 feet thick (Brosgé and others, 1962). Sable (1965, p. 49) believed that the thickness of the Lisburne Group may exceed 2,000 feet 3–10 miles east of the Jago River, whereas along the Hulahula River it may be only 1,000 feet thick. Exposures in the Lake Peters area are structurally complex and the thickness is not accurately known. The writer believes that the Lisburne Group is 1,300–1,600 feet thick.

#### AGE

Fossils collected from the lower part of the Lisburne Group in the Lake Peters area are similar to the Upper Mississippian lithostrotionoid assemblage collected by Brosgé, Dutro, Mangus, and Reiser (1962) in the same area (Brosgé, oral commun.). The base of the lower member (Mississippian and Pennsylvanian(?)) of the Wahoo(?) Limestone is the only part of the Wahoo present in the Lake Peters area. The writer collected corals 2½ feet below the contact of the Wahoo(?) Limestone and the Sadlerochit Formation near Katak Creek and also about 25 feet below this contact west of Lake Peters. Identification of the corals may provide a more definite age for the upper part of the Lisburne Group in the map area. On the basis of the information available (Brosgé and others, 1962), the writer tentatively assigns a Late Mississippian and Pennsylvanian(?) age to the Lisburne Group in the Lake Peters area.

## PERMIAN AND TRIASSIC

### SADLEROCHIT FORMATION

#### NAME AND DEFINITION

Leffingwell (1919, p. 113–115) applied the name Sadlerochit Formation to brownish-red sandstone, quartzite, shale, and minor conglomerate that overlie his so-called Lisburne Limestone and underlie the Shublik Formation. The name is derived from the Sadlerochit Mountains, which lie 18 miles north of Lake Peters. Brosgé, Dutro, Mangus, and Reiser (1962, p. 2194) applied the term Sadlerochit Formation to the clastic rocks of Permian and Early Triassic age that lie east of the Ivishak River within the northern Brooks Range.

In the Shaviovik and Sagavanirktok Rivers region, about 50 miles west of Lake Peters, Keller, Morris, and Detterman (1961, p. 177) divided the Sadlerochit Formation into two members. The lower Echooka Member consists of siliceous siltstone with interbedded chert and quartzite, siltstone, shale, and limestone. The upper Ivishak Member contains a lower shale and minor siltstone unit and an upper siltstone, shale, and sandstone unit. Sable (1965) divided the Sadlerochit Formation in the Romanzof Mountains area, 15 miles east of Lake Peters, into a lower ferruginous sandstone member, a middle shale member, and an upper quartzite member.

In this report, rocks between the Lisburne Group and the Shublik Formation have been designated the Sadlerochit Formation. They are informally separated into a lower siliceous sandstone–siliceous siltstone unit, a middle siltstone-shale unit, and an upper siltstone-sandstone unit.

#### OCCURRENCE

The dark-gray clastic rocks of the Sadlerochit Formation contrast strikingly with the light-gray-weathering carbonate rocks of the Lisburne Group. The Sadlerochit Formation is most conspicuous where it forms the northernmost resistant east-west ridge of dark-weathering sandstone and siltstone east of Lake Peters. South of this ridge, the Sadlerochit Formation occurs as a thin dark-gray unit within synclines or as a thin dark-gray covering on anticlines of the Lisburne Group (fig. 11). West of Lake Peters the Sadlerochit Formation occurs on the northernmost part of the ridge between Whistler Creek and Lake Peters. West of Whistler Creek, the Sadlerochit Formation is poorly exposed north of and adjacent to the Lisburne Group; its presence is indicated mainly by slope rubble. North of Lake Schrader small hills are flanked with the dark-weathering siltstone and sandstone of this formation.

#### CHARACTER AND THICKNESS

The Sadlerochit Formation was mapped as a single undifferentiated formation (pl. 1); however, the formation is discussed as three informal units: a lower siliceous sandstone-siliceous siltstone unit, a middle siltstone-shale unit, and an upper siltstone-sandstone unit. This division was established in the field without knowledge of a similar division of the formation by Keller, Morris, and Detterman (1961).

Generally, the lower rocks of the Sadlerochit Formation west of Lake Peters do not appear to be as siliceous as the lower rocks east of Lake Peters. Less competent shale and siltstone of the formation have poorly developed cleavage. Metamorphic fabrics are not well defined, and deformation has not destroyed the primary features of the rocks.

##### SILICEOUS SANDSTONE—SILICEOUS SILTSTONE UNIT

Siliceous sandstone is a rock composed essentially of well-sorted angular fine-grained and rarely medium-grained quartz and detrital plagioclase in a matrix of microcrystalline to cryptocrystalline quartz. Detrital quartz constitutes as much as 75 percent of the rock in some samples. Detrital plagioclase ($An_5$–$An_{10}$) recognized by its twinning, makes up less than 5 percent of the rock in the thin sections examined.

The siliceous sandstone–siliceous siltstone unit is thinly laminated to medium bedded, is tabular, and occurs in sets of beds 6 inches–10 feet thick. The rocks have a siliceous or cherty appearance and are very hard, dense, and generally resistant to weathering. They are medium gray to dark gray and weather to varying hues of orange, yellow, and brown. Sericite and minor chlorite are present as small flakes and discontinuous laminae. Pyrite, ferriferous dolomite, and minor amounts of siderite are locally abundant.

The siliceous siltstone consists of silt-size quartz grains cemented by microcrystalline and cryptocrystalline quartz. Sericite and chlorite are abundant and commonly form thin laminae and lenses. Leucoxene is rare. Chlorite is optically negative with birefringence nearly zero and exhibits abnormal blue interference colors. The generally dark-gray color of the siltstone results from diffuse iron oxides (probably hematite) and carbonaceous material, locally present in clots and stringers.

Chert sandstone and chert beds are interbedded with the siliceous sandstone and siliceous siltstone. The chert sandstone is similar in appearance to the siliceous sandstone but in thin section it can be seen that the detrital chert grains exceed the detrital quartz grains. Bedded chert is thin to medium bedded and is generally mottled medium to medium dark gray. It contains randomly oriented sponge spicules(?), dolomite rhombs, and a few small angular detrital quartz grains in a cloudy groundmass of microcrystalline to cryptocrystalline quartz. Intercalated with the chert are irregular lenses of dark-gray siliceous siltstone and a few beds of quartzose sandstone composed of fine angular quartz grains cemented by quartz overgrowths. Pyrite(?) concretions and clay ironstone nodules are scattered in the lower unit.

On Katak Creek, a ferruginous fine-grained sandstone unit about 10 feet thick containing clay ironstone concretions overlies the Lisburne Group. Thin sections show the ferruginous sandstone to be composed of fine angular detrital quartz and siderite with minor dolomite in a matrix of microcrystalline quartz and minor sericite. This bed is similar to the ferruginous sandstone described by Sable (1965, p. 62) in the Romanzof Mountains except that the thin pebble conglomerate, calcareous sandstone, and slate present in the ferruginous sandstone member in the Romanzof Mountains are absent in the Lake Peters area.

The siliceous sandstone and siliceous siltstone are more like the lower Echooka Member of the Sadlerochit Formation in the Shaviovik and Sagavanirktok Rivers region. Keller, Morris, and Detterman (1961, p. 178) noted that between the Echooka and Canning Rivers the Echooka Member is characterized by massively bedded dense cherty siltstone that is locally spotted by limonite and contains interbedded gray-green to black chert and light-gray quartzite. R. L. Detterman (oral commun., 1965) stated that eastward toward the Canning River the siltstone and sandstone of the Echooka Member become siliceous.

Poorly preserved indeterminate fossils are present in the lower 70 feet of the siliceous sandstone-siliceous siltstone unit immediately west of Lake Peters, but in general the unit is unfossiliferous. The thickness of the unit ranges from 190 to 240 feet and averages about 220 feet.

### SILTSTONE-SHALE UNIT

Interbedded siltstone, silty shale, and shale with as much as 10 percent sandstone compose the siltstone-shale unit. The rocks are medium gray to dark gray but weather to various hues of pale brown or rust.

The siltstone consists of quartz silt in a pastelike matrix of cryptocrystalline quartz, sericite, and minor chlorite. Lenticular to nodular aggregates of pyrite are oxidized on their surfaces. In thin section it can be seen that minor ferriferous dolomite and opaque lenses of iron oxides are also present. The siltstone is irregularly thinly laminated to thin bedded, in sets of beds as much as 60 feet thick. The unit is characterized by small-scale crossbedding, convolute bedding, and cleavage that partly alines sericite and chlorite. It weathers easily and is generally covered by talus and frost rubble. The only good exposures are along streambanks.

The silty shale and shale occur in uniformly thin interbeds less than 0.1–1 inch thick that form sets of beds 2–40 feet thick. This layering is due to variation in amount of carbonaceous material and alternation of silt- and clay-size particles. The shales are generally characterized by slaty cleavage and weather into flakes or chips. Sericite and chlorite in thin section show aggregate positive elongation and mass extinction parallel to bedding. Black opaque material and pyrite lenses are concentrated in streaks and laminae. X-ray diffraction studies show that the silty shale and shale are composed of quartz, 2*M* muscovite, and chlorite.

The shale and siltstone are interbedded with a fine-grained noncalcareous sandstone that makes up as much as 10 percent of the unit. The sandstone beds are 3 inches–4 feet thick and are similar to the sandstone in the overlying siltstone-sandstone unit. Both the siltstone and shale contain concretions of oxidized pyrite and clay ironstone.

The precise determination of the thickness of the siltstone-shale unit is prevented by its poor exposure, its lack of well-defined contacts, and its deformational thickening and thinning. A section at least 123 feet thick and probably about 400 feet thick is present on Karen Creek. West of Coke Creek the apparent thickness ranges from 350 to 450 feet. For the Lake Peters area in general, the average thickness is estimated to be between 400 and 500 feet.

The siltstone-shale unit occupies the same stratigraphic position in the Sadlerochit Formation as the middle shale member mapped by Sable (1965, p. 63) in the Romanzof Mountains. The siltstone-shale unit is also lithologically similar to the lower nonresistant shale and siltstone unit of the Ivishak Member of the Sadlerochit Formation in the Shaviovik and Canning Rivers region (Keller and others, 1961, p. 178). The lower unit of the Ivishak Member ranges from 400 to 600 feet in thickness in the Canning River region.

#### SILTSTONE-SANDSTONE UNIT

Interbedded light- to medium-dark-gray sandstone and medium- to dark-gray siltstone form the dominant lithology in the upper part of the Sadlerochit Formation in the Lake Peters area. These rocks form the northernmost ridges between Lake Peters and Katak Creek. A few beds of quartzose sandstone cemented by quartz overgrowths and beds of locally well-cleaved silty shale also are present. Small clay-ironstone and pyritic (?) concretions are scattered throughout the siltstone-sandstone unit.

Siltstone constitutes 60–80 percent of the upper siltstone-sandstone unit. The siltstone occurs in sets of thin, irregularly laminated and cross-laminated beds 2 inches–4 feet thick. Thin laminae and lenses of sandstone are present throughout the siltstone. In thin section the siltstone shows quartz silt in a finely laminated matrix of sericite, chlorite, and minute streaks and lenses of opaque material parallel to the bedding. Locally, pyrite and ferriferous dolomite give a rusty stain to weathered surfaces.

The sandstone is tabular, is thinly laminated to thin bedded, and occurs in sets of beds 6 inches–4 feet thick. Beds locally have oscillation ripple marks and contain thin, discontinuous veinlets of quartz and calcite. The sandstone is very fine grained to fine-grained and is generally well sorted. Major detrital constituents are subangular quartz and chert; the minor detrital constituent is twinned plagioclase. They are cemented by quartz overgrowths and microcrystalline quartz. Carbonate, mainly ferruginous euhedral dolomite and less commonly calcite aggregates, occurs both in the matrix and replacing detrital grains. The sandstone is only slightly calcareous. Sericite and chlorite occur as small streaks, single unoriented crystals, and as crystal aggregates. The accessory minerals are tourmaline, leucoxene, rutile, zircon, and detrital muscovite. The tourmaline is brownish green and locally has developed overgrowths. X-ray diffraction charts indicate more plagioclase than was identified in thin section; it is probably present as untwinned fine-grained metamorphic albite.

The top of the Sadlerochit Formation is not exposed in the mapped area because the formation is in fault contact with the Shublik Formation; therefore, the maximum thickness of the siltstone-sandstone unit is unknown. The minimum thickness of the siltstone-sandstone unit is estimated to be 600–700 feet. The siltstone-sandstone unit at Lake Peters is similar lithologically to the 700–800-foot-thick upper quartzite member of the Sadlerochit Formation in the Romanzof Mountains (Sable, 1956, p. 64–66) and to the 700–1,300-foot-thick upper siltstone, shale, and sandstone unit of the Ivishak Member of the Sadlerochit Formation in the Shaviovik and Sagavanirktok Rivers region (Keller and others, 1961, p. 179).

### MEASURED SECTIONS

Two stratigraphic sections (sec. *7B* and 8) of the Sadlerochit Formation were measured in the Lake Peters area. These sections are illustrated on plate 3 and their location is shown on inset map *A*, plate 1. The sections are described in descending stratigraphic order and are presented in the same succession as on plate 3.

Section *7B* (p. 120) is a continuation of section *7A*. Although the contact with the Lisburne Group is covered (fig. 13), it is estimated to lie about 6 feet below the lowest exposed siltstone unit. Strata of the measured section dip 75°–80° S. and are overturned. The top of the section ends at a covered interval at a small tributary stream on the east side of the creek. The lower 212 feet of the section (units 5–14) represent the lower siliceous sandstone-siliceous siltstone unit of the Sadlerochit Formation as exposed in the mapped area. This unit is lithologically similar to and probably correlative with the Echooka Member of the Sadlerochit Formation in the Shaviovik and Sagavanirktok Rivers region. The upper 123 feet represent the lower part of the middle siltstone-shale unit, which is probably 400 feet thick in this area.

Section 8 (p. 122) was measured on the east bank of Coke Creek, where the dip is 40°–55° S. Both the base and top of the section end in poorly exposed or covered areas. The section is representative of the upper siltstone-sandstone unit, although its exact stratigraphic position within the upper unit is not known.

### STRATIGRAPHIC RELATIONS AND MODE OF DEPOSITION

In the Lake Peters area, the Sadlerochit sediments were deposited on different beds of the Lisburne Group. The hiatus represented by the contact was a time of uplift, erosion, and possibly very minor tilting; however, as nearly as could be determined, bedding planes of the two formations seem to be parallel, and thus the contact of the two units is assumed to be disconformable. The stratigraphic relationship of the Sadlerochit Formation with the overlying Shublik Formation cannot be determined in the Lake Peters area because the Sadlerochit is faulted against the younger rocks. Furthermore, the Shublik Formation is poorly exposed in this area. In the Romanzof Mountains, 15 miles east of Lake Peters, the Shublik Formation rests with possible disconformity on the Sadlerochit Formation (Sable, 1965, p. 66), and west of Lake Peters in the Shaviovik-Sagavanirktok Rivers region, the Shublik Formation disconformably overlies the Sadlerochit Formation (Keller and others, 1961, p. 178).

The Sadlerochit Formation is believed to have been deposited in a fluctuating marine environment. Brachiopod fragments occur in the basal 80 feet of the formation west of Lake Peters. Coiled forms resembling ammonites were found in the middle siltstone-shale unit. Sable (1965, p. 69–70) and Keller, Morris, and Detterman (1961, p. 186–187) reported ammonites and pelecypods in the upper part of the Sadlerochit Formation. The presence of oscillation ripple marks in the upper siltstone-sandstone unit indicates that this unit was, at least in part, laid down in shallowing seas.

The northward coarsening of the clastics in the formation (Whittington and Sable, 1948; Leffingwell, 1919, p. 113; Brosgé and others, 1962, p. 2194; Keller and others, 1961, p. 178) suggests a northward source for the Sadlerochit sediments. Detrital grains of chert could have been derived from the Carboniferous and Permian carbonate sequence of the Lisburne Group. The presence of tourmaline, zircon, and rutile suggests that older crystalline rocks may have been available; however, the origin of these minerals could be from second cycle sedimentary rocks.

### AGE

Keller, Morris, and Detterman (1961, p. 177) assigned a Permian and Early Triassic age to the Sadlerochit Formation. The available evidence does not support a more precise age determination at this time. The lower unit of the Sadlerochit Formation west of Lake Peters so far has yielded only unidentifiable brachiopod fragments and possibly a spiriferoid (Norman Silberling, oral commun., 1965), and therefore its age must be inferred from its lithologic correlatives in other areas. The lithologically similar Echooka Member contains an assemblage of fossils of Permian age including spiriferoids (Keller and others, 1961, p. 182–186). The middle siltstone-shale unit of the Sadlerochit Formation in the Lake Peters area has yielded only unidentifiable coiled fossils that resemble ammonites (Norman Silberling, oral commun., 1965; Bernhard Kummel, oral commun., 1961). The lithologically similar lower part of the Ivishak Member of the Sadlerochit Formation in the Shaviovik-Sagavanirktok Rivers region contains a zone of Lower Triassic ammonites (Keller and others, 1961, p. 186).

## SHUBLIK FORMATION

### NAME AND DEFINITION

Leffingwell (1919, p. 115–116) defined the Shublik Formation as "about 500 feet of dark limestone, shale and sandstone [that] overlies the Pennsylvanian Sadlerochit sandstone and underlies the lower Jurassic Kingak shale." The type locality of the formation is at Shublik Island in the Canning River, at the southwest end of the Shublik Mountains. Smith and Mertie (1930, p. 185–194) described a belt of Triassic rocks in northwestern Alaska but did not designate it as the Shublik Formation. Gryc (in Payne and others, 1951, sheet 3) later applied the name Shublik Formation to the entire belt of Triassic rocks in northern Alaska.

### OCCURRENCE

Although the Shublik Formation forms a nearly continuous belt along the northern front of the Brooks Range, it is not well exposed in the Lake Peters area. It has been identified with certainty only along Karen Creek where the Sadlerochit Formation is thrust over the Shublik Formation (fig. 14). Rocks lithologically similar to the

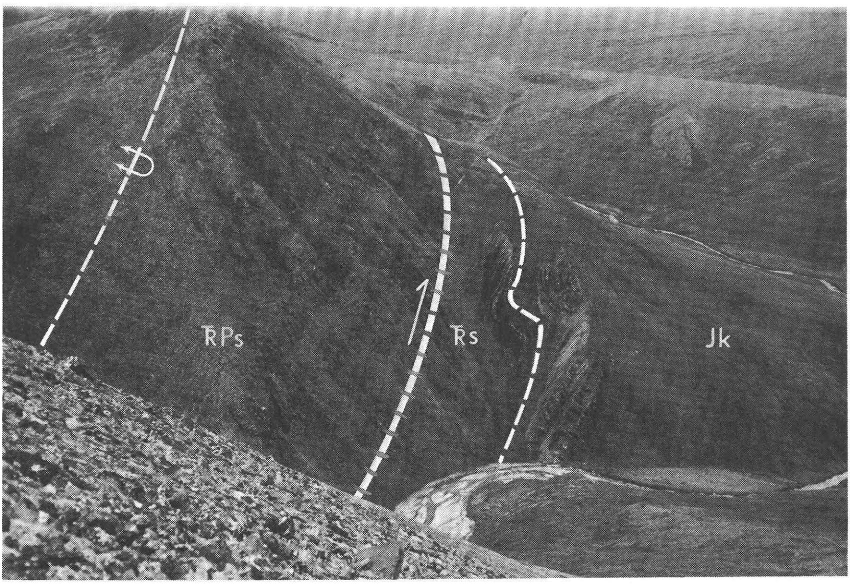


FIGURE 14.—View looking west across Karen Creek at Sadlerochit Formation (ꞦPs) in thrust fault contact with Shublik Formation (Ꞧs). Dashed line indicates approximate trace of axial plane of overturned anticline. Heavy dashed line indicates trace of thrust fault with arrow on upthrown side. Kingak Shale (Jk) is overturned to the south and shows no apparent angular discordance with Shublik Formation.

Shublik Formation occur in tightly folded and faulted beds along the northern part of Katak Creek and in poorly exposed cutbanks of Karen Creek 4 miles east of Lake Schrader. These rocks have been mapped as Permian through Jurassic undivided (pl. 1). Elsewhere the Shublik Formation can be mapped only from its rubble and frost heavings.

#### CHARACTER AND THICKNESS

The Shublik Formation where it is exposed on Karen Creek and as determined from weathered fragments brought to the surface by frost action is a distinctive dark-gray to grayish-black limestone and typically sooty carbonaceous calcareous shale. The limestone locally weathers light gray to light greenish gray and has a few dark-gray colloform crusts of gypsum. The shale weathers to a very soft sooty clay which, when wet, is sticky. Where best exposed the limestone forms tabular fossiliferous beds 1–4 feet thick, intercalated with calcareous shale (fig. 15). In the Lake Peters area, black calcareous fissile shale, present only as weathered fragments brought to the surface by frost action, forms as much as 30 percent of the uppermost part of the formation.

The limestone consists of calcite with minor silt of quartz and chert and with black carbonaceous material which is concentrated in stringers and lenses. Some beds of limestone contain an estimated 10 percent of dark-gray phosphatic ovoid nodules (½–4 inches in diameter) which weather to a bluish-white efflorescence. In thin section the nodules can be seen to consist of closely packed, cloudy light-brown isotropic pellets of carbonate fluorapatite and minor amounts of angular quartz silt, fish scales, and other unidentified fossil fragments, but a few show a concentric structure. Most pellets are structureless; they range from 0.03 to 0.3 mm in diameter. Anhedral calcite, apatite, and fluorite(?) are found in some of the pellets. The nodules are cemented by calcite and carbonaceous material. X-ray analysis shows that they consist of carbonate fluorapatite, calcite, fluorite(?) and quartz. Patton and Matzko (1959) have studied in some detail the phosphate deposits of northern Alaska. They reported that proportions of $P_2O_5$ in the Shublik Formation range from less than 5 percent to 35.8 percent.

Approximately 100 feet of the upper part of the Shublik Formation occurs in the Lake Peters area, but the lower contact is faulted out. Of the upper part only 30–40 feet is exposed in outcrop; the remainder occurs in rubble made up of small weathered fragments of fissile calcareous shale. In the Romanzof Mountains the Shublik Formation is about 700 feet thick (Sable, 1965, p. 74), and in the Shaviovik and Sagavanirktok Rivers region the Shublik Formation ranges from 200 to 400 feet in thickness (Keller and others, 1961, p. 188).


FIGURE 15.—Looking west at the overturned contact between the Shublik Formation (T̄RS) and the basal siltstone of the Kingak Shale (Jk). Photograph taken on Karen Creek.

## STRATIGRAPHIC RELATIONS

The stratigraphic relationship between the Shublik and the Sadlerochit Formations cannot be determined in the Lake Peters area because the Shublik is in fault contact with the underlying Sadlerochit. West of Lake Peters in the Shaviovik-Sagavanirktok Rivers region, the Shublik Formation disconformably overlies the Sadlerochit Formation (Keller and others, 1961, p. 178; Brosgé and others, 1962, p. 2178). East of Lake Peters, in the Romanzof Mountains, the Shublik Formation possibly disconformably overlies the Sadlerochit Formation (Sable, 1965). The contact between the upper part of the Shublik Formation and the overlying Kingak Shale in the Lake Peters area is apparently in structural concordance east of Lake Peters on Karen Creek (fig. 15), but Keller, Morris, and Detterman (1961, p. 188) reported that the Shublik-Kingak contact is disconformable west of Lake Peters in the Shaviovik-Sagavanirktok Rivers region.

#### AGE

Throughout northern Alaska a Late Triassic age has been established for the upper part of the Shublik Formation. East of Lake Peters on Karen Creek, pelecypods were collected from limestone beds which were 60–80 feet below the top of the Shublik Formation. The pelecypods were identified by Norman Silberling of the U.S. Geological Survey as *Halobia* cf. *H. zitteli* of Karnian (early Late Triassic) age, a species commonly found in the middle part of the Shublik Formation near the type area (Norman Silberling, oral commun., 1965). The lower part of the Shublik Formation is not represented in the Lake Peters area but in the Killik-Itkillik region, 150 miles southwest of Lake Peters, the lower part of the Shublik Formation contains fossils of Early(?) and Middle Triassic age (Patton and Tailleur, 1964, p. 435).

## JURASSIC

### KINGAK SHALE

#### NAME AND DEFINITION

Leffingwell (1919, p. 119) gave the name Kingak Shale to about 4,000 feet of black shales that overlie the Shublik Formation and underlie the Ignek Formation in the Canning River region. The name was taken from Kingak Cliff at the southeast end of the Sadlerochit Mountains. In the Lake Peters area, the Ignek Formation is not present, and the Kingak Shale is overlain by surficial deposits. Keller, Morris, and Detterman (1961, p. 191) mapped the Kingak Shale to the west of the type area, and Whittington and Sable (1948) and Sable (1959) mapped it east of the type area. Sable also (1965, p. 78) mapped a 75- to 100-foot resistant siltstone unit at the base of the Kingak Shale. This resistant basal unit is also present in the Lake Peters area.

#### OCCURRENCE

The Kingak Shale is poorly exposed in the Lake Peters area. The basal siltstone forms east-west-trending ridges north of the mountain front east of Lake Peters (fig. 16). A good exposure of the basal siltstone is on the west side of Karen Creek (fig. 15). The less resistant shale above the siltstone is seen only as frost-heaved rubble in a few streamcuts north of the siltstone outcrops; elsewhere the shale is covered by glacial deposits and tundra.

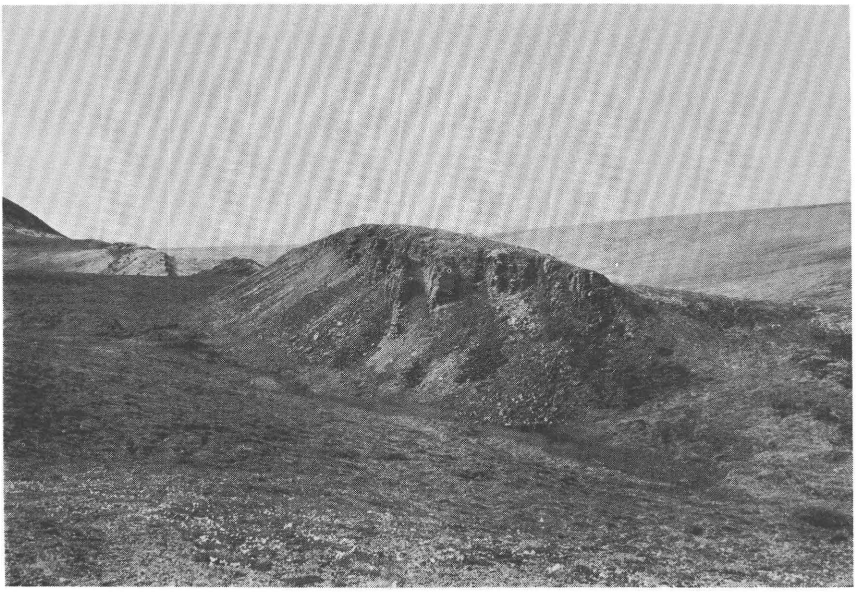

FIGURE 16.—Ridge of resistant basal siltstone of Kingak Shale. Photograph taken east of Lake Schrader, looking west-northwest.

### CHARACTER AND THICKNESS

The Kingak Shale is composed of a basal 70- to 100-foot-thick unit of siliceous quartzitic siltstone overlain by a shale unit of unknown thickness. The basal siltstone is best exposed along the west side of Karen Creek (figs. 14, 15), and on Coke Creek.

The basal siltstone is medium gray to medium dark gray and weathers pale brown to brownish gray; it is in tabular, resistant, ungraded beds 1–4 feet thick. The upper part is nonresistant and weathers light brown. A few dark-gray phosphatic nodules up to 3 inches in diameter are scattered in the siltstone beds and are concentrated in thin shaly units that separate them.

In thin section it can be seen that the siliceous quartzitic siltstone consist of angular to subangular coarse silt to very fine sand of quartz with small amounts of twinned plagioclase grains in a matrix of microcrystalline quartz and carbonate. Microcrystalline quartz is intimately mixed with carbonaceous and iron oxide material and a few flakes of sericite. The quartz matrix makes up as much as 30 percent of the rocks examined in thin section. The carbonate of the matrix is dolomite and calcite, and all beds contain one or both minerals. Dolomite is generally more abundant than calcite, and it is found as both isolated and small aggregate clusters of iron oxide-coated rhombs that replace the quartz matrix and detrital grains. Calcite is more abundant than dolomite in the lower 20 feet of the siltstone, and the rocks effervesce in dilute hydrochloric acid. Here, calcite forms a clear anhedral cement that locally replaces quartz. Dolomite in iron oxide-coated rhombs replaces both quartz and calcite. The heavy minerals identified were moderately well-rounded grains of zircon, brownish-green tourmaline, and rutile(?). Scattered throughout the siltstone are minute clear authigenic crystals of carbonate fluorapatite. Fractures in the siltstone contain small, well-developed, white to colorless, quartz crystals. There are a few white to light-gray colloform crusts of gypsum on the weathered surfaces of the siltstone.

Phosphatic nodules consist of angular detrital quartz cemented by an interlocking mosaic of microcrystalline anisotropic carbonate fluorapatite. The carbonate fluorapatite is clouded with finely divided iron oxide and carbonaceous material. Small (0.02–0.08 mm) spherical or ovoid pellets and oolites are also present in the nodules. At the center of many oolites is a brownish-black opaque carbonaceous material. In hand specimen the boundary between the phosphatic nodules and the surrounding siltstone appears to be sharp, but in thin section the contact is quite irregular. Microcrystalline quartz cement locally extends into the nodules, and similarly, carbonate fluorapatite locally extends for several tenths of a millimeter into the siltstone.

The overlying shale is exposed mainly along Karen Creek and on the west side of Coke Creek. In both places the rocks are dark-gray slaty shales that have been crumpled, tightly folded, and cut by many faults of unknown, but probably small, displacement. A few 2- to 6-inch discontinuous beds of dark-gray hard siltstone and fine-grained sandstone lie within the shale. X-ray diffraction charts of the slaty shale show it to be composed mostly of quartz, *2M* muscovite, and chlorite. None of the samples examined was phosphatic. In frost-heaved rubble north of the mountain front the upper part of the formation is a dark-gray fissile silty shale.

The thickness of the shale unit in the Lake Peters area is not known. However, by analogy with the estimated thicknesses given by Sable (1965, p. 79) in the Romanzof Mountains, and by Keller, Morris, and Detterman (1961, p. 192) in the Sagavanirktok Rivers region, the thickness of the shale unit probably exceeds 1,000 feet.

#### STRATIGRAPHIC RELATIONS AND AGE

There is no visible structural discordance between the Shublik Formation and the Kingak Shale on Karen Creek (fig. 15). In the Shaviovik and Sagavanirktok Rivers region the Kingak Shale disconformably overlies the Shublik Formation (Keller and others, 1961, p. 188). Sable (1959, p. 72–73, 1965, p. 79–80) suggested that the phosphatic "pebbles" found in the basal Kingak Shale in the Romanzof Moun-

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tains were derived from the underlying Shublik Formation and that these pebbles, plus the marked change in sedimentation, indicate an erosional break between the two formations. The writer does not believe that the phosphatic pebbles in the basal siltstone beds of the Kingak Shale in the Lake Peters area were derived from the Shublik Formation for the following reasons:

1. The amount and angularity of detrital quartz in the Kingak nodules is identical to that in the surrounding sandstone, and therefore the nodules do not seem to be foreign to their present environment.
2. Shublik nodules do not contain nearly as much detrital quartz as nodules in the Kingak Shale.
3. Carbonate fluorapatite is isotropic in the Shublik nodules, whereas it is anisotropic in the Kingak nodules.
4. If the nodules now found in the Kingak Shale represent eroded Triassic rocks, there should be other evidence of eroded limestone of the Shublik Formation within the basal Kingak.
5. Small authigenic crystals of carbonate fluorapatite occur throughout the basal clastics; their presence indicates that the postdepositional environment was favorable for the formation of phosphorite.
6. At the contact of nodules, carbonate fluorapatite extends into the enclosing beds.

However, as Sable (1965) has noted, there is an abrupt lithologic change between Shublik and Kingak rocks. A hiatus probably exists between the two formations because the upper Shublik Formation is Upper Triassic. Lowermost Jurassic (Hettangian) rocks have not been identified by megafossils in northern Alaska, and a conspicuous change in the microfossil assemblages occurs at the boundary between the Triassic and Lower Jurassic in the northern Alaska area (Tappan, 1955, p. 32, 33; Bergquist, 1966, p. 96–99 and table 2).

Geologists of British Petroleum Company collected *Amaltheus* cf. *A. margaritatus* (Montfort) (Upper Pleinsbachian) near the stream junction 3 miles S. 60°E. from the outlet of Lake Schrader (Imlay, 1964). Imlay (1955) reported that the Kingak Shale in northeastern Alaska contains fossils of Early, Middle, and Late Jurassic age and suggested that there are three depositional breaks within the Jurassic sequence.

## QUATERNARY

### GLACIAL DEPOSITS

#### PREVIOUS WORK

Several early workers in the Brooks Range, among them Schrader (1900, 1904), Mendenhall (1902), Leffingwell (1919), Mertie (1925, 1930), and Smith (1939), described some of the glacial deposits there. Detterman (1953) recognized and described five glaciations. Detterman, Bowsher, and Dutro (1958) gave a more detailed account of glacial advances in three selected areas along the northern front of the central Brooks Range. In the eastern Brooks Range, Kunkle (1958), Keeler (1959), and Sable (1965) studied the glacial deposits in the Mount Michelson area. A detailed account of the glaciation in the Anaktuvuk Pass area was given by Porter (1962, 1964). Holmes (1959) and Holmes and Lewis (1961) mapped the glacial deposits of the Mount Chamberlin area and gave these deposits local names. More recently Holmes and Lewis (1965) made another tentative correlation of the glacial advances in the Mount Chamberlin area. The writer uses the local names given by Holmes and Lewis (1965) but his correlation of the glacial advances differs from theirs in that one advance, not recognized by them, is added. Figure 17 shows the northern part of the area mapped by Holmes and Lewis (1961). The writer's work was confined to an area south of lat 69°25′N. of figure 17, and the following discussion is limited to the writer's observations on the Schrader, Peters, Alapah Mountain, and Katak Glaciations. The distribution of Chamberlin deposits shown on plate 1 is largely the same as the distribution mapped by Holmes and Lewis (1965). Table 4 summarizes the glacial advances mapped in the Brooks Range and the ages assigned them by various workers.

#### SCHRADER GLACIATION

The Schrader Glaciation was named by Holmes (Holmes and others, 1959, p. 50) for the well-preserved lobate moraines east, west, and north of Lake Schrader. The Schrader Glaciation represents the last advance of ice that extended beyond the mountain front. A well-defined terminal moraine of the Schrader Glaciation is present as much as 8 miles north of the mountains, and four or five recessional moraines lie behind this terminal moraine. One partially breached moraine, believed to be a recessional moraine or a late readvance of the Schrader Glaciation, is present immediately north of Whistler Creek (fig. 18). Poorly preserved remnants of a lateral moraine above the later Peters moraine on the east side of Lake Peters are correlative with this moraine. East of the stream that joins Lake Peters and Lake Schrader, glacial erratics of the Neruokpuk Formation are found approximately 1,580 feet above the water surface (fig. 18). This is the highest point at which material from the Schrader Glaciation was found.

Fresh angular erratics up to 6 feet in diameter are numerous on Schrader drift. Partly filled kettle lakes are common. The moraines

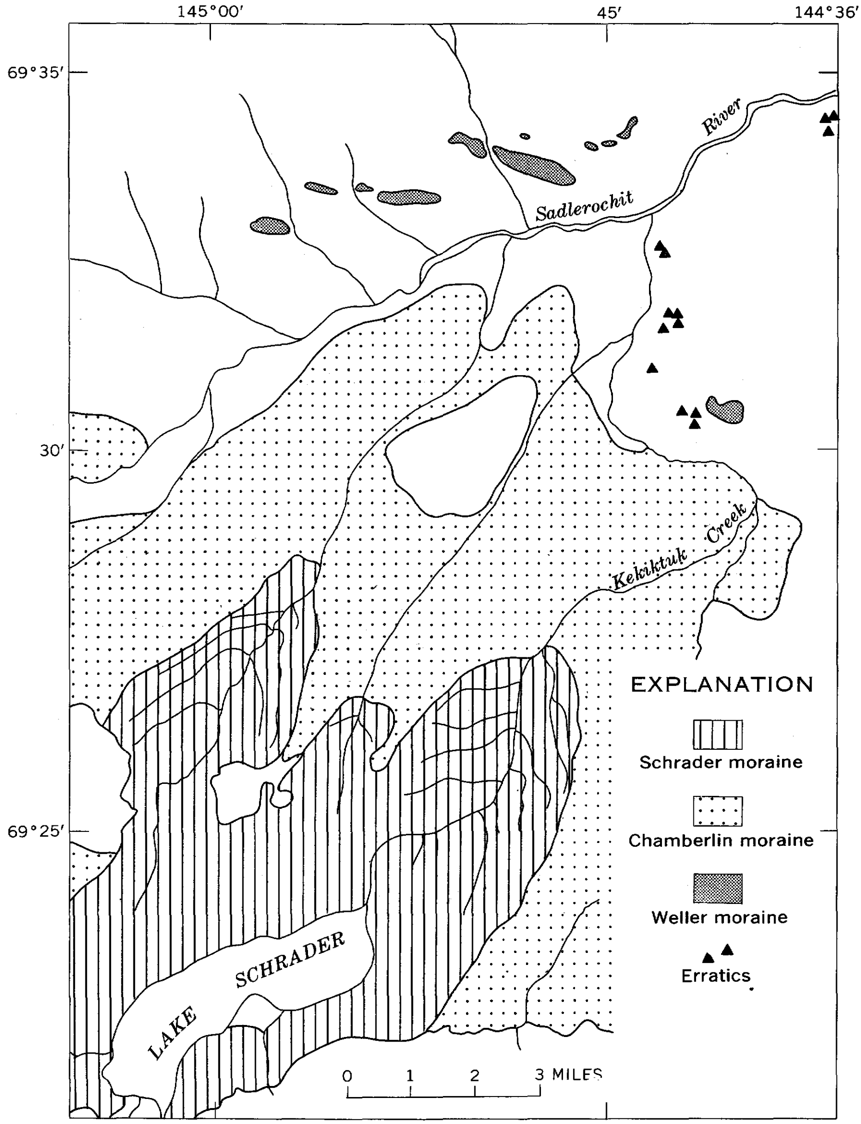


**Figure 17.**—Glacial deposits north of area covered by this report. (After Holmes and Lewis, 1961.)

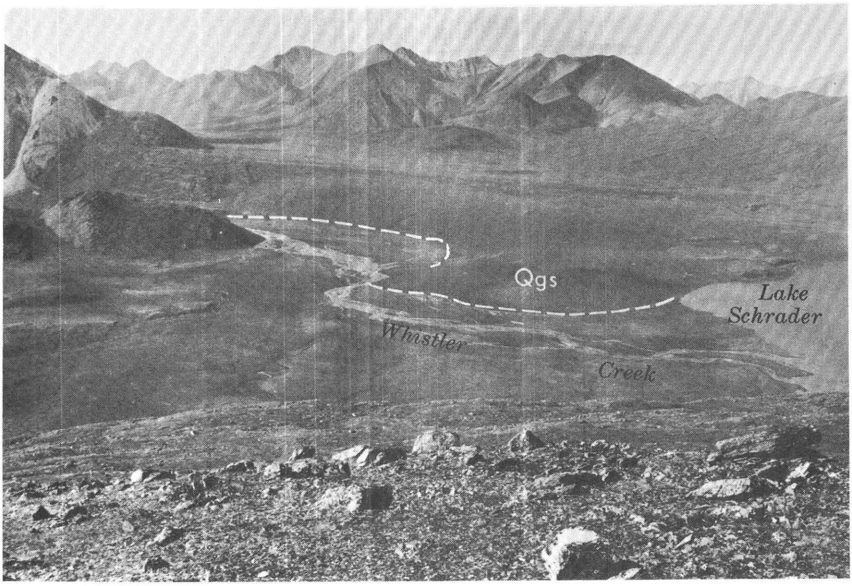


FIGURE 18.—View looking west showing recessional moraine of Schrader Glaciation (Qgs) at mouth of Whistler Creek. Erratics of Neruokpuk Formation from Schrader Glaciation present in foreground.

have as much as 40 feet of relief. Streams form an arcuate pattern bordering the lateral moraines of the Schrader Glaciation and flow in valleys parallel to the recessional moraines north of Lake Schrader.

Holmes and Lewis (1961, p. 863) correlated the Schrader Glaciation with the Echooka River Glaciation of Detterman (1953). They stated, "Echooka and Schrader moraines are similar, each having modified knob and kettle topography and each damming lakes at present." In 1965 Holmes and Lewis tentatively correlated the Schrader Glaciation with the Itkillik Glaciation. Because recessional moraines are characteristic of the Itkillik Glaciation wherever it is recognized (Detterman and others, 1958, p. 51–53; Porter, 1962, p. 137, and 1964) and because the Itkillik Glaciation represents the last advance of ice beyond the mountain front, the Schrader Glaciation is best correlated with the Itkillik Glaciation of Detterman, Bowsher, and Dutro (1958) and the lower three substages of the Itkillik Glaciation of Porter (1964).

#### PETERS GLACIATION

Holmes (in Holmes and others, 1959, p. 52) named the Peters Glaciation for the well-preserved lateral and terminal moraines at Lake Peters. This glaciation was confined to the north-south valleys and extended to the mountain front only in the major valleys. On Coke Creek, a prominent terminal moraine is partially preserved 1½

TABLE 4.—*Nomenclature and age assignments applied*

[Asterisk indicates radiocarbon ages

| North American chronology | Central Brooks Range: Detterman (1953) | Central Brooks Range: Detterman, Bowsher, and Dutro (1958) | Jago River area: Kunkle (1958) | McCall Valley: Keeler (1959) | Mount Chamberlin area: Holmes and Lewis (1961) | |
|---|---|---|---|---|---|---|
| Recent | Unmapped | Fan Mountain | Fan Mountain | Fifth advance | Recent | Cirque moraine II |
| | | | | | | Cirque moraine I |
| Late Wisconsin | Echooka River | Alapah Mountain | Alapah Mountain | Fourth advance | Pleistocene | Peters |
| Early Wisconsin | Itkillik | Echooka River | Echooka River | Third advance | | Schrader |
| | | Itkillik | Itkillik | Second advance | | Chamberlin |
| Pre-Wisconsin | Sagavanirktok River | Sagavanirktok River | Sagavanirktok River | First advance | | Weller |
| | Anaktuvuk River | Anaktuvuk River | Anaktuvuk River | | | |

[1] Sable (1965) correlated his Fifth advance with the cirque moraine I and cirque moraine II of Holmes and Lewis (1961). The report of Holmes and Lewis (1965) was not yet published.

[2] Holmes and Lewis (1965) correlated the Peters Glaciation with the Alapah Mountain and Echooka River Glaciations of Detterman, Bowsher, and Dutro (1958) and to the later advances of the Itkillik Glaciation of Porter (1963).

*to glacial sequences of northern Brooks Range*

in years B.P. given by Porter (1964)]

| | Anaktuvuk Pass area: Porter (1962) | North Central Brooks Range: Porter (1964) | | Mount Chamberlin area: Holmes and Lewis (1965) | Romanzoff Mountains: Sable (1965) | This report |
|---|---|---|---|---|---|---|
| Post-Wisconsin | Fan Mountain II | Fan Mountain II | Recent | Katak Glaciation | Fifth advance [1] | Katak Glaciation |
| | Fan Mountain I | Fan Mountain I | | | | |
| | Alapah | Alapah *2830±120 | | | | Alapah Mountain Glaciation |
| | | Hypsithermal | | | | |
| Classical Wisconsin | Echooka River | Itkillik: *6,260±160 *7,241±95 Anivik Lake | Pleistocene | Peters Glaciation [2] | Fourth advance | Peters Glaciation |
| | Itkillik | Itkillik: Antler Valley Anayaknaurak *13,270±160 Banded Mountain | | Schrader Glaciation | Third advance | Schrader Glaciation |
| Pre-Classical Wisconsin | Sagavanirktok River | Sagavanirktok River | | Chamberlin Glaciation [3] | Second advance | Chamberlin Glaciation |
| | Anaktuvuk River | Anaktuvuk River | | Weller Glaciation [3] | First advance | Weller Glaciation (exposed north of map area) |

[3] Holmes and Lewis (1965) did not correlate the Chamberlin and Weller Glaciations to Porter's (1963) pre-Itkillik Glaciations. They correlated the Chamberlin and Weller Glaciations with Sagavanirktok River and Anaktuvuk River Glaciations of Detterman, Bowsher, and Dutro (1958).

miles south of the large alluvial fan on Lake Schrader. On Katak Creek, remnants of lateral and ground moraines are present. On Whistler Creek, scattered remnants of lateral moraines are found along the lower part of the valley wall, and a terminal moraine is present 1 mile south of the mountain front.

Moraines of the Peters Glaciation possess a distinct knob-and-kettle topography; they are covered locally with tundra. The tops of the lateral moraines at Lake Peters consist of boulder-size fragments. These moraines have steep slopes toward the lake and are locally cut by mountain streams leaving alluvial fans, which in turn encroach upon the moraines (fig. 19).

FIGURE 19.—Lateral moraine of Peters Glaciation on east side of Lake Peters. Moraine is cut by an alluvial fan. View is looking southeast at the east shore of Lake Peters.

On the west side of the Lake Peters valley, a lateral moraine can be traced to a terminal moraine with a kettle lake and a small outwash fan to the north (pl. 1). This terminal moraine is not as well developed as the laterial moraine which leads to it. Possibly the ice of the Peters advance terminated in a proglacial lake. Holmes and Lewis (1961, p. 860) also suggested that this was a possibility. East of the stream that joins Lake Peters and Lake Schrader, another small outwash fan is attached to the Peters terminal moraine (fig. 20). The uniform level of outwash fans and terraces on the north side of the Peters terminal moraine and the southwest edge of Lake Schrader (pl. 1), about 47 feet

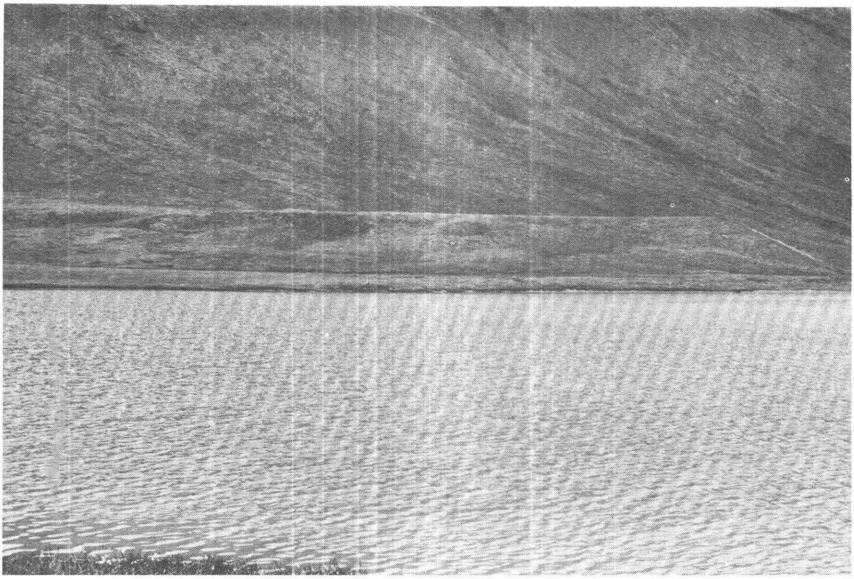

FIGURE 20.—Outwash fan on east side of Lake Peters valley.

above the present water level, is an indication that Lake Schrader once stood at a higher level.[5] The older lake-level terrace can be traced with difficulty for about three-fourths of a mile north along the west shore of Lake Schrader. This lake was dammed to the north by the Schrader moraine. At some time after the Peters Glaciation, the moraine was cut through by what is now called the Kekiktuk River. After Lake Schrader was lowered, the Peters terminal moraine was breached by the stream that connects Lake Peters and Lake Schrader. The moraine was also cut laterally by Whistler Creek. The south end of Lake Schrader is shallow, and deltalike deposits have been built outward from the shore for more than 200 feet.

Erratics in the Peters lateral moraines are lichen covered, fresh, and striated, and they consist of rocks from the Neruokpuk Formation. Where the bedrock is exposed in the major north-south valley (fig. 21) striated pavement and locally developed stoss-and-lee topography can be seen. The bedrock supports irregular patches of lichen.

Holmes and Lewis (1961, p. 863) correlated the Peters Glaciation with the Alapah Mountain Glaciation. However, Holmes and Lewis' table 4 (1965, p. B29) showed the Peters Glaciation to be equivalent

[5] Artifacts were found at the top of the 47-foot-high outwash fan along the southwest shore of Lake Schrader in gravel 1–4 inches below a thin mat of mossy vegetation. It is not known whether the artifacts represent an ancient campsite at the time the lake was at or near the higher level, or whether they occupy a position which allowed good visibility for hunters of a more recent age.

FIGURE 21.—Striated pavement on Neruokpuk Formation in Carnivore Creek valley. The striations are parallel to the trend of the valley. Note irregular patches of lichen growth.

to both the Alapah Mountain and Echooka River Glaciations of Detterman, Bowsher, and Dutro (1958) and to the later advances of the Itkillik Glaciation of Porter (1963, 1964). The writer correlates the Peters Glaciation with the Echooka River Glaciation (or Anivik Lake of Porter, 1964). The position of the Peters terminal moraines, in the Lake Peters area, at or near the mountain front is similar to the positions of the Echooka and Anivik Lake moraines in the north-central Brooks Range (Detterman and others, 1958; Porter, 1962). In further support of this correlation it is necessary to describe the occurrence of morainal deposits intermediate in age between the Peters and Katak Glaciations (see discussion under "Alapah Mountain Glaciation"). These deposits are found at the junctions of Carnivore Creek and its tributary valleys south of the mapped area and on the north sidewall of Chamberlin Creek. Porter (1962, fig. 50) stated that during Alapah Mountain Glaciation the ice filled the tributary valleys and did not reach the major north-south valleys; thus, moraines most typically representing Alapah Mountain Glaciation are present in the Lake Peters area, but were not recognized by Holmes and Lewis. Because the Alapah Mountain Glaciation is represented in the mapped area, Holmes' and Lewis' (1965) correlation of the Peters glacial deposits with Alapah Mountain deposits elsewhere should be changed and the Peters Glaciation should be correlated with the Echooka or Anivik Lake deposits.

### ALAPAH MOUNTAIN GLACIATION

The Alapah Mountain Glaciation was named by Detterman, Bowsher, and Dutro (1958, p. 54) for moraines on the slopes of Alapah Mountain, which is about 165 miles southwest of Lake Peters. Holmes and Lewis (1961, 1965) did not recognize deposits in the Lake Peters area intermediate in age between the Peters and Katak Glaciations, but stated (1965, p. B18) that "On the valley sidewall [of Chamberlin Creek] beyond the outer loop is a lateral moraine remnant which may represent an earlier readvance or possibly a recessional moraine of the Peters Glaciation." Although both possibilities exist, the writer mapped this moraine as a separate advance that took place between the Peters and Katak Glaciations and assigns it to the Alapah Mountain Glaciation.

The Alapah material is much fresher in appearance than deposits of the Peters Glaciation, but it lacks the barren bouldery appearance of the Katak deposits. The moraine is higher in altitude than and downstream from the terminus of the Katak deposits. It is similar in appearance to the moraines that occur at the junctions of Carnivore Creek with its tributary valleys south of the mapped area. R. L. Detterman (1965, oral commun.), who has inspected the aerial photographs of the Lake Peters area, agreed that Alapah Mountain deposits in the central Brooks Range are similar in appearance and distribution to the morainal deposits found near the junctions of the tributary and major north-south valleys in the Lake Peters area. Sable (1965) has mapped similar terminal and lateral moraines in valleys tributary to major north-south valleys. Although Sable assigned these moraines to his Fourth advance, he recognized the possibility that they may represent an advance between the Fourth and Fifth advances (Sable, 1965, p. 100). Thus, within the Lake Peters areas, the Alapah Mountain Glaciation is recognized as a relatively minor advance restricted to within 5 miles of the present-day cirques in the upper parts of the main north-south valleys as well as in the tributary valleys.

### KATAK GLACIATION

Holmes (in Holmes and others, 1959, p. 53) termed the small fresh moraines that lie immediately in front of present-day glaciers, and in valleys recently evacuated by glaciers, the cirque glaciation. Holmes and Lewis (1961, p. 861) divided the cirque glaciation into cirque moraine I and cirque moraine II. Subsequently Holmes and Lewis (1965, p. B18) renamed these glacial deposits the Katak Glaciation. Most of the Katak deposits are found on north slopes at or above an altitude of 4,500 feet. Katak moraines are well developed in front of the terminus of Chamberlin Glacier (fig. 22), and others are present in the higher cirque valleys of Mount Chamberlin and in the ice-free cirque valleys west of Carnivore Creek. Katak deposits are found south of the mapped area in all of the major north-south valleys and in most of the larger tributary valleys.

The character of the deposits indicates a relatively recent disappearance of the glaciers. The till of this glaciation is fresh, locally derived, and tundra-free. The outer moraines have more stable slopes than the inner moraines. Vegetation is starting to grow in the sandy parts of the till but the innermost moraines lack vegetation, and the surfaces of the boulders are lichen-free. The deposits occur as terminal, recessional, lateral, and ground moraines.

A study of aerial photographs taken in 1950 and of topographic maps reveals that the two outermost moraines were 1,900±100 and 1,250±100 feet from the terminus of the Chamberlin Glacier. Mapping completed in 1961 showed that the glacier had retreated about 150 feet from the 1950 position. Sable (1961) has studied the retreat of the Okpilak Glacier, which lies 20 miles to the southeast of the Chamberlin Glacier. He compared observations and photographs taken in 1907

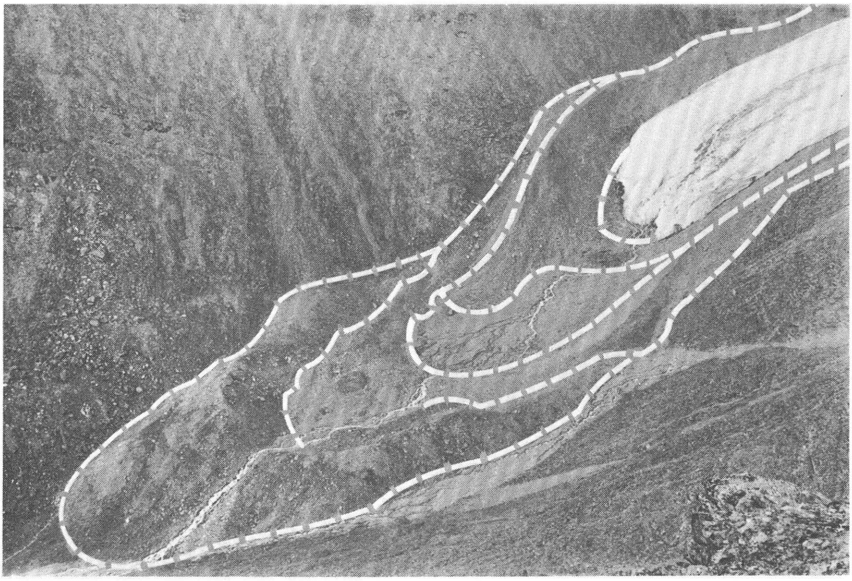

FIGURE 22.—Terminal and recessional moraines of Katak Glaciation. The outer two moraines are believed to be equivalent to Fan Mountain I deposits; the innermost moraine is equivalent to Fan Mountain II deposits. View looking northeast across Chamberlin Creek at the terminus of Chamberlin Glacier.

and 1958. In 1958 the Okpilak Glacier was 1,000±100 feet behind the terminus observed in 1907. Sable estimated that the glacier had retreated 300 feet between 1950 and 1956. The recessional moraine that lies 1,250±100 feet in front of the terminus may represent the position of the Chamberlin Glacier at the beginning of the century. The amount of retreat of the Katak Glacier between 1950 and 1961 is about half that of the Okpilak Glacier, but the retreat in recent years suggests that the local climate is warming. In support of this, Anderson (1959) reported that Chamberlin Creek had a streamflow discharge in excess of the projected annual precipitation and concluded that the Chamberlin Glacier was undergoing considerable ablation. Hamilton (1965) also presented data which indicates a general warming trend in Alaska from the late 1800's to the present.

In this report the Katak Glaciation is correlated to the west with the Fan Mountain Glaciation of Detterman, Bowsher, and Dutro (1958, p. 57). To the east it is represented by the Fifth advance of Keeler (1959) and Sable (1965), and by the Fan Mountain Glaciation of Kunkle (1958). Holmes and Lewis (1961, p. 861) named the outer two moraines in front of the Chamberlin Glacier, cirque moraine I, and the innermost moraine, cirque moraine II, but they did not make this subdivision when they renamed these deposits the Katak Glaciation (Holmes and Lewis, 1965, p. B18). The writer recognizes earlier moraines of the Katak Glaciation (cirque moraine I) only as the two outer moraines in front of the Chamberlin Glacier (fig. 22). These outer moraines are believed to be equivalent to the Fan Mountain I Glaciation as defined by Porter (1962, 1964), which occurs at varying distances downstream from cirque thresholds, whereas Fan Mountain II deposits lie within cirques.

Detterman, Bowsher, and Dutro and Keeler and Kunkle all agree that it is very difficult to distinguish between the Fan Mountain Glaciation and the deposits now being formed, and that the Fan Mountain Glaciation was an extremely recent and short-lived advance. Sable (1961) had good evidence to relate the presence of glaciers within this century to morainal deposits 1,000–3,000 feet from the present ice terminus. He was of the opinion that the outermost end moraine represented the farthest advance of Fan Mountain Glaciation and that the present terminus was undergoing a recession of the same glacial stage. He believed (p. 186–187) that general shrinkage occurred during the last half of the 19th and the first half of the 20 century.

#### CORRELATION OF GLACIAL ADVANCES

Radiocarbon data on glacial deposits of the Brooks Range are available only in the Anaktuvuk Pass area. Several samples (Porter, 1962, 1964) analyzed by the Yale Geochronometric Labratory have provided the basis for a revised correlation of the glacial advances (table 4). The dates given in table 4 are those of Porter (1964).

The Itkillik date of 13,270±160 years B.P. (before present) was derived from willow twigs in sand that is overlain and underlain by Itkillik till. It represents a readvance during Itkillik Glaciation along the Anaktuvuk River and is equivalent to the classic Wisconsin Glaciation of north-central United States (Flint, 1963, p. 403). Porter (1964, p. 458) suggested that the oldest advance of the Itkillik Glaciation (Banded Mountain advance) may fall between 18,000 and 20,000 years B.P.

Two of the dates for the Echooka River Glaciation are derived from material included in silt that "is interpreted as a late-glacial deposit that accumulated in an ice-margin lake" (Porter, 1962, p. 200). The dates of 7,241±95 and 6,260±160 B.P. are believed to represent a minimum age for the Anivik Lake advance. A radiocarbon date on willow twigs found in an outwash deposit downstream from an Alapah Mountain terminal moraine gives an age of 2,830±120 years. "The sample should give an approximate age for the maximum stand of this ice advance" (Porter, 1962, p. 201).

As the Sagavanirktok and Anaktuvuk deposits are considerably more modified than the Itkillik and Echooka deposits and lie several miles north of the mountain front, they probably represent much older advances and are assigned to the pre-classical Wisconsin. Correlation of the glacial deposits of the Lake Peters area with those of the central Brooks Range is based on physical criteria; therefore, any correlation attempted with advances up to 200 miles away is necessarily tenuous. Reasons for correlating the glacial advances as shown in table 4 are discussed under the individual glacial advances. The dates given in table 4 are valid only for the Anaktuvuk Pass area. Future quantitative work, including radiocarbon dating and pollen analysis, will show whether correlations given for the Lake Peters area are acceptable.

### ALLUVIUM

Deposits mapped as alluvial material (pl. 1) have been divided into flood-plain alluvium and alluvial fans and cones. Included with the latter are talus cones at the south end of Lake Peters.

The material mapped as flood-plain alluvium is confined to narrow flood plains produced by laterally shifting streams. The flood plains are locally braided. One or more low terraces of older flood plains are present. Fresh terraces are evidence that the streams are actively downcutting their beds. The terraces are generally unpaired and vary in height from 2–6 feet. The alluvial material along presently active stream channels do not support any vegetation. Older terraces have areas of willow growth.

Alluvial material is derived primarily from the glacial deposits which fill the valleys. Exposed bedrock also supplies material. Most of the material is well rounded and water worn and ranges in size from silt to boulder. The finer material is found along the lower gradient reaches of streams, on the downstream end of bars, and in overflow lagoon areas.

Alluvial fans are well developed on both sides of Lake Peters valley and to the south along Carnivore Creek valley. The source of alluvial fan material is twofold: debris eroded from bedrock by postglacial streams, and lateral and terminal moraines along the sides of the valleys. The large fan on the south shore of Lake Schrader consists chiefly of material eroded from the terminal moraine of the Peters Glaciation 1½ miles upstream on Coke Creek. In the Lake Peters valley, steep postglacial streams have eroded nearby bedrock material and carried it down the deep V-shaped gorges toward the axis of the valley. The material is deposited over the lateral moraines, which are covered locally by the fan deposits. The apices of the fans extend back into the gorges to altitudes higher than the crest of the lateral moraines (fig. 23). In summer, the streams diminish in size and many flow beneath the surface below the apex of the fan. Fans generally have two or more abandoned stream channels which radiate from the apex. These channels are commonly entrenched as much as 15 feet near the apex of the fan. The amount of entrenchment decreases downslope. Some fans

FIGURE 23.—Alluvial fan on east shore of Lake Peters. Note apex of fan above the lateral moraine of the Peters Glaciation.

coalesce to form a series of aprons along the base of the valley wall (fig. 24). The slopes of the fans range from 5° to 18°. The fans are tundra covered and frost features have developed on their surfaces. Trenches dug into the fans in July show that the depth to the top of permafrost ranges from 1 to 3 feet.

The size of the material in the alluvial fans ranges from fine sand to boulder; the material is poorly sorted and poorly stratified. Along stream channels the boulders show a general increase in size toward the apex of the fans. Most of the material is derived locally and shows evidence of being water worn, although angular boulders are commonly present.

### OUTWASH

Two areas mapped as outwash deposits (pl. 1) are associated with the Peters terminal moraine north of Lake Peters. A third outwash deposit is near the mouth of Spawning Creek on the southwest end of Lake Schrader. The significance of these deposits has been discussed previously in the section on the Peters Glaciation. The similarity of altitudes of the outwash deposits (47 ft) above the water level indicate that they represent a higher lake level of Lake Schrader. An altitude measurement made with an aneroid barometer indicates that the outwash north of the terminal moraine at the northwest end of Lake Peters is about 50 feet above the present water level.

FIGURE 24.—Coalescing alluvial fans on west side of Lake Peters. View looking southwest.

East of the stream that connects Lake Peters and Lake Schrader the outwash is poorly sorted well-rounded sand and gravel with sparse cobble-size clasts. Most of the clasts are from the Neruokpuk Formation. The top of the outwash is covered locally with a 3- to 5-inch mat of mossy vegetation. The gravel terrace on Lake Schrader near Spawning Creek probably represents material eroded from the Schrader moraine and deposited by Spawning Creek when Lake Schrader was at a higher level.

#### UNDIVIDED COLLUVIUM

Several kinds of microrelief features commonly found in arctic environments have been classed here as undivided colluvium. Among the more common features are mudflows, lobate terraces, terracettes, stone rings, stone garlands, stone stripes, polygons, frost mounds, and tussocks. These features are formed by sheet erosion and other processes including unconcentrated runoff, frost action, and mass-movement.

Various types of patterned ground occur on gentle slopes and flat valley floors. Sorted and nonsorted stone rings, which grade with increasing slope into stone garlands and stone stripes, are common on gravel-topped ridges. Sorted nets from 2 to 12 feet in diameter form on the flat parts of the higher country east and west of Lake Peters. Low center polygons, 10–75 feet in diameter, form in the swampy alluvial plain between Lake Peters and Lake Schrader. Ridges of peat-rich material 1–2½ feet high form the boundaries between adjacent polygons. The lower ground within these polygons is normally covered with a few inches of stagnant water.

Several mudflows are present on the slopes of the lateral moraines surrounding Lake Schrader. The relatively rapid movement of the mudflows has left semicircular scarps 2–8 feet high with channels varying in width as much as 50 feet in the slopes of the moraines. At the base of the flows irregular lobate mats of tundra are piled up and mixed with soil and rubble. These features are forming now, as is shown by the fresh bare rubble left in the depressions behind the termini of the flows.

## STRUCTURE

### GENERAL STATEMENT

The eastern Brooks Range is characterized by two structural terrains: an older one composed of rocks of the Neruokpuk Formation of Devonian or older age which have a complex structure and a younger one composed of post-Neruokpuk rocks of Late Devonian (?) through Jurassic age which contains east-trending folds and east-striking

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faults. Rocks of both structural terrains are exposed in the Lake Peters area. The purpose of this investigation was to determine what structural features existed in the Neruokpuk Formation prior to Late Devonian(?) and Mississippian deposition.

The Lake Peters area lies in the northern part of the structurally positive Romanzof Uplift (fig. 1). The mapped area is divided into the Peters structural province and the Schrader structural province. Their common boundary is the contact between the Neruokpuk Formation and the younger rocks (inset map *A*, pl. 1).

The Peters structural province, composed chiefly of rocks of the Neruokpuk Formation, lies on the north limb of a large east-west-trending anticlinorium (inset map *A*, pl. 1). Rocks in this province strike east-west, dip generally to the south, and are overlain by the Kekiktuk Conglomerate (pl. 1) with profound angular unconformity. This general southerly dipping sequence of Neruokpuk rocks suggests that in pre-Kekiktuk time there must have been an anticline in the northern part of the mapped area and a syncline to the south. Furthermore, the great thickness of Neruokpuk Formation that was removed by erosion (in excess of 6,000 ft, sec. *B–B′*, pl. 1) prior to Kekiktuk deposition indicates that the hiatus represented by the unconformity at the base of the Kekiktuk Conglomerate is one of considerable magnitude.

Broad open folds, thrust faults, and high-angle reverse faults are the most characteristic structural features in this province. Three generations of structural features were recognized. The first two generations were formed prior to deposition of the Kekiktuk Conglomerate and are believed to have resulted from one more or less continuous period of deformation that involved south-southwest—north-northeast compressive stresses. Third generation structural features were formed by north-south compressive stresses after deposition of the Kekiktuk Conglomerate and younger rocks.

The first generation is represented by broad open major folds (first folds) with east-southeast-striking subvertical axial planes (pl. 1, sec. *B–B′*) and axes that plunge about 15° ESE. These folds were seen in the field only on the east side of Lake Peters.

Second generation structural features are subparallel to first generation folds and consist of east-southeast-trending minor folds (second folds) with south-dipping axial planes, and thrust faults that strike east and dip 10°–20° S. The minor folds range in size from crenulations a millimeter or less in wavelength to folds tens of feet in wavelength. The axes of the minor folds plunge gently to the east-southeast and west-northwest. As the axial planes of the minor second folds dip to the south on both the north and south limbs of the major first folds, they are incongruent with the major first folds and, hence, of a different generation. In many places the thrust faults are nearly bedding plane thrusts. They are geometrically related to the second folds, and both structural features are believed to have resulted from the same compressive stresses. The fault planes are truncated by the unconformity of the base of the post-Neruokpuk rocks.

Third generation structural features in the Peters structural province consist of open folds (third folds) that in general trend east-west and faults that strike east-southeast and dip south. High-angle thrust faults and normal faults are the most prominent type of third generation yielding in the Peters structural province. Locally, south blocks of faults may also have rotated counterclockwise relative to north blocks (when viewed looking to the north). The third folds are exposed along the northern border of the province (pl. 1). They were formed at the same time that the unconformity at the base of the Kekiktuk Conglomerate was folded, and the faults locally truncate the Kekiktuk Conglomerate. The third folds are related to a regional warping of the basement which is shown by the two large anticlinoria that expose the Neruokpuk Formation 20 miles south of Lake Peters and by a smaller anticlinorium 10 miles northwest of Lake Peters (inset map *B*, pl. 1). The broad-scale basement folds shown on inset map *B*, plate 1, have a wavelength of about 15 miles and represent folding of the unconformity at the base of the Kekiktuk Conglomerate. The base of the Kekiktuk Conglomerate on section *A–A′* (pl. 1) outlines the north limb of a broad anticline which is part of the north limb of the large anticlinorium (or basement fold) south of Lake Peters shown in inset map *B*, plate 1.

The Schrader structural province lies on the south limb of a synclinorium and is composed of sedimentary rocks younger than the Neruokpuk Formation (inset map *B*, pl. 1). The structural features in this province are coeval with third generation structural features in the Peters province. East-trending en echelon folds and south-dipping thrust faults, characteristic of structural features found elsewhere in the younger terrain of the eastern Brooks Range, dominate the Schrader province.

En echelon folds in the Schrader province (pl. 1) trend east-northeast in the western part of the Lake Peters area, east in the central part, and east-southeast in the eastern part. The folds plunge gently to the east and west; axial planes dip south. The folds are locally overturned with vertical to steep south-dipping north limbs. The wavelength of the larger folds is about 2,500 feet, but the wavelength ranges from 1,500 to more than 4,000 feet. The amplitude of the larger folds is variable and ranges from 1,200 to 2,500 feet. Major thrust faults at the mountain front strike east-west and dip 30°–40°S. Displacement on these thrust faults seems to be in the order of 1,500 feet or less. Minor thrust faults, in the Lisburne Group at the southern border of the Schrader province, strike east-west and have small apparent displacement.

### ANALYSIS

Projections of structural elements on the lower hemisphere of the equal area net supplemented the conventional methods used to study the geometry of rocks. Geometrical relations between the first and second generation of structural elements, not satisfactorily shown on the cross sections and map (pl. 1), were thus clarified. The nomenclature used in the description of the structural elements in the Peters structural province is as follows:

- $S_0$ Bedding; also bedding-plane schistosity
- $S_1$ Axial plane of first folds
- $S_2$ Axial plane of second folds; also cleavage coeval with second folds
- $F_1$ Axis of first folds
- $F_2$ Axis of second folds
- $L_2$ Lineation related to second generation folds; defined by intersection of bedding ($S_0$) and cleavage ($S_2$), and crenulations.

The Peters structural province was subdivided into thirteen structurally homogeneous domains generally bounded by faults of the third generation (pl. 4). Bedding pole diagrams for two domains were plotted to describe more definitively the orientation of the axes and axial planes of first generation folds. Projection of second generation fold axes, axial planes, cleavage, and lineation shows the subparallel geometrical relation between first and second generation structural elements; it also shows second generation folds superimposed on first generation folds but indicates that both generations are probably related to one more or less continuous phase of deformation that involved south-southwest—north-northeast compressive stresses.

#### PETERS STRUCTURAL PROVINCE

#### FIRST GENERATION

Folds of the first generation were seen in the field only on the east side of Lake Peters (pl. 1, sec. *B–B'*; pl. 4, domains 1 and 2). Here they are characterized by broad open folds with subvertical axial planes. The orientation of the axial plane ($S_1$) is derived from the macroscopic form of the fold itself (fig. 25) and by construction of bedding pole diagrams for domains 1 and 2 (fig. 26). The bedding

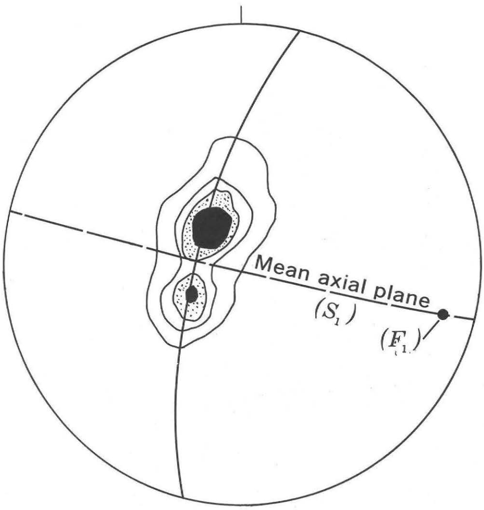

FIGURE 25.—Open first folds in Peters structural province; view looks east-southeast across Lake Peters. Fold plunges away from viewer at 10°–15°; dashed line indicates trace of bedding ($S_0$), solid vertical line indicates axial plane ($S_1$) of first fold. Mount Chamberlin in right background; buildings on alluvial fan belong to Arctic Research Laboratory station.

pole diagrams of domains 1 and 2 (fig. 26) show that the axes of the first folds ($F_1$) on the east side of Lake Peters plunge about 15° ESE. Low-angle thrust faults, associated with the second generation folds, produced only minor displacement of the first folds (pl. 1, sec. *B–B′*).

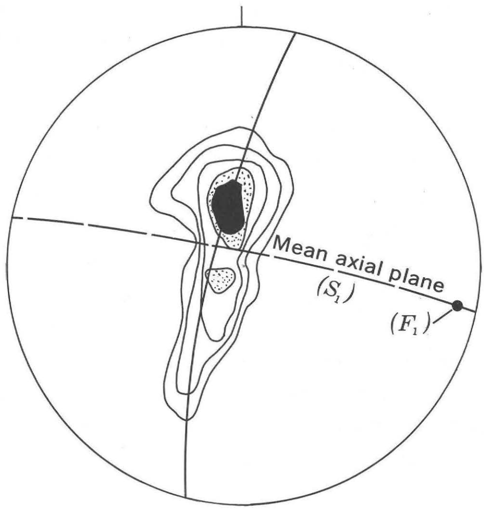
Schistosity, coeval with first folds, is defined microscopically by preferred orientation of platy minerals parallel to the bedding. Folding did not attain the stage at which axial plane cleavage is developed. The relatively uniform south-dipping beds in the southern part of the Peters structural province suggest that other folds of the first generation must have been relatively broad, open structural features similar to the first folds on the east side of Lake Peters.

### SECOND GENERATION

Folds of the second generation affect first generation schistosity and are superposed on the first folds. They are irregular or absent in the competent metamorphic quartz wacke and chert. The more rigid rocks occasionally fold concentrically (fig. 27), whereas the less competent interbedded phyllites and quartz semischists show similiar folding with well-developed axial plane cleavage (fig. 28). Second generation (minor) folds range in size from crenulations a millimeter or less in




Domain 1
(58 measurements)
*A*




Domain 2
(50 measurements)
*B*

FIGURE 26.—Bedding pole diagrams showing orientation of axial planes and axes of first folds in domains 1 and 2 in Peters structural province. *A*. Contours 2–9–14–24 percent per 1 percent area. *B*. Contours, 2–4–8–14–24 percent per 1 percent area. $F_1$ are axes of first folds.

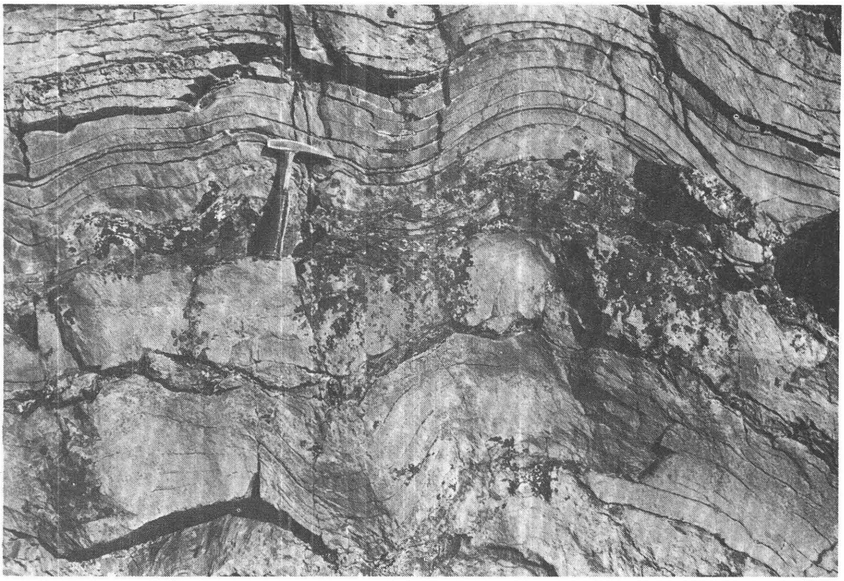


FIGURE 27.—Concentric second folds in competent quartz wacke. Note poorly developed fracture cleavage which is parallel to the axial planes of the second folds.

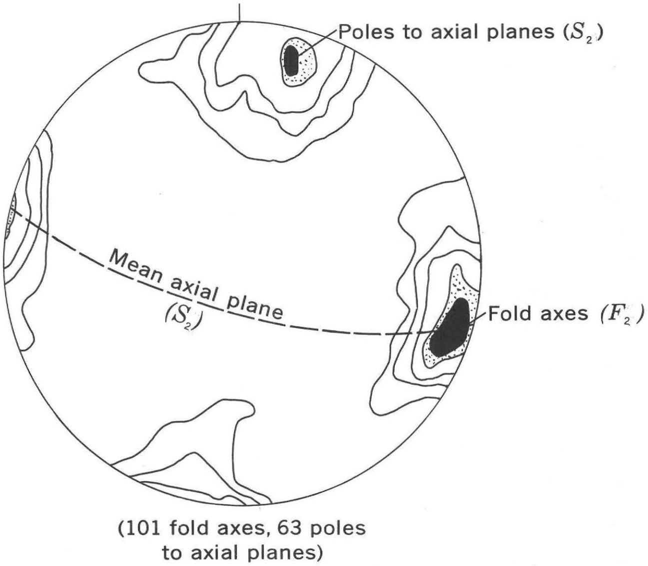

FIGURE 28.—Similar second folds in incompetent phyllite showing well-developed axial plane cleavage. $S_0$ is bedding (also bedding-plane schistosity); $S_2$ is axial plane cleavage defined by strain-slip cleavage (see figs. 30 and 31).

wavelength to folds tens of feet in wavelength. The latter are well shown on the west side of Whistler Creek (pl. 1). The style of the folds is variable, but in general they are asymmetric with long south limbs and shorter north limbs. Axial planes strike east-southeast and in general dip steeply to the south (fig. 29). Axial planes locally dip to the north, but this may be controlled by later faulting (p. 85). Axes of second folds plunge east-southeast and west-northwest subparallel to the axes of the first folds (figs. 29 and 26).

Axial plane cleavage ($S_2$) includes both fracture cleavage and strain-slip cleavage. Cleavage not associated with folds is coplanar with axial plane cleavage and considered coeval with the second generation of folds (fig. 29). Fracture and strain-slip cleavage is clearly revealed in thin section. It is parallel to the axial planes of the folds (figs. 30 and 31) and involves a differential displacement of bedding plane schistosity ($S_0$). There is a suggestion of incipient growth of micaceous minerals along the surfaces of slip, but true slaty cleavage, in which minerals have recrystallized parallel to cleavage, was not observed in any of the thin sections examined. Fracture cleavage has developed locally into small microfaults (fig. 30).

Figure 32 diagrammatically represents the superposition of second folds on first folds in domain 1. $S_2$ surfaces are subparallel and dip to the south on opposite limbs of the large open first folds. In figure 32 the angle between the axes of the first folds ($F_1$) and the axes of the second folds ($F_2$) is exaggerated for convenience of illustration. Divergence of the axial planes of the first and second folds suggests that the second folds were formed later than, and not contemporaneous with, the first folds (fig. 33). Evidence that the open folds did not form later than the minor folds is also shown in figure 33. Here domain 1 is subdivided into subdomains 1*a* and 1*b*, which lie on the south and north limbs of the first fold, respectively. The stereographic projection shows the orientation of second generation folds and cleavage ($S_2$) of subdomains 1*a* and 1*b* and also the mean axial plane ($S_1$) of the first fold. If the broad open first fold, whose axial plane is shown by $S_1$, represented post-$S_2$ folding (assuming $S_2$ surfaces had a subparallel south dip prior to folding), then $S_2$ surfaces on the north limb of the fold would have been rotated to a more gentle southerly dip than the $S_2$ surfaces on the south limb of the fold. The overlapping orientation of $S_2$ surfaces on the two limbs of the first fold (fig. 33) indicates that this is not the case.

Inspection of plate 4 and of the collective diagrams showing second generation structural features (fig. 29) shows that lineation and fold axes plunge gently east-southeast and west-northwest and lie on a circle corresponding to the mean axial surface of $S_2$. This would be



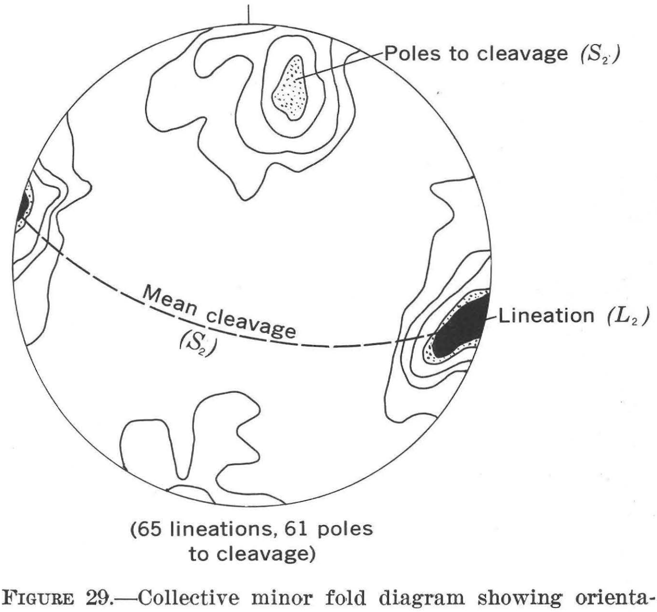




FIGURE 29.—Collective minor fold diagram showing orientation of axial planes and axes second folds, and cleavage and lineation in Peters structural province. Lineation is defined by bedding-cleavage intersections and crenulations. Contours 1–4–8–16–24 percent per 1 percent area.

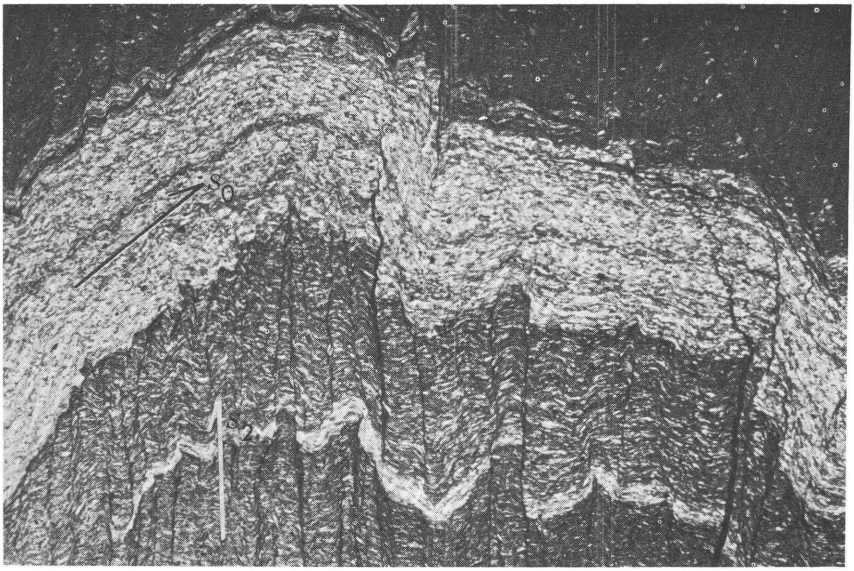



FIGURE 30.—Crest of minor second fold in phyllite showing strain-slip and fracture cleavage parallel to the axial plane of the fold. White band is a more competent quartz-rich lamina. $S_0$ is bedding (also bedding-plane schistosity) crossed by a later strain-slip and fracture cleavage ($S_2$) that is parallel to axial plane of fold (plane light, × 68).

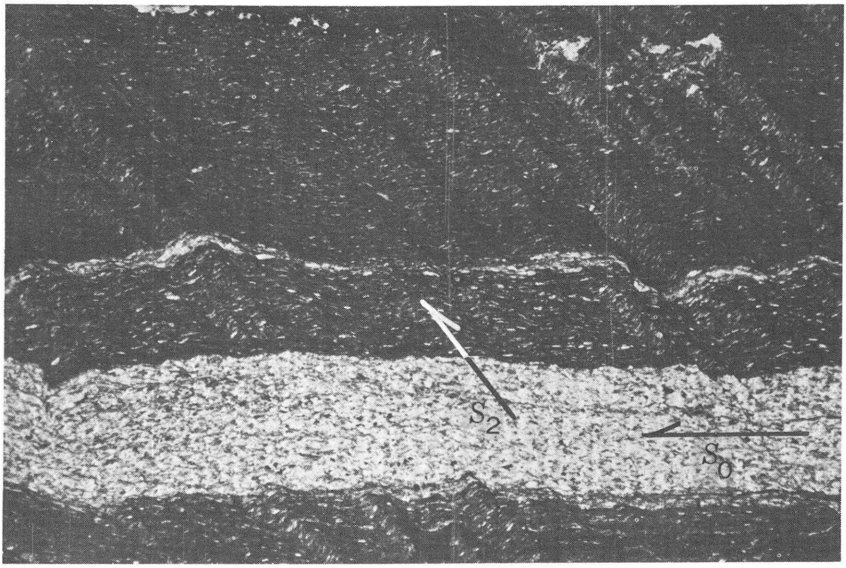



FIGURE 31.—Right limb of minor fold shown in figure 30. $S_2$ in figure 30 is parallel to $S_2$ in figure 31 (plane light, × 68).

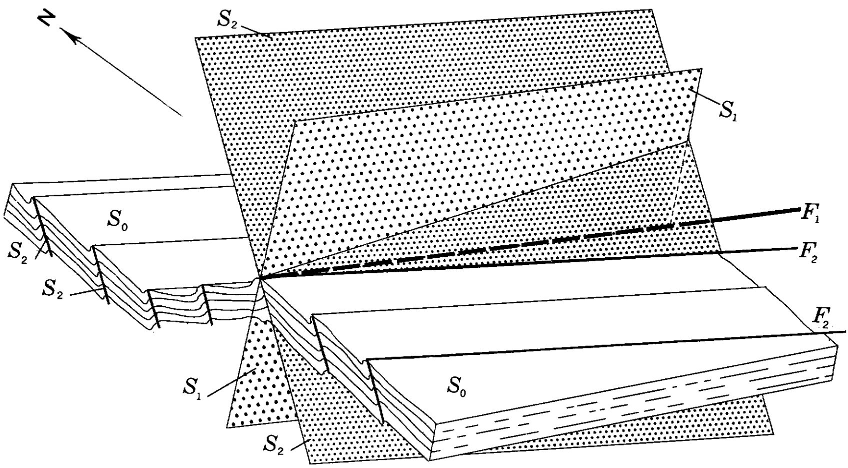



FIGURE 32.—Diagram of domain 1 showing superposition of minor second folds with south-dipping axial planes, $S_2$, on both limbs of major first fold. $S_0$ is bedding (also bedding plane schistosity), $S_1$ is axial plane of first fold, $F_1$ is axis of first fold, $F_2$ are axes of second folds.

expected from theoretical considerations (Weiss and McIntyre, 1957, p. 579). Furthermore, since the orientation of fold axes for a given stress field is controlled by the preexisting orientation of the surface being folded, departures from the ideally envisioned broad open first folds would affect the orientation of superposed fold axes. This could account for the small spread of $F_2$ shown in some of the domains.

Thrust faults are associated with the second generation of folds. Owing to the lack of distinctive marker beds in the Neruokpuk Formation, faults of this generation are difficult to recognize. Breccia zones are not well developed, and the presence of the faults is best observed from a distance at which a slight discordance in bedding planes above and blow the fault is apparent. The faults strike east-west and dip gently to the south. The relative age of folding to thrusting could not be ascertained, but they are geometrically related to and believed to have resulted from the same north-northeast—south-southwest compressive stresses.

South-dipping thrust faults are characteristic of Laramide deformation throughout the Brooks Range (Gryc, 1959; Lathram, 1965); however, some south-dipping thrust faults are associated with the second deformation and are truncated by post-Neruokpuk rocks. This is best shown by the thrust fault near the headwaters of Coke Creek (pl. 1). East of Katak Creek other south-dipping thrust faults are truncated by the Kekiktuk Conglomerate but could not be examined closely because high waters prevented crossing the creek. Other thrust faults

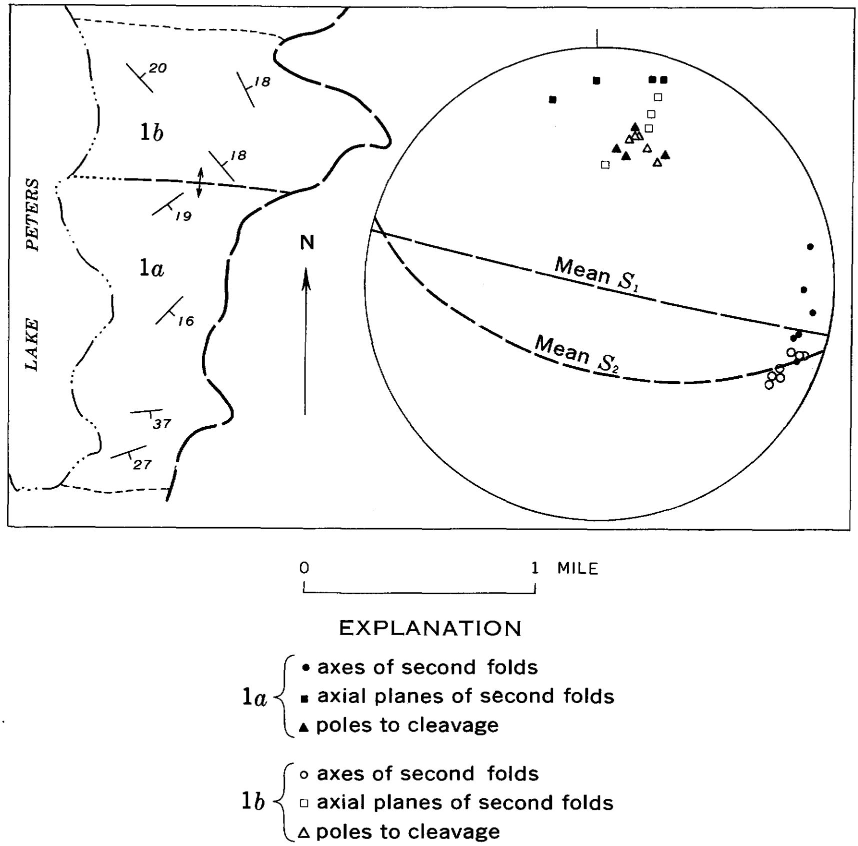



FIGURE 33.—Diagram showing the overlapping orientation of the second generation folds and cleavage ($S_2$) in domain 1 which is subdivided into subdomain 1*a* (which lies on the south) and subdomain 1*b* (which lies on the north limb of the first fold). Equal-area projection shows mean axial plane of first fold ($S_1$) and second generation ($S_2$) surfaces.

believed to be related to the second generation structural features are present on both sides of Lake Peters (pl. 1, secs. *A–A,′ B–B′*). Their age is difficult to determine because of subsequent erosion of the Kekiktuk Conglomerate.

#### THIRD GENERATION

Structural features of the third generation are post-Kekiktuk in age and consist of folding and high-angle faulting.

Open, generally east-trending folds (third folds) are related to regional warping of the basement. The third folds are exposed along the northern border of the Peters structural province (pl. 1) and were formed at the same time that the unconformity at the base of the Kekiktuk Conglomerate was folded. This folding is diagrammatically shown in figure 34. The related basement folds, shown by the two large anticlinoria south of Lake Peters and a small anticlinorium northwest of Lake Peters (inset map *B*, pl. 1), have a wavelength of about 15 miles.

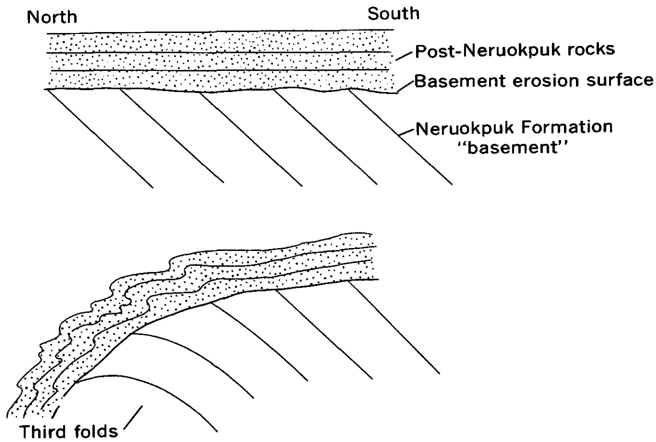



**FIGURE 34.—Diagram showing basement prior to deformation and formation of third folds by warping of basement.**

The most prominent type of yielding in the Peters province during this generation was faulting. The faults dip moderately to steeply south and strike east-southeast; they may, in part, have been controlled by the preexisting structural grain of the Neruokpuk Formation. Many of these faults are probably high-angle reverse faults. Breccia zones, locally tens of feet wide, and local overturning of beds attest to the presence of faults. Section *A–A′* (pl. 1) shows the Kekiktuk Conglomerate truncated by faults of this generation. Faulting has caused a rotation of $S_2$ surfaces which locally dip steeply to the north. This is well demonstrated in domains 8 and 9 (pl. 4). North-dipping $S_2$ surfaces were observed only near disturbed zones related to faulting.

Counterclockwise rotation of south blocks relative to north blocks (when viewed looking to the north) is suggested by the gentle westerly plunge of $F_2$ in some domains. If the westerly plunge of $F_2$ is related to fault movement, the amount of rotation is small, probably less than 20°. For a given orientation of compression, however, the orientation of second-fold axes ($F_2$) that form in a given surface in response to the compression depends on the orientation of the surface at the onset of folding. Thus the divergence in second-fold axes ($F_2$) could be attributed to the orientation of the preexisting surface (first folds) on which the second folds were superposed.

Figure 35 is a diagrammatic representation of the structural features in the Peters province following the third deformation. $S_0$ is bedding and bedding plane schistosity, $S_1$ is the axial plane of the first fold, and $F_1$ is the axis of the first fold. $S_2$ are axial planes of second folds, and $F_2$ are axes of the second folds. Thrust faulting associated with the second generation of folds is shown in the north fault block. Third folds are not illustrated on this diagram (see fig. 34). Post-Kekiktuk third generation faulting and associated west-plunging second generation fold axes ($F_2$) with north-dipping $S_2$ surfaces and possible counterclockwise rotation are illustrated in the south fault block.

#### JOINTS

Attitudes of joints in the Peters province are shown in figure 36. Quartz-filled joints (fig. 36*A*) may represent early joints. They are cut by subparallel unfilled joints on which displacement is, at most, only a few millimeters. Quartz-filled joints and unfilled joints (fig. 36*B*) are essentially parallel; they strike N.10°W. to N.20°W., and have a subvertical east dip. Joints in the Schrader structural province (fig. 41*B*) show essentially the same trend, which suggests that joints in the Peters province are, in part, related to a post-Lisburne tectonic event.

The strike of the maxima of the quartz-filled joints forms an angle of about 60° to the structural grain of the Peters province and about 30° to the compressive stress axis. Although speculative, assuming these joints represent an earlier joint pattern, they could be shear joints in which only one set is well developed. A poorly developed complementary set may be represented by the northeast-striking submaxima (fig. 36*A*). Unfilled joints could be of similar origin, but some of them are probably related to north-northwest-striking subvertical transverse faults which cut post-Neruokpuk rocks throughout the Romanzof and Franklin Mountains (Sable, 1959; Lathram, 1965) in response to a post-Lisburne orogenic maximum, or to relaxation of the compressive stresses and uplift.

### SCHRADER STRUCTURAL PROVINCE

Structural features in the Schrader province consist mainly of east-trending folds and south-dipping thrust faults. Jointing and cleavage are locally well developed.

#### FOLDS

From west to east, folds in this province trend east-northeast, east, and east-southeast. Their form and distribution is shown on plate 1. The average wavelength of the major folds is about 2,500 feet, but the wavelength ranges from 1,500 to more than 4,000 feet. The amplitude

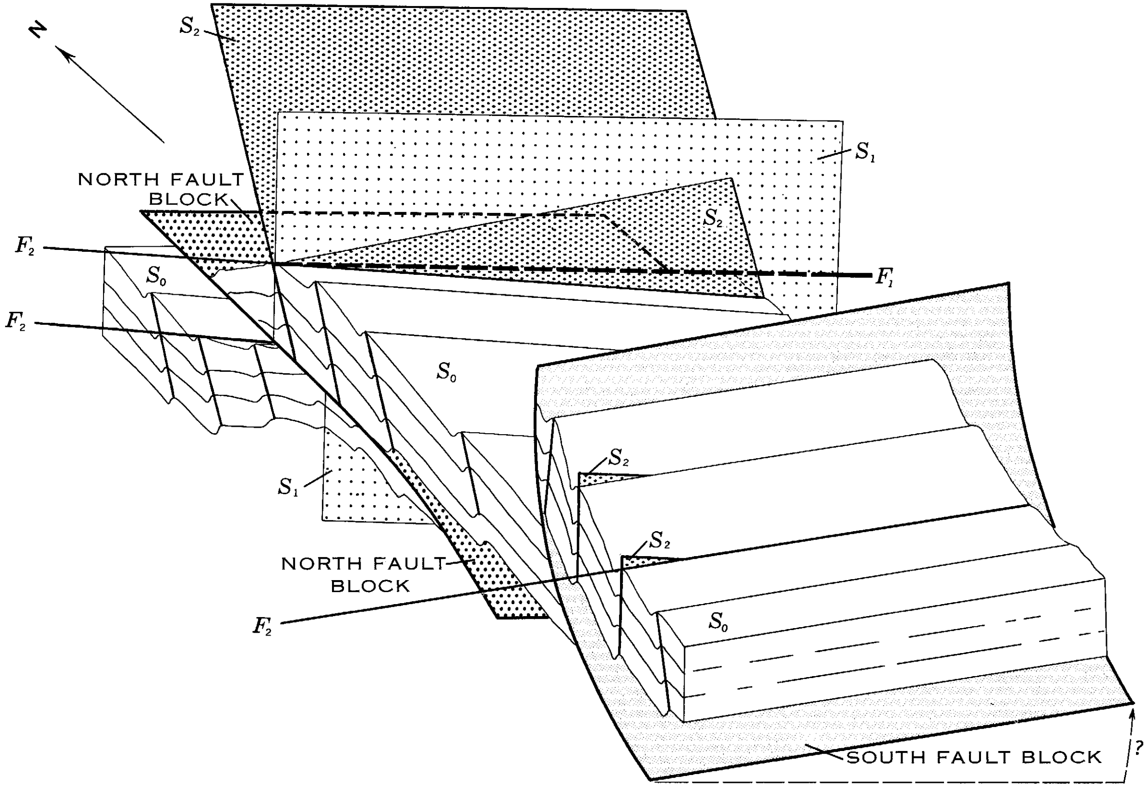



FIGURE 35.—Diagram of Peters structural province. See text for explanation.

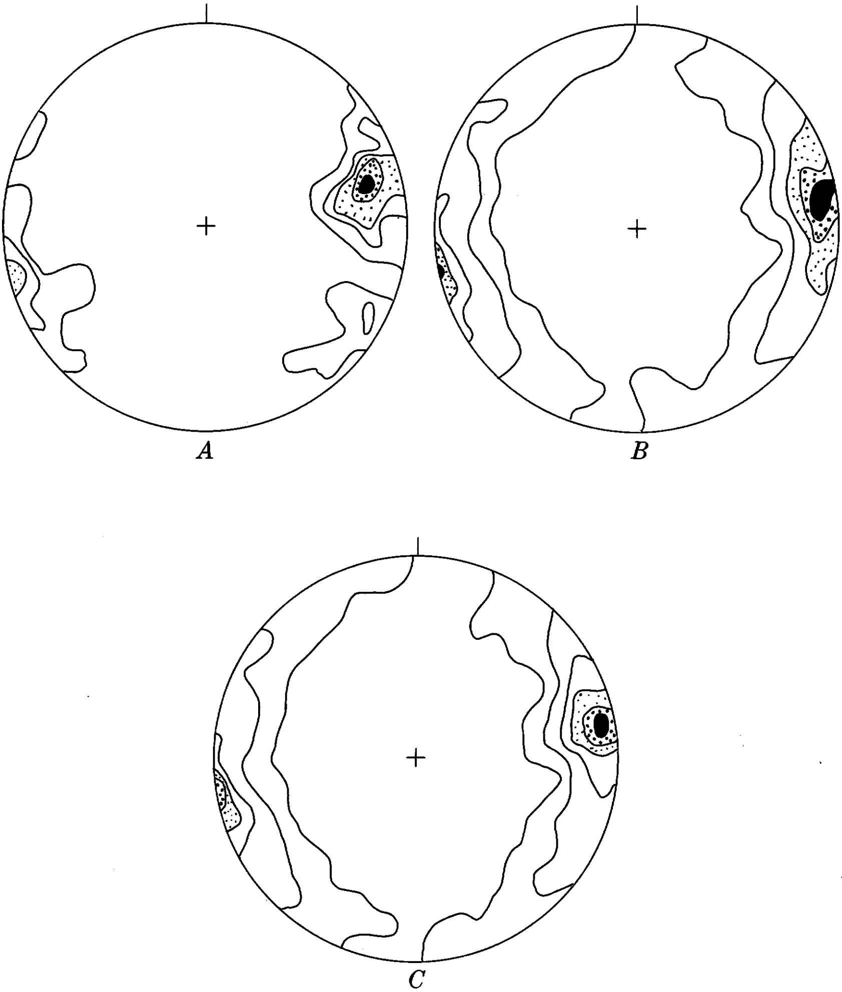



FIGURE 36.—Diagrams showing orientation of poles to joints in the Peters structural province. *A*. 59 quartz filled joints; contours 1.7–5–10–17–22 percent per 1 percent area. *B*. 373 unfilled joints; contours 0.5–2–4–6–8 percent per 1 percent area. *C*. Collective diagram of 432 quartz filled and unfilled joints; contours 0.5–2–4–6–8–10 percent per 1 percent area.

of the major folds is variable and ranges from 1,200 to 2,500 feet. The folds plunge gently to the east and west with a north-trending line of axial culmination between Coke Creek and Katak Creek. Subsidiary folds with wavelengths ranging from a few inches to tens of feet are

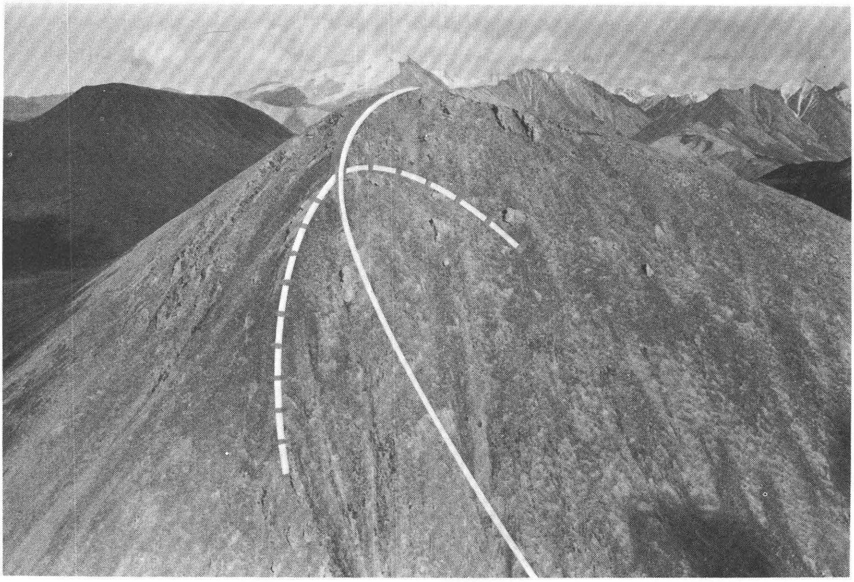


FIGURE 37.—View looking east at overturned anticline in Lisburne Group. Trace of axial plane shown by solid line; bedding shown by dashed line. Snow covered peaks in background are Romanzof Mountains.

superimposed on the limbs of the major folds. In general, the axial planes dip south; the folds are locally overturned with vertical to steep south-dipping north limbs (fig. 37).

Folding becomes more intense toward the southern border of the province where a bending of the basement and heterogeneous yielding of the less competent sedimentary rocks has taken place. Here the sedimentary rocks form the south limb of a synclinorium. Subsidiary asymmetric and disharmonic folds are present in the generally north-dipping limestone of the Lisburne Group (fig. 38). Discontinuous thrust faults of small apparent displacement are associated with this intense folding (fig. 39). This zone of heterogeneous yielding may be an indication of small-scale gravity gliding localized where the basement takes on a steeper northward dip. Yielding of this nature is at least suggested by figure 34 and the cross sections (pl. 1). The basal shearing plane most likely would be in the incompetent Kayak(?) Shale; however, the absence of Lisburne and Sadlerochit klippen north of the mountain front precludes large-scale gravity gliding as

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FIGURE 38.—View looking southeast at subsidiary folds formed in the Lisburne Group. Photograph is taken close to section line *C–C′* on plate 1.

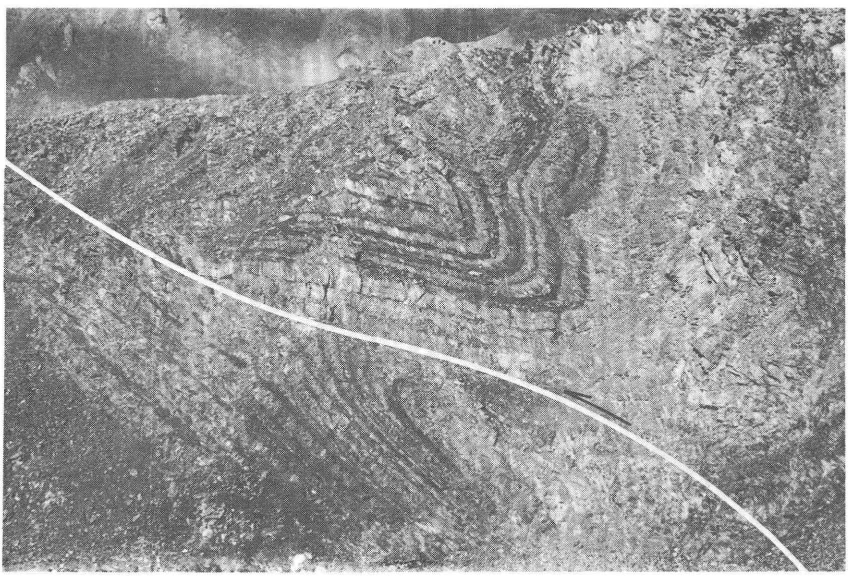


FIGURE 39.—View looking east at small thrust fault within the Lisburne Group.


FIGURE 40.—View looking east at less intensive folding of the Lisburne Group (Cl) and Sadlerochit Formation (ꞦPs). Trace of axial plane shown by solid line.

a dominant structural process. Folding is less intense northward toward the mountain front, but axial planes continue to dip south (fig. 40). North of the mountain front along Karen Creek, the few beds of the incompetent Kingak Shale that are exposed are all tightly folded. The folds are asymmetric to overturned. Axes trend east-west, and axial planes dip steeply to the south.

## CLEAVAGE

The orientation of slaty cleavage in the Schrader province is shown in figure 41*A*. In general, cleavage strikes east, dips moderately to the south, and coincides with axial planes of folds. Cleavage is well developed in shale and siltstone. In interbedded sequences of sandstone and siltstone the less competent siltstone shows a thinning on limbs of folds accompanied by closely spaced fracture cleavage. Cleavage is widely spaced or lacking in the sandstone beds. Recrystallization on cleavage planes was not observed. Axial plane or slaty cleavage, as defined by Billings (1954, p. 339–349), is developed where shale is tightly folded.

### FAULTS

Faults in the Schrader province consist of major and minor thrust faults and one northwest-trending transverse fault (pl. 1). Two major thrust faults occur at the mountain front. They strike east and dip 30°–40°S. The northern major thrust fault (fig. 14) involves an overriding of the Sadlerochit Formation on the Shublik Formation and the Kingak Shale. The exact displacement of this fault is not known but seems to be in the order of 1,500 feet (sec. *C–C′*, pl. 1). The trace of the southern major thrust fault is in the Sadlerochit Formation east and west of Coke Creek. The displacement of this fault seems to be less than that of the northern major thrust.

Minor thrust faults of small displacement cut the Lisburne Group along the southern border of the province (fig. 39). North of the mountain front along Karen Creek, small breccia zones associated with tight folding in the Kingak Shale indicate the presence of thrust faults and duplication of section.

One subvertical transverse northwest-trending fault of small displacement is present west of Whistler Creek. This fault is probably the result of relaxation of compressive stresses following folding.

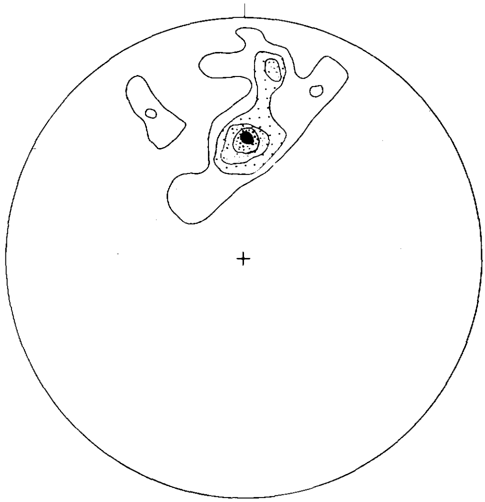
### JOINTS

The attitudes of joints in the Schrader province are shown in figure 41*B*. The joints are subvertical and strike mainly N.5°W. to N.15°W. Because the trend of the joints is approximately perpendicular to the axes of folds, these joints may represent extension joints.

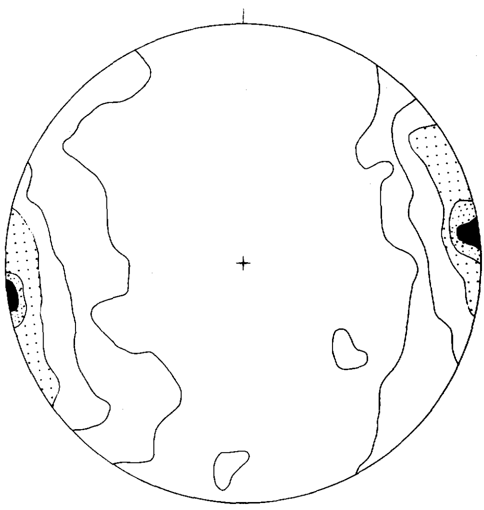
## METAMORPHISM

### NERUOKPUK FORMATION

The sediments within the Neruokpuk Formation have been regionally metamorphosed to quartz wacke, phyllite, and semischist. Although a comprehensive study of the metamorphism has not been made, the following description is presented in the hope that it may serve as a guide to future work in this area. The original clastic texture of much of the quartz wacke is still recognizable (fig. 4). The finer grained argillaceous lithologies are more intensely deformed and



*A*



*B*

FIGURE 41.—Orientation of cleavage and joints in the Schrader structural province. *A*. Shows orientation of 19 poles to cleavage; contours 5–10–16–21–36 percent per 1 percent area. *B*. Shows orientation of 176 poles to joints; contours 0.5–2–6–10–15 percent per 1 percent area.

recrystallized and have been converted to quartz semischist (fig. 5). There seems to be no relation between degree of reconstitution and depth of burial in these rocks.

Mineral assemblages commonly contain quartz, albite, muscovite, and chlorite. Chloritoid and pyrophyllite (p. 16) are present locally, but epidote is rare. All of these minerals generally are present as extremely fine-grained aggregates; X-ray diffraction techniques were used in their identification. Calcite and dolomite are sparingly present throughout the Neruokpuk Formation undivided, but in the calcareous sandstone member, carbonates compose as much as 40 percent of the rock (sec. 1*A*, pl. 2). White mica is identified as the 2*M* polymorph of muscovite using the criteria of Loder and Eugster (1955). Using the method described by Smith and Yoder (1956), albite was found to range from $An_2$ to $An_7$, most samples falling below $An_5$. Chlorite is optically negative and iron rich (p. 19).

The above mineral assemblages indicate that the rocks of the Neruokpuk Formation belong to the quartz-albite-muscovite-chlorite subfacies of the greenschist facies (Turner and Verhoogen, 1960, p. 534–537). The rocks in the mapped area did not reach the metamorphic grade at which biotite is formed. Moreover, the rocks do not show evidence of a polymetamorphic history although there is evidence of a polystructural history. It is believed that during the regional metamorphism which resulted in the above described mineral assemblages, the principal structural element was bedding plane schistosity which developed contemporaneously with broad open folding.

### POST-NERUOKPUK ROCKS

Rocks overlying the Neruokpuk Formation are slightly metamorphosed and slaty cleavage is locally developed. The rocks in general, however, do not possess a well-developed metamorphic fabric as do the underlying Neruokpuk rocks. Mineral assemblages commonly contain quartz, sericite (2*M*), albite, and locally, chlorite. Thus, these rocks can also be classified as low-grade metamorphic rocks (greenschist facies).

Pyrophyllite occurs as a matrix mineral in the Kekiktuk Conglomerate (p. 30) and in minor amounts in the underlying Neruokpuk Formation and the overlying Kayak(?) Shale. It is restricted, however, to within a few feet of the contact with Kekiktuk Conglomerate.

Experimental studies have shown that pyrophyllite is to be expected as a stable phase in some low- and medium-grade metamorphism (Hemley, 1959; Hemley and Jones, 1964). In rocks of the greenschist facies, pyrophyllite-bearing assemblages would be the Al-Si equivalents of albite-chlorite-muscovite-bearing associations. Pyrophyllitization of kaolinite in the presence of quartz is readily demonstratable at temperatures above about 390°C for pure water at 1,000 bars $PH_2O$. The reaction is:

$$Al_2Si_2O_5(OH)_4+2SiO_2 \rightarrow Al_2Si_4O_{10}(OH)_2+H_2O$$

The reaction has not been reversed, however, in the time range of the experiments, and so the true thermodynamic temperature may be much lower.

A possible origin for the pyrophyllite, consistent with the mineral assemblage of quartz-pyrophyllite-sericite, has been discussed by Reed and Hemley (1966). There appears to be no apparent inconsistency between known experimental relations in the alumina-silica-water system and the occurrence of pyrophyllite in this geologic setting. The most important requisite for pyrophyllite formation in low-grade metamorphism (greenschist facies) is a relatively pure almina-silica bulk composition for the material involved.

## TECTONIC HISTORY AND CONCLUSIONS

Within the Lake Peters area pre-Mississippian fold axes have an approximate eastwest orientation. The first two (pre-Mississippian) generations of structural features in the Peters province have been discussed as two separate deformations. This was done to clarify and to emphasize the features of the two deformations, but there is no evidence that the first two generations were widely separated in time. They may well represent successive phases of one more or less continuous orogenic event that occurred prior to Mississippian deposition.

Defining the orientation of pre-Mississippian structural features in the Lake Peters area leads to another enigmatic problem in the understanding of the tectonics of this part of the Brooks Range, that is, the age of the pre-Mississippian folding. An upper age is definitely established by Mississippian fossils in the Kayak(?) Shale. A lower age limit is not known because identifiable fossils have not been found in the Neruokpuk Formation. On the basis of lithologic similarities the Neruokpuk Formation is in part correlated with Upper Devonian rocks in the southern Brooks Range (Brosgé and others, 1962). Granitic rocks in the Romanzof Mountains, 15 miles east of Lake Peters, intrude the Neruokpuk Formation. The presence of biotite in the Neruokpuk Formation near this pluton (Sable, 1965) indicates an apparent increase in metamorphic grade towards the intrusive. The general contemporaneity of regional metamorphism, deformation, and batholithic intrusion suggests that pre-Mississippian folding may well have been associated with the intrusion of the Romanzof granite. Lead-alpha age determinations on zircon from two samples of the Romanzof granite give ages of 310±35 million years and 405±45 million years

(Sable, 1965, p. 168). Potassium-argon determinations on biotite from the same two samples give ages of 128 and 125 million years (Sable, 1965, p. 169). Sable believed that the Romanzof granite was an Upper Devonian pluton in which the biotite age has been updated by a Mesozoic orogeny. A pre-Kekiktuk age for the Romanzof instrusive is also indicated by the presence in the Kekiktuk Conglomerate (p. 31–33) of tourmaline and cassiterite that appear to be genetically related to intrusive rocks associated with the Romanzof granite.

It therefore seems reasonable to suggest the following sequence of events before deposition of the Kekiktuk Conglomerate: Upper Devonian(?) regional metamorphism, more or less contemporaneous with folding, led to development of bedding plane schistosity ($S_0$, fig. 42*A*). The axial planes ($S_1$) of these first folds strike east-southeast and have a subvertical dip. In a more or less continuing phase of the same deformation, a second generation of east-southeast-trending folds were superimposed on the earlier open folds (fig. 42*B*). The superimposed folds plunge gently east-southeast and west-northwest and axial planes ($S_2$) dip steeply to the south. The second generation was accompanied by thrust faulting, $T_1$ in figure 42*C*.

The diagrams (figs. 42*A*–*C*) and cross sections (pl. 1) indicate that in pre-Kekiktuk time an anticlinal axis must have been in the northern part of the map area and a synclinal axis somewhere to the south. Moreover, the unconformity at the base of the Kekiktuk Conglomerate is of great magnitude and indicates that more than 6,000, and possibly as much as 10,000 feet, of Neruokpuk rocks (pl. 1, sec. *A*–*A'*, *B*–*B'*) were eroded prior to Kekiktuk deposition. Rocks of the Neroukpuk Formation were folded, regionally metamorphosed, faulted, uplifted, and eroded before deposition of the Kekiktuk Conglomerate. Thus, the Neruokpuk Formation in the Lake Peters area may be older than Devonian and could represent early Paleozoic deposition. Although the Kekiktuk Conglomerate is thin to absent in the Lake Peters area, a great thickness of time-equivalent conglomerate and sandstone was shed southwestward into the eastern Brooks Range (Brosgé and others, 1962). The main center of uplift for the Upper Devonian and Mississippian clastic sequence was probably southeast of Lake Peters in the area the Romanzof Mountains. The lack of feldspar in the Kekiktuk Conglomerate suggests that the Romanzof granite was not unroofed at this time. However, tourmaline-quartz pebbles and cassiterite in the conglomerate suggest that igneous material, genetically related to the intrusive, was available as a source. East-to-northeast transgressing seas deposited marine shales. Following this, the dominantly carbonate rocks of the Lisburne Group were deposited (fig. 42*D*).

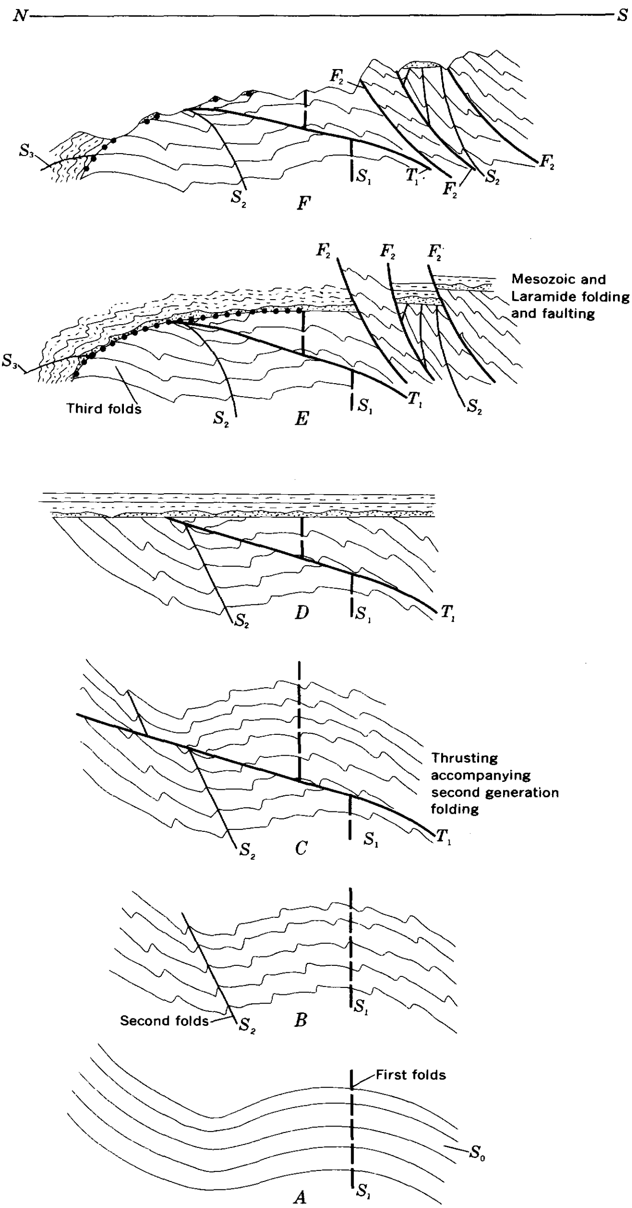



**FIGURE 42.**—Diagram showing evolution of tectonic elements in the Lake Peters area. For explanation see text.

Late Paleozoic and Mesozoic tectonics of the Brooks Range have been described by Payne and others (1951), Gryc (1959), and Gates and Gryc (1963). The area of the present Brooks Range was described as the site of late Paleozoic deposition which continued into the Triassic Period. Clastics were derived from the north. In Early Jurassic time late Paleozoic and Triassic sediments were uplifted and gave rise to the Brooks Range geanticline. Deposition continued intermittently into the Early Cretaceous in the Kobuk Trough to the south and the Colville geosyncline to the north. A late Mesozoic orogeny deformed the sedimentary rocks into an east-west structural grain in the northern part of the Brooks Range; intrusion and metamorphism took place in the southern part of the range. The updated biotite ages of the Romanzof granite apparently reflect this orogeny. Uplift of the Brooks Range geanticline continued throughout the remainder of the Cretaceous and into the early Tertiary. A final Laramide deformation intensified the east-west structural grain and caused the south-dipping imbricate thrust faults and overturned folds.

Both Mesozoic and Laramide folding (dotted line at unconformity, and $S_3$) and faulting ($F_2$) are shown in figure 42*E*. In the eastern Brooks Range, which had been consolidated by the older Late Devonian(?) orogenic phase, the basement (Neruokpuk Formation) yielded by broad-scale bending and high-angle faulting. The regional basement folds have a wavelength of about 15 miles (inset map *B*, pl. 1). Third folds were formed and local rotation of $S_2$ surfaces took place in the Peters province at this time (fig. 42*E*). Axial planes of third generation overturned folds in post-Neruokpuk rocks in the Schrader province are shown as $S_3$ on figure 42*E*. The arcuate trend of fold axes in the Schrader province may have been influenced by the shape of the basement. Tertiary uplift (Romanzof Uplift) followed by glaciation and erosion (fig. 42*F*) also influenced the topographic expression of the structural features as they are seen today.

## MEASURED SECTIONS

The following description of measured sections consists of both field stratigraphic observations and a brief petrographic description of the different rocks. The sections are illustrated on plates 2 and 3 and their locations are shown on inset map *A*, plate 1.

*Section 1A on east side of Coke Creek. Lat 69°19'50'' N.; long 144°55'30'' W.; approximately 3.6 miles from the mouth of Coke Creek*

[Measured with tape and compass by B. L. Reed and R. Fisher, 1961. Graphic section, pl. 2; location, inset map, pl. 1]

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Kayak(?) Formation (see section 1*B*, a continuation of this section). | |
| Neruokpuk Formation, calcareous sandstone member (section incomplete): | |
| 16. Micaceous quartz wacke and phyllite. Quartz wacke: pale olive (10*Y*6/2), weathers grayish yellow (5*Y*8/4) to light olive gray (5*Y*6/1); very fine grained with a few scattered medium grains; poorly sorted; angular; single quartz grains show varying degrees of undulose extinction; a few polycrystalline grains of quartz are present; matrix is fine-grained quartz, albite, sericite, and chlorite; local bedding surfaces have rusty spotted appearance caused by small (less than 0.5 mm) aggregates of siderite partly weathered to iron oxide; siderite replaces matrix and detrital quartz grains and is associated with small cubes of pyrite; small detrital flakes of muscovite, generally less than 0.5 mm, visible on bedding surfaces; unit is thickly laminated to thin bedded; weathers slabby (up to 10 in.). Phyllite: light olive gray (5*Y*6/1), weathers dusky yellow (5*Y*6/4) to pale reddish brown; thinly laminated (0.25–2 mm) with alternating silt- to fine sand-size quartz and pelitic laminae of sericite, chlorite, minor quartz, and altered porphyroblasts of chloritoid; chloritoid is altered to reddish-brown iron oxides and is restricted to pelitic laminae; phyllite makes up 40 percent of unit | 251 |
| 15. Micaceous quartz wacke: similar to micaceous quartz wacke of unit 16; pale olive (10*Y*6/2), weathers light olive gray (5*Y*5/2); thin bedded; matrix predominantly sericite with minor chlorite; a few thin quartz veins | 243 |
| 14. Phyllite: similiar to phyllite in unit 16; pale olive (10*Y*6/2), weathers dusky yellow (5*Y*6/4) to light olive gray (5*Y*5/2); soft | 238 |
| 13. Quartz wacke: similar to micaceous quartz wacke of unit 16; yellowish gray (5*Y*7/2); weathers light olive gray (5*Y*4/1); slightly micaceous; thin to medium bedded; one 2-foot-thick resistant bed at base of unit | 236 |
| 12, Quartz wacke and phyllite. Quartz wacke: pale olive (10*Y*6/2), weathers brownish-gray (5*YR*4/1) to grayish red (5*R*4/2); very fine to fine grained; beds 0.5–2 in. thick; constitutes 60 percent of unit. Phyllite: greenish gray (5*GY*6/1) to dark greenish gray (5*GY*4/1); beds 0.1–0.5 in. thick. Unit is nonresistant with many small crenulate folds | 231 |

*Section 1A on east side of Coke Creek*—Continued

| | Cumulative thickness above base of section (feet) |
|---|---|
| Neruokpuk Formation—Continued | |
| 11. Micaceous quartz wacke: pale olive (10*Y*6/2), weathers light olive gray (5*Y*5/2), very fine to fine grained, poorly sorted, angular, quartz grains in fine-grained matrix of sericite and very minor chloritoid; chloritoid as small crystal aggregates in which single crystals rarely exceed 0.05 mm in length; small siderite crystals (generally less than 0.5 mm) altered to dark-reddish-brown to opaque iron oxides; quartz wacke is very thin to thin bedded (0.5–2 in.), weathers as one unit; a few thin laminae of greenish-gray (5*GY*6/1) phyllite constitute less than 5 percent of unit | 221 |
| 10. Micaceous quartz wacke: pale olive (10*Y*6/2), weathers pale yellowish brown (10*YR*6/2); very fine grained to fine-grained quartz with a few medium-size angular quartz grains; borders of quartz grains locally penetrated and replaced by siderite; other minor detrital grains are muscovite, tourmaline, zircon, and rutile(?); matrix is fine-grained quartz and sericite, with minor chlorite and chloritoid(?); where matrix forms a higher percentage of the rock, imperfect schistose texture develops; local thin (0.2–0.6 mm) lenses of siderite are altered to opaque iron oxides; quartz wacke is very thin to thin bedded (0.5–3 in.); weathers as one massive bed; the most resistant unit in this section | 218 |
| 9. Micaceous quartz wacke and phyllite: similar to unit 12. Micaceous quartz wacke: yellowish gray (5*Y*7/2), weathers pale yellowish brown (10*YR*6/2); small (less than 1 mm) specks of iron oxide scattered throughout; very fine to fine grained; thinly laminated to thin bedded; weathers slabby to blocky. Phyllite: interbeds of greenish-gray (5*GY* 6/1) to dark-greenish-gray (5*GY*4/1) phyllite constitutes 25 percent of unit. Less resistant than overlying and underlying units | 212 |
| 8. Micaceous quartz wacke and phyllite: similar to unit 9. Phyllite constitutes about 10 percent of unit | 198 |
| 7. Phyllite: light olive gray (5*Y*6/1), weathers olive gray (5*Y*4/1); fine intergrowths sericite, silt-size quartz, minor chlorite impart fissility parallel to original layering; layering accentuated by microscopic streaks of finely crystalline quartz; poorly developed postcrystalline strain-slip cleavage, small (0.5–1 mm) reddish-brown lenses (chiefly noncrystalline iron oxides) scattered throughout; a few thin sandy beds 0.5–6 in. thick make up less than 10 percent of unit | 175 |
| 6. Quartz wacke, dolomitic: light brownish gray (5*YR*6/1), weathers brownish gray (5*YR*4/1); very fine grained to fine-grained scattered subangular quartz grains in matrix of brownish-gray dolomite and very minor sericite; dolomite is finely crystalline with a few well-developed rhombs up to 0.2 mm in diameter; rhombs replace both detrital quartz and matrix; intermixed with dolomite are small scattered dark-reddish-brown patches of iron oxides; sericite is mainly thin fringes around quartz grains; quartz wacke is very thin bedded; nonresistant | 147 |

*Section 1A on east side of Coke Creek*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation—Continued | |
| 5. Covered, possible fault | 125 |
| 4. Quartz wacke, slightly calcareous: medium gray, weathers light olive gray (5*Y*6/1) to olive gray (5*Y*4/1); quartz very fine to fine grained; quartz grains in matrix of clear calcite and dolomite, minor sericite and chlorite; calcite replaces sericite and chlorite matrix, and detrital quartz grains; dolomite as scattered iron oxide-coated rhombs 0.02–0.07 mm in diameter; dolomite rhombs replace calcite, quartz grains, and matrix; detrital muscovite flakes up to 0.3 mm long common, frequently bent around quartz grains; a few detrital plagioclase grains replaced by calcite; quartz wacke is thickly laminated to thin bedded (0.5–2 in.) with a few 6 in. beds | 87 |
| 3. Quartz wacke, calcareous: medium dark gray, weathers same; same as unit 4 except dolomite rhombs (in thin section) are not as prevalent and do not have an iron oxide coating; (clear) calcite forms varied-size interlocking anhedral grains; calcite grains replace detrital quartz and matrix; calcite twinning not deformed; thin veins of quartz and calcite locally present; quartz wacke is very thin bedded; weathers blocky to massive (2–5 ft) | 27 |
| 2. Phyllite: medium gray, weathers olive gray (5*Y*4/1); calcareous; small crenulate folds common; soft, nonresistant; thinly laminated | 16 |
| 1. Quartz wacke, calcareous; similar to unit 4 | 10 |
| Measured thickness | 251 |

*Section 1B on east side of Coke Creek, Base of section (1A in Neruokpuk Formation) at lat 69°19′50″ N., long 144°55′30″ W.; base of section 1B located at contact between Neruokpuk Formation and Kayak(?) Shale approximately 3.4 miles S. 21°E. from the mouth of Coke Creek.*

[Measured with tape and compass by B. L. Reed and R. Fisher, 1961. Graphic section, pl. 3; location, inset maps, pl. 1]

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Lisburne Group (see stratigraphic section 1*C*, a continuation of this section). | |
| Kayak(?) Shale: | |
| 30. Limestone: medium to dark gray, weathers dark yellowish orange (10*YR*5/4) to pale reddish brown (10*R*5/4); coarse-grained ferruginous biosparite contains 20–60 percent fragmental fossil material and a few scattered dolomite rhombs; dolomite rhombs have oxidized to opaque iron oxide around grain boundaries; iron oxides (limonite(?)) irregularly distributed as discontinuous laminae; small angular quartz grains and irregular patches of microcrystalline quartz throughout; limestone is medium bedded; hard | 488 |

*Section 1B on east side of Coke Creek Base of section*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Kayak(?) Shale—Continued | |
| 29. Shale: dark gray to grayish black, weathers medium gray to light brownish gray (5*YR*6/1); thin discontinuous laminae of clay- to very fine silt-size quartz and sericite clouded by opaque material; thickly laminated; weathers to small chippy fragments; local small (less than 1.5 in. diam) oval ironstone concretions; shear with 1-foot gouge zone at 428 ft, displacement unknown | 479 |
| 28. Shale; similar to unit 26 | 426 |
| 27. Limestone: medium gray to medium dark gray, weather grayish orange (10*YR*7/4) to light brown (5*YR*6/4) with pale-reddish-brown (10*R*5/4) iron oxide stains; poorly washed medium- to coarse-grained intrasparite with a few fragmental fossil allochems and scattered angular quartz grains; medium bedded; hard | 424 |
| 26. Shale: medium gray, weathers very light gray to white, fissile; composed of sericite and quartz; no calcite (from X-ray diffraction) although weathered surfaces are calcareous; very soft, nonresistant | 416 |
| 25. Cherty limestone: similar to unit 23; dark gray; finely crystalline; elongate dark-gray chert nodules up to 1 ft long and 3 in. wide; nodules make up about 35 percent of unit; a few dark-gray shaly beds 2–6 in. thick make up less than 10 percent of unit; corals at 413 ft | 414 |
| 24. Argillaceous limestone: medium gray, weathers pale red (10*R*6/2); very thin to thin bedded (0.05–4 in.); a few small chert nodules 0.5–1 in. maximum diameter; soft, nonresistant | 407 |
| 23. Cherty dolomitic limestone: light brownish gray (5*YR*6/1) and dark gray, weathers mottled pale yellowish brown (10*YR*6/2) to light brown (5*YR*6/4); fine-grained anhedral mosaic of calcite and some microcrystalline quartz replaced by irregularly distributed coarse-grained brownish-gray locally zoned dolomite rhombs; medium bedded; small irregular black chert nodules throughout; nodules make up about 50 percent of unit | 403 |
| 22. Calcareous sandstone: medium gray to pale yellowish brown (10*YR*6/2), weathers grayish orange pink (5*YR*7/2) to moderate yellowish brown (10*YR*5/4); fine to coarse grains of angular quartz in matrix of cryptocrystalline to microcrystalline quartz, subordinate anhedral aggregates of calcite and minor sericite and dolomite; accessory minerals of detrital mica, tourmaline, and cassiterite; small, irregular composite calcite and quartz veinlets throughout; medium to thick bedded | 396 |

*Section 1B on east side of Coke Creek Base of section*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Kayak(?) Shale—Continued | |
| 21. Sandy dolomite: light brownish gray (5*YR*6/1) to grayish red (5*R*4/2), weathers grayish orange pink (5*YR*7/2); fine angular quartz in a fine- to medium-crystalline subhedral mosaic of brownish-gray zoned dolomite with very minor anhedral calcite; peripheral parts of zoned dolomite relatively clear; iron oxide pigments concentrated between dolomite grains and in zoned structure of dolomite rhombs; local concentrations of cryptocrystalline quartz between dolomite grains; lenticular dark-gray chert throughout makes up less than 30 percent of unit; dolomite is thin to medium bedded; unit is gradational with overlying calcareous sandstone | 390 |
| 20. Chert and minor limestone. Chert: banded dark gray and grayish black, weathers moderate pink (5*R*7/4) and pale red (10*R*6/2); thin to thick (4 in.–2 ft) irregularly bedded; irregular white quartz veinlets throughout; thin section shows chert composed of cryptocrystalline quartz clouded by ill-defined irregular brownish to opaque clots of carbonaceous(?) material; minor sericite uniformly scattered throughout rock. Limestone: dark gray; finely crystalline; thin (2–3 in.), discontinuous, irregular beds; beds make up less than 15 percent of unit. Corals in 2-foot-thick chert bed near top. Unit is hard, resistant, jointed; gradational with overlying sandy dolomite | 387 |
| 19. Quartzite: yellowish gray (5*Y*8/1) to grayish yellow (5*Y*8/4), weathers grayish orange (10*YR*7/4); quartz grains medium to coarse, clear to light gray, subangular, strained and unstrained, in interlocking locally sutured texture with secondary overgrowths that show straight boundaries; irregular interstitial clots of sericite; small irregular iron-stained voids (0.2–1 mm) throughout suggest another mineral has been leached out; voids less than 5 percent rock; quartzite is thin to medium bedded; hard, resistant | 346 |
| 18. Covered; probably same argillite as unit 17 | 334 |
| 17. Argillite: dark gray to grayish black, weathers medium gray to medium dark gray; finely divided laminae of quartz, sericite, and chlorite alternate with thin opaque laminae (0.005–0.01 mm; thick) locally poorly developed cleavage parallel to bedding; weathers to small chippy fragments; non-resistant; similar to unit 4, section 6 | 281 |
| Total measured thickness of Kayak(?) Shale | 237 |

Neruokpuk Formation: see stratigraphic section 1*A*, a continuation of this section.

***Section 1C on east side of Coke Creek. Base of section (1A) in Neruokpuk Formation at lat 69°19'50'' N., long 144°55'30'' W. This section is a continuation of Section 1B. Base of Section 1C located at contact between Kayak(?) Shale and Lisburne Group approximately 3.4 miles S. 21°E. from the mouth of Coke Creek***

[Measured with tape and compass by B. L. Reed and R. Fisher, 1961. Graphic section, pl. 3, location, inset map, pl. 1]

*Cumulative thickness above base of section (feet)*

Lisburne Group (section incomplete), equivalent to lower part of Alapah Limestone:

41. Dolomitic limestone: medium gray, weathers pale red; fine grained; medium bedded; no fossils; well jointed; partly covered. About 40 ft partly covered similar limestone overlies top of unit before major covered interval ---- 690+
40. Limestone: medium dark gray, weathers light brownish gray (5*YR*6/1); medium-grained coral biolithite; thick to massive bedded (1–4 ft); less than 5 percent bedding-oriented lenses of black chert; very resistant ---- 675
39. Dolomite: medium dark gray, weathers light gray; finely crystalline; subhedral to euhedral, locally zoned dolomite (more than 75 percent) with minor cryptocrystalline quartz (which appears nearly isotropic in thin section) and calcite; medium to thick bedded (6 in.–2.5 ft, average 15 in.); hard, uniformly dense texture ---- 662
38. Argillaceous limestone; similar to unit 35 ---- 646
37. Limestone: medium to dark gray, weathers dark yellowish orange to reddish brown; coarse-grained biosparite, contains more than 30 percent fragmented fossil material; unit is one massive bed ---- 628
36. Covered interval: probably the same argillaceous limestone beds as unit 35 ---- 625
35. Argillaceous limestone, slightly dolomitic: medium dark gray, weathers to a conspicuous grayish orange pink (5*YR*7/2); finely crystalline calcite in a microcrystalline admixture of cryptocrystalline quartz and clay (illite(?)) with less than 10 percent brownish-gray, locally zoned, iron oxide-stained dolomite rhombs (0.03–0.17 mm. avg 0.05 mm) and silt-size quartz scattered throughout; calcite commonly occurs as thin microcrystalline lenses and streaks; limestone is less than 10 percent allochems (fossil fragments and intraclasts(?)); small patches and cubes of reddish-brown to opaque iron oxides suggest oxidation of pyrite; unit is nonresistant, weathers to small platy to flaggy fragments ---- 586
34. Limestone: same as unit 33, but thin bedded (1–4 in.) ---- 552
33. Limestone: dark gray, weathers brownish gray; poorly washed intramicrosparite similar to unit 31, but contains 3–8 percent fine angular silt-size quartz and 20–40 percent allochems, mainly intraclasts with some indeterminate fossil fragments; one large allochem of oolitic limestone, a few scattered normal oolites; discontinuous, disrupted lenses and streaks of opaque organic material; thin to thick bedded (4–18 in.) with calcite crystals in open fractures ---- 534

*Section 1C on east side of Coke Creek*—Continued

*Cumulative thickness above base of section (feet)*

Lisburne Group—Continued

32. Argillaceous limestone: similar to unit 31, but with a definite shaly appearance; medium to dark gray, weathers light brownish gray (5*YR*6/1); thickly laminated to very thin bedded (0.3–1 in.); less resistant than unit 31 ---------------------------------- 519
31. Limestone: dark gray to grayish black, weathers moderate yellowish brown (10*YR*5/5); finely crystalline biomicrosparite containing 20–30 percent fragmental fossil material (0.04–2.4 mm, average 0.1 mm), mainly bryozoa debris and a few scattered organic-rich circular to ellipsoidal pellets of microcrystalline calcite with an average diameter of 0.2 mm; scattered detrital subangular silt-size quartz grains; also minor authigenic quartz (0.06–0.1 mm) filled with carbonate inclusions; thin to medium bedded (1–6 in.); less resistant than unit 30; weathers to small blocky fragments; partly covered ---------------------------- 508

Total measured thickness ---------------------------------- 202+

Kayak(?) Shale: See Section 1*B*, a continuation of this section.

*Section 2 on west side of Lake Peters. Lat 69°19′19″ N.; long 145°04′00″ W.; approximately 1.6 miles on a S.31°W. bearing from the outlet of Lake Peters*

[Measured with tape and compass by B. L. Reed and R. Fisher, 1961. Graphic section, pl. 2; location, inset maps, pl. 1]

*Cumulative thickness above base of section (feet)*

Neruokpuk Formation, calcareous sandstone member (section incomplete):

10. Quartz wacke and phyllite, slightly calcareous. Quartz wacke: medium gray, light brownish gray (5*YR*6/1) with grayish-orange (10*YR*7/4) thin calcareous crusts on joint and bedding surfaces; fine, with scattered medium, gray subangular quartz grains in a fine matrix of calcite with some sericite and minor chlorite; calcite replaces matrix and penetrates into borders of detrital quartz grains; dolomite present as scattered euhedral whitish-gray rhombs; minor detrital plagioclase is sericitized, shows greater replacement by calcite than does quartz; tourmaline present as single detrital grains and as small euhedral grains within detrital quartz; detrital muscovite flakes up to 0.5 mm long give micaceous appearance on bedding surfaces; calcite veins common, generally thin discontinuous veinlets less than 0.5 in. thick in which individual calcite grains show bending of glide planes; quartz wacke generally thin bedded, weathers to thin platy fragments; a few beds up to 2 ft thick contain a greater amount of calcite as a replacing matrix. Phyllite: medium dark gray; light-brown (5*Y*6/4) calcareous crusts on

*Section 2 on west side of Lake Peters*—Continued

| | Cumulative thickness above base of section (feet) |
|---|---|
| Neruokpuk Formation—Continued | |
| joint and bedding surfaces; thinly laminated; in beds 2–6 in. thick that make up 30–40 percent of unit; more prominent in upper part of unit; small crenulate folds common. Unit is partly covered | 438 |
| 9. Quartz wacke and phyllite, calcareous. Quartz wacke: medium to coarse grained, subangular, moderately well sorted; gray to white quartz grains in a matrix of fine quartz with lesser amounts of sericite and chlorite replaced by calcite; detrital grains of plagioclase replaced by calcite which encroach on the borders of the plagioclase grains and occur as small crystals within the grains; detrital biotite sparse, altered; a few large light-green chlorite flakes may represent complete replacement of biotite; detrital bent and broken flakes of muscovite occur throughout; quartz wacke is thin bedded (1–3 in.), with a few beds up to 2 ft thick. Phyllite: medium gray; consists of sliverlike quartz grains, 0.05–0.15 mm long, in a matrix of fine sericite and chlorite replaced by equal amounts calcite and dolomite; has small euhedral dolomite rhombs coated with iron oxide material; thinly laminated beds 4–12 in. thick; small crenulate folds common; makes up about 25 percent of unit | 262 |
| 8. Quartz wacke, calcareous: similar to unit 9; very thin bedded to medium bedded (0.5–6 in.); interbeds of dark-gray phyllite 1–12 in. thick make up less than 20 percent of unit; unit is more resistant than overlying and underlying units; bluff former | 228 |
| 7. Breccia: medium gray, white, gray and dark gray; angular, tabular metachert and quartz wacke fragments in a microbreccia matrix of fine angular quartz (0.01–0.2 mm), sericite, calcite, and minor chlorite; metachert fragments contain small dolomite rhombs and range in size from 1 to 8 mm in length | 215 |
| 6. Quartz wacke, calcareous: light olive gray, weathers olive gray; quartz very fine to fine grained, clear to light gray; quartz and minor detrital plagioclase in a matrix of fine quartz and albite with lesser amounts of sericite and chlorite replaced by calcite and dolomite; calcite and dolomite present in about equal amounts; dolomite occurs as small iron oxide-coated rhombs that impart a dark-reddish-brown speckled appearance to rock; quartz wacke is very thin to thin bedded (0.5–2 in.); weathers blocky; well jointed, some joints are healed with white quartz; bluff former | 208 |
| 5. Quartz wacke, calcareous: similar to unit 6 except that it is very fine grained and dolomite predominates over calcite; thin bedded; weathers blocky, upper 10 ft weathers slabby; two metachert beds 2.5 ft thick similar to unit 4; thin, discontinuous veins of calcite and quartz throughout unit | 182 |

*Section 2 on west side of Lake Peters*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation—Continued | |
| 4. Metachert: dark gray to grayish black, weathers same; microcrystalline interlocking aggregate of anhedral quartz (0.003–0.01 mm); sericite present throughout as fine, needlelike crystals (0.008–0.025 mm long) subparallel to original bedding; thin, discontinuous laminae of sericite, chlorite, and opaque material impart a phyllitic sheen on bedding surfaces; rock has chert or porcellanitelike appearance on fractures across bedding; is thinly laminated; resistant | 147 |
| 3. Quartz wacke, dolomitic: light brownish gray (5*YR*6/1), weathers brownish gray (5*YR*4/1); very fine grained to fine-grained angular quartz in matrix of fine quartz with lesser sericite and very minor chlorite; small dolomite rhombs (0.03–0.09 mm) replace both detrital quartz and matrix, have a thin coating of iron oxide material; small irregular patches of reddish-brown, nearly opaque, iron oxides are found throughout; tourmaline and zircon present as accessories; unit slightly calcareous in lower 15 ft; interbeds of dark-gray phyllite in beds 1–6 in. thick make up about 10 percent of unit; quartz wacke is thickly laminated to very thin bedded; weathers to thin platy fragments; unit is partly covered | 139 |
| 2. Quartz wacke, calcareous: similar to unit 6; thickly laminated to thin bedded (0.1–2 in.); weathers to thin platy units 0.1–5 in. thick; interbeds of dark-gray phyllite 3–6 in. thick make up 25 percent of unit; small sericite flakes visible on bedding surfaces | 71 |
| 1. Quartz wacke, calcareous: medium gray, weathers same; yellowish-gray calcite crusts on joint and bedding surfaces; fine, angular quartz in a matrix of fine quartz, albite, chlorite, and sericite replaced by calcite; dolomite rhombs subordinate to calcite, (in thin section examined) not coated by iron oxides; zircon, tourmaline, and altered biotite minor accessories; interbeds of crenulated noncalcareous medium-gray phyllite in beds 1–2 in. thick make up 15 percent of unit; quartz wacke thickly laminated to thin bedded (0.2–3 in.); weathers blocky to massive (2–6 ft.); resistant, bluff former | 49 |
| Total measured thickness | 438 |

*Section 3 on valley wall at northwest end of Lake Peters. Lat 69°19′53″ N. long 145°04′10″ W.*

[Measured with tape by B. L. Reed and R. Workum, 1960, checked by B. L. Reed and R. Fisher, 1961. Graphic section, pl. 2; location, inset map, pl. 1]

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Kekiktuk Conglomerate. | |
| Neruokpuk Formation, calcareous sandstone member (section incomplete): | |
| 10. Covered, probably same as unit 9, contact believed to be angular unconformity | 146 |

*Section 3 on valley wall at northwest end of Lake Peters*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation—Continued | |
| 9. Metachert: alternating discontinuous light-gray to medium-gray layers (0.1–0.5 in. thick), weathers light brown (5*YR*5/6); fine quartz in an interlocking aggregate of equidimensional grains (0.003–0.025 mm in diameter) that change in size throughout the thin section over a distance of a few millimeters; minor sericite flakes, in subparallel orientation with bedding, scattered throughout; sericite concentrated as thin, discontinuous laminae which give a phyllitic sheen to bedding surfaces; when fractured across bedding surfaces, the rock has a chert or porcellanitelike appearance; discontinuous crisscrossing vienlets of quartz throughout rock; unit is very hard, resistant | 135 |
| 8. Covered | 100 |
| 7. Metachert: dark gray, weathers moderate brown (5*YR*4/4) to moderate reddish brown (10*R*4/6); interlocking aggregate of fine (0.003–0.025 mm in diam) quartz grains with a few scattered (less than 5 percent) white angular quartz granules and pebbles (2–25 mm); granules and pebbles most commonly composite, similar to a stretched metamorphic quartzite in which the subindividual grains of the pebbles are strongly undulose; granules and pebbles elongated, have both crenulated and smooth borders; a few thin, disrupted laminae of fine sericite; unit is hard, resistant, thick to very thick bedded (1–4 ft) | 83 |
| 6. Metaconglomerate: medium to dark gray with angular to subangular white to medium-gray quartz pebbles and cobbles up to 10 in. long; weathers light brown; a few dark- and light-gray banded, tabular quartzite pebbles; discontinuous white quartz pebble conglomerate lenses throughout; unit fractures across pebbles; metachert matrix as in unit 7 with local clots of opaque to reddish-brown iron oxides; most common pebbles white and gray stretched metamorphic quartzite; subindividual grains of quartzite pebbles elongate with sutured borders and with a few sericite inclusions between the grains; thick bedded; massive, very hard, resistant, bluff former | 68 |
| 5. Metachert: similar to unit 7; very thin to thin bedded (0.5–2 in.) | 34 |
| 4. Covered, contact relations of units 5 and 3 unknown | 28 |
| 3. Metachert: similar to unit 9; light gray; rock approaches a phyllonite similar to unit 2; thin (0.5–2 mm) quartz veins locally sheared; thin sericite laminae smeared along schistosity planes | 18 |
| 2. Phyllonite: medium gray; fine recrystallized quartz with flakes of sericite scattered throughout rock; thin sericite laminae show evidence of differential movement and in many places trend at high angles to the original bedding; microfaults present throughout; possible shear zone | 10 |

*Section 3 on valley wall at northwest end of Lake Peters*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation—Continued | |
| 1. Quartz wacke: medium light gray, weather pale yellowish brown (10*YR*6/2); coarse silt- to very fine sand-size (0.02–0.1mm), sliver-like quartz grains generally parallel to bedding in a fine matrix of quartz, sericite, chlorite, and minor albite; quartz grains penetrated by sericite; minor chlorite as small aggregate crystals, detrital muscovite flakes, a few grains of tourmaline, iron oxides, and cubes of pyrite scattered throughout; small aggregate pyrophyllite crystals locally present; quartz wacke is thin bedded (1–2 in.); weathers blocky; thin interbeds of pale-olive 10*Y*6/2) phyllite makes up less than 15 percent of unit | 6 |
| Total measured thickness | 146 |

*Section 4 on valley wall at the southeast end of Lake Peters. Lat 69°17′43″ N., long 145°00′58″ W.*

[Measured with tape and compass by B. L. Reed and P. Workum, 1960; checked by B. L. Reed, 1961. Graphic section, pl. 2; location, insert map, pl. 1]

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation undivided (section incomplete): | |
| 56. Quartz wacke and phyllite. Metaquartz wacke: light greenish gray (5*G*8/1), weathers pale olive (10*Y*6/2); thin bedded; weathers blocky to massive (2–5 ft); hard; similar to unit 45. Phyllite: greenish gray (5*GY*6/1) to dark greenish gray (5*GY*4/1); interbedded with quartz wacke; in beds up to 3 ft thick; makes up 20 percent of unit | 1,360 |
| 55. Covered; probably same as grayish-purple phyllite in unit 54 | 1,320 |
| 54. Phyllite: similar to unit 43; grayish purple (5*P*4/2); very dusky red purple (5*RP*2/2) near top; well-developed cleavage; weathers into long pencillike fragments; nonresistant | 1,310 |
| 53. Phyllite: dark greenish gray (5*G*4/1); fine quartz, with chlorite and minor sericite flakes parallel to bedding; cut by discontinuous quartz veins that include minor amounts of siderite; thinly to thickly laminated; hard, locally approaches a cherty phyllite; gradational with unit 54 | 1,300 |
| 52. Phyllite: dark gray to grayish black; thickly laminated; soft, non-resistant; gradational with unit 53 | 1,277 |
| 51. Metachert and cherty phyllite: dark gray to grayish black; thinly laminated; metachert predominates in lower part, grades upward into softer dark-gray phyllite; unit is partly covered | 1,271 |
| 50. Metachert: dark gray to grayish black, weather same; recrystallized mosaic of quartz (0.003–0.04 mm diam, avg size 0.01–0.02 mm); thickly laminated; weathers as one massive unit; composed mainly of interlocking microcrystalline aggregates of quartz; fine flakelike sericite crystals 0.02–0.03 mm long, subparallel to original bedding uniformly scattered throughout; | |

*Section 4 on valley wall at the southeast end of Lake Peters*—Continued

| | Cumulative thickness above base of section (feet) |
|---|---|
| Neruokpuk Formation—Continued | |
| thin (0.01–0.05 mm) discontinuous layers of sericite and finely divided opaque material (probably graphitic); layers impart phyllitic sheen to bedding surfaces; when fractured across bedding planes, rock has chert or porcellanitelike appearance; a few small scattered (0.02–0.06 mm) dolomite rhombs with thin surrounding film of opaque to reddish-brown iron oxide material present; thin, discontinuous quartz veins crosscut and parallel beds throughout unit; veils frequently wavy or S-shaped; local individual quartz crystals elongate, show preferred orientation of their axes parallel to bedding; unit is very hard, resistant, bluff former; thickness varies | 1,234 |
| 49. Phyllite and metachert: dark gray to grayish black; interbeds grayish yellow green (5*GY*7/2) phyllite in lower half of unit; gradational from phyllites below to metachert above (similar to unit 50); thin, discontinuous quartz veins common | 1,184 |
| 48. Phyllite: upper 11 ft interbedded grayish-purple (5*P*4/2) and grayish-yellow-green (5*GY*7/2) phyllite beds 2–10 in. thick; middle 17 ft grayish-purple phyllite, similar to unit 43; lower 17 ft 60 percent thinly laminated grayish-purple phyllite in beds up to 3 ft thick with thin to medium interbeds grayish-yellow-green phyllite | 1,151 |
| 47. Quartz wacke, quartz semischist, and phyllite. Quartz wacke: similar to unit 45; gradational into quartz semischist. Quartz wacke and quartz semischist thickly laminated to very thin bedded; weather slabby. Phyllite: pale olive (10*Y*6/2) and dark gray; beds 2–6 in. thick; makes up 25–30 percent of unit | 1,106 |
| 46. Phyllite: upper 3 ft grayish olive (10*Y*4/2); middle 16 ft grayish purple (5*P*4/2) as in unit 43; lower 1 ft grayish olive; thinly laminated | 1,076 |
| 45. Quartz wacke and phyllite. Quartz wacke: light greenish gray (5*G*8/1), weathers light olive gray (5*Y*4/1); fine to medium grained, subangular to subrounded; detrital grains very light gray to white quartz with minor detrital plagioclase; quartz grains nainly single grains showing varying degrees of undulose extinction; matrix fine-grained quartz and albite; sericite thin broken discontinuous laminae 0.03–0.05 mm thick; minor chlorite as small individual crystals scattered throughout; heavy mineral separation shows tourmaline (in many cases with two color zones at opposite ends of the vertical axis), colorless to light-gray zircon and deep-red rutile; this unit is the cleanest quartz wacke in section; thin bedded; weathers massve. Phyllite: thinly laminated; grayish green (5*G*6/1); beds 2–4 in. thick; makes up less than 10 percent of unit | 1,056 |

*Section 4 on valley wall at the southeast end of Lake Peters*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation—Continued | |
| 44. Quartz wacke, quartz semischist and phyllite. Quartz wacke: greenish gray; similar to unit 35, where matrix includes more micaceous minerals; rock has semischist appearance similar to unit 40; thin to medium bedded. Phyllite: greenish gray (5*GY*6/1); occurs as thin interbeds; comprises 30 percent of unit; similar to phyllite in unit 40 | 1,036 |
| 43. Phyllite: grayish purple (5*P*4/2), weathers same; thinly laminated; very finely divided sericite and quartz with lesser amounts of chlorite and albite; elongated aggregates (0.002–0.01 mm) of hematite scattered throughout; main schistosity of phyllite is from aligned flakes of sericite and chlorite which have crystallized parallel to bedding planes; this crossed by later strain-slip cleavage which also affects thin quartz veins; unit gradational with overlying quartz wacke and quartz semischists | 993 |
| 42. Quartz semischist and phyllite: similar to unit 40; phyllite makes up 20 percent of unit | 989 |
| 41. Quartz semischist: light gray, weathers light greenish gray (5*GY*8/1); medium to very coarse grained; poorly sorted; angular; clear to very light gray quartz grains; thin bedded; weathers massive | 970 |
| 40. Quartz semischist and phyllite. Quartz semischist: medium gray to greenish gray (5*G*6/1); fine to coarse grained, subangular; poorly sorted; quartz grains lie in an imperfectly schistose aggregate of fine quartz, sericite, chlorite, and minor albite; micaceous minerals locally concentrated in thin laminae, impart a schistose sheen to rocks when fractured along bedding planes; detrital minerals include shreds of muscovite, a few grains of plagioclase, and rare silt-size grains of tourmaline and zircon; detrital quartz predominantly single grains with extinction ranging from sharp to strongly undulose, a few composite grains of undulose quartz; quartz semischist is very thin bedded to thin bedded (0.5–1.5 in.); weathers slabby to blocky; a few medium beds (10–12 in.) weather massive. Phyllite: greenish gray 5*GY*6/1); thickly laminated to very thin bedded; in beds 2–10 in. thick; increases from about 10 percent in lower part of unit to 30–40 percent in upper part; beds discontinuous | 954 |
| 39. Quartz semischist: similar to unit 19; thick bedded | 863 |
| 38. Phyllite: lower 2 ft grayish purple (5*P*4/2) overlain by 2 ft of greenish-gray phyllite (5*G*6/1) and 1 ft of grayish-purple phyllite (5*P*4/2); thinly laminated; soft, nonresistant | 846 |
| 37. Quartz semischist and phyllite. Quartz semischist: greenish gray (5*GY*6/1); otherwise similar to unit 19. Phyllite: greenish gray (5*G*6/1); thinly laminated; beds up to 10 in. thick, average thickness 2–6 in.; composes about 20 percent of unit | 841 |

*Section 4 on valley wall at the southeast end of Lake Peters*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation—Continued | |
| 36. Quartz wacke, quartz semischist, and phyllite. Unit greenish gray (5*G*6/1) to dark greenish gray (5*G*4/1). Quartz wacke: similar to unit 35. Quartz semischist: contains thin laminae of phyllite; occurs in beds 4–8 in. thick; makes up 5–10 percent of unit. Phyllite: laminae dark green and light green; chloritic; have penecontemporaneous deformation structures at contact with overlying coarser grained beds. Small crenulate folds and irregular quartz segregations throughout unit | 769 |
| 35. Quartz wacke: grayish green (10*GY*5/2) to greenish gray (5*G*6/1), weathers greenish gray (5*FY*6/1); fine to coarse grained; subangular; poorly sorted; detrital quartz grains white to gray; lesser amounts of sericitized plagioclase grains surrounded by fine-grained admixture of quartz, albite, sericite, and chlorite; detrital quartz predominantly single grains with straight and undulose extinction, composite grains also present; locally predominance of matrix imparts a semischist appearance to rocks; quartz wacke is very thin bedded (0.5–1 in.); weathers slabby to blocky (6–18 in.). Phyllite: interbedded; greenish gray (5*GY*6/1); thinly laminated; 2–4 in. thick; makes up less than 5 percent of unit; hard, resistant beds | 760 |
| 34. Quartz semischist: grayish yellow green (5*GY*7/2); thinly laminated; soft; composed of fine grains of quartz, chlorite, and sericite with scattered oxidized pyrite cubes | 640 |
| 33. Quartz semischist: grayish purple (5*P*4/2); same as unit 31; gradational with overlying unit | 633 |
| 32. Quartz wacke: light bluish gray (5*B*7/1), weathers light olive gray (5*Y*6/1); scattered pyrite cubes (up to 1 mm edge) throughout; very hard, resistant; similar to unit 27; lenses to 1 ft thick within 30 ft of section line | 628 |
| 31. Quartz-chlorite-muscovite semischist: grayish purple (5*P*4/2), with thinly laminated chlorite-rich grayish-yellow-green (5*GY*7/2) schist in lower 1 ft of unit; locally sandy with thin graded beds; small crenulate folds common; small epidote(?) crystals and hematite scattered throughout purple schist | 625 |
| 30. Quartz-chlorite-muscovite-albite phyllite and semischist. Phyllite: greenish gray to dark greenish gray with ferruginous stains on bedding planes; thinly laminated; phyllite predominates in lower half of unit; small crenulate folds common; lithology similar to unit 26; small slump folds and associated slide planes locally present, gradational with semischist. Semischist: beds 0.5–2 in. thick; detrital quartz grains in imperfectly schistose matrix of fine-grained quartz, albite, chlorite, and muscovite; chlorite locally penetrates boundaries of quartz grains | 620 |

*Section 4 on valley wall at the southeast end of Lake Peters*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation—Continued | |
| 29. Quartz wacke: medium light gray, weathers greenish gray (5*GY*6/1); fine to very coarse grained; poorly sorted; medium to thick bedded; thin, discontinuous white quartz veinlets throughout; resistant. Phyllite: interbedded; greenish gray (5*G*6/1); beds 2–5 in. thick; makes up less than 5 percent of unit | 600 |
| 28. Phyllite: medium gray; thinly laminated; good cleavage; ferruginous stain on bedding planes | 570 |
| 27. Quartz wacke; thick bedded; similar to unit 29 | 568 |
| 26. Phyllite and interbedded quartz semischist. Phyllite: grayish olive green (5*GY*3/4); locally weathers dark reddish brown (10*R*3/4) on bedding planes; thinly laminated (1–2 mm thick) grayish-olive (10*Y*4/2) chlorite-sericite layers alternate with pale-olive (10*Y*6/2) quartz-chlorite-sericite layers; original schistosity (parallel to bedding) crossed by later strain-slip cleavage; oxidized pyrite cubes up to 6 mm edge present throughout phyllite. Quartz semischist: greenish gray (5*GY*6/1); thickly laminated; similar to unit 19; constitutes 20 percent of unit | 498 |
| 25. Quartz wacke: light gray, weathers medium light gray; very fine to medium grained; subangular; poorly sorted; relatively clean; thick laminae (1–4 mm) of clear to grayish-white detrital quartz and minor plagioclase in microcrystalline matrix of quartz and albite, minor sericite and chlorite separated by dark-greenish-gray (0–3.44 mm) chlorite-sericite-rich laminae; detrital quartz predominantly single grains with few polycrystalline grains; tourmaline both as detrital grains and as incllusions in quartz; unit resistant, weathers blocky; quartz wacke is interbedded with 5–10 percent greenish-gray (5*GY*6/1) phyllite beds 2–5 in. thick | 475 |
| 24. Quartz wacke: similar to unit 22; weathers light olive (5*Y*6/1) to olive gray (5*Y*4/1); a few 4–10 in. thick units thinly laminated greenish-gray (5*GY*6/1) phyllite with well-developed cleavage | 389 |
| 23. Quartz semischist: medium gray, weathers moderate yellowish brown (10*YR*5/4); dark-reddish-brown (10*R*3/4) stains on bedding planes; similar to unit 19, except fine to medium grained; a few thin interbeds of dark-greenish-gray (5*GY*/1) phyllite | 360 |
| 22. Quartz wacke: medium gray, weathers light olive gray (5*Y*6/1); fine to coarse grained; subangular; poorly sorted; composite grains of quartz and sericitized plagioclase common; detrital quartz predominantly single grains with straight to slightly undulose extinction; a few composite quartz grains with both sutured and smooth individual boundaries; tourmaline, bent and broken flakes of detrital muscovite (0.1–0.22 mm long), zircon, and porphyroblasts of pyrite scattered throughout; some pyrite crystals have imperfectly developed chlorite and chalce- | |

*Section 4 on valley wall at the southeast end of Lake Peters*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation—Continued | |
| donic silica fibrously intergrown and oriented perpendicular to the crystal faces; matrix fine-grained admixture of quartz, albite, muscovite, and chlorite; local areas predominantly micaceous material have strain-slip cleavage; small amount of calcite irregularly replaces detrital grains (mainly plagioclase, rarely quartz) and matrix; quartz wacke has thick- to massive-bedding; unit is resistant; thin quartz veins throughout | 357 |
| 21. Quartz semichist and phyllite. Interbedded 4-inch thick beds. Quartz semischist: Similar to unit 19. Phyllite: Greenish gray (5*GY*6/1) to dark greenish gray (5*GY*4/1); ferruginous stains on bedding planes; thinly laminated | 314 |
| 20. Quartz wacke: slightly calcareous; light gray, weathers greenish gray (5*GY*6/1); fine to coarse grained; clear to light-gray angular quartz grains in fine matrix of quartz with lesser amounts of albite, sericite, chlorite, and calcite; sericitized plagioclase and composite quartz and plagioclase grains scattered throughout; discontinuous laminae sericite and chlorite locally impart a schistose sheen to bedding planes; calcite locally crystal aggregates that replace matrix and detrital grains; slight effervescence with acid on hand specimen; other detrital grains are bent muscovite flakes up to 0.55 mm long, tourmaline, and zircon; small crystalline aggregates of chlorite may represent replaced detrital hornblende or biotite; quartz wacke is medium to thick bedded; unit is resistant | 308 |
| 19. Quartz semischist: medium gray, weathers dark greenish gray (5*GY*4/1); fine to coarse grained; angular; very poorly sorted; gray to bluish-gray quartz and sericitized plagioclase randomly distributed in imperfectly schistose aggregate of fine quartz and muscovite; with minor amounts of chlorite and albite; detrital tourmaline and zircon scattered throughout; a 1-inch-thick dark-green phyllite lamina at bottom | 278.9 |
| 18. Quartz wacke: similar to unit 20; thin, white quartz veins and irregular segregations of quartz common | 278 |
| 17. Quartz wacke and phyllite. Quartz wacke: similar to unit 13; vague crossbeds(?) on small scale confined to layers 3–6 in. thick. Phyllite: constitutes 15 percent of unit; grayish olive (10*Y*4/2); thinly laminated; beds 4–10 in. thick | 258 |
| 16. Phyllite; same as unit 14 | 240.8 |
| 15. Quartz wacke; same as unit 13 | 239 |
| 14. Phyllite: dark gray; thinly laminated; shows good cleavage | 227 |
| 13. Quartz wacke: medium gray, weathers light olive gray (5*Y*6/1), becomes medium light gray toward top of unit; fine to medium grained; poorly sorted gray to white quartz with scattered plagioclase grains in fine-grained quartz, albite, sericite, and chlorite matrix; thinly laminated to thin bedded; discontinuous laminae of sericite and chlorite which impart a slight sheen on | |

*Section 4 on valley wall at the southeast end of Lake Peters*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation—Continued | |
| bedding surfaces; weathers slabby to blocky; graded bedding in which a 0.5-inch-thick layer of very coarse angular quartz grains grades upward into fine grains with scattered medium-size grains in a thickness of 3 in.; locally matrix predominant and rock approaches a semischist; heavy mineral separation shows tourmaline, sphene, and rutile | 226 |
| 12. Quartz semischist; similar to unit 3 | 209 |
| 11. Quartz wacke: greenish gray (5*GY*6/1), weathers light olive gray (5*Y*6/1); very fine grained to very coarse grained, 0.1–1.5 mm; average grain size 0.5 mm; quartz grains subangular, elongated, splinterlike poorly sorted, predominantly clear, milky white, and gray; a few quartz grains contain small flakes of biotite; a few plutonic(?) rock fragments of quartz and myrmekitic plagioclase and numerous detrital flakes of muscovite, commonly bent and subparallel to stratification, present; matrix microcrystalline quartz with subordinate sericite, albite, and chlorite; minor amounts of irregularly distributed calcite replace both matrix and grains; accessory grains include tourmaline, zircon, and rutile; quartz wacke massively bedded; phyllite beds less than 5 percent of unit; phyllite, pale olive (10*Y*6/2), in beds 2–4 in. thick: unit is bluff former | 207 |
| 10. Quartz semischist: greenish gray (5*GY*6/1), weathers light olive gray (5*Y*6/1); similar to unit 3 | 199 |
| 9. Quartz wacke: similar to unit 11 | 197 |
| 8. Phyllite: greenish gray (5*G*6/1), weathers olive gray (5*Y*4/1); thinly laminated; nonresistant; angular silt-sized quartz grains and a few fine sand-sized quartz grains in matrix of chlorite and sericite; discontinuous, thin laminae of opaque iron oxides present; small (0.01–0.05 mm) limonitic pyrite porphyroblasts scattered throughout | 140.5 |
| 7. Quartz wacke: light olive to greenish gray (5*GY*6/1), weathers brownish to olive gray; fine to medium grained; subangular; poorly sorted clear to gray quartz grains; thickly laminated to very thin bedded (0.25–1 in.); weathers blocky to massive (1–5 ft); well indurated, resistant; partly covered | 138 |
| 6. Quartz wacke: massive; similar to unit 4; partly covered | 107 |
| 5. Quartz semischist and phyllite: similar to unit 3. Phyllite constitutes 25 percent of unit. Unit is partly covered; less resistant than units 6 and 4 | 100 |
| 4. Quartz wacke: light to medium gray; weathers light olive gray (5*Y*6/1); medium to coarse grained; clear to gray, angular, poorly sorted quartz; resistant; partly covered | 40 |

*Section 4 on valley wall at the southeast end of Lake Peters*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Neruokpuk Formation—Continued | |
| 3. Quartz semischist and phyllite. Quartz semischist: medium dark gray; medium grained; scattered quartz grains up to 3 mm in diameter; poorly sorted; thickly laminated to thin bedded; quartz grains predominantly subangular sliverlike, locally penetrated by sericite and chlorite, lying in imperfect schistose aggregate of fine quartz, muscovite, chlorite, and albite; detrital, angular plagioclase shows various stages of sericitization; composite quartz grains common; one detrital grain of interlocking quartz and sericitized plagioclase; accessory detrital grains of tourmaline and zircon present, beds of semischist are well indurated. Phyllite: interbedded with quartz semischist; constitutes 15–20 percent of unit; medium to dark gray; thinly laminated; beds 10 in.–2 ft thick; small crenulate folds common. Unit is partly covered | 35 |
| 2. Phyllite: interbedded with thinly laminated silty units; dark gray; thin section shows graded bedding in silt laminae; small crenulate folds common | 16.5 |
| 1. Quartz wacke: medium light gray, weathers light olive gray (5*Y*6/1); medium with scattered coarse clear to milky white subangular quartz grains; poorly sorted; massive bedding; well indurated | 15 |
| **Total measured thickness** | **1,360** |

***Section 5 on west side of Lake Peters. Lat 69°19′35″ N., long 145°04′43″ W.; approximately 1.5 miles on a S.46°W. bearing from the outlet of Lake Peters***

[Measured with tape by B. L. Reed and P. Workum, 1960. Graphic section pl. 3; location, inset map, 1]

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Kekiktuk Conglomerate (section incomplete): | |
| 6. Pyrophyllitic quartzite: medium gray, mottled with intergranular yellowish gray (5*Y*8/1), weathers light brown (5*YR*5/6) to light brownish gray (5*YR*6/1); quartz grains coarse to granular, light to medium gray, subangular; quartz grains and a few dark-gray chert grains in a matrix of pyrophyllite and quartz; pyrophyllite replaces original matrix and detrital quartz grains; some quartz grains show overgrowths; quartzite is medium bedded | 98 |
| 5. Pyrophyllitic siltstone: grayish-black lens that weathers medium light gray; fine silt-size quartz scattered in a matrix of pyrophyllite, sericite, and black carbonaceous(?) material; weathers into small chippy fragments | 89.4 |

*Section 5 on west side of Lake Peters*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Kekiktuk Conglomerate—Continued | |
| 4. Pyrophyllitic quartzite and conglomerate: medium gray to medium dark gray, weathers pale yellowish brown (10*YR*6/2) to moderate yellowish brown (10*YR*5/4); Quartzite: coarse to granular white to medium-gray subangular quartz grains; a few thin lenses of fine- to medium-grained quartzite. Conglomerate: discontinuous lenses in the quartzite; pebbles make up 40 percent of lenses; pebbles subangular, in places tabular, composed of white quartz and minor dark-gray chert. 0.25–1 in. in diameter. Unit is thick to massive bedded, well jointed | 89 |
| 3. Covered; beds probably quartzite | 60 |
| 2. Pyrophyllitic quartzite: medium gray, weathers light brown (5*YR*6/4) to moderate reddish brown; coarse to granular white to medium-gray subangular quartz grains and a few dark-gray chert grains; thin (1–3 in.), discontinuous stringers of white quartz pebbles up to 0.75 in. in diameter; a few 0.1–0.5 in. thick discontinuous quartz veinlets; thick to massive bedded | 45 |
| 1. Pyrophyllitic quartzite and conglomerate: light gray to medium dark gray, weathers moderate yellowish brown (10*YR*5/4) and locally moderate reddish brown (10*R*4/6). Pyrophyllitic quartzite; clean white to light-gray subangular to subrounded coarse to granular quartz grains and a few medium- to dark-gray chert grains in a matrix of fine interlocking quartz that is largely replaced by pyrophyllite; pyrophyllite encroaches upon borders, partly replaces larger quartz grains. Conglomerate: discontinuous lenses make up less than 20 percent of unit; lenses contain 0.5–2-in. pebbles, predominantly subangular to subrounded white quartz with some gray chert; white quartz pebbles up to 5 in. in diameter in lower 5 ft of unit; a few dark-gray siltstone lenses 1–3 in. thick make up less than 10 percent of unit. Unit is medium to massive bedded, well jointed | 29 |
| Total measured thickness | 98 |

*Section 6A on west side of the ridge between Whistler Creek and Lake Peters. Lat 69°19'50'' N., long 145°04'30'' W.; approximately 1.4 miles on a S.58° W. bearing from the outlet of Lake Peters*

[Measured with tape by B. L. Reed and P. Workum, 1960. Graphic section pl. 3; location, inset map, pl. 1]

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Kayak (?) Shale (see section 6*B*, measured approximately 0.1 mile west of this section). | |
| Kekiktuk Conglomerate: | |
| 1. Pyrophyllitic quartzite and conglomerate: medium gray to medium light gray, weathers moderate reddish brown (10*R*4/6) at top of unit and light brown (5*YR*6/4) to pale yellowish brown (10*YR*6/2) at bottom of unit; white and light-gray subangular quartz and a few dark-gray chert grains in a matrix of pyrophyllite and quartz. Unit shows gradation in grain size from coarse with scattered granular quartz grains at top to granular with scattered coarse grains at bottom. Lower part of unit contains lenses of subangular to subrounded pebble conglomerate composed of 70 percent white quartz and 30 percent gray to dark-gray chert; average diameter of pebbles 0.5–1 in., maximum diameter 6 in.; thin section shows both interlocking and interpenetration of grains and cementation by secondary quartz overgrowths; pyrophyllite replaces the finer quartz matrix and the overgrowths and encroaches upon the borders of the larger quartz; most contacts between adjacent grains are between authigenic overgrowths, the number of detrital grain contacts is high; unit weathers blocky (1–3 ft) | 40 |
| Total measured thickness of Kekiktuk Conglomerate | 40 |

*Section 6B on the west side of the ridge between Whistler Creek and Lake Peters, Base of section (1A in Kekiktuk Conglomeratc) at lat 96°19'5'' N., long 145°05' W.*

[Measured with tape and compass by B. L. Reed and P. Workum, 1960. Graphic section pl. 3, location, inset map, pl. 1]

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Kayak (?) Shale (section incomplete): | |
| 4. Argillite: dark gray to grayish black, weathers medium to medium dark gray, with local moderate reddish-brown (10*R*4/6) iron oxide stains; finely divided, predominantly silt with some clay-size quartz, sericite, chlorite, and opaque carbonaceous material; locally crumpled with poorly developed cleavage; a few thin (0.25–0.5 in.) discontinuous white quartz veinlets; weathers to small chippy fragments; nonresistant | 141 |

*Section 6B between Whistler Creek and Lake Peters*—Continuel

| | *Cumulative thickness above base of section (feet)* |
| --- | --- |
| Kayak(?) Shale—Continued | |
| 3. Siliceous siltstone: medium dark gray, weathers light brown (5*YR*5/6) to moderate reddish brown (10*R*4/6); coarse silt with a few scattered fine sand-size, angular, locally interlocking quartz grains in a matrix of cryptocrystalline quartz and minor pyrophyllite and sericite; small (less than 0.1 mm on edge) scattered pyroblasts of pyrite; discontinuous laminae of carbonaceous material; thickly laminated to thin bedded; local small crossbeds (0.25–0.5 in. deep, 2–3 in. long); very hard, resistant unit, appears cherty when fractured across bedding planes | 61 |
| 2. Argillaceous siltstone: medium dark gray, weathers medium to medium light gray with irregular moderate reddish-brown stains; silt-size angular quartz grains in a matrix of quartz and minor pyrophyllite and sericite; thin, irregular bedding with cross laminae of sericite and opaque carbonaceous material throughout; nonresistant | 46 |
| Total measured thickness of Kayak(?) Shale | 101 |

Kekiktuk Conglomerate: see stratigraphic section 6*A*, a continuation of this section.

*Section 7A measured on Karen Creek. Base of section at lat 69°21′36″ N., long 144°48′10″ W.*

[Measured with tape and compass by B. L. Reed and R. Fisher, 1961. Graphic section pl. 3, location, inset map, pl. 1]

| | *Cumulative thickness above base of section (feet)* |
| --- | --- |
| Sadlerochit Formation (see stratigraphic section 7*B*, a continuation of this section). | |
| Lisburne Group (section incomplete), probably equivalent to lower part of Wahoo(?) Limestone: | |
| 4. Covered interval; contact estimated at 177 ft | 183 |
| 3. Limestone, partly dolomitic with subordinate chert: medium light gray, weathers pale yellowish brown (10*YR*6/2) to light brown (5*YR*6/2); coarse-grained intrasparite becomes increasingly finer grained intrasparite with patches and disturbed lenses of partly dolomitized intramicrite in lower part of unit; allochems make up 40–80 percent of total volume of which 25–60 percent are subangular poorly sorted intraclasts that range in size from 0.05 to 6 mm with an average size of 1.3 mm; subordinate fragmental fossil allochems include pellets, bryozoa and crinoids; sparite finely crystalline with irregular patches of chert throughout, replaces both sparite and allochems; grayish-black chert occurs as lenticular bedding oriented nodules 1–3 in. thick, up to 2 ft long at 141 and 146 ft; dolomite restricted to micrite lenses as small (0.03 mm) scattered rhombs; minor authigenic pyramidal-developed quartz with inclusions of carbonate throughout unit; pyrite a minor constituent, tends to form a cubic habit, partly altered to iron oxides; bedding ranges from 2 to 4 ft at 131–163 ft, from 1 to 2 ft at 163–166 ft, from 8 to 14 in. at 166–175 ft | 175 |

*Section 7A measured on Karen Creek*—Continued

| | Cumulative thickness above base of section (feet) |
|---|---|
| Lisburne Group—Continued | |
| 2. Limestone: medium light gray, weathers light gray; medium to coarse grained poorly sorted subangular intrasparite or biosparite(?); many allochems may be unrecognized fossil fragments; unit is about 65 percent allochems, 35 percent sparry calcite matrix that contains very minor disseminated chert; intraclasts range in size from 0.2 to 0.5 mm; sparite matrix is finely crystalline calcite, slightly disturbed by light and dark laminae and lenses (0.02–0.15 mm thick) which continue around allochems, locally show depressions from the allochems; fossil allochems make up to 10–40 percent of total allochems, fragmental oolites, bryozoa, crinoid, and echinoderm plates(?); one massive unit with 2–4 ft beds in lower 8 ft | 131 |
| 1. Dolomitic limestone and subordinate chert: dark gray, medium gray above 73 ft; aphanocrystalline to finely crystalline dolomitized micrite containing 20–50 percent fragmental fossil material; dark gray to grayish black; irregular lenticular beds; chert nodules up to 3 ft long and 8 in. thick (avg 10 in. long, 2 in. thick), make up less than 10 percent of unit; thin sections chert show many small (0.02 mm avg diam) euhedral dolomite rhombs scattered throghout microcrystalline quartz; covered interval 66.5–73 ft | 91 |
| Total measured thickness | 177± |

*Section 7B on east side of Karen Creek. Base of section (Section 7A, Lisburne Group, pl. 3) at lat 69°21′36″ N., long 144°48′10″ W.*

[Measured with tape and compass by B. L. Reed and R. Fisher, 1961. Graphic section pl. 3, location, inset map, pl. 1]

| | Cumulative thickness above base of section (feet) |
|---|---|
| Sadlerochit Formation (section incomplete): | |
| 16. Siltstone, silty shale, and minor sandstone: medium gray to medium dark gray, weathers light olive gray (5*YR*6/1) to various hues of pale brown to yellowish brown; siltstone is common in upper 70 ft of unit and consists of fine to medium with a few coarse silt-size angular quartz grains in a pastelike matrix of quartz, sericite, and minor chlorite; unit has iron oxides and opaque laminae throughout; is thinly laminated to thin bedded; has thick to massive parting with thin interbeds of silty shale and a few very fine grained well-sorted angular sandstone lenses. Lower 44 ft less resistant, than upper 70 ft, predominantly thinly laminated silty shale with intercalated beds of fine siltstone. Entire unit has poorly developed cleavage; weathers to small chippy fragments | 512 |

*Section 7B on east side of Karen Creek*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Sadlerochit Formation—Continued | |
| 15. Covered interval | 398 |
| 14. Siliceous siltstone: medium gray, weathers moderate brown 5*YR*4/4); coarse silt and local thin laminae of very fine sand-size quartz in matrix of microcrystalline quartz, minor sericite and a few flakes of chlorite; thin, discontinuous opaque laminae, small clots of oxidized pyrite throughout; thin irregular bedding (1–3 in.); blocky to massive parting; moderately resistant unit | 389 |
| 13. Siliceous sandstone and siltstone; medium gray to dark gray, weathers varying shades of light olive gray (5*YR*6/1) through light brown; intercalated coarse silt and very fine sand composed mainly of angular quartz grains in finely divided microcrystalline to cryptocrystalline matrix of quartz, minor sericite and chlorite; about 60 percent very fine siliceous sandstone which is more resistant to erosion than siltstone; accessory minerals of pyrite, leucoxene, a few detrital grains of tourmaline, opaque stringers of carbonaceous material; thin to thick bedded (4–18 in.); upper 5 ft. is one massive bed | 377 |
| 12. Covered interval, probably siltstone | 321 |
| 11. Pyritic siliceous sandstone: medium dark gray, weathers light brown (5*YR*5/6); very fine grained (0.07 mm) angular quartz in matrix of microcrystalline quartz; small (range 0.07–0.3 mm, avg 0.15 mm) well-developed brassy yellow pyrite cubes scattered throughout (pyrite cubes comprise perhaps 5–7 percent of unit) impart a pinpoint sparkle on fresh fractures and a limonitic stain on weathered bedding surfaces; thin discontinuous opaque laminae throughout; thin to thick bedded (1–18 in.); weathers blocky; very hard, resistant | 314 |
| 10. Intercalated siliceous sandstone and siltstone with subordinate chert: medium gray to dark gray, weathers light olive gray (5*YR*6/1) to light brown; coarse silt-size to very fine sand-size angular quartz with subordinate subangular chert grains in matrix of microcrystalline to cryptocrystalline quartz; local concentrations ferriferous dolomite rhombohedra impart limonitic stain to rocks. Chert: gradational with sandstone and siltstone; medium gray to dark gray; well stratified; thin to thick bedded (4–20 in.); flaggy to blocky parting, siltstone weathers to small chippy fragments | 305 |
| 9. Chert: mottled light to medium gray, weathers pale (10*YR*6/2) to moderate (10*YR*5/4) yellowish brown; microcrystalline and cryptocrystalline quartz with a few elongate spicules(?) and scattered euhedral ferriferous dolomite rhombs; medium to thick bedded (1–25 ft); very hard, resistant | 257 |

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*Section 7B on east side of Karen Creek*—Continued

*Cumulative thickness above base of section (feet)*

Sadlerochit Formation—Continued

8. Chert sandstone: medium to dark gray, weathers moderate brown (5*YR*3/4) to moderate yellowish brown (10*YR*5/4); very fine to fine grained; similar to unit 6 but in thin sections subangular chert grains predominate over detrital angular quartz grains; matrix microcrystalline quartz clouded with organic material; a few scattered yellowish glauconite(?) grains; well stratified, medium bedded (6 in.–1 ft); weathers blocky to massive (2.5–4 ft); upper 10 ft ferruginous (limonitic staining); slightly less resistant than unit 9 ---- 251
7. Covered interval, probably siltstone ---- 219
6. Siliceous sandstone: dark gray, weathers light brown (5*YR*6/4 to 5*YR*5/6); very fine (0.07–0.1 mm) angular quartz with subordinate chert grains in microcrystalline to cryptocrystalline quartz matrix; matrix contains scattered flakes and laminae of sericite; opaque iron oxide rhombs (carbonate?) and cubes of pyrite scattered throughout; sandstone is thick bedded 1–2.5 ft) at bottom becoming medium bedded (6–14 in.) at top of unit; local thin (2–3 in.) beds of siltstone make up less than 5 percent of unit; unit is very hard, resistant ---- 204
5. Argillaceous siltstone: medium dark gray, weathers light olive gray (5*YR*6/1), irregular light-brown (5*YR*5/6) stains on bedding planes; coarse silt-size angular quartz and minor chert grains (avg. 0.05 mm) in finely laminated matrix of microcrystalline quartz and sericite(?); matrix has thin (0.005–0.01mm) opaque carbonaceous stringers throughout; siltstone is thickly laminated to very thin bedded; unit is partly covered ---- 188
4. Covered; contact with underlying Lisburne Group estimated at 177 ft ---- 183

Total measured thickness ---- 335

Lisburne Group: see Section 7*A*, a continuation of this section.

*Section 8 measured on east side of Coke Creek. Base of section at lat 69°21'22'' N., long 144°57'30'' W., approximately 1.6 miles S. 15°E. from the mouth of Coke Creek*

[Measured with tape and compass by B. L. Reed and R. Fisher, 1961. Graphic section pl. 3, location, inset map, pl. 1]

*Cumulative thickness above base of section (feet)*

Sadlerochit Formation (section incomplete):

3. Siltstone and sandstone, interbedded, partly covered. Siltstone: medium dark to dark gray, weathers pale yellowish brown (10*YR*6/2) to grayish red (10*YR*4/2); composed chiefly of fine to coarse angular silt-size quartz in a pastelike matrix of very finely divided microcrystalline quartz, sericite, chlorite, and an abundance of opaque carbonaceous material distributed as irregular clots, stringers, and lenses; a few scattered oxidized pyrite cubes; thin (2–7 mm), discontinuous sandstone lenses throughout; cross-

*Section 8 measured on east side of Coke Creek*—Continued

| | *Cumulative thickness above base of section (feet)* |
|---|---|
| Sadlerochit Formation—Continued | |
| bedded on a small scale; local thin laminae of silt show flowage and injection structures; a few small iron oxide coated clay ironstone nodules; thin, irregular laminated beds 3–18 in. thick; weathers to small chippy fragments; makes up about 60 percent of unit. Sandstone: medium to medium dark gray, weathers light olive gray; very fine angular quartz and sparse detrital twinned plagioclase grains in a cement of microcrystalline quartz, sericite and minor chlorite; dolomite (about 5–8 percent) occurs as small (0.01–0.06 mm) poorly developed ferriferous rhombs that show a preference for replacing the microcrystalline quartz cement but also replace detrital quartz grains; detrital flakes of muscovite up to 0.5 mm long abundant, in places visible on bedding surfaces; sandstone is thinly to thickly laminated (in places ripple-laminated) in tabular well-stratified sets of beds 6 in.–2 ft thick; makes up about 40 percent of unit | 340 |
| 2. Sandstone and siltstone, interbedded. Sandstone: medium light gray, weathers light olive gray (5*YR*6/1) to dark yellowish brown (10*YR*4/2); very fine angular quartz grains in an interlocking texture with some overgrowths and local pore-filling microcrystalline quartz; less than 5 percent detrital twinned plagioclase and perhaps 5–10 percent small locally zoned replacement dolomite rhombs scattered throughout; accessory minerals of detrital muscovite, subrounded zircon, tourmaline, and rutile; tourmaline with secondary overgrowths; well-stratified thin-bedded sets of beds up to 4 ft thick; thin, discontinuous veinlets of quartz and calcite; makes up 60 percent of unit, more predominant at middle of unit. Siltstone: medium dark to dark gray; similar to siltstone in unit 3; in sets of beds 3 in.–1 ft thick; weathers to small chippy fragments; makes up 40 percent of unit | 245 |
| 1. Siltstone and sandstone, interbedded. Siltstone: medium to dark gray; similar to siltstone of unit 3; thin, irregular laminae in sets of beds 6 in.–5 ft thick; a few small (max diam 2 in.) ironstone nodules; constitutes 70–80 percent of unit. Sandstone: medium to dark gray, weathers pale yellowish brown (10*YR*6/2) to pale brown (5*YR*5/2); subangular quartz grains ranging from coarse silt to fine sand size, with individual beds well sorted; cement variable; interlocking quartz grains with secondary quartz overgrowths predominant; dolomite, microcrystalline quartz and minor calcite also present; dolomite locally makes up as much as 20 percent of rock, replaces both detrital quartz grains and microcrystalline quartz cement; a few detrital twinned plagioclase grains and flakes of sericite and chlorite scattered throughout the sandstone; detrital muscovite, tourmaline, and zircon present as accessories; sandstone is thickly laminated to thin bedded in well-stratified sets of beds 6 in.–2 ft thick; has a few poorly defined ripple laminae; makes up 20–30 percent of unit; more abundant in upper part | 148 |
| Total measured thickness of Sadlerochit Formation | 340 |

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