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DEPARTMENT OF THE INTERIOR
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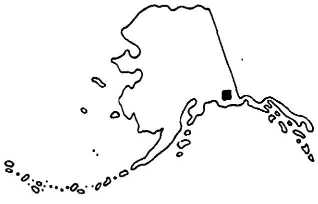
GEOLOGIC QUADRANGLE MAPS OF THE UNITED STATES

GEOLOGIC MAP OF THE McCARTHY C-4 QUADRANGLE ALASKA

By
E. M. MacKevett, Jr.



QUADRANGLE LOCATION

MAP GQ-844

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By E. M. MacKevett, Jr.

INTRODUCTION

This text is intended to supplement the map and stresses descriptions of the quadrangle's rock units. It also briefly describes some other relevant geologic topics, including economic geology. The McCarthy C-4 quadrangle is centered about 260 miles east of Anchorage in a remote part of the Wrangell Mountains. The quadrangle is characterized by glacially sculptured peaks and ridges and by numerous glaciers and snowfields; its altitudes range from about 2,200 feet to 9,124 feet. It is drained by the Nizina and Chitistone Rivers and their tributaries, which are part of the Copper River system.

The geologic mapping utilized 1:48,000 topographic base maps augmented by aerial photographs and helicopter support. Previous geologic investigations in the quadrangle are described in reports by Capps (1916) and by Moffit (1938). A preliminary version of this map was published in 1964 (MacKevett and others, 1964).

STRATIGRAPHY AND STRUCTURE

The layered rocks in the quadrangle form a sequence about 20,000 feet thick that includes abundant sedimentary shelf deposits; lavas and associated rocks that reflect three volcanic episodes; and less common continental sedimentary rocks, intrusive rocks, and surficial deposits. This sequence includes rocks that range in age from Permian and possibly older rocks designated Permian(?) to Quaternary. The Permian(?) and Permian rocks are widespread throughout the eastern Wrangell Mountains and nearby regions. The Triassic and Jurassic sedimentary rocks are largely confined to a northwest-trending belt along the southern flank of the range. The northern parts of this belt are overlapped by the extensive Tertiary and Quaternary Wrangell Lava that dominates the high parts of the range. Southern parts of the belt are overlapped by Cretaceous sedimentary rocks or by Quaternary surficial deposits.

Volcanic rocks in the quadrangle consist of Permian(?) submarine lavas and associated volcaniclastic rocks, Middle and (or) Upper Triassic flows that are largely or entirely continental in origin, and Tertiary and Quaternary continental lavas that contain subordinate pyroclastics. The intrusive rocks of the quadrangle are gabbro of Permian or Triassic age and hypabyssal rocks of Tertiary and Quaternary age. Rocks adjacent to some of the intrusive masses have been locally contact-metamorphosed, and the Permian(?) and Permian rocks have been weakly regionally metamorphosed.

Most structures in the quadrangle probably formed during the major regional orogeny at or near the close of the Jurassic or in the Early Cretaceous. The dominant faults are near vertical and constitute two poorly defined sets that strike northeast and northwest approximately perpendicular to each other. Most of the folds are moderately open and trend between N. 60° W. and west.

Besides a major angular unconformity that marks the base of the Cretaceous, less pronounced unconformities separate Permian from Triassic rocks, Cretaceous from Tertiary rocks, and Quaternary surficial deposits from older rocks.

The glaciers and snowfields include large valley glaciers such as the Nizina and Frederika, alpine glaciers, and irregular masses of snow, firn, or ice that range from small patches to extensive sheets. The modern glaciers are mainly remnants of larger glaciers whose extents are inferred from scoured, fluted, striated, and grooved bedrock surfaces, ice terraces, and similar glacial phenomena. The Nizina and Frederika Glaciers probably exceed 200 feet in thickness; most other glaciers and snowfields probably are thinner. Some of the glaciers are strongly crevassed, and the steeper reaches of a few glaciers are characterized by icefalls. Surfaces of the glaciers range from smooth through pitted to extremely jagged.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

The mapped Quaternary surficial deposits comprise alluvium and older alluvium, talus, landslides, diverse moraines, and rock glaciers. Discontinuous thin veneers of surficial deposits that only partly obscure bedrock were not mapped. Besides the mapped units, the surficial deposits include minor slope wash, mudflows, soil, and colluvium. Most of the surficial deposits are poorly consolidated. Glaciation, either directly or indirectly, influenced the development of many of the deposits. Many of the surficial deposits have gradational relationships, are physically similar, or are partly contemporaneous products of recurrent deposition. These features inhibit their systematic chronologic differentiation.

Alluvium and older alluvium.—The alluvium and older alluvium consists of flood-plain and older terrace deposits that are locally imbricated and composed of poorly sorted silt, sand, gravel, and boulders. Generally the alluvial deposits are light colored, but they have local color variations that reflect their dominant detritus. Most of the alluvial deposits probably are only a few feet or a few tens of feet thick, but the deposits that underlie flood plains of the Nizina and Chitistone Rivers probably are more than 100 feet thick. The older alluvium underlies terraces that support small trees and bushes and are incised by modern streams.

Talus.—The talus mainly forms thin veneers less than 25 feet thick. Commonly it is crudely lobate, but locally it has coalesced and forms aprons. The talus is chiefly monolithologic and consists largely of disarrayed angular boulders.

Landslides.—The only mapped landslide is in the south-central part of the quadrangle. It forms a hummocky mass about half a mile long and a quarter of a mile wide that consists mainly of blocky boulders.

Moraines.—The moraines include lateral, medial, recessional, and end (ablation) moraines on or off ice and ground moraines that are remnants of older, more extensive glaciation. The moraines probably are less than 100 feet thick. The lateral and especially the medial moraines are best developed on large valley glaciers and commonly are sinuous. The moraines consist largely of angular and subangular blocky boulders that generally are poorly sorted. They are rough and hummocky and display broad color variations.

Rock glaciers.—The rock glaciers are lobate or spatulate masses as much as 1½ miles long and probably more than 100 feet thick. They are best developed contiguous to the felsic (rhyodacite) massif in the southwestern part of the quadrangle. They consist of poorly sorted boulders and subordinate pebbles and cobbles that chiefly form monolithologic aggregates partly cemented by ice.

WRANGELL LAVA

The name Wrangell Lava was first applied by Mendenhall (1905, p. 54–62). The Wrangell Lava commonly gradationally overlies the Frederika Formation, but some older Wrangell Lava flows are interlayered or interfingered with the Frederika Formation. Locally the Wrangell Lava unconformably overlies the Nikolai Greenstone or rocks of the Skolai Group. It is cut by andesitic dikes and sills. The Wrangell Lava is more than 4,500 feet thick and consists predominantly of subaerial flows between 2 and 20 feet thick. It is composed mainly of andesite and basaltic andesite with subordinate dacite, basalt, vitrophyre, pyroclastic rocks, and conglomerate lentils.

Wrangell Lava volcanism extended from the Miocene into the Quaternary. Some older Wrangell Lava flows bracket sedimentary rocks of the Frederika Formation that contain leaves indicative of Miocene age. The formation's upper age limit is indefinite in the C–4 quadrangle, but in some nearby regions Wrangell Lava volcanism extended well into the Holocene.

Andesite and basaltic andesite.—Most of the andesitic lavas are olive gray, medium dark gray, or brownish gray and porphyritic with fine or very fine grained groundmasses. Many of them are amygdaloidal, and a few are scoriaceous. Uncommonly they have seriate porphyritic or glomeroporphyritic textures. The andesites generally contain between 5 and 25 percent phenocrysts (by volume). Their groundmass textures are intersertal, and less commonly, intergranular, pilotaxitic, felty, cryptofelsic, and hyalopilitic. The phenocrysts are subhedral and include plagioclase crystals, between 1 and 7 mm long, and sparsely distributed clinopyroxene crystals, between 0.5 and 2 mm long. Some of the andesitic lavas have well-developed flow structure, and some are cut by quartz or quartz-calcite veinlets.

The dominant primary minerals in the andesite and basaltic andesite are plagioclase, chiefly zoned sodic labradorite-calcite andesine, and clinopyroxene, chiefly augite. Subordinate primary constituents of the andesitic rocks include glass, pigeonite, magnetite, ilmenite, relict olivine, hypersthene, and trace amounts of K-feldspar, quartz, apatite, and zircon. Their alteration products include chlorite and similar ferruginous serpentine minerals, clay minerals (chiefly montmorillonite), hematite, calcite, and rare biotite, uralitic hornblende, leucoxene, ankerite, clinozoisite, and epidote. Minerals forming the amygdules and the vesicle linings comprise chlorite, chalcedony, calcite, quartz, zeolites (chiefly analcite), and uncommon hematite, goethite, siderite, dolomite, magnesite, ankerite, chlorophaeite, and clay minerals.

Basalt.—A few flows of dark-gray basalt are interlayered with the andesite and basaltic andesite flows. The basalt is porphyritic with widely scattered plagioclase phenocrysts as much as 5 mm long in fine-grained intergranular groundmasses. Commonly it is also amygdaloidal or vesicular. The basalt is generally similar to the andesitic rocks in mineral content, but it contains more labradorite and relict olivine.

Vitrophyre.—The vitrophyre is dark gray to black and forms lava domes that are locally columnar jointed. It has well-developed flow structure and uncommon amygdules. The vitrophyre contains scattered phenocrysts between 0.5 and 7 mm long in glassy or hyalopilitic groundmasses. Its phenocrysts include plagioclase that is strongly oscillatorily zoned sodic labradorite-calcic andesine and rare hypersthene or relict olivine. They are partly resorbed, and some are surrounded by reaction rims. The predominantly glassy groundmasses contain plagioclase microlites and, uncommonly, K-feldspar microlites, apatite, opaque dust, and cristobalite. The amygdules and alteration products consist of chlorite, chlorophaeite, clay minerals, siderite, dolomite, hematite, chalcedony, and sericite.

Dacite and rhyodacite.—The dacite and rhyodacite mainly form subordinate flows interlayered with the dominant andesitic flows. Local flow sequences near the Golden Horn and south of lower Skolai Creek are largely dacitic. The dacite and rhyodacite are light gray or, less commonly, pinkish or olive gray. They are mainly porphyritic and contain plagioclase phenocrysts as much as 3 mm long in fine-grained intersertal, felty, or uncommonly intergranular groundmasses. A few dacites and rhyodacites contain chlorite-calcite-chalcedony amygdules. Some contain subparallel wisps and streaks that probably indicate collapsed pumice. The dacites and rhyodacites consist of plagioclase (andesine), less abundant quartz, K-feldspar, and augite, and abundant alteration products that include clay minerals, chlorite, calcite, sericite, clinozoisite, and hydrous iron oxides.

Pyroclastic rocks.—Pyroclastic rocks are minor constituents of the Wrangell Lava in the C–4 quadrangle and are not delineated on the map. They include light-gray, tan, or buff tuff and ash and reddish-brown agglomerate and volcanic breccia. Some of the tuff is altered to thin heulandite-rich layers.

Conglomerate lentils.—The conglomerate lentils are best exposed on the ridge east of Frederika Glacier, where they are about 500 feet thick and several miles long. Elsewhere they form much smaller bodies interspersed in the lava. The lentils are light or medium gray when fresh and light gray or tan when weathered. They grade vertically and laterally into flows and are cut by a few andesitic dikes. In addition to their dominant conglomerate, the lentils contain minor sandstone, andesitic flows, and tuff. They are moderately well indurated and generally well bedded and consist of subangular boulders, cobbles, and pebbles of Wrangell Lava in a medium- to coarse-sandstone matrix.

HYPABYSSAL ROCKS

The hypabyssal rocks of the quadrangle are divided into felsic, andesitic, and basaltic types that mainly represent feeders and shallow-seated (epizonal) equivalents of parts of the Wrangell Lava. They are largely or entirely Tertiary and Quaternary in age, but possibly some of them are older. Except for locally baking their wallrock, the hypabyssal intrusives produced scant metamorphic effects. Some of the hypabyssal rocks have thin aphanitic chilled margins.

Felsic types.—The felsic hypabyssal rocks form dikes and sills between 3 and 30 feet thick and small stocks. They consist of rhyodacite and less common dacite, quartz latite, and alaskite(?). Commonly these rocks are porphyritic; some contain sufficiently abundant phenocrysts to be termed porphyries. The felsic hypabyssal rocks cut rocks of the Frederika Formation or the lower part of the Wrangell Lava and, uncommonly, older rocks. They are pinkish gray or light gray and weather light brown. Their phenocrysts are partly resorbed, irregular in outline, and generally between 0.5 and 4 mm long. They include plagioclase that is strongly oscillatorily zoned sodic labradorite-andesine and uncommon biotite, hornblende, and quartz. Their groundmasses are extensively altered very fine grained felty, cryptofelsic, or microcrystalline aggregates of plagioclase and generally less abundant quartz and K-feldspar. The groundmasses also contain subordinate brown biotite and traces of apatite, ilmenite, magnetite, and pyrite. Many of the felsic rocks have been pervasively altered to chlorite, sericite, calcite, clay minerals, and less common hematite, epidote, clinozoisite, quartz, chalcedony, zeolites, leucoxene, and limonite.

Andesitic types.—The andesitic hypabyssal rocks include andesite and basaltic andesite dikes and sills that commonly are between 2 and 8 feet thick and exceptionally are as much as 20 feet thick. They cut the Wrangell Lava, the Frederika Formation, and, uncommonly, older formations. They are medium or dark gray with green or olive casts. A few of them contain quartz-calcite amygdules and vesicles. The andesitic dikes and sills commonly are porphyritic and rarely glomeroporphyritic with fine-grained intersertal, felty, or pilotaxitic groundmasses. Their phenocrysts are as much as 3 mm long and consist of zoned plagioclase (labradorite-andesine) and subordinate uralitic or basaltic hornblende and clinopyroxene. Their groundmasses consist of andesine and lesser amounts of clinopyroxene, magnetite, ilmenite, quartz, apatite, and glass. Their alteration products include chlorite, calcite, and minor hematite, epidote, clay minerals, sericite, and thomsonite.

Basaltic types.—Basalt and olivine basalt form a few dikes and sills between 2 and 20 feet thick that mainly intrude the Moonshine Creek and Frederika Formations. They are dark greenish gray, medium gray, or dark gray, weather brown, and generally lack amygdules and vesicles. These mafic hypabyssal rocks are porphyritic with labradorite and less abundant clinopyroxene and olivine phenocrysts as much as 3 mm long in fine or very fine grained intersertal or hyalopilitic groundmasses. Their groundmass constituents comprise plagioclase (mainly labradorite), clinopyroxene, olivine, and minor biotite, glass, opaque minerals, quartz, and K-feldspar. Their alteration products are mainly chlorite (including antigorite), and subordinately secondary iron minerals, clay minerals, sericite, and epidote.

FREDERIKA FORMATION

The name Frederika Formation is here applied to diverse continental sedimentary rocks that gradationally underlie or are intercalated with basal flows of Wrangell Lava. The type area is designated as the valley walls of a westward-flowing tributary of Frederika Creek southeast of the terminous of Frederika Glacier. Sediments of the formation were deposited in depressions on an early Tertiary erosion surface, largely in paludal or lacustrine environments. Consequently, the formation is unevenly distributed. It ranges from a few tens to at least 1,500 feet in thickness. The Frederika Formation overlies the Moonshine Creek Formation with slight angular unconformity, or older rocks, particularly those of the Skolai Group, with a strong angular unconformity. Locally it is cut by hypabyssal rocks.

The formation comprises a heterogenous assemblage of conglomerate, sandstone, siltstone, shale, and subordinate low-rank coal. Except for the dark carbonaceous shale and coal, these rocks are conspicuously light colored, being buff, tan, white, and light gray when fresh and light brown when weathered. Adjacent to intrusive rocks they are locally red or reddish brown.

Beds in the formation range widely in thickness. Those in the fissile shales are characteristically less than an inch thick and those in some conglomerates as much as 25 feet thick. The outcrop manifestations are likewise diversified, ranging from bold to subdued depending largely on rock type. Most rocks of the formation are moderately or well indurated; a few are poorly indurated and friable. Some of the rocks are crossbedded or show scour-and-fill relationships.

The conglomerates range from pebble to coarse boulder conglomerate. They are commonly polymict and less commonly essentially monomict with predominant quartz pebbles. Their clasts are subrounded or rounded and include rocks derived from the Nikolai Greenstone and Wrangell Lava along with quartz, granitic rocks, chert, phyllite, and hornfels. Matrices of the conglomerates are largely coarse sandstone that is calcite cemented.

The sandstones include coarse-grained lithic arkose, wacke, and arenite (terminology of Williams, Turner, and Gilbert, 1954). Generally they are poorly sorted and consist of subangular lithic fragments, plagioclase, quartz, clinopyroxene, K-feldspar, and chlorite enclosed in fine matrices of chalcedony, chlorite, sericite, clay minerals, and widely dispersed iron oxides and their alteration products. Some of the sandstones are cemented by carbonate minerals.

The shales and siltstones contain diverse proportions of detrital components, chiefly quartz and plagioclase, and clays, chiefly montmorillonite and illite. A few shales contain cristobalite and may represent reworked volcanic ash. Some of the siltstones are calcite cemented. The carbonaceous shale locally grades into thin seams of low-rank coal.

The Frederika Formation is Miocene in age. Plant debris is widely scattered in its pelitic rocks, particularly in the carbonaceous shales, and many shaly horizons near the base of the formation contain well-preserved leaves. According to J. A. Wolfe (written commun., 1963), the fossil leaves are middle Miocene and indicate a cool temperate climate.

MOONSHINE CREEK FORMATION

The Moonshine Creek Formation was named by Jones and MacKevett (1968, in press), and its type area designated as along Moonshine Creek in the C–4 quadrangle. The formation is approximately 3,500 feet in maximum thickness. It disconformably overlies the Kennicott Formation and unconformably overlies the Nikolai Greenstone and other Triassic rocks. It is unconformably overlain by the Frederika Formation and locally cut by hypabyssal rocks. The formation consists of moderately indurated beds as much as 10 feet thick composed of siltstone and fine- or medium-grained sandstone and subordinate pebble or boulder conglomerate, shale, and mudstone. Some of the siltstones contain locally abundant fossiliferous calcareous concretions.

The siltstones are gray or olive gray and moderately well sorted. They consist of subangular to subrounded silt clasts of quartz, plagioclase, chlorite, and uncommon small lithic fragments and opaque minerals in a clay-rich matrix that contains some chlorite, calcite, epidote, heulandite, and sericite.

The sandstones are greenish gray or green moderately or poorly sorted feldspathic wacke with minor lithic wacke and arenite. Clasts in the sandstones are subrounded or subangular and are predominantly of quartz and plagioclase associated with less common calcite, chlorite, glauconite, K-feldspar, biotite, epidote, lithic fragments, opaque minerals, and zircon. The sandstone matrices are microcrystalline and contain chlorite, chalcedony, clay minerals, and minor secondary iron minerals, carbonaceous debris, sericite, zeolites, calcite, and siderite.

The shales and mudstones are medium-gray rocks largely composed of argillaceous minerals and minor detrital quartz and plagioclase. The conglomerates are diverse shades of gray. They commonly grade into sandstone and consist of subangular or subrounded pebbles and boulders derived from the Kennicott Formation or Triassic rocks and set in a sandstone matrix.

The Moonshine Creek Formation probably was deposited in a restricted or isolated Cretaceous basin. It contains abundant ammonites and Inoceramus, chiefly in concretions, that indicate an age span from probable middle Albian to late Cenomanian. Some of the pelitic rocks contain abundant chalcedonic tests of microfossils.

KENNICOTT FORMATION

Rocks of the Kennicott Formation were originally included in Rohn's (1900, p. 433) Kennicott Series. The name Kennicott Formation was introduced later and inconsistently and loosely applied to one or more of the disparate Cretaceous or Jurassic rock units of the region. Modern geologic mapping and previous discrepancies in usage of the name have led to a redefinition of the Kennicott Formation by Jones and MacKevett (1968, in press).

The Kennicott Formation formed largely in a transgressive shallow marine environment. Only the younger part of the formation is represented in the C–4 quadrangle, where it attains a maximum thickness of about 400 feet.

The Kennicott Formation overlies Jurassic or Triassic rocks, mainly the Nikolai Greenstone, with a strong angular unconformity. It disconformably underlies the Moonshine Creek Formation and is cut by a few dikes.

The formation consists of a basal conglomerate that grades upward into sandstone, siltstone, and shale. It also contains uncommon thin conglomerate lenses and calcareous concretions. The basal conglomerate is as much as 70 feet thick and composed of beds between 2 and 20 feet thick. Other rocks in the formation commonly form strata between 1 and 3 feet thick. Rocks of the Kennicott Formation generally are moderately or well indurated and medium or dark gray when fresh; they weather to diverse shades of brown.

The conglomerates include granule, pebble, cobble, and boulder conglomerate whose clasts, predominantly Nikolai Greenstone, reflect local provenances. Matrices of the conglomerates are mainly medium-grained feldspathic and lithic sandstone.

The sandstones are poorly to moderately sorted and consist of subangular clasts in microcrystalline matrices. They include feldspathic and lithic varieties of wacke and subordinate arenite that generally is calcite cemented. Their clasts are quartz, plagioclase, and less abundant K-feldspar, lithic fragments, calcite, chlorite, glauconite, and opaque minerals. Their matrices are chiefly aggregates of chalcedony, chlorite, clay minerals, and hydrous iron oxides.

The siltstones are mineralogically similar to the sandstones, but their clasts are smaller, generally better sorted and rounded, and composed predominantly of quartz. The shales include silica-rich types (porcellanites) and more abundant clay-rich types that contain subordinate detrital grains.

The Kennicott Formation is Early Cretaceous in age, and it can be divided into two well-defined early Albian faunal zones. Only the upper zone, which is characterized by the ammonite Brewericeras hulenense, indicative of late early Albian, is represented in the C–4 quadrangle. Fossil wood and plant debris are widely scattered in the formation, particularly in its basal strata, and microfossils are abundant in some of the pelitic rocks.

LUBBE CREEK FORMATION

The Lubbe Creek Formation was named by MacKevett (1968, in press) for exposures in the McCarthy C–5 quadrangle. It underlies two small areas in the southwestern part of the C–4 quadrangle, where it attains maximum thicknesses of about 120 feet. The Lubbe Creek Formation conformably overlies the upper member of the McCarthy Formation and unconformably underlies the Kennicott or Frederika Formations. It forms bold outcrops and is composed of beds 1/2 to 3 feet thick. The formation is medium gray when fresh and light, medium, or yellowish brown when weathered. It consists of impure spiculite and minor coquina. The spiculite is fine grained and silica rich and contains chalcedonic spicules and radiolaria, calcareous fragments of belemnites and pelecypods, and grains of calcite and less abundant quartz, dolomite, and plagioclase in a chalcedony-rich matrix. Some of the spiculites contain minor amounts of chlorite, hematite, pyrite, carbonaceous material, biotite, and apatite. The coquina consists of abundant poorly sorted bioclastic fragments, chiefly shells of megafossils, and subordinate mineral grains in a chalcedony-rich matrix.

The Lubbe Creek Formation is of near-shore marine genesis and is Early Jurassic in age. Its most abundant and most diagnostic fossils are pelecypods of the genus Weyla that are indicative of the Toarcian and probably Pliensbachian Stages.

McCARTHY FORMATION

Rocks of the McCarthy Formation were named McCarthy Creek Shales by Rohn (1900, p. 426). After several nomenclatural revisions, the McCarthy Formation was divided into two informal members by MacKevett (1963).

Upper member.—The upper member of the McCarthy Formation underlies small areas near the southwestern corner of the C-4 quadrangle and is about 1,250 feet in maximum thickness. It grades downward into the lower member and upward into the Lubbe Creek Formation and locally is unconformably overlain by the Kennicott Formation. Most of its beds are between 1/2 and 2 feet thick. The lowermost 500 feet of the member forms ribby outcrops that reflect differential erosion of intercalated strata. Stratigraphically higher parts of the member characteristically form smooth subdued outcrops. Most rocks of the upper member are medium or dark gray and weather yellow brown and less commonly light or medium shades of brown or gray.

The upper member consists of very fine grained spiculite, impure chert, and subordinate shale and impure limestone. The spiculites are similar to those of the Lubbe Creek Formation except that they generally are finer grained. They contain abundant chalcedonic spicules, commonly less than 0.5 mm long, that have uncommon calcite or chlorite cores. The cherts consist predominantly of chalcedony, but they also contain widely scattered detrital grains. Both the spiculites and the cherts contain abundant chalcedonic tests of radiolaria, typically less than 0.1 mm in diameter. The impure limestones contain abundant calcite grains in a chalcedonic matrix and scattered minor constituents similar to those of the spiculites. The shales are very fine grained friable assemblages of quartz, plagioclase, calcite, and clay minerals.

The upper member of the McCarthy Formation is largely or entirely Early Jurassic in age. Ammonites indicative of the Sinemurian and, less commonly, the Pliensbachian Stages were collected from the uppermost few hundred feet of the member, and ammonites indicative of the Hettangian Stage were collected about 500 feet above the base of the member in nearby parts of the B-4 quadrangle. No diagnostic fossils have been found in the basal strata of the upper member or in the upper part of the lower member, and possibly parts of this stratigraphic interval represent the Rhaetian Stage (uppermost Triassic).

Lower member.—The lower member is confined to the southwestern part of the quadrangle, where it attains a thickness of about 430 feet. It conformably overlies the Nizina Limestone and gradationally underlies the upper member. Locally it is unconformably overlain by the Kennicott or Moonshine Creek Formations. Beds in the lower member are mainly between 1 inch and 3 feet thick and consist of carbonaceous shale, impure limestone, and impure chert in relative order of abundance. The shales are dark gray to black and weather dark brown. They are highly susceptible to folding and are calcareous as well as carbonaceous rocks that contain abundant clay minerals and uncommon organic and inorganic clasts. Some of the shales contain discoidal calcareous concretions 1 to 2 inches long. The impure limestone forms a stratigraphic sequence about 50 feet thick in the medial part of the member and uncommon interbeds in the shale and chert. It is medium or dark gray and weathers to diverse shades of gray and brown. The limestone consists of subangular calcite grains between 0.05 and 0.2 mm long and small amounts of carbonaceous debris, quartz, opaque minerals, chiefly pyrite, and chlorite. The impure cherts are dark-gray finely laminated rocks composed mainly of chalcedony. They contain subordinate clastic calcite, opaque dust, and carbonaceous material. Spherical chalcedonic tests of radiolaria as much as 0.1 mm in diameter and commonly with serrated surfaces are abundant in most of the cherts. Many rocks of the lower member are cut by quartz and (or) calcite veinlets, generally at high angles.

Abundant pelecypods of the genus Monotis constitute a conspicuous and diagnostic faunal zone in the lower part of the member. They indicate the Norian Stage of the Late Triassic.

NIZINA LIMESTONE

The name Nizina Limestone was applied by Martin (1916, p. 693) to predominantly thin-bedded limestones that previously were relegated to the upper part of the Chitistone Limestone. The Nizina Limestone is exposed locally in the southwestern part of the quadrangle, where it attains a maximum thickness of 400 feet. Its contacts with the underlying Chitistone Limestone are broadly gradational, difficult to map with fidelity, and regionally transgress time boundaries.

The Nizina Limestone conformably underlies the lower member of the McCarthy Formation or unconformably underlies the Kennicott Formation and is cut by a few small Tertiary plutons. Its characteristic beds are 1/2 to 2 feet thick, medium or dark gray when fresh, and brown or brownish gray when weathered. The formation contains moderate amounts of erosion-resistant black chert that forms irregular nodules as much as 6 inches long, extensive lenses as much as 6 inches thick, and coalescing tuberous aggregates. Commonly the formation forms moderately rugged outcrops.

The Nizina Limestone is mainly lime mudstone, pelletoidal grainstone, and fine-grained wackestone (terminology of Dunham, 1962, p. 117). These rocks are intergradational and include relatively undisturbed lime mudstones, rocks characterized by disarrayed aggregates of lime mud, and rocks that contain fairly abundant mud-supported bioclastic fragments. Their typical clasts are calcareous and derived chiefly from echinoderms, crinoids, and pelecypods. Less commonly the clasts comprise quartz, dolomite, and siliceous spherical or rodlike remnants of microfossils. Argillaceous minerals and scattered opaque minerals are lesser constituents of the Nizina Limestone. Quartz or calcite veinlets cut parts of the formation.

The Nizina Limestone was deposited in a shallow marine environment, generally in deeper water than the Chitistone Limestone (A. K. Armstrong, oral commun., 1968). It is Late Triassic in age. No diagnostic fossils were collected from the Nizina Limestone in the C-4 quadrangle, but fossils from Nizina Limestone in the adjacent McCarthy C-5 quadrangle indicate the late Karnian, early Norian, and early middle Norian Stages (N. J. Silberling, written commun., 1963).

CHITISTONE LIMESTONE

The Chitistone Limestone was named by Rohn (1900, p. 425). It crops out in the southwestern part of the quadrangle, where it is as much as 900 feet thick, although its base is not exposed. Elsewhere in the southern Wrangell Mountains the Chitistone Limestone disconformably overlies the Nikolai Greenstone. It is gradationally overlain by the Nizina Limestone. Beds in the Chitistone Limestone are between 1 and 20 feet thick. They are light or olive gray and, uncommonly, medium or dark gray; they weather light or medium gray or light or yellowish brown. The formation forms bold outcrops and cliffs and in places contains caves and other solution cavities. It consists of limestone with less abundant dolomite, dolomitic limestone, and chert. The dominant carbonate rocks include limy mudstone, packstone, wackestone, and grainstone (terminology of Dunham, 1962, p. 117). They mainly are characterized by scattered bioclastic fragments and by pellets of limy mud that locally are cemented by carbonate minerals or by younger limy mud. Rare constituents of the carbonate rocks include quartz, opaque minerals, and clay minerals. The chert forms nodules less than 6 inches long and uncommon interlacing networks. Veinlets of calcite and uncommonly quartz transect parts of the Chitistone Limestone.

Some of the Chitistone Limestone is difficult to distinguish from the Nizina Limestone. Generally the Chitistone Limestone is thicker bedded and lighter colored and contains more dolomite and less chert than the Nizina Limestone.

The Chitistone Limestone was deposited in shallow seas, in part in intertidal, supratidal, and shoaling environments (A. K. Armstrong, oral commun., 1968). Its Late Triassic age is documented by fragmentary remnants of the ammonite Tropites (identified by N. J. Silberling, written commun., 1965), indicative of the late Karnian Stage.

NIKOLAI GREENSTONE

The Nikolai Greenstone was named by Rohn (1900, p. 425) and constitutes a widely distributed, mainly volcanic unit largely or entirely of continental origin. The upper contact of the greenstone is not exposed in the C-4 quadrangle, but incomplete sections of the formation are as much as 1,400 feet thick. The greenstone mainly unconformably overlies rocks of the Skolai Group and, less extensively, gabbro. North of Skolai Creek it conformably overlies the Middle Triassic "Daonella beds."

The Nikolai Greenstone forms moderately rugged outcrops. It consists of a basal conglomerate as much as 200 feet thick and a thick overlying sequence of basaltic flows. Most contacts between the conglomerate and the flows are sharp, but some are gradational and characterized by intercalated conglomerate and lava. Discrete conglomerate beds are between 2 and 12 feet thick, and the flows are between 1 and 25 feet thick.

The conglomerate is mottled in shades of gray, predominantly olive gray. It is pebble and granule conglomerate that consists of subrounded clasts derived from the Skolai Group and uncommonly from gabbro and the "Daonella beds" enclosed in a poorly sorted sandstone matrix. The matrix constituents include calcite, altered plagioclase, clinopyroxene, chlorite, clay minerals, small lithic fragments, opaque minerals, chiefly disseminated pyrite, and secondary iron oxides.

The Nikolai flows are altered basalts that are greenish gray, dark gray, or olive gray. They commonly are both porphyritic and amygdaloidal and contain labradorite phenocrysts between 1 and 4 mm long in fine-grained intergranular groundmasses that consist largely of labradorite and clinopyroxene. Their less abundant primary minerals include pigeonite, relict olivine, magnetite, and ilmenite. Alteration products are widespread in the lavas and include chlorite and related ferruginous serpentine minerals, and less abundant hematite, sphene, clay minerals, and epidote. The amygdules are crudely spherical, between 0.5 and 8 mm in diameter, and are composed largely of chlorite, which locally surrounds calcite cores. A few amygdules contain minor quartz, chalcedony, epidote, prehnite, pumpellyite, native copper, cuprite, and diverse zeolites, chiefly thomsonite, natrolite, and leonhardite.

No fossils were found in the Nikolai Greenstone. On the basis of its stratigraphic position, the greenstone is late Middle and (or) early Late Triassic in age.

"DAONELLA BEDS"

The "Daonella beds" form small, moderate to subdued outcrops north of Skolai Creek, where they are 65 feet in maximum thickness. They unconformably overlie the Golden Horn Limestone Lentil of the Skolai Group, conformably underlie the Nikolai Greenstone, and are cut by a few thin felsic dikes. They are dark gray and weather dark brown and consist of thin-bedded siltstone, shale, uncommon impure limestone, and scattered chert nodules. The chert is black and forms spheres between 1 and 2 inches in diameter. The shale and siltstone contain quartz and kaolinite and less abundant calcite, dolomite, carbonaceous debris, and opaque minerals. The impure limestones are limy mudstones and wackestones with detrital calcite, quartz, and carbonaceous debris.

The "Daonella beds" contain abundant pelecypods of two species of Daonella: Daonella frami Kittl and D. cf. D. subquadrata Yabe and Shimuzi (N. J. Silberling, written commun., 1962). According to Silberling the genus Daonella generally is restricted to the middle and upper part of the Middle Triassic, and on this basis the "Daonella beds" are assigned a Middle Triassic age.

GABBRO

The gabbro plutons are crudely stratiform or discordant and range from thin dikes and sills to a mass more than 3 miles long and 1 mile wide. The gabbro cuts rocks of the Skolai Group and, at a few places, is overlain by the Nikolai Greenstone, Frederika Formation, or Wrangell Lava.

The gabbro is dark greenish gray or, uncommonly, medium gray; it weathers rusty brown to greenish black. It is generally fine to medium grained with hypidiomorphic granular texture. Generally labradorite and clinopyroxene (probably augite) occur in near-equal amounts and constitute about 90 percent of the volume. The accessory minerals include magnetite, ilmenite, and traces of apatite, sphene, and pyrite. Some of the gabbros are partly serpentinized and contain abundant ferruginous serpentine minerals. Their other alteration products include chlorite, clay and secondary iron minerals, sericite, clinozoisite, calcite, and biotite. Locally quartz veinlets that contain minor amounts of chlorite, opaque minerals, calcite, barite, and zeolites cut the gabbro.

The precise age of the gabbro is not known, but it is Permian or Early or Middle Triassic because gabbro cuts Permian rocks and gabbro clasts are constituents of the basal conglomerate of the Nikolai Greenstone.

SKOLAI GROUP

The Skolai Group and its subdivisions, the Station Creek and Hasen Creek Formations, and the Golden Horn Limestone Lentil of the Hasen Creek Formation, were named by Smith and MacKevett (1968, in press), and the following descriptions are mainly from this source. The Skolai Group constitutes a widespread marine sequence of lava flows and their derivative volcaniclastic rocks and overlying, generally thin-bedded sedimentary rocks. Rocks of the group show evidence of regional slight metamorphism and, adjacent to gabbro plutons, local contact-metamorphism. Exposures of the base of the group were not found. The Skolai Group mainly unconformably underlies Middle or Late Triassic rocks. It is cut by gabbro and, uncommonly, by small felsic plutons. No fossils were found in the older rocks of the Skolai, the Station Creek Formation. Fossils in the younger units indicate an Early Permian age.

Hasen Creek Formation.—The Hasen Creek Formation is about 900 feet in maximum thickness, but generally it is much thinner because of erosion. It gradationally overlies the Station Creek volcaniclastic rocks and is overlain by the Nikolai Greenstone with slight angular unconformity or by the Frederika Formation or Wrangell Lava with strong angular unconformity. Locally the Golden Horn Limestone Lentil of the formation is unconformably overlain by the Middle Triassic "Daonella beds." The Hasen Creek Formation mainly forms subdued to moderate outcrops. Its rocks are mostly thin bedded and include chert, shale, sandstone, conglomerate, and impure limestone. Except for the chert and shale, which typically are black, most rocks of the formation are shades of gray.

The cherts consist of fine quartz and chalcedony with subordinate opaque dust, radiolaria tests, spicules, and rare detrital mineral grains. The shales are extremely fine grained and rich in clay minerals, carbonaceous detritus, and quartz. Most of the sandstones are impure arkose and subgraywacke. They are poorly sorted and contain lithic fragments, chiefly of nonvolcanic origin, quartz, plagioclase, K-feldspar, and micas, embedded in very fine grained matrices. The conglomerates contain diverse subrounded clasts of pebbles and boulders in a sandstone matrix. The impure limestones are rich in bioclastic calcite and carbonaceous debris.

Golden Horn Limestone Lentil.—The Golden Horn Limestone Lentil occurs at or near the top of the Hasen Creek Formation in the northern part of the C-4 quadrangle. It is almost 800 feet in maximum thickness and composed of strata between 1 and 10 feet thick. The lentil is light gray with variegated yellow- and red-stained weathered surfaces, and it forms bold outcrops with local solution cavities. The Golden Horn Limestone Lentil consists of bioclastic packstone and grainstone with subordinate wackestone (terminology of Dunham, 1962, p. 117). The packstones consist of coarse disarticulated crinoid stems and uncommon sand grains embedded in lime mud. The grainstones are similar but lack lime mud. The wackestones consist mainly of lime mud with minor clastic and bioclastic detritus. Remnants of brachiopods and bryozoa are important rock-forming elements in some of the limestones. Lesser constituents of the limestones include quartz pebbles and granules and secondary dolomite. Some of the limestone near gabbro bodies has been recrystallized to coarse marble.

Hasen Creek fossil collections are from both the richly fossiliferous Golden Horn Limestone Lentil and other strata in the formation. The collections were studied by R. E. Grant in consultation with E. L. Yochelson and J. T. Dutro, Jr. (written commun., 1966). According to Grant, the brachiopod fauna is assigned to the Early Permian mainly by default, inasmuch as it contains Permian elements, but none that definitely indicate Late Permian. This conclusion is supported by Yochelson's tentative assignment of the gastropods to the Early Permian. The collections are listed and more fully discussed by Smith and MacKevett (1968, in press).

Station Creek Formation.—The Station Creek Formation includes two informal members, a lower volcanic flow member and an overlying volcaniclastic member. The volcaniclastic member is about 2,000 feet in maximum thickness in the quadrangle. Both its upper and lower contacts are gradational. Its individual beds range in thickness from a few feet to about 100 feet and commonly form moderate outcrops. The member contains diverse volcaniclastic rocks that range from coarse volcanic breccias to finely laminated volcanilutites; volcanic graywackes are dominant. A few flows are intercalated with volcaniclastic rocks in the lower part of the member. Most of the volcaniclastic rocks are shades of gray and green. They consist of minerals and lithic fragments that mainly were derived from underlying flows and are composed chiefly of the dominant secondary minerals of the flows.

The volcanic flow member is about 4,000 feet thick. Its base is not exposed, and it grades upward into the volcaniclastic member. Most of its flows are between 10 and 100 feet thick, and most outcrops are moderately rugged. Upper parts of many of the flows are characterized by pillow complexes. The volcanic flow member consists mainly of basalt and basaltic andesite flows. Volcaniclastic rocks and subordinate dacite and andesite flows constitute about 25 percent of the member. Typical Station Creek flows are dark greenish gray to greenish black. They mainly are porphyritic and amygdaloidal and contain altered phenocrysts of plagioclase and less commonly clinopyroxene in groundmasses whose original textures have been obliterated by alteration. The uncommon unaltered phenocrysts are andesine or sodic labradorite, or calcium-rich augite. Except for minor amounts of magnetite and ilmenite, the groundmass minerals consist of an array of alteration products including chlorite, quartz, sphene, actinolite, calcite, albite, biotite, hematite, prehnite, pumpellyite, sericite, clinozoisite, and epidote.

No fossils were found in rocks of the Station Creek Formation. Its field relationships provide inconclusive chronological data, but its conformity with overlying fossiliferous Permian rocks favor a Permian age assignment, and the formation is considered Permian(?).

ECONOMIC GEOLOGY

There are no mines or prospects within the quadrangle. A few small outcrops that contain copper minerals were found during the mapping, and their locations are shown on the map. Two of these are along the major northwest-striking fault that juxtaposes

Nikolai Greenstone and the Moonshine Creek Formation east of the terminus of the Nizina Glacier. They consist of quartz-calcite veinlets and veins as much as 8 inches thick confined to two zones less than 1 foot thick adjacent to the greenstone wall of the fault and traceable for less than 50 feet. The veinlets and veins contain sporadically distributed chalcocite and its alteration products, chiefly malachite. Similar copper-bearing quartz-calcite veinlets are poorly exposed along a parallel fault about three-fourths of a mile to the north.

Secondary copper minerals, mainly malachite, form thin coatings on fault fractures that cut Nikolai Greenstone north of the Chitistone River near the southern boundary of the quadrangle.

Copper minerals occur in dacitic Wrangell Lava south of lower Skolai Creek, where dacite float encrusted with azurite is fairly abundant. Two quartz veins between 1 and 4 inches thick that contain scattered chalcopyrite and azurite were found cutting the dacite. Judging from the appearance of the float, it is unlikely that the veins are its sole source. The dacite body is remotely situated and snow covered for most of the year.

Native copper is a sparse amygdule constituent of some Nikolai Greenstone flows. It was found at only a few places in the quadrangle where it forms small anhedral masses a few millimeters long, locally coated with oxidized copper minerals.

Copper-stained outcrops of the Wrangell Lava were allegedly seen by airborne prospectors near the icefall of Hole-in-the-Wall Glacier. We were unable to find this occurrence, probably because of snow cover.

The basal strata of the Chitistone Limestone are hosts for most bonanza copper sulfide deposits at the nearby Kennecott mines (in the McCarthy C-5 and C-6 quadrangles). Correlative strata are inferred to underlie the terrain near the southwestern corner of the C-4 quadrangle, and like the major Kennecott lodes, are near a Tertiary pluton.

The scarce, thin, low-rank coalbeds in the Frederika Formation probably do not justify serious economic consideration.

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