Stratigraphy and General Geology of the McCarthy C–5 Quadrangle, Alaska

By E. M. MacKEVETT, Jr.

GEOLOGICAL SURVEY BULLETIN 1323

Descriptions of the rocks of a quadrangle famous for its copper mines

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1971

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

William T. Pecora, *Director*

Library of Congress catalog-card No. 79-609946

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 30 cents (paper cover)

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STRATIGRAPHY AND GENERAL GEOLOGY OF THE McCARTHY C–5 QUADRANGLE, ALASKA

By E. M. MACKEVETT, JR.

ABSTRACT

The McCarthy C–5 15-minute quadrangle includes a rugged area on the southern flank of the Wrangell Mountains having a relief of about 12,000 feet. The quadrangle contains a sequence of consolidated layered rocks, approximately 25,000 feet thick, local intrusive rocks, and widely distributed surficial deposits. The layered rocks are chiefly Mesozoic, but they range from Permian to Quaternary in age. They include two sequences of subaerial volcanic rocks, abundant shelf deposits, and continental sedimentary rocks. Some of the shelf deposits and the continental sedimentary rocks contain abundant fossils. The intrusive rocks are mainly Tertiary and include dikes and sills, largely of dacitic or andesitic composition, and a few small stocks of granodiorite. The diverse Quaternary surficial deposits are largely related to glacial processes.

The main faults and folds of the quadrangle formed during a major orogeny at or near the close of the Jurassic or in the pre-Albian Cretaceous. The quadrangle contains the main Kennecott mines of Alaska, for many years among the world's foremost copper producers, and a few lesser copper deposits and occurrences. The physiography of the quadrangle strongly reflects glacier-related erosional and depositional processes.

INTRODUCTION

This report supplements the McCarthy C–5 15-minute geologic quadrangle map (MacKevett, 1970b) by providing data on the stratigraphy and lithology of the map units and on other geologic topics. The McCarthy C–5 quadrangle is in the eastern part of southern Alaska on the southern flank of the Wrangell Mountains (fig. 1), a scenic alpine range characterized by several snow-clad volcanic peaks (fig. 2). The relief in the quadrangle is about 12,000 feet. The quadrangle is drained by McCarthy Creek and the Nizina River and their tributaries, parts of the Copper River system. The two largest of Kennecott's Alaskan copper mines, for many years among the major copper producers of the world, are near the southwestern corner of the quadrangle. The quadrangle is uninhabited and is accessible mainly to foot travel or helicopter.

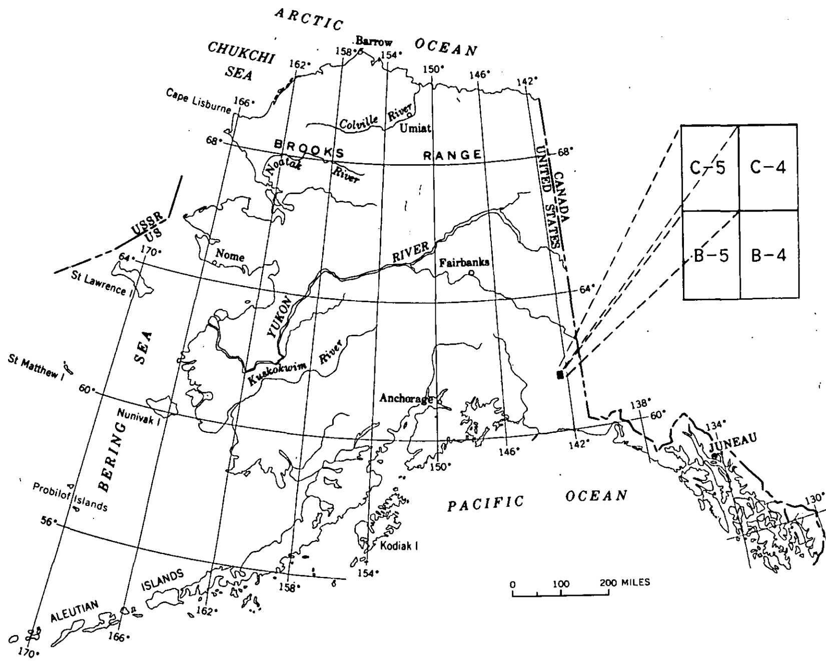


FIGURE 1.—Location of the McCarthy C-5 quadrangle.

Extensive ice and snowfields cover bedrock throughout the high terrane in the northwest part of the quadrangle and sustain the large Regal and West Fork valley glaciers. The upper reaches of the valley glaciers are generally marked by icefalls. Parts of some glaciers are strongly crevassed or have extremely jagged surfaces; other glaciers, such as the West Fork Glacier, are relatively smooth and accessible throughout most of their extent. Smaller glaciers that are relicts of more widespread glaciation are widely scattered throughout the quadrangle. These and many patches of perennial snow in the higher terranes attest to the rigorous climate of the quadrangle.

The geologic mapping was done with helicopter support in 1961 with minor additions and revisions in 1962, 1964, and 1965. A 1:48,000 topographic base was used and to a lesser extent aerial photographs. Supplementary investigations consisted of thin-section studies, spectrographic, X-ray, and chemical analyses, feldspar and carbonate staining, and paleontologic studies. Grateful acknowledgment is made to D. L. Jones for his thorough studies of Cretaceous stratigraphy and paleontology; to M. C. Blake, Jr., who participated in the 1961 mapping; to N. J. Silberling, R. W. Imlay, and J. A. Wolfe, who respectively studied the Triassic, Jurassic,

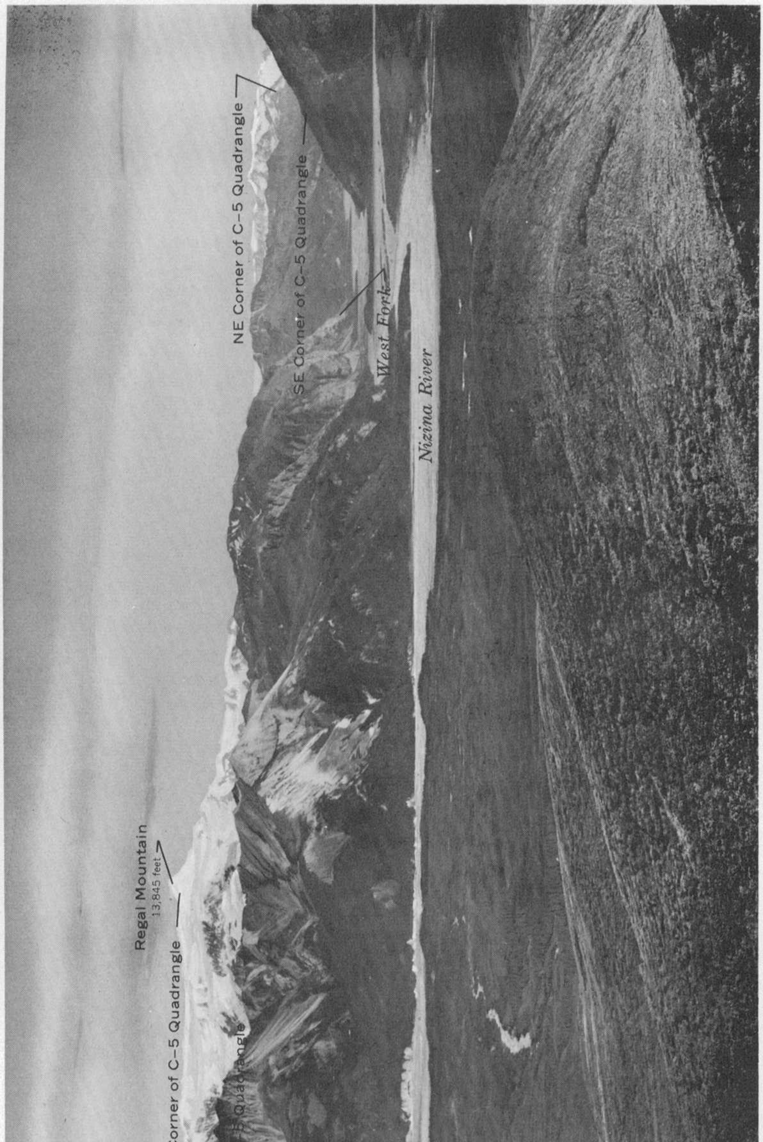


FIGURE 2.—Panorama of part of the Wrangell Mountains showing the McCarthy C-5 quadrangle and nearby geographic features.

and Tertiary fossils; to S. W. Muller, who studied specimens of the Jurassic *Weyla,* and to C. H. Schulze, Tom Gilmore, Howard Knutson, and Jack Wilson, who shared their knowledge of the local geography, logistic problems, and mining activity. Previous descriptions of the geology of the quadrangle are mainly in a report by Moffit (1938) and maps by MacKevett (1963 and 1970b). Fossils collected during the investigation are listed in the section following "Stratigraphy and lithology."

GEOLOGY

GENERAL SUMMARY, REGIONAL SETTING, AND STRUCTURE

The layered rocks in the quadrangle, which have a cumulative thickness of about 25,000 feet, are mainly Mesozoic but range from Permian to Quaternary in age (table 1). They comprise two sequences of continental volcanics, abundant shelf deposits, continental sedimentary rocks, and surficial deposits (fig. 3). The in-

TABLE 1.—*Summary of rocks in the McCarthy C–5 quadrangle*

Formation or unit	System	Series	Estimated maximum thickness (feet)	Dominant lithology
Surficial deposits.	Quaternary			
Wrangell Lava.	Tertiary and Quaternary.		5,000+	Andesite and basaltic andesite.
Felsic hypabyssal rocks.	Tertiary			Dacite and rhyodacite.
Intermediate intrusive rocks.	do			Granodiorite.
Andesitic dikes and sills.	Tertiary and Quaternary.			Andesite.
Frederika Formation.	Tertiary	Miocene	2,000	Sandstone, conglomerate, siltstone, and shale.
Moonshine Creek Formation.	Cretaceous	Lower and Upper Cretaceous.	550	Sandstone and siltstone.
Schulze Formation.	do	Lower(?) and Upper Cretaceous.	200	Siliceous shale.

TABLE 1.—*Summary of rocks in the McCarthy C–5 quadrangle*—Continued

Formation or unit	System	Series	Estimated maximum thickness (feet)	Dominant lithology
Kennicott Formation.	do	Lower Cretaceous.	700	Conglomerate, sandstone, siltstone, and shale.
Root Glacier Formation.	Jurassic	Upper Jurassic.	3,000+	Mudstone and siltstone.
Nizina Mountain Formation.	do	Middle and Upper Jurassic.	1,350	Graywacke.
Lubbe Creek Formation.	do	Lower Jurassic.	300	Impure spiculite.
Upper member of McCarthy Formation.	Triassic(?) and Jurassic.	Upper Triassic(?) and Lower Jurassic.	2,000+	Impure chert and spiculite.
Lower member of McCarthy Formation.	Triassic and Jurassic(?)	Upper Triassic and Lower Jurassic(?).	950	Carbonaceous shale, impure limestone, and chert.
Nizina Limestone.	Triassic	Upper Triassic.	1,250	Limestone.
Chitistone Limestone.	do	do	2,100	Limestone and dolomite.
Nikolai Greenstone.	do	Middle and (or) Upper Triassic.	3,000+	Basalt.
Hasen Creek Formation.	Permian	Lower Permian.	250	Bioclastic limestone.

trusive rocks are mainly Tertiary and consist of diverse dikes and sills, chiefly andesitic and altered felsic types, and uncommon small stocks of granite rocks intermediate in composition. The widely distributed surficial deposits are mainly related to glacial processes.

The pre-Cretaceous rocks occupy part of an extensive northwest-trending belt along the southern flank of the Wrangell Mountains. This belt is overlapped from the north by the voluminous Wrangell Lava and continental sedimentry rocks of the Frederika Formation and from the south by marine Cretaceous sedimentary rocks and widespread fluvioglacial deposits.

Most structural features in the quadrangle probably formed during the major orogeny near the close of the Jurassic or in the

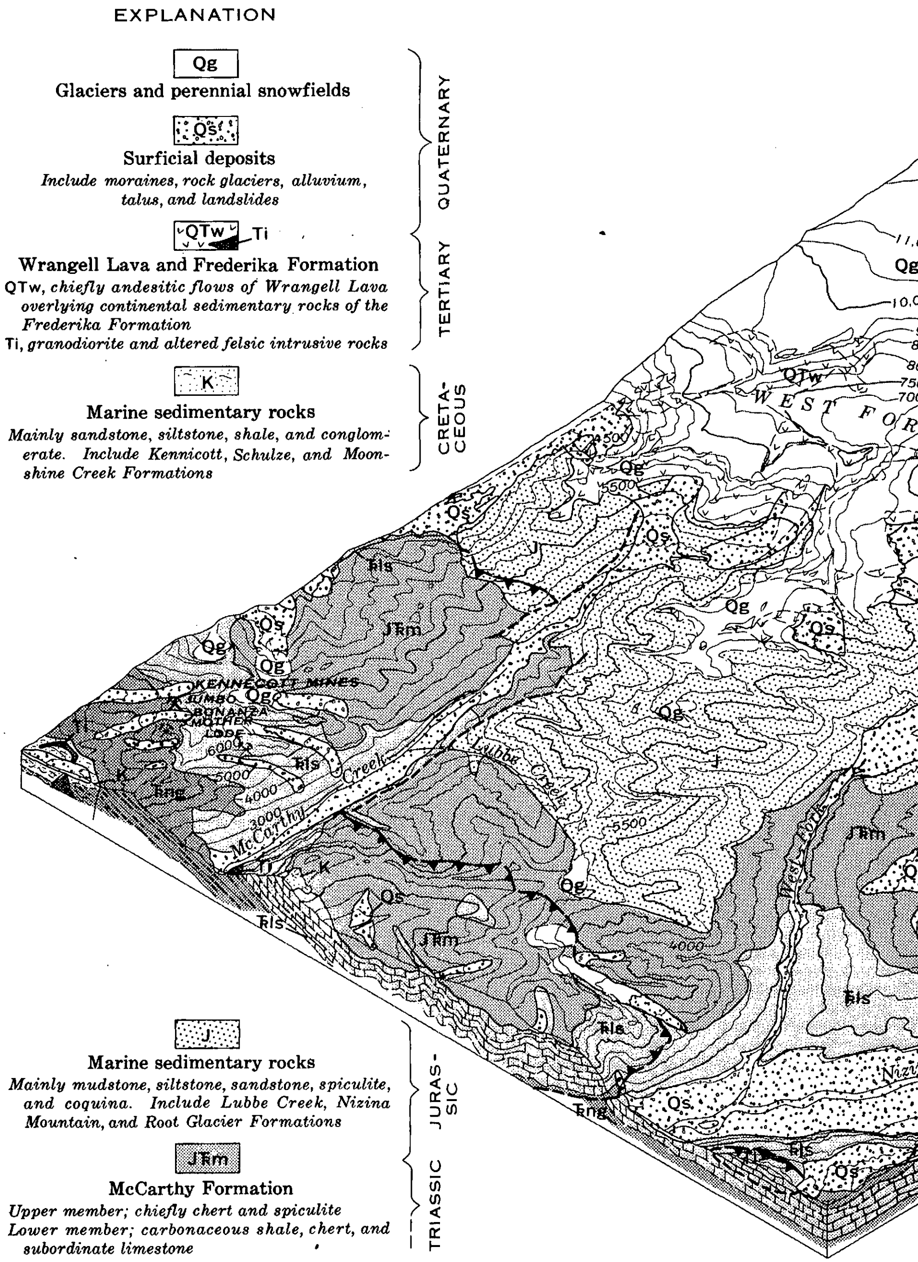
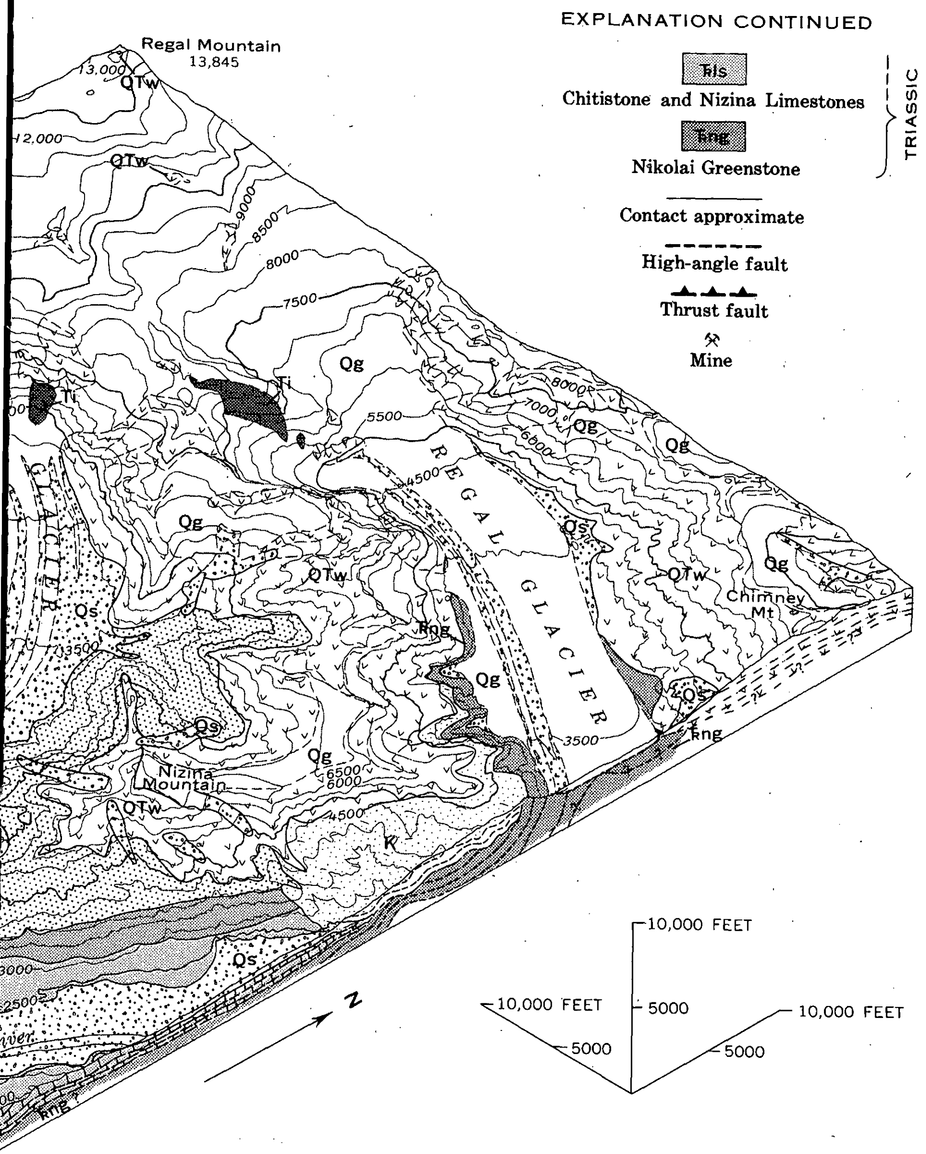


FIGURE 3.—Isometric block diagram showing



generalized geology of the McCarthy C–5 quadrangle.

pre-Albian Cretaceous. They are largely represented by a conspicuous northwest-striking thrust fault in the southern part of the quadrangle (fig. 3) and by a series of northwest-trending, generally moderately open folds. Younger structures are chiefly manifested by steep north-striking faults that include one east of McCarty Creek having right-lateral displacement of more than a mile (fig. 3). A pronounced angular unconformity separates Cretaceous and older rocks, and a slight angular unconformity separates Cretaceous and Tertiary rocks. Disconformities separate several of the Mesozoic formations.

STRATIGRAPHY AND LITHOLOGY

HASEN CREEK FORMATION

A small outcrop of coarse bioclastic limestone near the extreme northeast corner of the quadrangle (not shown in fig. 3) represents a northwestward extension of the Golden Horn Limestone Lentil of the Hasen Creek Formation (Smith and MacKevett, 1970, p. Q20–Q25) which is well developed in the adjacent McCarthy C–4 quadrangle. The exposed thickness is about 250 feet, but neither its base nor its top is visible. The lentil forms bold outcrops that are light gray with variegated red or yellow stained surfaces. Its strata are less than 10 feet thick and locally slabby or flaggy. Following Dunham's classification (1962, p. 117), the lentil consists largely of bioclastic grainstone and packstone. These rocks are composed mainly of coarse disarticulated crinoid fragments with or without matrices of lime mud. A few beds of black shale and chert are associated with the limestone lentil. More detailed descriptions of the Golden Horn Limestone Lentil and other rocks within the Skolai Group are given by Smith and MacKevett (1970). Fossils collected from the limestone lentil in the C–4 quadrangle are indicative of an Early Permian age.

NIKOLAI GREENSTONE

The Nikolai Greenstone, named by Rohn (1900, p. 425), is an extensive sequence of subaerial basaltic lavas. It probably underlies a large part of the quadrangle, but its exposures are confined to the southern part of the quadrangle and to its northeastern part near Regal Glacier. The base is not exposed in the C–5 quadrangle. Contacts between the Nikolai Greenstone and the overlying Chitistone Limestone are disconformities marked by an apparent concordance of subjacent Nikolai flows with overlying Chitistone strata. Where the Chitistone Limestone is absent, Nikolai Greenstone unconformably underlies younger rocks. Accuracy of thickness estimates of the Nikolai is limited by faults. The incomplete greenstone section probably is 3,000 to 4,000 feet thick in the quadrangle. Most Nikolai flows are 2 to 15 feet thick; exceptionally, they are as much as 30 feet thick. The greenstone forms moderately rugged slopes that are locally cliffy and craggy.

The Nikolai Greenstone consists of altered basalts characterized by diverse secondary minerals, chiefly chlorite, and by several textural variations. Its fresh surfaces are greenish gray or dark greenish gray and less commonly dark or medium gray. Its weathered surfaces are medium brown and subordinately greenish, yellowish, or reddish brown. Veinlets, composed mainly of quartz and epidote or of calcite and chlorite, cut some of the greenstones. Amygdules of a variety of secondary minerals are distributed rather uniformly throughout most Nikolai flows. They form spheroidal, ellipsoidal, and dumbbell-shaped pods 0.5 to 10 mm (millimeters) long.

Most Nikolai Greenstones are fine-grained porphyritic rocks with intergranular groundmasses composed chiefly of plagioclase and augite. Generally, they contain labradorite phenocrysts 1 to 4 mm long in groundmasses whose major constituents are less than 0.5 mm long. Uncommon textural variants in the greenstones are intersertal, felty, subophitic, and pilotaxitic. Sparsely distributed corroded phenocrysts of augite and relict olivine occur in some of the greenstones. Primary minerals in the greenstone, in general order of decreasing abundance, are plagioclase (chiefly labradorite), augite, relict olivine, opaque minerals, sphene, and apatite. Secondary minerals are abundant chlorite, less abundant iron oxides, epidote, clay minerals, calcite, sericite, prehnite, ferruginous serpentine minerals, pumpellyite, quartz, and rare zeolites. Opaque minerals, chiefly magnetite, subordinately ilmenite, constitute as much as 10 percent of some greenstones. Several varieties of chlorite, the dominant secondary mineral, are particularly well developed in the amygdules, forming spherulites, radial lamellar bundles, and scaly aggregates. Most of the amygdules are composed of chlorite with or without calcite; the rest are rich in quartz and epidote, and a few contain small amounts of native copper and associated secondary copper minerals.

The abundance of amygdaloidal minerals and alteration products makes the Nikolai Greenstone difficult to classify lithologically. The Nikolai Greenstone is a voluminous sequence of altered flood basalts that probably covered large areas in the Wrangell Mountain region and nearby Yukon Territory in the late Middle and(or) early Late Triassic time. Its age limits are imposed by the greenstone conformably overlying fossiliferous Middle Triassic strata in the McCarthy C–4 quadrangle (MacKevett, 1970a) and by its stratigraphic position beneath the Late Triassic Chitistone Limestone.

CHITISTONE LIMESTONE

The Chitistone Limestone, named by Rohn (1900, p. 425), underlies topographically rugged areas in the southeastern and southwestern parts of the quadrangle. This formation is the best cliff former in the quadrangle. A few of its outcrops are marked by caverns and smaller solution cavities. Thickness of the Chitistone Limestone within the quadrangle ranges from 1,250 to 2,100 feet; its constituent strata are 2 to 20 feet thick. The Chitistone disconformably overlies the Nikolai Greenstone and gradationally underlies the Nizina Limestone.

The Chitistone Limestone consists of limestone, subordinate dolomite, and minor amounts of chert. Following Dunham's classification (1962, p. 117), the Chitistone carbonates comprise lime mudstone and wackestone, subordinate packstone and grainstone, and some crystalline dolomite, dolomitic limestone, and limestone. Most Chitistone rocks are cut by calcite veinlets, and a few contain stylolites. Some Chitistone and Nizina limestones, particularly mudstones and wackestones, emit fetid odors when broken. The carbonate petrography and depositional environments of the Chitistone and Nizina Limestones have been investigated in some detail in the southern Wrangell Mountains, including the C–5 quadrangle (Armstrong and others, 1970). Much of the petrographic information concerning these formations and many of the inferences about their depositional environments are results of this investigation.

The mudstones and wackestones are dark greenish gray, dark gray, or dark medium gray and weather to various shades of gray and brown. These rocks contain matrices of lime mud, generally partly recrystallized, and sparse to abundant very fine-grained clastic components, chiefly clots of lime mud, fragments of echinoids and mollusks, and calcite grains. Some of the lime mudstones and wackestones contain widely dispersed opaque minerals, including pyrite, and small quantities of carbonaceous detritus, secondary iron oxides, quartz, chalcedony, and clay minerals. Dolomitic lime mudstones and less abundant argillaceous lime mudstones occur near the base of the formation.

The packstones and grainstones form several zones, each about 100 feet thick, throughout the formation. Typically these rocks are medium gray or medium dark gray. They contain well-sorted clasts, generally about 0.1 mm in diameter, that consist of rounded pellets of lime mud, ooids, and sparse bioclastic fragments. The packstones contain interstitial lime mud; the grainstones are cemented by sparry calcite.

The crystalline carbonates are lighter colored than most other Chitistone rocks. They are mainly light or medium gray and weather to light brownish gray. They consist of interlocking mosaics of carbonate crystals, generally between 0.1 and 1.0 mm long, and uncommon scattered opaque and clay minerals. The crystalline dolomites have been recognized only from the stratigraphic interval between 100 and 300 feet above the base of the formation near the copper mines in the southwestern part of the quadrangle. The crystalline limestones, though not abundant, have a wider stratigraphic range, but generally are best developed in the lower part of the formation. Some of the crystalline limestones are dolomitic. Carbonate veinlets generally are abundant in the crystalline carbonates, particularly in the dolomites.

The chert which is usually associated with lime mudstone or wackestone forms irregular grayish-black nodules less than 6 inches long and a few small lenses.

Armstrong, MacKevett, and Silberling (1970, p. 055) imply that the Chitistone reflects an early intertidal and supratidal depositional environment and subsequent low-energy, restricted shallow-water marine deposition alternating with high-enegry shoaling-water deposition. The transition from Chitistone to Nizina deposition accompanied a rise in sea level and the drowning of the Chitistone carbonate platform. Several lesser fluctuations in sea level are indicated during the period of Chitistone and Nizina deposition.

Diagnostic fossils are sparsely distributed in the Chitistone Limestone; none were found in the C–5 quadrangle. Chitistone fossils from nearby quadrangles studied by N. J. Silberling contain a fauna characterized by the ammonite genus *Tropites* and are indicative of the late Karnian Stage of the Late Triassic.

NIZINA LIMESTONE

Martin (1916, p. 693) applied the names Nizina Limestone to the predominantly thin-bedded limestone that previously was considered to constitute the upper part of the Chitistone Limestone. The Nizina is widely distributed in the southern part of the quadrangle, where it generally forms bold, cliffy outcrops. Its approximate thicknesses range from 350 to 1,250 feet in the C–5 quadrangle. Most strata in the formation are between ½ and 3 feet thick, but a few are as much as 10 feet thick. The Nizina Limestone gradationally overlies the Chitistone Limestone and conformably underlies the lower member of the McCarthy Formation.

The Nizina Limestone consists of very fine grained limestone and subordinate chert. According to Dunham's classification (1962, p. 117), the limestone includes grainstone, mudstone, and wackestone. Many of these rocks are micropelletoidal and some are bioclastic. Most Nizina Limestone is dark greenish gray and weathers to various shades of brown; its uncommon phases are light or medium gray and weather brownish gray. Calcite veinlets are fairly abundant in many of the limestones. The grainstones are composed of pellets of lime mud, fragments of fossils, and uncommon ooids less than 1 mm in diameter. Their grains are generally well sorted, rounded, and cemented by sparry calcite.

The lime mudstones and wackestones are characterized by matrices of lime mud. Clasts are sparsely distributed in the lime mudstone and abundant in the wackestone. They include subrounded pellets from 0.05–0.2 mm long of lime mudstone, calcareous fossil fragments, minor quartz, plagioclase, and widely scattered opaque minerals, chiefly pyrite. The matrices of the pellets contain small amounts of carbonaceous material and silica and clay minerals.

The chert forms irregular nodules and lenses throughout much of the formation. Commonly the nodules are less than 6 inches in diameter. The lenses are as much as 30 feet long and 6 inches thick. Locally the chert forms interlacing networks. It is dark gray or grayish black and generally is flecked with rhombohedrons of calcite or dolomite as much as 0.02 mm across. Most of the chert contains a few grains of opaque minerals and is cut by calcite veinlets.

Regional mapping augmented by biostratigraphic studies by N. J. Silberling indicates some contemporaneity between older parts of the Nizina Limestone and younger parts of the Chitistone Limestone and a similar partial contemporaneity between the uppermost Nizina strata and basal strata of the McCarty Formation. The Nizina Limestone is interpreted as having formed in a gently sloping basinal apron fronting a carbonate platform of Chitistone Limestone and in part on a contiguous shallow marine shelf. Generally limestones of the Nizina reflect a deeper water environment than the Chitistone carbonates and a shallower environment than the McCarthy Formation.

Fossils useful for age determinations are not found widely distributed in the formation. They consist mainly of pelecypods of the genus *Halobia*. Paleontologic studies by N. J. Silberling (written commun., 1962) indicate that the Nizina Limestone is Late Triassic and ranges in age from late Karnian or early Norian to early middle Norian.

McCARTHY FORMATION

The McCarthy Formation, originally named the McCarthy Creek Shales (Rohn, 1900, p. 426), was divided into two informal members by MacKevett (1963).

LOWER MEMBER

The lower member of the McCarthy Formation crops out in the southern part of the quadrangle, where it conformably overlies the Nizina Limestone and gradationally underlies the upper member. Maximum thickness is about 950 feet, but reliable thickness estimates are precluded by numerous folds and plications in the incompetent rocks. Discrete strata range from less than an inch to about 4 feet in thickness. The member consists of calcareous carbonaceous shale, impure limestone, and impure chert. Its outcrop pattern strongly reflects lithology; the shale forms subdued outcrops, and the chert and limestone generally form bold outcrops. Most of the rocks are conspicuously dark colored which is attributed to their carbonaceous content. Characteristically they are dark gray, dark greenish gray, or grayish black and weather dark brown, but some of the limestones are paler shades of gray.

The lower member is crudely tripartite in lithology. Its lowermost 300 fet consists of interbedded shale and chert; its middle 300 feet are dominated by impure limestone; and its stratigraphically higher parts are composed of intercalated shale and chert with subordinate limestone. Calcite veins and veinlets, including gash veins that are well developed along crests and troughs of folds, are widely distributed in parts of the member. Discoidal calcareous concretions less than 2 inches in diameter occur locally near the top, and similar but larger concretions occur sparsely near the base.

The calcareous and carbonaceous shales are finely laminated and contain calcite, partly of bioclastic derivation, along with carbonaceous material, illite, clay minerals, and chlorite and subordinate quartz, chalcedony, dolomite, pyrite, and secondary iron minerals.

The impure cherts have fine wispy laminations and are chalcedony-rich rocks containing subordinate clastic and carbonaceous material and siliceous fragments of Radiolaria and sponge spicules. Their clasts include calcite and minor amounts of quartz, plagioclase, dolomite, pyrite and other opaque minerals, apatite, and biotite. Most of the cherts also contain minor quantities of illite, clay minerals, and secondary iron oxides.

The impure limestones range from varieties with dominant calcite grains in chalcedony-rich matrices to those whose matrices are partly recrystallized lime mud. Most of the impure limestones are partly recrystallized bioclastic wackestone (terminology of Dunham, 1962). These rocks are composed of abundant clastic grains, chiefly calcite of bioclastic origin, embedded in partly crystallized lime mud. They contain minor amounts of other clasts similar to those in the impure cherts and varying amounts of carbonaceous material aud clay minerals. Most of the clasts are subrounded or subangular and less than 0.1 mm long.

Most rocks of the lower member probably formed in a fairly deep sea, partly in a starved basin. The lower member is Late Triassic and Early Jurassic(?) in age. Pelecypods of the genus *Monotis* are abundant and widespread through a stratigraphic interval from 200 to 400 feet above the base and indicate the late Norian Stage of the Late Triassic. Middle and early Norian fossils have been collected from the member in nearby quadrangles and studied by N. J. Silberling. A conformable stratigraphic succession about 800 feet thick and apparently barren of diagnostic fossils intervenes between the highest documented Triassic beds of the lower member and beds of the upper member that have yielded Hettangian fossils in the McCarthy B-4 quadrangle. Parts of this succession may represent the Rhaetian or Hettangian Stages. The lower part of the lower member probably is a deeper water temporal equivalent of the upper part of the Nizina Limestone.

UPPER MEMBER

The upper member of the McCarthy Formation is well developed in the southern part of the C-5 quadrangle, where it attains a maximum thickness of more than 2,000 feet. It is separated from the overlying Lubbe Creek Formation and the subjacent lower member by gradational contacts. Where the Lubbe Creek Formation is absent, the upper member disconformably underlies the Nizina Mountain Formation. Strata of the upper member are between ½ and 3 feet thick and form rugged, ribby, or, less commonly, subdued outcrops.

Rocks of the upper member include impure calcareous organic chert and spiculite and subordinate shale and impure limestone. Most of the shale is near the top of the member. The rocks of the member are shades of dark gray and weather dark yellowish brown or medium brown. Limy concretions, generally less than 6 inches in diameter, are sparsely distributed in the upper part.

The abundant impure cherts and spiculites commonly are finely laminated, are chalcedony rich, and contain diverse amounts of detrital grains, chiefly calcite less than 0.2 mm across. Most of these rocks contain abundant chalcedonic or calcareous spicules and siliceous Radiolaria. As calcite content increases, the cherts and spiculites grade into impure limestones characterized by abundant calcite grains and subordinate chalcedonic matrix material. There are wide lithologic gradations between the dominant chalcedony-rich cherts and spiculites and the less common calcite-rich impure limestones. Subordinate clasts in most of these rocks are quartz, plagioclase, dolomite, apatite, and cherty fragments. Some of the cherts, spiculites, and impure limestones also contain minor amounts of carbonaceous material, pyrite, hematite, potassium-feldspar, albite, ilmenite, leucoxene, chlorite, biotite, and clay minerals. Some of these minerals probably formed authigenically. Many of the carbonate grains have overgrowths and are partly recrystallized.

The shales typically are fissile, calcareous, and carbonaceous and are composed of clay minerals, quartz, chalcedony, calcite, carbonaceous debris and minor plagioclase, dolomite, opaque minerals, and carbonate fluorapatite.

The upper member probably formed mainly in a rather quiet sea where siliceous organisms flourished. Its dominant rocks probably reflect the fixation of biogenic silica and the admixture of small to large quantities of clastic components. This member is largely or entirely Early Jurassic in age, although its oldest strata possibly range into the latest Triassic. Fossils that provide critical age data were found only near the top of the member within the quadrangle and are indicative of the Sinemurian and probably Pliensbachian Stages. Unequivocal Pliensbachian fossils were collected from near the top of the member in the adjacent McCarthy C–4 quadrangle (MacKevett, 1970a) and Hettangian fossils were collected from near the base of the member in the nearby McCarthy B–4 quadrangle.

LUBBE CREEK FORMATION

The Lubbe Creek Formation, named by MacKevett (1969, p. A37) from excellent exposures along Lubbe Creek in the C–5 quadrangle, extends nearly across the southern part of the quadrangle, where it conformably overlies the upper member of the McCarthy Formation and disconformably underlies the Nizina Mountain and Root Glacier Formations. It constitutes an excellent marker horizon, being less than 300 feet thick, lithologically distinctive, and exposed in bold outcrops that contain diagnostic fossils. Strata in the formation are commonly ½ to 3 feet thick, exceptionally as much as 8 feet thick.

The formation consists of impure spiculite with lesser amounts of coquina in its stratigraphically higher parts. Its rocks are medium gray and mainly weather medium brown. A few chert lenses, as much as 10 feet long and 6 inches thick, occur in some of the spiculite. The spiculites are dense fine-grained silica-rich rocks that contain organic and inorganic clasts in chalcedony-rich matrices. Their clasts include spicules, Radiolaria, fragments of pelecypods, echinoderms, belemnites, and the minerals calcite, quartz, dolomite, and plagioclase. Calcite is the principal constituent of both the clastic grains and the fossil fragments. Most of the clasts are ragged or subangular to subrounded particles less than 0.2 mm across. The abundant spicules are less than 0.2 mm long and composed of chalcedony, or, less commonly, of calcite. A few have chloritic cores. Minor constituents of the spiculite are chlorite, hematite, pyrite, carbonaceous material, ilmenite, and rare biotite and apatite.

The coquina consists of poorly sorted bioclastic material, chiefly whole and comminuted shells of megafossils, in a chalcedony-rich matrix that forms a small part of the rock. It also contains minor quantities of detrital grains similar to those of the impure spiculite.

The Lubbe Creek Formation is of nearshore marine genesis, and its depositional site was subjected to local wave action. Its fauna, chiefly diagnostic pelecypods of the genus *Weyla*, are indicative of the Toarcian and probably Pliensbachian Stages of the Lower Jurassic Series.

NIZINA MOUNTAIN FORMATION

The name Nizina Mountain Formation was applied by MacKevett (1969, p. A42) to a sequence of reddish-brown-weathering graywacke exposed in the central part of the C–5 quadrangle. Both the upper and the lower stratigraphic boundaries are disconformities marked by irregular erosion surfaces without apparent discordance of the juxtaposed strata. Thickness of the formation ranges from a few feet to about 1,350 feet. The Nizina Mountain is characterized by well-bedded strata, commonly ½ to 2 feet thick, that form slopes of moderate relief.

The formation consists of fine and very fine grained feldspathic graywacke with sparsely distributed yellowish shaly partings, limy lenses, and limy concretions as much as 2 feet in diameter. The graywacke is dark greenish gray and locally finely laminated. It is composed of poorly sorted subangular to subrounded clasts 0.05 to 0.5 mm in maximum dimensions in a microcrystalline matrix. The clasts consist of plagioclase, chiefly sodic labradorsite, and quartz along with less abundant cherty lithic fragments, calcite, opaque minerals, and rare biotite and apatite. The dominant matrix constituents, chalcedony, chlorite, and clay minerals locally are associated with epidote, leonhardite, calcite, and prehnite. Opaque minerals in the formation include pyrite, hematite, ilmenite, and magnetite. Fractures in a few of the graywackes are coated with gypsum. Sparsely distributed small spheres of chalcedony or calcite in a few of the rocks may be microfossil remains.

The Nizina Mountain Formation probably formed in a moderately deep sea. It contains fairly abundant fossils, including ammonites indicative of the Bathonian and Callovian Stages of the Middle and Upper Jurassic Series.

ROOT GLACIER FORMATION

The Root Glacier Formation named by MacKevett (1969, p. A45) is widely distributed throughout the central part of the C–5 quadrangle, where it disconformably overlies the Nizina Mountain Formation or the Lubbe Creek Formation. Its contacts with younger rocks are unconformities. Maximum thickness is probably between 3,000 and 4,000 feet, but accurate thickness estimates are precluded by its unconformable upper contact. Numerous andesitic dikes and sills and a few sandstone dikes cut the formation. The Root Glacier Formation consists of mudstone and siltstone with lesser amounts of shale, sandstone, and conglomerate. It contains a few thin beds and lenses of impure limestone and uncommon small limy concretions. The dominant mudstones are thick bedded to massive; other strata range widely in thickness. The conglomerate is maily confined to a lentil about 200 feet thick that grades vertically and laterally into sandstone. Rocks of the formation characteristically weather to moderately smooth slopes that are locally breached by resistant conglomeratic or limy beds. Parts of the formation are strongly jointed. Some Root Glacier rocks show small-scale cut-and-fill relations, and a few have graded bedding. Many of the siltstones and shales are finely laminated. Most rocks of the formation are dark greenish gray or dark gray and weather to various shades of brown.

The mudstones, siltstones, and shales contain mineralogically similar, poorly to moderately well sorted, subangular to subrounded clasts, chiefly quartz, calcite, and plagioclase, in microcrystalline matrices. These pelitic rocks are differentiated by the sizes of their clasts, by the proportions of microcrystalline matrix relative to clasts, and the shales, by the development of fissility. Clastic constituents predominate in the siltstone and matrix material in the mudstone and shale. The matrix material consists of calcite, chlorite, clay minerals, and lesser quantities of chalcedony, sericite, illite, secondary iron oxides, leucoxene, carbonaceous trash, and rarely leonhardite. Uncommon grains in the mudstone, siltstone, and shale include pyrite, biotite, magnetite, and ilmenite and rare epidote, apatite, and zircon. Some of the pelitic rocks contain reworked shaly fragments, scattered fossil wood, minute calcite spheres with concentric structures, and calcite veinlets.

Sandstones in the Root Glacier Formation, following the terminology of Williams, Turner, and Gilbert (1954, p. 289–301), which is used throughout this report except where otherwise noted, include graywacke, wacke, and arenite. Characteristically, these rocks are fine to medium grained, but they include a few coarser grained types. The graywackes and wackes are poorly sorted and composed of subangular clasts in microcrystalline matrices that constitute between 10 and 30 percent of their volumes. The graywackes differ from the wackes by being extremely well indurated and darker. Most of the graywackes and wackes are feldspathic and contain clasts of quartz, plagioclase, and less abundant clinopyroxene; lithic fragments, chiefly chert; biotite, potassium-feldspar, hornblende, calcite, and opaque minerals, chiefly magnetite, pyrite, and hematite. Their matrices consist of calcite-chlorite-clay assemblages with subordinate chalcedony and sericite.

The arenites contain less matrix material than the other sandstones and generally have moderately well sorted subrounded clasts. They comprise fine or very fine grained feldspathic, lithic, or calcareous arenite with grains of quartz, calcite, and plagioclase that are either calcite cemented or embedded in microcrystalline matrices composed of chlorite, clay minerals, chalcedony, calcite, and sericite. Less abundant clasts in the arenites include biotite, opaque minerals and their alteration products, and rare apatite, epidote, and potassium-feldspar.

The impure limestones are mainly calcite-cemented detrital rocks that contain clasts of calcite and rarer quartz and plagioclase.

The conglomerate consists of well-indurated cobble and pebble conglomerate. Generally it grades into very coarse and coarse-grained sandstone that locally contains wood fragments. Its constituent pebbles commonly are well rounded and embedded in a sandstone matrix. The dominant lithic clasts are limestone, probably derived from the Nizina and Chitistone Limestones. Its rarer cobbles and pebbles include mudstone and siltstone derived from the Root Glacier Formation, pink granite rich in potassium feldspar, Nikolai Greenstone, chert, and quartz.

The Root Glacier Formation probably was deposited in a moderately shallow sea. Paleontologic studies by R. W. Imlay, of the U.S. Geological Survey, indicate that the formation is Late Jurassic, more specifically, late Oxfordian and Kimmeridgian. Its diagnostic fauna are mainly pelecypods of the genus *Buchia* (*Aucella*) and less abundant ammonites.

KENNICOTT FORMATION

The Kennicott Formation was redefined by Jones and MacKevett (1969, p. K7) to correct disparities in previous use of the name. It is exposed south of Regal Glacier near the eastern border of the quadrangle and in a small outlier near Green Butte. Maximum thickness in the quadrangle is approximately 700 feet; its constituent beds are mainly 1 to about 30 feet thick. Outcrops range from bold, for some of the conglomerate, to subdued, for most of the shale.

The Kennicott Formation is the basal Cretaceous unit in the quadrangle and overlies older rocks with a strong angular unconformity. It is disconformably overlain by the Moonshine Creek Formation and unconformably overlain by the Frederika Formation. The formation consists of a basal conglomerate, as much as 100 feet thick and overlying sandstone, siltstone, and shale. Calcareous concretions are locally abundant. Most of the conglomerates and sandstones are dark greenish gray and weather dark greenish brown. The constituent cobbles, pebbles, and boulders of the conglomerates reflect local provenances and consist chiefly of Nikolai Greenstone. They commonly are subrounded or subangular. Matrices of the conglomerates are mainly coarse-grained sandstone.

The sandstones include feldspathic wacke and arenite and less abundant arkosic wacke. They generally are fine-grained, fairly well–sorted rocks that contain diverse subangular clasts embedded in a microcrystalline matrix that constitutes between 5 and 25 percent of the rock. Their clasts include quartz and plagioclase, smaller quantities of glauconite, chert, opaque minerals, chlorite, biotite, calcite, and rare epidote and garnet. The matrices consist of chlorite, chalcedony, sericite, calcite, secondary iron minerals, montmorillonite, and kaolinite. Some of the sandstones are partly zeolitized and contain heulandite or analcite.

The siltstones are mineralogically and texturally similar to the sandstones. Their clasts are finer grained and generally better sorted than those of the sandstones. Most shales in the formation are medium gray and weather to dark brown. They consist of clay minerals and scattered detrital grains, chiefly quartz.

The Kennicott Formation probably formed in a shallow marine environment. Only the younger of its two well-defined early Albian faunal zones is represented in the quadrangle. Age of the Kennicott is best documented by the ammonite *Brewericeras hulenense* (Anderson), which along with other megafossils is abundant in some of the concretions. Fossil wood and plant debris are found locally in the formation, mainly near its base. Some of the finer-grained rocks of the formation contain spherical or rodlike remains of microfossils.

SCHULZE FORMATION

The Schulze Formation, named by Jones and MacKevett (1969, p. K13), underlies a small area near the southwestern corner of the quadrangle, where it is about 200 feet in maximum thickness. It is in fault contact with the Nikolai Greenstone and locally cut by felsic hypabyssal rocks. Rocks of the formation are characteristically thin bedded and weather to aggregates of small chips that partly mask their outcrops.

The Schulze Formation consists of siliceous shale or porcellanite and smaller amounts of siltstone and very fine grained sandstone. Rocks of the formation are light or medium gray when fresh and light or yellowish brown when weathered. The siliceous shale consists of extremely fine-grained quartz and minor amounts of calcite; clay minerals, chiefly kaolinite; plagioclase, sericite, and secondary iron oxides. The siltstone and very fine grained sandstone consist of small clasts, mainly quartz, in silica- or carbonate-rich matrices that contain scattered clay minerals, chlorite, sericite, and secondary iron minerals. The siliceous shales and a few of the other rocks contain abundant Radiolaria or less abundant Foraminifera.

The megafossil fauna of the formation is meager in the C–5 quadrangle, but paleontologic studies of megafossils from the B–5 quadrangle indicate that the Schulze Formation is contemporaneous with part of the Moonshine Creek Formation and that it has an age span from late Albian(?) (Early? Cretaceous) to Cenomanian (Late Cretaceous) (Jones and MacKevett, 1969, p. K14, 15).

MOONSHINE CREEK FORMATION

The Moonshine Creek Formation, named by Jones and MacKevett (1969, p. K11), crops out near the eastern boundary of the quadrangle between Regal Glacier and "the amphitheatre," where it attains a maximum thickness of about 550 feet. Its exposure in the C–5 quadrangle constitute the western margins of an extensive and much thicker Moonshine Creek sequence that underlies nearby parts of the McCarthy C–4 quadrangle (MacKevett, 1970a). The Moonshine Creek Formation unconformably underlies the Frederika Formation and disconformably overlies the Kennicott Formation. It apparently unconformably overlies pre-Cretaceous rocks near its poorly exposed southernmost exposures. Strata in the formation are as much as 10 feet thick and form moderate to subdued outcrops.

The Moonshine Creek Formation consists of diverse sandstone, siltstone, and less common shale and conglomerate and locally contains calcareous concretions from ½ to 3 feet in diameter, mainly in the siltstones. The sandstones are greenish gray or medium gray and weather to various shades of brown. Most of them are fine grained, but they range from very fine to very coarse varieties. Generally they are moderately well indurated, moderately well sorted, and contain subrounded to subangular clasts. The sandstones consist of feldspathic or lithic wacke and arenite. Their clasts include quartz, plagioclase, K-feldspar, lithic fragments, and subordinate glauconite, opaque minerals, calcite, and biotite; generally quartz and plagioclase are dominant. The wackes contain more than 10 percent microcrystalline matrix composed of chlorite, chalcedony, sericite, secondary iron minerals, clay minerals, and rare zeolite. The arenites differ from the wackes in containing less than 10 percent microcrystalline matrix, or more commonly by being calcite cemented. A few of the coarse sandstones grade into granule conglomerates that generally contain lithic clasts.

The siltstones are moderately well sorted gray or olive-gray rocks that contain fine clasts, mainly of quartz and plagioclase, in microcrystalline matrices. The matrices are clay rich and also contain subordinate chlorite, calcite, sericite, and rare epidote and heulandite.

Shales in the formation are medium gray and weather dark yellowish brown. They consist of abundant clay minerals, including montmorillonite and kaolinite, and less abundant fine quartz, plagioclase, sericite, and heulandite. The shales and some of the other rocks contain calcareous or siliceous remains of microfossils.

The Moonshine Creek Formation probably was deposited in a shallow, restricted marine basin. Its megafossils are mainly preserved in concretions and include diagnostic ammonites indicating an age span from probable middle Albian (Early Cretaceous) to late Cenomanian (Late Cretaceous).

FREDERIKA FORMATION

The Frederika Formation, named by MacKevett (1970a), consists of diverse continental sedimentary rocks that are widely distributed in the northern part of the quadrangle. The formation is intercalated with older flows of Wrangell Lava and gradationally underlies the Wrangell Lava. Its basal contacts are unconformities: those with the Moonshine Creek Formation are slightly angular; those with older rocks generally are moderately angular. Locally abundant andesitic sills and a few andesitic dikes cut the formation, which is from 1,000 to 2,000 feet thick. Thicknesses of its strata range from a few millimeters for fissile shales to about 100 feet for massive conglomerates. Outcrop patterns reflect the varied lithology and include gentle subdued slopes underlain by shale or some siltstone and sandstone as well as bold cliffy exposure characteristic of the conglomerate.

The Frederika Formation contains several varieties of conglomerate and sandstone along with siltstone, shale, and some lignite. The conglomerates are mainly pebble or cobble conglomerate but include subordinant boulder conglomerate. They range from well-indurated rocks to poorly indurated crumbly masses. The conglomerates are variegated with multicolored clasts in light-gray, light-brown, or yellowish-brown matrices. Generally their cobbles and pebbles are well rounded and their boulders subrounded or subangular. Matrices of most of the conglomerates consist of poorly sorted coarse-grained calcite-cemented sandstone that is rich in quartz and plagioclase. The conglomerates are polymict, and their clasts generally consist of Wrangell Lava, some Nikolai Greenstone, and rare chert, quartz, granitic rocks, quartzite, shale, and limestone.

The sandstones are mainly feldspathic and arkosic wackes that typically are coarse grained and less commonly fine or medium grained. Some of the sandstones are tuffaceous. Most of them are well cemented and light brown, buff, light greenish brown, or pale olive. They consist largely of poorly sorted angular to subrounded grains of quartz and plagioclase with interstitial chlorite, illite, and clay minerals, chiefly montmorillonite, and minor amounts of calcite, quartz, or chalcedony cement. Common detrital components of the wackes are lithic clasts, potassium-feldspar, biotite, magnetite, ilmenite, and apatite. Pyrite and hematite are sparse constituents of a few of the wackes. Some of the wackes are cut by calcite veinlets.

Siltstones of the formation are light gray and weather mottled brown. Some have crude graded bedding. They are essentially finer grained replicas of the wackes and are characterized by poorly sorted subangular clasts of quartz and plagioclase, including some albite, associated with chlorite, illite, and montmorillonite and cemented by chalcedony or calcite. They contain sparse magnetite, ilmenite, leucoxene, and secondary iron oxides and are cut by a few veinlets of calcite and secondary iron minerals.

Other rocks in the formation are extremely fine grained and include shale, carbonaceous shale, and lignite. The shale is light to dark gray and weathers to shades of brown. Where baked and welded near contacts with some flows and sills, the shale is red or reddish brown. The shales are finely laminated and composed of quartz and clay minerals with rare biotite, muscovite, and opaque dust. The carbonaceous shale is fissile and grayish black. It contains detrital quartz and feldspar along with authigenic minerals and organic matter, including abundant plant remains. The lignite is finely laminated and dark gray to black, in alternating dull and glistening layers. It is composed chiefly of organic remains and, with the addition of detrital and authigenic components, grades into carbonaceous shale.

The Frederika Formation contains abundant plant debris, including leaves that according to J. A. Wolfe (written commun., 1961, 1964), indicate a Miocene age.

INTRUSIVE ROCKS

Intrusive rocks, which are mainly Tertiary in age, in the C–5 quadrangle include varied andesitic dikes and sills, felsic hypabyssal plutons, and granodiorite. Some of the andesitic rocks and possibly a few felsic dikes are Quaternary, and some andesitic dikes and sills may be late Mesozoic.

ANDESITIC DIKES AND SILLS

The andesitic dikes and sills (not shown in figure 3) are mainly related to Wrangell Lava volcanism, but they cut most of the bedrock units and are particularly abundant in the Frederika and Root Glacier Formations. Most of these dikes and sills, which commonly form bold outcrops, are between 1 to 10 feet thick, but a few are as much as 50 feet thick. They include andesite and rare dacite, basalt, diabase, and lamprophyre. These rocks are greenish gray and weather to medium or dark brown. They are predominantly fine-grained altered intergranular or intersertal rocks that locally have thin very fine grained chilled borders. Many of the andesitic dikes and sills are porphyritic; a few are amygdaloidal. Most of the porphyritic varieties contain plagioclase or clinopyroxene phenocrysts 1 to 4 mm long.

The andesites consist mainly of plagioclase and clinopyroxene. The plagioclase forms oscillatorily-zoned phenocrysts of labradorite and andesine and abundant small elongate crystals of andesine. The clinopyroxene consists of augite and less common pigeonite that forms a few partly resorbed phenocrysts and more abundant small crystals scattered throughout the bulk of the rock. Rare primary constituents in the andesite are quartz, brown biotite, potassium feldspar, sphene, and opaque minerals. Secondary minerals in the andesite include calcite, clay minerals, sericite, chlorite, and hydrous iron oxides. The amygdules consist of calcite and chlorite with uncommon chalcedony in their cores, and rare botryoidal masses of hematite and limonite.

Dacites associated with the andesitic rocks are darker than dacites of the felsic hypabyssal rocks. They resemble andesite in texture and color but contain more quartz than andesite. The few diabase and basalt dikes in the quadrangle are richer in labradorite than the andesites; the diabases are medium grained and have subophitic textures. The lamprophyres are fine-grained porphyritic rocks whose groundmasses have been largely obliterated by alteration. They contain phenocrysts of brown biotite or clinopyroxene in altered groundmasses rich in calcite and chlorite. Their minor constituents include magnetite, apatite, plagioclase, potassium-feldspar, quartz, and secondary iron minerals.

INTERMEDIATE ROCKS

Granite rocks of intermediate composition, chiefly granodiorite, are exposed in a few rugged nunataks between the heads of Regal and West Fork Glaciers. These rocks cut the lower part of the Wrangell Lava and are cut by a few andesitic dikes. They are fine- to medium-grained speckled rocks that locally contain fine-grained mafic inclusions as much as 10 cm long. The intermediate intrusive rocks are hypidiomorphic granular and mainly of plagioclase and slightly less abundant quartz and potassium-feldspar. The plagioclase is normally zoned sodic andesine, commonly with altered borders. Less abundant primary minerals include brown hornblende, reddish-brown biotite, and rare apatite, magnetite, and ilmenite. Sparsely distributed alteration products in the granodiorite and related rocks include epidote, chlorite, clay minerals, calcite, and hematite.

FELSIC HYPABYSSAL ROCKS

The felsic hypabyssal rocks are exposed chiefly in the southwestern part of the quadrangle, where they mainly cut the Schulze Formation. They represent apophyses of shallow felsic plutons that are well exposed in nearby parts of the adjoining McCarthy B-5 quadrangle (MacKevett, 1965). The felsic dikes and sills, which form bold outcrops, typically are 2 to 10 feet thick, rarely as much as 200 feet thick. The felsic plutons, many of which are extensively altered, are light gray or pinkish gray and weather light brown to yellowish brown. Uncommonly they are vesicular or amygdaloidal, and locally they are cut by calcite veinlets.

The felsic hypabyssal rocks consist of dacite and rhyodacite and variants of these rocks. They are porphyritic or, less commonly, seriate with very fine grained felty or, uncommonly, pilotaxitic or intersertal groundmasses. Phenocrysts, 0.5 to 2.5 mm in maximum dimensions, constitute as much as 30 percent of the felsic rocks. They consist of normally zoned andesine and less abundant quartz, biotite, and relicts of clinopyroxene and amphibole. The groundmass minerals consist of andesine, quartz, and potassium-feldspar, generally with copious secondary minerals and less common to rare biotite, magnetite, ilmenite, zircon, and apatite. The secondary minerals include clay minerals, chlorite, calcite, and iron minerals, chiefly hematite. A few of the felsic hypabyssal rocks contain sparsely disseminated pyrite. Probably components of some of their groundmasses represent devitrified glass.

WRANGELL LAVA

The Wrangell Lava (Mendenhall, 1905, p. 54) constitutes the youngest bedrock in the quadrangle. It underlies most high parts of the Wrangell Mountains throughout their extent and is widespread in the northern part of the C–5 quadrangle. Some older Wrangell Lava flows are intercalated with Miocene strata of the Frederika Formation, but most of the Wrangell Lava conformably overlies the Frederika. Locally, the Wrangell Lava unconformably overlies the Nikolai Greenstone or the Golden Horn Limestone Lentil of the Hasen Creek Formation. Many exposures are nunataks. Wrangell Lava volcanism probably extended intermittently from the Miocene into the Holocene, but the age of its younger flows is not well documented in the quadrangle.

The Wrangell Lava forms a sequence of subaerial lava flows, less common pyroclastic rocks, vitrophyre, and conglomerate more than 5,000 feet thick. Thickness of its constituent flows range from 1 to 25 feet but commonly are 2 to 10 feet. Generally the Wrangell Lava forms rugged outcrops. Columnar joints are well developed in a few of the flows. Flows of Wrangell Lava are predominantly andesite and basaltic andesite, but a few flows consist of dacite, rhyodacite, or basalt. The andesites and basaltic andesites commonly are medium dark gray or greenish gray when fresh and medium brown when weathered. They generally are porphyritic and contain about 10 percent phenocrysts, chiefly plagioclase crystals less than 2 mm long. Many of the andesitic rocks contain amygdules or vesicles between 0.1 and 0.5 mm in diameter. Textures of the andesites and basaltic andesites are fine-grained intersertal or, less commonly, pilotaxitic and hyaloptilitic. Plagioclase, the dominant mineral, forms oscillatorily zoned phenocrysts of sodic labradorite and calcic andesine and abundant andesine microlites. Pyroxene in the andesitic rocks forms numerous small anhedral crystals and scarce phenocrysts of augite, hypersthene, and rare pigeonite. A few of the andesitic rocks contain scattered phenocrysts of relict olivine. Sparse primary constituents in the andesites and basaltic andesites are opaque minerals, chiefly magnetite, and glass, hornblende, biotite, and quartz. Secondary minerals that generally occur as alteration products in these rocks include uralitic hornblende, biotite, chlorite, calcite, goethite, hematite, limonite, sericite, clay minerals, chalcedony, and epidote. The secondary minerals of the amygdules and vesicles are generally calcite, chlorite, and silica minerals, and uncommonly, siderite, ankerite, and zeolites.

The dacites and rhyodacites are light gray or buff and weather light brown. They are porphyritic with fairly abundant phenocrysts between 0.5 and 2.5 mm long in very fine grained groundmasses commonly hyalopilitic or pilotaxitic in texture. A few of the dacitic rocks are amygdaloidal and contain amygdules compositionally similar to those of the andesitic rocks. Flow structure manifested by alined microlites is well developed in some of the dacitic rocks. Andesine is the most abundant mineral in the dacites and rhyodacites and constitutes nearly all of the phenocrysts and most of the groundmass microlites. Quartz forms rare phenocrysts in some of the dacite. Potassium feldspar is abundant in groundmasses of the rhyodacite. Less abundant groundmass constituents of the dacitic rocks include quartz, biotite, glass, magnetite, ilmenite, and trace amounts of zircon and sphene. Secondary minerals in these rocks consist of chlorite, calcite, clay minerals, illite, leucoxene, sericite, chalcedony, and hydrous iron oxides.

The basalt flows are dark gray and porphyritic with plagioclase and (or) less common relict olivine phenocrysts in a fine-grained intergranular groundmass. Most of the basalts are amygdaloidal. They are mineralogically similar to the andesitic rocks but contain more labradorite and relict olivine.

Vitrophyre forms a few small lava domes in the Wrangell Lava sequence. It commonly is greenish black and is characterized by scattered quartz and (or) plagioclase phenocrysts in a glassy groundmass. Most of the vitrophyre has good flow structure and numerous microfractures perpendicular to the flow structure or, uncommonly, reticulate or concentric.

Pyroclastic rocks, which are rare in the quadrangle, consist of tuffs that generally are light gray and well indurated and of variegated reddish-brown and gray volcanic breccias.

Conglomerate forms a few small lentils within the Wrangell

Lava. It consists of light-gray well-indurated boulder conglomerate containing subangular boulders of Wrangell Lava in a coarse-grained sandstone matrix.

SURFICIAL DEPOSITS

The Quaternary surficial deposits include alluvium and older alluvium, talus, moraines, landslides, rock glaciers, and minor unmapped colluvium, slope wash, soil, and mudflows. The surficial deposits are poorly consolidated, and precise ages and age relations have not been ascertained, because many of the deposits represent products of recurrent deposition or are partly contemporaneous.

ALLUVIUM AND OLDER ALLUVIUM

Alluvium and older alluvium occupy flood plains along the Nizina River and McCarthy Creek, with other small deposits of alluvium being localized along most other streams. The alluvial deposits consist of detritus, chiefly poorly sorted, sometimes imbricated, sand and gravel, largely outwash from overloaded glacial streams. The older alluvium forms terraces that support vegetation and succesively are 1 to 6 feet higher than the modern flood plains or contiguous streamward terraces. Many alluvial deposits are ephemeral and subject to destruction by the shifting channels of modern flood plains. Maximum thicknesses are not known.

TALUS

Only a few talus masses were mapped, but smaller exposures of talus are numerous, particularly along oversteeped valley walls of the Nizina River and McCarthy Creek and near bases of cirque walls. The talus forms elongate or crudely lobate thin veneers whose lower extremities have locally coalesced to form aprons. It is largely composed of monolithologic angular boulders of various sizes.

MORAINES

Moraines are abundant in the quadrangle. They include several types that are associated with, and in places overlie, modern glaciers and scattered ground moraines that are mainly relicts of older more extensive glaciation. The moraines consist largely of angular and subangular boulders that have a great range in size and a diverse lithology, although parts of some moraines are virtually monolithologic. The moraines have rough, hummocky surfaces. Probably none exceed 100 feet in thickness.

LANDSLIDES

The only mapped landslides are near the western boundary of the quadrangle adjacent to Root Glacier. They consist of hummocky, jumbled masses of boulders and probably are less than 100 feet thick. Their upper extremities are partly bounded by escarpments.

ROCK GLACIERS

Rock glaciers are well developed in the southern part of the quadrangle. They consist of crudely lobate, spatulate, or sinuous masses that attain lengths of more than a mile. Throughout most of their extent they are typically narrow and constricted, but commonly their lower margins have steep-fronted lobate configurations. Characteristically, the rock glaciers occupy subjacent valleys emanating from cirques occupied by small glaciers. Hummocky on their surfaces, they are composed of angular, slabby, and locally blocky rocks a few inches to 10 or 12 feet across, partly cemented by ice and in a few places stabilized enough to support scanty vegetation. Lithologically they are related to the rocks of the cirques from which they are derived. Maximum thicknesses are not known but probably are less than 200 feet.

FOSSIL COLLECTIONS

Fossils collected from the McCarthy C–5 quadrangle are given in the following list. Locations of the fossil collections are keyed numerically to the geologic quadrangle map, U.S. Geological Survey GQ-series (MacKevett, 1970b). Credit for the fossil identifications is as follows: Triassic invertebrates, N. J. Silberling, Stanford University and U.S. Geological Survey. Jurassic invertebrates (except *Weyla* from the Lubbe Creek Formation), R. W. Imlay, U.S. Geological Survey. *Weyla* from the Lubbe Creek Formation, S. W. Muller, Stanford University. Cretaceous invertebrates, D. L. Jones, U.S. Geological Survey. Tertiary flora, J. A. Wolfe, U.S. Geological Survey.

Map No.	*USGS Mesozoic locality No.*	*Fauna*
		Nizina Limestone
1	....	*Gryphaea*?
2	....	*Halobia* cf. *H. brooksi* Smith
3	1792	*Halobia "austriaca* Mojsisovics" of Smith
4	1793	*Halobia "austriaca* Mojsisovics" of Smith
		Discophyllites cf. *D. ebneri* (Mojsisovics)
		Juvavites sp. indet.
5	1794	*Halobia "austriaca* Mojsisovics" of Smith
		Indet. ammonite
6	1695	*Pterotoceras* cf. *P. helminae* Diener
		Lower member of the McCarthy Formation
7	....	*Monotis subcircularis* Gabb
8	....	Carditoid pelecypod
		Monotis sp. indet.
9	....	*Monotis* cf. *M. subcircularis* Gabb
10	....	*Monotis subcircularis* Gabb

Map No.	*USGS Mesozoic locality No.*	*Fauna*
		Lower member of the McCarthy Formation—Continued
11	....	*Monotis* cf. *M. subcircularis* Gabb
12	....	*Monotis salinaria* ssp.
13 (float)	....	*Monotis subcircularis* Gabb
14	2207	Impressions of small, evolute, ribbed ammonite
		Indet. pelecypods, including *Halobia*?
15	....	Indet. impressions of haloritid ammonites
		Upper member of the McCarthy Formation
16	28534	*Crucilobiceras* sp.
		Aegasteroceras? or *Arctoasteroceras* Frebold, 1962
17	....	"*Entolium*" *semiplicatum* (Hyatt)
18	28536	*Crucilobiceras*? sp.
19 (float)	....	*Arniceras* sp.
20	....	*Megarietites*?
21	....	*Arnioceras* sp.
22	28537	*Lima* sp.
		Camptonectes? sp.
		Crucilobiceras sp.
23	....	"*Entolium*" *semiplicatum* (Hyatt)
24	28540	*Crucilobiceras* sp.
		Crucilobiceras? sp.
25	28684	*Oxytoma*? sp.
26	28685	Pelecypod fragment, undet.
27	28686	"*Entolium*" *semiplicatum* (Hyatt)
28	28687	cf. *Paracoroniceras*
		Belemnite, undet.
		Oxytoma sp.
29	28688	*Arnioceras* cf. *A. semicostatum* (Young and Bird).
		cf. *Arctoasteroceras*.
		Belemnite fragment
		Weyla sp.
		Gastropod, undet.
		Oxytoma sp.
		Myophorella sp.
		Cardinia sp.
30	28690	*Crucilobiceras*? sp.
		"*Entolium*" *semiplicatum* (Hyatt)
31	28694	*Uptonia*? sp.
		Chlamys?
32	28695	*Crucilobiceras*? sp.
33	28704	*Crucilobiceras*? sp.
34	28705	Ammonite fragment, undet.
35	28706	cf. *Paracoroniceras*
		Lubbe Creek Formation
36	28678	*Peronoceras*? sp.
		Ammonite, undet.
		Gryphaea sp.
		Ostrea sp.
		Weyla sp.
		Camptonectes sp.
37	28679	*Weyla* sp.
38	....	*Weyla dufreynoyi* d'Orbigny
		Gryphaea sp.
		Camptonectes sp.
		Chlamys sp.
39	....	*Weyla dufreynoyi* d'Orbigny
40	....	*Weyla dufreynoyi* d'Orbigny
		Chlamys sp.
		Camptonectes sp.
		Gryphaea sp.

Map No.	*USGS Mesozoic locality No.*	*Fauna*
		Lubbe Creek Formation—Continued
41	....	*Liostrea* sp.
		Camptonectes sp.
		Chlamys? sp.
42	....	*Weyla dufreynoyi* d'Orbigny
43	....	*Liostrea* sp.
44	....	*Weyla dufreynoyi* d'Orbigny
		Camptonectes sp.
		Nizina Mountain Formation
45	28524	*Parareineckeia* cf. *P. hickersonensis* Imlay
		Parareineckeia cf. *P. shelikofana* (Imlay)
		Belemnites, undet.
		Entolium sp.
		Thracia sp.
46	28525	*Cobbanites* cf. *C. talkeetnanus* Imlay
		Parareineckeia? sp.
		Cranocephalites cf. *C. costidensus* Imlay
		Cranocephalites? sp.
		Arctocephalites? sp.
		Belemnites, undet.
		Inoceramus cf. *I. ambiguus* Eichwald
		Entolium sp.
47	28256	*Parareineckeia* sp.
		Belemnites, undet.
48	28257	*Parareineckeia* cf. *shelikofana* (Imlay)
		Parareineckeia cf. *P. hickersonensis* Imlay
		Cranocephalites? cf. *C. pompeckji* (Madsen)
		Cranocephalites? sp.
		Cobbanites? sp.
		Belemnites, undet.
		Aptychus, undet.
		Coelastarte sp.
		Pleuromya? sp.
49	28681	*Parareineckeia* cf. *P. shelikofana* (Imlay)
		Parareineckeia cf. *P. hickersonensis* Imlay
		Cranocephalites cf. *C. costidensus* Imlay
		Cranocephalites cf. *C. pompeckji* (Madsen)
		Belemnites, undet.
		Liostrea sp.
		Entolium sp.
		Camptonectes sp.
		Pleuromya? sp.
		Coelastarte sp.
50	28682	*Reineckeia*? sp.
		Parareineckeia hickersonensis Imlay
		Parareineckeia cf. *P. skelikofana* (Imlay)
		Cobbanites cf. *C. talkeetnanus* Imlay
		Cobbanites sp.
		Cranocephalites? cf. *C. pompeckji* (Madsen)
		Cranocephalites? cf. *C. costidensus* Imlay
		Cranocephalites? sp.
		Belemnites, undet.
		Inoceramus cf. *I. ambiguus* Eichwald
		Oxytoma sp.
		Entolium sp.
		Camptonectes sp.
		Pleuromya sp.
		Thracia? sp.
		Quenstedtia? sp.
		Coelastarte sp.
		Fish scales
		Crustacean appendage

Map No.	USGS Mesozoic locality No.	Fauna
		Nizina Mountain Formation—Continued
51	28683	*Parareineckeia* cf. *P. shelikofana* (Imlay)
52	28691	*Cranocephalites*? sp.
53	28692	*Parareineckeia*? sp.
		Inoceramus cf. *I. ambiguus* Eichwald
54	28696	*Parareineckeia* cf. *P. shelikofana* (Imlay)
		Cranocephalites? sp.
		Belemnites, undet.
55	28697	*Pleuromya*? sp.
56	28698	*Parareineckeia* cf. *P. hickersonensis* Imlay
		Parareineckeia cf. *P. shelikofana* (Imlay)
		Cranocephalites? sp.
		Belemnites, undet.
		Inoceramus cf. *I. ambiguus* Eichwald
		Oxytoma sp.
		Entolium sp.
		Thracia sp.
		Coelastarte sp.
57	28699	*Parareineckeia* sp.
		Cobbanites cf. *C. talkeetnanus* Imlay
		Cranocephalites? sp.
		Belemnites, undet.
		Oxytoma sp.
58	28701	*Parareineckeia* cf. *P. hickersonensis* Imlay
		Belemnites, undet.
		Root Glacier Formation
59	....	*Partschiceras* sp.
		Buchia rugosa (Fischer)
60	....	*Partschiceras* sp.
		Buchia rugosa (Fischer)
61	....	*Buchia rugosa* (Fischer)
62	....	*Buchia* cf. *B. rugosa* (Fischer)
		Lima sp.
63	....	*Buchia rugosa* (Fischer)
		Camptonectes sp.
		Belemnite fragments
64	....	*Ctenostreon* sp.
		Belemnite fragments
65	....	*Buchia rugosa* (Fischer)
66	....	*Buchia* cf. *B. rugosa* (Fischer)
67	....	*Buchia concentrica* (Sowerby)
68	....	*Buchia* cf. *B. concentrica* (Sowerby)
69	....	*Buchia rugosa* (Fischer)
		Buchia mosquensis (von Buch)
		Belemnites, undet.
70	....	*Buchia concentrica* (Sowerby)
71	....	*Buchia rugosa* (Fischer)
		Belemnite fragments
72	....	*Buchia rugosa* (Fischer)
73	....	*Buchia* cf. *B. rugosa* (Fischer)
74	....	*Buchia concentrica* (Sowerby)
75	....	*Buchia rugosa* (Fischer)
76	....	*Buchia* sp.
77	....	*Buchia* cf. *B. rugosa* (Fischer)
78	....	*Partschiceras* sp.
79	....	*Buchia* cf. *B. concentrica* (Sowerby)
80	....	*Amoeboceras* (*Prionodoceras*) sp.
81	....	*Buchia* cf. *B. rugosa* (Fischer)
		"*Turbo*" sp.
82	....	*Amoeboceras* (*Prionodoceras*) sp.
83	....	*Buchia* cf. *B. concentrica* (Sowerby)

Map No.	USGS Mesozoic locality No.	Fauna
		Root Glacier Formation—Continued
84	28680	*Buchia mosquensis* (von Buch)
		Cylindroteuthis sp.
85	28700	*Buchia mosquensis* (von Buch)
		Amoeboceras (*Prionodoceras*) sp.
86	28702	*Buchia concentrica* (Sowerby)
87	28703	*Lima* sp.
		Kennicott Formation
88	1376	*Brewericeras hulenense* (Anderson)
		Arcthoplites belli (McLearn)
89	1377	*Brewericeras hulenense* (Anderson)
90	1378	*Grantziceras*? sp.
91	1471	*Arcthoplites belli* (McLearn)
92	1467	*Brewericeras hulenense* (Anderson)
93	1380	*Brewericeras hulenense* (Anderson)
		Fauna and flora
		Moonshine Creek Formation
94	1381	*Desmoceras* (*Pseudouhligella*) *dawsoni* Whiteaves
95	1469	*Pseudohelicoceras* sp.
96	1468	Seed pods
97	1470	*Desmoceras* (*Pseudouhligella*) *dawsoni* Whiteaves
98	1357	*Desmoceras* (*Pseudouhligella*) *dawsoni* Whiteaves
99	1358	*Desmoceras* (*Pseudouhligella*) *dawsoni* Whiteaves
100	1361	*Anioceras* sp.
		Desmoceras (*Pseudouhligella*) *dawsoni* Whiteaves
101	1359	*Desmoceras* (*Pseudouhligella*) *dawsoni* Whiteaves
102	1362	*Marshallites cumshewaensis* (Whiteaves)
		Desmoceras (*Pseudouhligella*) *dawsoni* Whiteaves
103	2080	Fragments of *Desmoceras* (*Pseudouhligella*) *dawsoni* Whiteaves
104	2081	*Desmoceras* (*Pseudouhligella*) *dawsoni* Whiteaves
		Fauna
		Schulze Formation
105	1473	*Inoceramus* scraps
	USGS Paleobotany locality No.	*Flora*
		Frederika Formation
106	....	*Carpinus* sp.
107	....	*Metasequoia glyptostroboides* Hu and Cheng
		"*Betula*" *confusa lata* Hollick
		Betula sp.
108	....	*Corylus* cf. *C. kenaiana* Hollick
		Acer sp.
109	9935	*Glyptostrobus* sp.
		Picea sp.
		Pinus sp. (five needled)
		Populus kenaiana Wolfe
		Alnus largei (Knowlton) Wolfe
		Betula sublutea Tansi and Suzuki
		Symphoricarpos n. sp.

ECONOMIC GEOLOGY

The two largest of the Kennecott mines in Alaska, the Bonanza and Jumbo, and a third Kennecott mine, the Mother Lode, are in the southwestern part of the quadrangle. These mines and another Kennecott mine, the Erie in the C–6 quadrangle, are interconnected by extensive underground workings. Between 1911 and 1938

Kennecott's Alaskan mines ranked among the world's major copper producers, producing about 1.2 billion pounds of copper and significant quantities of byproduct silver (Bateman, 1942, p. 501). The only recent production from the mines consisted of several hundred tons of copper ore derived from surficial operations during the 1960's.

The Kennecott mines contain the only important known mineral deposits in the quadrangle and have been well described by Bateman and McLaughlin (1920). Stratigraphically the Kennecott deposits are mainly confined to the lowermost few hundred feet of the Chitistone Limestone; they are best developed near the troughs of minor northeast-plunging synclines. Most of the deposits are in crystalline dolomite that is locally brecciated, but a few occur in limestone. The Kennecott lodes formed largely as replacement masses and subsidiary veins, disseminations, and stockworks and are renowned for the size and tenor of their chalcocite-rich ore. Sulfide minerals constitute about 75 percent of the Kennecott ore and oxidized minerals about 25 percent. Chalcocite and related cuprous sulfides form more than 90 percent of the typical sulfide ore. Other sulfide minerals in the ore include covellite and enargite and minor to rare bornite, chalcopyrite, luzonite, tennantite, pyrite, sphalerite, and galena. The oxidized ore consists chiefly of malachite and azurite. Silver is probably incorporated in the lattices of some of the sulfides, as no discrete silver minerals are found in the deposits. Some of the limestone near the Kennecott deposits contains disseminated pyrite. Small potassium-rich hydrothermally altered zones are locally developed along the Chitistone-Nikolai contact near the Kennecott mines (MacKevett and Radtke, 1966).

Armstrong, MacKevett, and Silberling (1970, p. D61, note that the lower part of the Chitistone Limestone at the Kennecott mines differs from typical Chitistone Limestone by containing a section of crystalline dolomite approximately 200 feet thick near its base, and that this dolomite is the host rock for most of the Kennecott ore. Armstrong and his associates also believe that much of the lower Chitistone strata formed in intertidal and supratidal depositional environments.

An attractive speculation is that thermal brines may have been important in the genesis of the Kennecott lodes. The efficacy of thermal brines as metal solvents and carriers has been stressed in recent years (White, 1967, p. 575–631; 1968, p. 301–335; Davidson, 1965, p. 942–954). Conceivably brines developed in an early Chitistone intertidal-supratidal depositional environment were heated and mobilized during a later thermal event, such as the

Tertiary plutonism manifested by the presence of felsic plutons near the mines mainly in the McCarthy B-5 quadrangle (MacKevett, 1965), or the early stages of Wrangell Lava volcanism. The mobilized thermal brines could have migrated through parts of the subjacent Nikolai Greenstone, acquired their copper, and subsequently recycled to sites of the Kennecott deposits, where structure favored ore formation. Probably hydrothermal dolomitization and the recrystallization of primary dolomite preceded the initial stages of ore deposition. Additional evidence for the presence of Chitistone brines is from the thorough investigations of dolomite by Friedman and Sanders (1967, p. 331), who conclude that probably all dolomites were deposited from hypersaline brines. The brines may have acquired sulfur by dissolving intertidal-supratidal evaporites or by subsequent dissolving sulfides during their migration. Although this speculation provides a plausible mechanism for the genesis of the Kennecott lodes, much additional data is needed before it can be confirmed.

Probably some of the mining claims on Kennecott-type lodes east of McCarthy Creek extend into the southern part of the C-5 quadrangle, but the known lodes and workings on these claims are confined to the B-5 quadrangle (MacKevett, 1965). A few small copper-bearing veins cut Nikolai Greenstone at the Independence mine and elsewhere in the vicinity of the Kennecott mines. Most of these veins have been explored by small pits and trenches, but none of them is large enough or rich enough to encourage exploitation. In contrast to the Kennecott lodes, the veins generally contain chalcopyrite, bornite, and pyrite in a quartz-rich gangue. Scattered copper-bearing veinlets cut parts of the McCarthy Formation and the Nizina and Chitistone Limestones at a few places in the southwestern part of the quadrangle, generally near the Kennecott mines. The only other known copper mineralization away from the mines is in Nikolai Greenstone amygdules which in places contain small pods of native copper and associated secondary copper minerals.

No potentially minable deposits of commodities other than copper are known in the quadrangle. The lignite seams in the Frederika Formation are too small and of too low rank for exploitation.

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☆U.S. GOVERNMENT PRINTING OFFICE: 1971 O—405–123