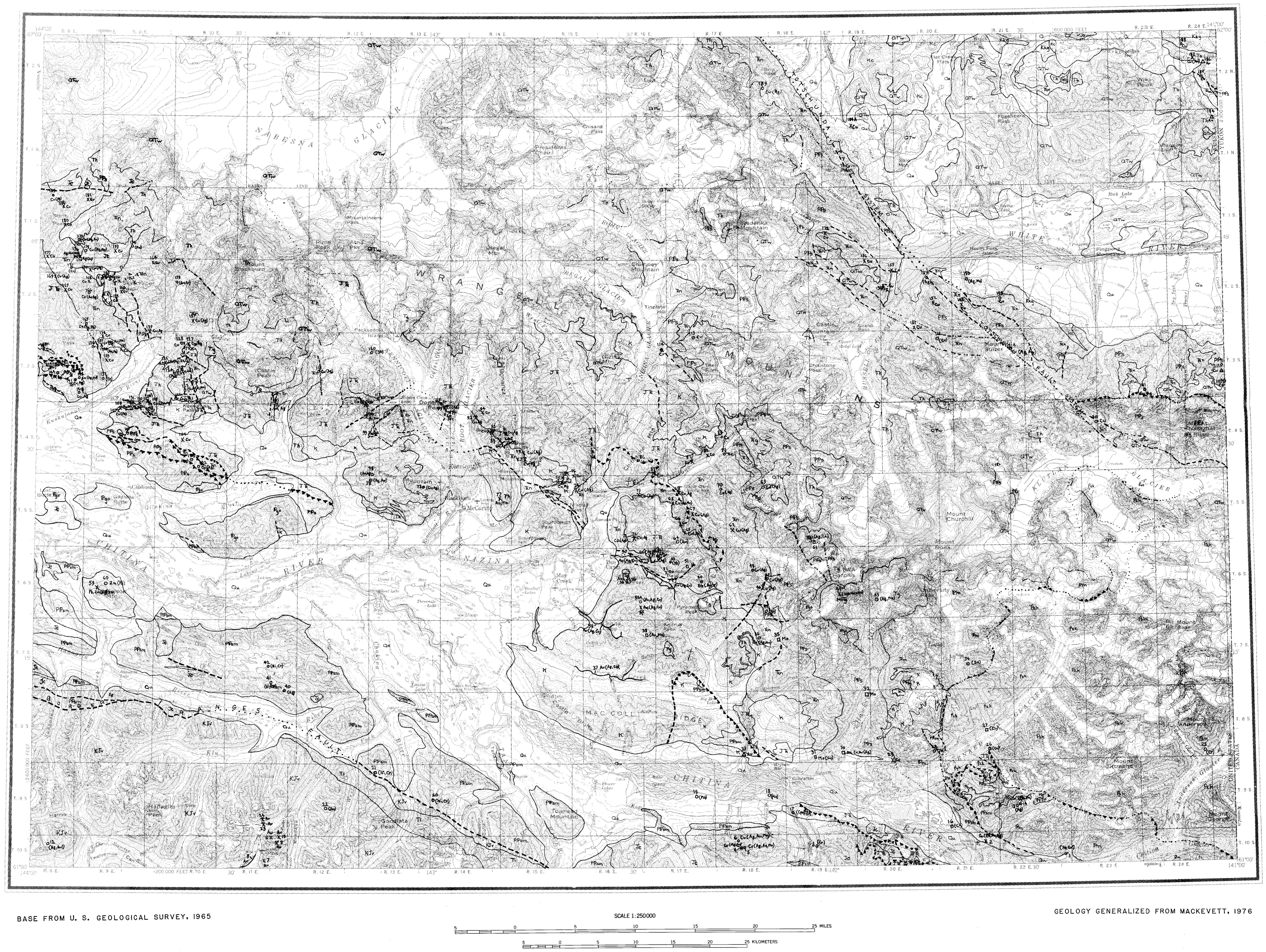
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

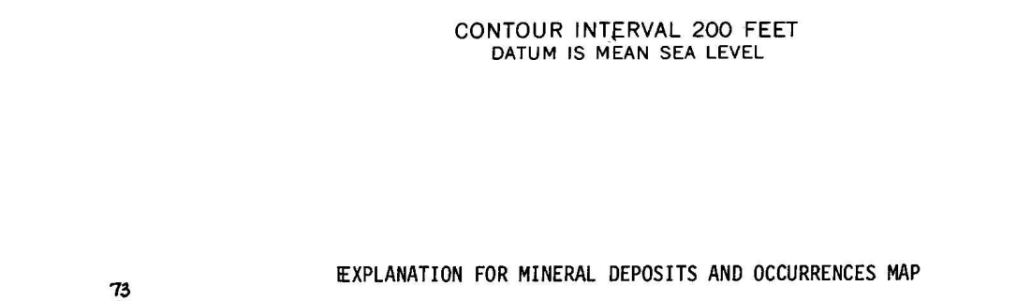
FOLIO OF THE McCARTHY QUADRANGLE, ALASKA
MAP MF-773B
SHEET 1 OF 2

MACKEVETT--MINERAL DEPOSITS AND OCCURRENCES MAP



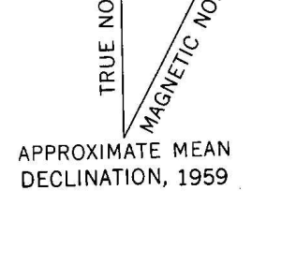
BASE FROM U. S. GEOLOGICAL SURVEY, 1965

GEOLOGY GENERALIZED FROM MACKEVETT, 1976

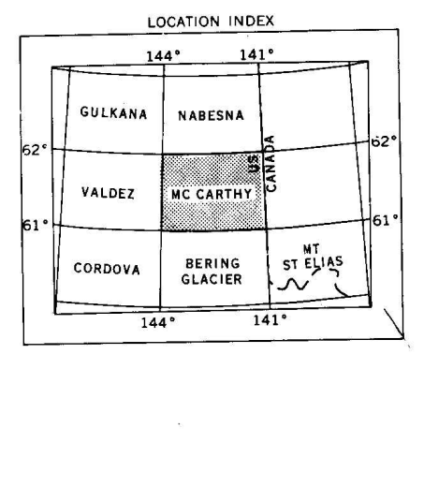


CONTOUR INTERVAL 200 FEET
DATUM IS MEAN SEA LEVEL

QUADRANGLE LOCATION



APPROXIMATE MEAN DECLINATION, 1959



EXPLANATION FOR MINERAL DEPOSITS AND OCCURRENCES MAP

73 ⚒ Cu(Ag)	Mine
X	Prospect
~	Drainage worked for placer gold
△	Placer locality
○ •	Location of deposit or occurrence found during recent U.S. Geological Survey investigations or, in the northeastern corner of the quadrangle, reported by Knaebel (1970).
□	Location of mineralized float sample

Number at location corresponds to map no. given in the accompanying descriptive table.

Chemical symbols at location, for example Cu (copper), indicate the metal commodities; those in parentheses represent apparent minor occurrences or possible potential by-products.

DESCRIPTION OF MAP UNITS

	SURFICIAL DEPOSITS
Qu	UNCONSOLIDATED SEDIMENTARY DEPOSITS (Quaternary)
	SOUTH OF BORDER RANGES FAULT
	METAMORPHIC ROCKS
KJv	VALDEZ GROUP (Cretaceous and Jurassic?)
	INTRUSIVE ROCKS
Ti	INTRUSIVE ROCKS (Eocene?) Typically, foliated granodiorite and tonalite
	BETWEEN BORDER RANGES FAULT AND TOTSCHUNDA FAULT SYSTEM
	SEDIMENTARY, VOLCANIC, AND METAMORPHIC ROCKS
QTw	WRANGELL LAVA (Quaternary and Tertiary) Chiefly subaerial andesitic lava flows and tephra; includes local subaerial sedimentary rocks of the Frederika Formation
K	MARINE SEDIMENTARY ROCKS (Upper and Lower Cretaceous) Includes MacColl Ridge, Chititu, Moonshine Creek, Schulze, and Kennicott Formations, and unnamed Lower Cretaceous rocks
JŦ	MARINE SEDIMENTARY ROCKS (Jurassic and Triassic) Includes Root Glacier, Nizina Mountain, Lubbe Creek, and McCarthy Formations, Kotsina Conglomerate, and Nizina and Chitistone Limestones
Ŧn	NIKOLAI GREENSTONE (Upper and (or) Middle Triassic) Mainly subaerial tholeiitic basalt; includes subordinate Chitistone Limestone north of Totschunda fault system
PPs	SKOLAI GROUP (Permian and Pennsylvanian) As mapped includes a few scattered remnants of Middle Triassic sedimentary rocks in northeastern part of quadrangle
PPsm	METAMORPHOSED SKOLAI GROUP (Permian and Pennsylvanian) Includes a few small outcrops of serpentinized ultramafic rocks near Border Ranges fault
Pzk	KASKAWULSH GROUP OF KINDLE (1953) (Devonian?)
	INTRUSIVE ROCKS
Th	FELSIC HYPABYSSAL ROCKS (Pliocene) Mainly porphyritic dacite
Tg	GRANODIORITE (Pliocene) Unfoliated granodiorite with local mafic border facies
Jc	CHITINA VALLEY BATHOLITH (Jurassic) Mainly foliated quartz monzodiorite, granodiorite, and tonalite
Ŧg	GABBRO
Pm	MONZONITIC-GRANITIC COMPLEX (Pennsylvanian) Mainly nonfoliated quartz monzonite and granite, local mafic border facies
Pgo	GABBRO AND ORTHOGNEISS (Pennsylvanian)
	NORTH OF TOTSCHUNDA FAULT SYSTEM
	SEDIMENTARY AND VOLCANIC ROCKS
QTw	WRANGELL LAVA See above
Kc	CHISANA FORMATION (Lower Cretaceous) Marine and subaerial volcaniclastic and volcanic rocks
KJs	NUTZOTIN MOUNTAINS SEQUENCE (Lower Cretaceous and Upper Jurassic)
Ŧn	NIKOLAI GREENSTONE See above
PPs	SKOLAI GROUP See above
	INTRUSIVE ROCKS
Th	FELSIC HYPABYSSAL ROCKS See above
Kkg	KLEIN CREEK PLUTON (Cretaceous) Chiefly granodiorite
—⋯	Contact; dotted where concealed
- -⋯	High-angle fault; dotted where concealed
▲▲⋯	Thrust fault; sawteeth on upper plate. Dotted where concealed
NOTE:	Areas without letter symbols are glaciers and snowfields

MINERAL DEPOSITS AND OCCURRENCES IN THE McCARTHY QUADRANGLE, ALASKA

BY

E. M. MACKEVETT, JR.

1976

MINERAL DEPOSITS AND OCCURRENCES

This section briefly describes the mineral deposits and main occurrences in the McCarthy quadrangle. It briefly describes the different types of deposits and provides information on their geologic settings, mineralogy, and probable origins. A companion map and text (Singer and MacKevett, 1976) integrates the basic geologic, geophysical, geochemical, and telegeological data and provides an estimate of the quadrangle's mineral resources and their potential.

The term "deposit" as used in this section refers to both deposits and occurrences. In a restricted sense, a deposit contains indications of ore minerals sufficient to encourage exploration; an occurrence is an unexplored site that apparently contains only minor amounts of ore minerals.

The mineral deposits shown on the map and table are divided nearly equally into previously known mines and prospects and deposits and occurrences found during our investigations. Undoubtedly some of the occurrences are more significant than was apparent from our brief reconnaissance examinations and may be worth exploring. Many apparently minor occurrences, such as many of the numerous and widespread occurrences of copper-stained and (or) native copper-bearing Nikolai Greenstone, are not included in the map and table. Deposits of nonmetallic or energy commodities are not shown in the map and table, mainly because they either are insignificant or because some, such as limestones, are integral constituents of extensive rock units and are not amenable to separate representation.

INTRODUCTION

The McCarthy quadrangle contains numerous and diverse mineral deposits in various geologic settings. Copper is the dominant mineral commodity, both historically and in terms of potential future production. Gold and silver are the only other metals that have been produced. The metalliferous deposits are concentrated in a northwest-trending belt along the southern flank of the Wrangell Mountains, and, to a lesser extent, in a similar belt along the northeast flank of the range. Both belts have upper Paleozoic (Skolai Group) basements, abundant Mesozoic rocks, and some Tertiary intrusive rocks. They are marked by numerous faults, mainly northwest-striking. Mineral deposits are uncommon elsewhere in the quadrangle, especially in large tracts underlain by Wrangell Lava and in smaller areas underlain by the Kaskawulsh Group of Kindle (1953). Both the Wrangell Lava and the Kaskawulsh underlie rugged mountainous regions with extensive snow and ice cover, and could conceivably contain undetected concealed deposits.

The metallic, nonmetallic, and energy resources of the quadrangle are descibed sequentially. Copper, gold, and silver, because of their importance, are described early in the section on metal commodities; descriptions of the other metals follows in alphabetic sequence. Locations of the deposits and relevant supplementary data for individual deposits are given in the accompanying map and table.

METAL COMMODITIES

Copper

The numerous copper deposits in the quadrangle are categorized into the following types: (1) Kennecott[1], (2) veins and associated deposits, (3) porphyry, (4) native copper, (5) contact metamorphic, and (6) placer.

Kennecott type

Kennecott-type deposits dominate the quadrangle's mineral production. They are exemplified by the major Kennecott mines (89, 91, 92, 93)[2] and by a few other deposits such as (67), (87), (88). The Kennecott mines were renowned for the size and richness of their copper sulfide lodes, and for many years were substantial contributors to the world's copper production. They produced important amounts of byproduct silver. During their major operations, between 1913 and 1938, the mines produced about 1.2 billion lbs copper and 9 million oz silver. Intermittent small-scale surficial mining since 1938 has yielded minor production. The Kennecott deposits are most thoroughly described by Bateman and McLaughlin (1920). Kennecott-type deposits are localized in lower, largely dolomitic, parts of the Chitistone Limestone generally less than 100 m above contacts with the regionally subjacent Nikolai Greenstone. This part of the Chitistone contains products of intertidal-supratidal cyclical deposition in a sabkha environment (Armstrong, MacKevett and Silberling, 1970; Armstrong and MacKevett, 1975). The major deposits are mainly irregular massive veinlike bodies that in cross section have outlines resembling upright isosceles triangles. The largest known ore body, that at the Jumbo mine, averaged about 110 m (360 ft) in height, was between 0.6 m (2 ft) to 18.5 m (60 ft) wide, and extended along its northeasterly plunge for 460 m (1,500 ft) (Bateman and McLaughlin, 1920, p. 31). Other, smaller ore bodies include veins, pods, and irregular masses, mainly confined to discrete stratigraphic horizons. Except at the Westover mine (72), which contains abundant bornite, the dominant ore minerals consist of chalcocite and several other phases of the chalcocite-covellite system. In an early report, Bateman and McLaughlin (1920, p. 66-76) suggested that the copper sulfides mainly replaced pre-existing bornite; recent studies have borne this out (R. W. Potter, oral commun., 1975). Oxidized ore constituted a minor part of the production.

The origin and geologic history of Kennecott-type deposits are complex and have been obscure for many years. They still are not thoroughly understood. Most geologists familiar with the deposits believe that the ore copper was derived from the Nikolai Greenstone, which has an intrinsically high copper content. Other factors relevant to the ore genesis are: the lack of igneous activity that can be related to the deposits; indications that near major deposits the Chitistone contains more abundant secondary dolomite and is more highly fractured than elsewhere; the scarcity of iron in the typical ore.

Armstrong and MacKevett (1975) believe that the initial ore localization was controlled by sabkhas, barren evaporite flats bordering partially landlocked seas. According to Renfro (1974, p. 37) sabkhas differ from evaporite pans by having subaerial rather than subaqueous depositional interfaces. Armstrong and MacKevett postulate that highly oxygenated groundwater containing copper derived from an extensive subaerial terrane of Nikolai Greenstone entered a restricted subsiding basin floored by Chitistone sabkha deposits and that throughout the depositional history of the basin, which extended from the Late Triassic Karnian Stage locally until the Late Jurassic Kimmeridgian Stage, copper was precipitated in a strongly reducing environment in the permeable, mainly buried, sabkha. Subsequent deformation and remobilization during postore thermotectonic events, mainly or entirely during the Late Jurassic and Early Cretaceous regional orogeny, modified and remobilized some original ore bodies and, to some extent, accounts for their present configurations.

The sabkha-remobilization model appears to best explain most facets of the ore genesis at the present level of knowledge. Bateman and McLaughlin (1920, p. 77, 78) advocated that the copper was derived from the Nikolai, transported in thermal metoric water, and deposited at favorable structural sites in the Chitistone. Alternative hypotheses are: (a) paleoaquifers channeled copper-bearing solutions to the depositional sites, a mechanism similar to the one advocated for some zinc deposits in Tennessee and Virgina (Harris, 1971), (b) the deposits are in some way related to igneous processes.

Veins and associated deposits

Copper-bearing veins and associated deposits include numerous veins and less abundant, apparently genetically affiliated, deposits, such as small pods, local disseminations, and surface coatings. Characteristically, these deposits are localized along or near fractures, chiefly faults. Most of them have hydrothermally altered wallrocks, but some have little or no wallrock alteration. In some of the fault-controlled deposits, the combined effects of hydrothermal alteration and weathering mask the mineralized zones. Although the veins and associated deposits are localized in rocks that range from late Paleozoic (Skolai Group) to Cenozoic (Wrangell Lava), they are largely confined to the Triassic Nikolai Greenstone. Many of the deposits were located and cursorily explored during the first quarter of the century; only a few have been extensively explored. Their production is meager, consisting mainly of small shipments from a few properties (such as 73, 139).

The copper-bearing veins range from discrete solitary veins to multiple veins that are most common in altered and weathered zones along faults. The veins generally are small, typically ranging from a few centimetres to slightly more than a metre in width and rarely traceable for more than 200 m along strike. A few veins (such as 32, 48) are bordered by mineralized alteration zones much wider than the individual veins. Deposits of pods, disseminations, or surface coatings are generally small. Some veins and associated deposits (for example 67, 139) are rich, but most are lean or contain only sparse and irregular concentrations of ore minerals. Typical veins and associated deposits contain bornite, chalcopyrite, and chalcocite, and their oxidized derivatives in a quartz and (or) calcite gangue. Most of the deposits are characterized by bornite, pyrite, and lesser amounts of chalcopyrite, but some are dominantly chalcocite. A few of the veins contain some sphalerite and galena, or, uncommonly, stibnite and realgar or molybdenite. Most of the veins and associated deposits carry minor amounts of silver; a few of them contain a little gold.

The vein and associated deposits are inferred to be mainly products of hydrothermal processes related to Late Jurassic or Tertiary plutonism. Their abundance in the Nikolai Greenstone suggests that some deposits resulted from the mobilization and redistribution of copper from copper-rich parts of the Nikolai during the subsequent plutonic events.

Porphyry

The known porphyry copper deposits are associated with Upper Jurassic (5, 129, 178), Cretaceous (188), or upper Tertiary (30, 31) granitic rocks. The Tertiary copper-bearing pophyries are best termed copper-molybdenum porphyries because their copper content generally is only slightly greater than their molybdenum content. A few deposits (for example 144, 149) that contain disseminated sulfides or networks of veinlets in diverse host rocks, mainly dikes, may be properly termed porphyries, but most of them are small or of low grade. The Cretaceous plutons are equivalents of the Klein Creek pluton, the host for several porphyry copper deposits in the Nabesna quadrangle (Richter, 1975; Richter and others, 1975).

Except for two prospects (129, 137) where old exploratory workings were driven in search of veins, the deposits are unexplored. A few deposits (129, 137) have been examined by mining company geologists during recent years, but most are unprospected and some are unclaimed. Host rocks for the porphyry deposits include Jurassic granodiorite, quartz monzodiorite, and quartz diorite; Cretaceous granodiorite; and Tertiary granite and granodiorite.

The porphyry copper deposits consist of interlacing or reticulated networks of quartz veinlets and disseminations that contain chalcopyrite and pyrite and their oxidation products and generally some molybdenite. Most of the deposits contain minor amounts of silver and gold. Hydrothermal alteration effects were not studied in detail. In most of the deposits, hydrothermal alteration is manifest in sericite and less abundant chlorite within irregular zones that generally contain abundant dispersed pyrite and secondary iron minerals. Classical concentrically zoned alteration patterns of the Lowell and Guilbert (1970) model are lacking.

Native copper lodes

Native copper lodes occur widely throughout the Nikolai Greenstone. The copper occurs in specific flows, mainly in amygdules or in brecciated or rubbly upper parts of flows. A few flows contain broad, but erratic, disseminations of finely particulate native copper. Native copper is a minor constituent of many of the epidote-quartz or calcite-prehnite veinlets that locally abound in the Nikolai. It is a subordinate mineral in oxidized parts of several of the copper-bearing veins. Only a few of the numerous native copper occurrences are shown in the map and table. Extent of most of the native copper deposits is obscured by rugged topography and overburden, including snow and ice. Many such deposits are obviously small, but some appear to extend for several hundred metres along strike and attain thicknesses of a few metres.

The lode native copper ranges from microscopic particles to slabs at least 30 kg in weight. The larger slabs were from the Erickson mine (62), the source of the meager lode native copper production. Another notable locality (109) contains ramifying masses of native copper, a few kilograms in weight, associated with smaller irregularly shaped particulate copper. Most of the deposits contain native copper that ranges from shot size to irregular ellipsoidal pellets a few centimetres long. Many of the old prospects (164, 172, 180, 181, 182) represent attempts to exploit native copper lodes that failed to develop ore sufficient to justify mining under the prevailing economic conditions.

Some native copper is associated with subordinate tenorite and cuprite, and rare chalcocite and native silver. In many places it is coated with malachite. Native copper in amygdules and veinlets typically is accompanied by quartz and epidote or by prehnite and calcite.

Except for occurrences in oxidized copper-bearing veins, the native copper deposits were formed during terminal-stage magmatic processes related to subaerial Nikolai volcanism. Probably the lavas vented their sulfur in a gaseous phase, subsequently depositing the copper from the residual fluids at favorable sites in the Nikolai. The many geologic similarities between the McCarthy native copper and the well known Keweenawan native copper, including trace-metal contents (Forbes and Barsdate, 1969), imply comparable modes of origin. Jolly (1974) contends that the Keweenawan native copper was concentrated in hydrated parts of the lava pile during late-stage metamorphism, where it commonly is associated with prehnite-pumpellyite facies metamorphic mineral assemblages. Our investigations were not thorough enough to confirm or negate a similar origin for the McCarthy native copper.

Contact metamorphic deposits

A few contact-metamorphic deposits that contain copper are known in the quadrangle. With two insignificant exceptions (28, 187), the deposits are in skarn in Triassic carbonate rocks intruded by Jurassic granitic plutons. The contact-metamorphic deposits are concentrated in the western part of the quadrangle (localities 107, 108, 121, 130, 131). The skarn zones are as much as 6 m wide, but they cannot be traced laterally for appreciable extents because of overburden. They consist mainly of silicate minerals and magnetite. Copper minerals, chiefly chalcopyrite, are erratically disseminated in the skarn, but their distribution patterns are not accurately known. The chalcopyrite commonly is associated with magnetite, pyrite, pyrrhotite, small amounts of gold and silver, and rare molybdenite. One sample of skarn (locality 108) contained 20,000 ppm copper; most samples contained 1,500 or 1,000 ppm copper or less.

The contact-metamorphic deposits formed during plutonism, in invaded carbonate rocks in a high-temperature metamorphic environment; this process facilated the introduction and deposition of metals and other elements in the reactive carbonate hosts.

Placer

Placer copper deposits include native copper in alluvium along streams and nearby benches and the unique glacier placer and talus ore bodies at the Bonanza mine (89). Placer native copper is widely, but sparsely, distributed in alluvial deposits along streams that drain areas of Nikolai Greenstone. Despite its widespread minor occurrence, most placer copper is regarded as having minimal economic significance; only one placer locality (110) whose principal commodity is copper is shown on the map and table. Placer native copper is associated with most of the gold placers, particularly along Dan Creek and its tributaries (49, 57) and in the Chititu drainage system (39). Some native copper nuggets were utilized and bartered by aborigines of the region. Placer copper was regarded as a contaminant by the early placer gold operators, who generally discarded it during cleanups. Native copper nuggets, largely obtained from residues of placer gold operations along Dan and Chititu Creeks, are utilized to a small extent in making Alaskan jewelry and curios.

The placer native copper has a vast size range. It occurs mainly as shot- to peanut-size nuggets, but many large nuggets weighing a few kilograms or more and exceptionally, a few huge nuggets that weighed more than a tonne have been found. Notably large nuggets are one found in Nugget Creek (near locality 139) in 1900 (Moffit and Mertie, 1923, p. 133) and a huge nugget found during placer gold operations on Dan Creek in the 1950's. The largest copper nugget reported from the region, one weighing nearly 2500 kg, was from along the White River in the Yukon Territory, a few miles east of the quadrangle boundary (Moffit and Knopf, 1910, p. 53).

The copper nuggets contain minor amounts of native silver and are in many places coated with malachite. Locally, some native copper is enclosed in pebbles, cobbles, or boulders of Nikolai Greenstone. The native copper placers are clearly derived from native copper lodes in the Nikolai.

Bateman and McLaughlin (1920, p. 25, 26) described two unique placer deposits derived from the main chalcocite-rich lode at the Bonanza mine (89). One is an ore body in talus that contained more than 90,000 tons of high-grade ore, mainly finely comminuted chalcocite. The other, formed on the opposite side of a sharp ridge from the talus, contains fragmental chalcocite incorporated in an active glacier. The glacier deposit contained at least 220,000 tons of copper ore. Both deposits contributed small increments to the Kennecott production and have been exploited intermittently on a small scale during the past 20 years.

Gold

Lode and placer gold deposits occur widely in the McCarthy quadrangle, but placer deposits have provided almost all of the gold production, about 147,250 Troy ozs (Koschmann and Bergendahl, 1968, p. 14); Moffit (1914, p. 43-47).

Lode

The gold lodes are mainly quartz or quartz-calcite veins and their adjacent altered zones. They occur less extensively as veinlets and local disseminations in gouge and breccia along faults and in a few altered zones apparently unrelated to veins. Gold is a minor constituent of some of the porphyry and contact-metamorphic copper deposits and of many of the "veins and associated deposits" described under "Copper." Most of the small production of lode gold was from the Yellowband mine (9).

Typically, the gold-bearing veins are small, rarely exceeding 50 cm in width and a few hundred metres in traceable length. The other gold lodes, including mineralized parts of dikes, disseminations, brecciated and altered zones, and networks of veinlets, are in general larger but leaner than the veins. Some veins are discontinuous and marked by pinching and swelling. A few lodes contain sets of parallel quartz veins in wide, but lean or barren, altered zones. The deposits are characterized by erratically distributed gold, and despite local small gold-rich concentrations are mainly low in grade.

The lode deposits are in diverse host rocks that range from late Paleozoic to late Tertiary. Except for one lode (187), probably related to Cretaceous plutonism, the deposits are temporally and spatially linked to Upper Jurassic, lower Tertiary, or upper Tertiary igneous activity. Gold lodes south of the Border Ranges fault, exemplified by (9), (23), (24), occur in metasedimentary rocks of the Valdez Group or in lower Tertiary dacitic dikes. The main gold lodes along the southern flank of the Wrangell Mountains north of the fault (for example 55, 56, 57) are genetically related to upper Tertiary porphyritic dacite or granodiorite interpreted as shallow-seated affiliates of Wrangell Lava volcanism and generally are best developed in contiguous metasedimentary rocks, mainly Upper Cretaceous. Several other gold deposits north of the fault also are products of the upper Tertiary igneous processes. Many other lodes (such as 108) and most copper-bearing veins, porphyries, and skarns that contain minor amounts of gold resulted from Late Jurassic plutonism.

Most of the gold lodes contain pyrite and minor amounts of silver. Some veins associated with upper Tertiary igneous rocks contain stibnite and (or) realgar, or molybdenite, and, rarely, arsenopyrite or traces of galena and sphalerite. Those associated with lower Tertiary intrusive rocks may contain small amounts of galena and sphalerite; the veins genetically related to Upper Jurassic plutonic rocks generally contain copper minerals. We interpret the lode gold deposits as products of hyrothermal processes related to igneous activity in the Late Jurassic and early and late Tertiary.

Placer

The placer gold deposits are most abundant in the Nizina district, a poorly defined tract that essentially includes the drainage basin of the Nizina River. They are broadly distributed throughout the quadrangle, however, and probably all the drainage systems contain at least trace amounts of placer gold. Prior to 1959 the Nizina district produced approximately 143,500 Troy ozs gold (Koschmann and Bergendahl, 1968, p. 14), almost entirely from deposits along Dan and Copper Creeks and their tributaries (57), (49) and deposits in the Chititu Creek drainage (39). Young Creek and its tributaries (37) were minor producers. The Dan Creek placers, worked intermittently on a small scale since 1959, account for additional minor production. The only other significant placer production was from Golconda Creek (8).

Only a few of the lesser placer localities are shown on the map and table. By the evidence of stream-sediment sampling and from conversations with prospectors, minor (unplotted) placer gold occurs widely. Of possibly significance among these are gold placers associated with north-flowing streams that drain the Chugach Mountains and the environs of drainages northeast of the Totschunda fault. Prospectors reported and, to some extent, our samples confirmed that many streams along the north flank of the Chugach contain very fine placer gold. Moffit (1918b, p. 77, 78) mentions a flurry of prospecting activity along and near the Kiagna River in 1914 and 1915. The part of the quadrangle northeast of the Totschunda fault was prospected for placer gold during the Chisana gold rush that centered in nearby parts of the Nabesna quadrangle during 1913 and 1914. Except for a legacy of suggestive creek names such as Rocker, Shotgold, and Ophir, there is scant record of this activity in the quadrangle. Knaebel's stream-sediment samples from this area (1970) were not analyzed for gold.

Placer deposits in the Nizina district, best described by Moffit and Capps (1911, p. 98-108), include both stream and bench placers. Besides gold, the Nizina district placers contain some native copper and native silver, pyrite, and minor to trace amounts of barite, galena, and cinnabar. The Golconda placers are shallow and localized in a creek that cuts alluvial terraces. Other known placer deposits are mainly along shallow streams.

The placers were derived from local lode gold sources, mainly by fluvial processes of erosion, transport, and deposition. Most of the placer deposits have provenances that contain Tertiary igneous rocks, and most were largely or entirely derived from Tertiary lodes. Many placer-bearing streams, particularly those in the Nizina district, are partly entrenched in auriferous bench gravels; some stream placers have been enriched by recycling gold from the bench placers.

Silver

Silver occurs widely throughout the quadrangle in a variety of geologic settings. Despite its broad distribution, silver is the dominant metal in only a few deposits, such as (175), (176). The approximately 9 million Troy ozs of byproduct silver recovered during the major Kennecott operations dwarfs the lesser silver production from other Kennecott-type deposits, copper-bearing veins, gold placers, and the recent small-scale surficial operations at some Kennecott mines.

The silver-bearing lodes are in diverse host rocks that range from late Paleozoic to Tertiary. Almost all of the sulfide deposits contain silver, generally in minor amounts to potential byproduct quantities. Most of the silver-bearing deposits are associated with numerous lodes that are notable mainly for copper. Some are associated with zinc-rich deposits (59, 65) or gold lodes. Silver is a constituent of the gold and copper placer deposits described. Only a few prospects such as the Silver Star (176) and an adjacent prospect (175) were explored mainly for silver. At these prospects the silver values are largely in argentiferous tetrahedrite (freibergite) that is localized in narrow quartz veins. In Kennecott-type lodes, the silver probably is mainly a constituent of a finely dispersed unidentified copper-silver sulfide that exsolved from the copper sulfides (R. W. Potter, oral commun., 1975). Most of the silver in the other copper- or zinc-bearing deposits apparently is in solid solution in sulfide minerals. Selected samples from copper-bearing veins at localities (39, 140) contained 200 ppm silver, but the overall silver content of these and similar veins is lower. The closely spaced copper-bearing veinlets in Daonella beds (locality 111) contain silver in minor amounts. Silver values typically less than 10 ppm characterize most of the larger silver-bearing deposits such as the porphyries and broad altered zones (154).

Except for Kennecott types and native copper deposits, the silver-bearing lodes are interpreted as products of hydrothermal processes related to late stages of granitic plutonism. The upper Paleozoic, Upper Jurassic, Cretaceous, lower Tertiary, and upper Tertiary granitic rocks all have inferentially related deposits that contain silver; a large majority of these deposits are near Upper Jurassic or upper Tertiary plutons.

Other Metals

The category "other metals" includes all metals detected in anomalous concentrations except copper, gold, and silver. In general, we regard the commodities included under "other metals" as minor occurrences; some may have economic potential, mainly as byproducts. For this reason, and on the premise that a comprehensive listing might be useful, we systematically describe their occurrence, regardless of the insignificance of some of them in current economic context.

Antimony

The antimony deposits are mainly represented by stibnite-bearing veins in the Nizina district and a vein south of Kennicott Glacier (120). Antimony is a minor constituent of the few tetrahedrite-bearing deposits, such as (176) and probably (178), and of a hornfels that contains disseminated sulfides (27). The stibnite lodes characteristically are epithermal quartz veins in faults that cut Mesozoic sedimentary and volcanic rocks or Tertiary granodiorite. Most of them are less than 30 cm thick and apparently lack continuity for great distances. A few deposits that occupy major fault zones, such as (53), are much larger. Some veins, for example at locality (50) and near (56), are rich in antimony. North of (56) a few veins in granodiorite contain large masses of stibnite more than a metre long and as much as 12 cm wide. The stibnite lodes are associated with lesser amounts of realgar, orpiment, pyrite, gold, and, rarely, marcasite or a tungsten mineral, probably scheelite. Stibnite is an uncommon constituent of the copper deposit at the Radovan Low-contact prospect (65).

Except for the tetrahedrite deposits, which have affinities with Jurassic plutonism, and the hornfels, the antimony deposits are products of hydrothermal processes related to upper Tertiary granitic rocks.

Arsenic

Arsenic is associated with many of the mineral deposits. Arsenic-bearing lodes occur in diverse host rocks that range from upper Paleozoic monzonite to upper Tertiary granodiorite and have a broad size range from minute veinlets to extensive altered zones as much as 50 m wide. The arsenic minerals include enargite and other sulfosalts associated with some copper deposits; arsenopyrite, which occurs in a few gold or copper lodes; and realgar and orpiment, characteristically in late Tertiary veins better known for their antimony or gold contents. The Crumb Gulch prospects (56) are good exmples of vein occurrences. Several Kennecott-type deposits contain subordinate enargite and, in their oxidized zones, minor amounts of orpiment. Arsenopyrite and arsenian sulfosalts are minor constituents of some copper veins and related lodes, and arsenopyrite occurs in some Late Jurassic or Tertiary quartz veins that may contain gold.

Our samples that contained 5,000 ppm or more arsenic represent: (a) a vein at the Midas prospect (107), (b) float of sulfide-rich gossan (13), (c) an altered zone in Nikolai Greenstone (48), and (d) quartz veins in Tertiary granodiorite (79). The abundance of arsenic-bearing deposits in the Nizina district, generally in the Nikolai Greenstone, may partly reflect more intense sampling density in that area. Analytical data for the Nizina district samples are given in MacKevett and Smith (1968). The arsenic deposits are mainly of hydrothermal origin.

Bismuth

Bismuth is rare; it was detected in minor amounts in only a few deposits. Small quantities of bismuth are associated with the Silver Star tetrahedrite lodes (176) (Moffit and Mertie, 1923, p. 112) and with a few other deposits (13, 43, 134, 145). No bismuth minerals were identified.

Boron

Boron was detected in appreciable amounts at only two localities (38, 146). At locality (38) it constituted 1,000 ppm of a sample of Cretaceous hornfels laced with quartz veinlets, at locality (146) more than 2,000 ppm of veins that cut gabbro. Both samples contained trace amounts of gold. No boron minerals were identified at either locality. Tourmaline, a boron-bearing mineral, is a very minor constituent of some metamorphic rocks in the Valdez and Skolai Groups.

Cadmium

Cadmium, a geochemical satellite of zinc, is sparsely distributed in some of the sphalerite-bearing deposits such as the O'Hara prospect (59) and at localities (60) and (165).

Chromium

Chromium is a minor constituent of the mafic and ultramafic rocks; no significant concentrations were found. The ultramafic rocks contain small amounts of chromite. Samples from localities (20), (41), (42) contained 3,000 ppm chromium, samples of mafic rocks (3, 25, 105) and one vein (32) 1,000 ppm chromium.

Cobalt

No cobalt minerals were identified. The largest amounts of cobalt detected in our samples were 500 ppm in a sulfide-bearing skarn (108) and 300 ppm in a vein (123). Cobalt is a minor constituent of the serpentinized ultramafics and of a few gabbros and veins.

Iron

Although iron is abundantly represented in the rock-forming, lode, and placer minerals, its only modes of possible economic significance are the contact-metamorphic deposits described under "Copper." These deposits, exemplified by (28, 107, 108, 121, and 131), are magnetite-rich zones in skarns localized in marble adjacent to granitic plutons. With the exception of (28), which is associated with Permian marble and upper Paleozoic monzonite, the skarns formed in Triassic marble near Jurassic plutons. Local zones in the skarns consist almost entirely of magnetite, yet none of the deposits appear to be large enough to encourage development for their iron alone. Some other iron-bearing deposits, including networks of specular hematite-rich veinlets in upper Paleozoic quartz monzonite (1), several pyrite-rich veins and disseminations that contain 15 to greater than 20 percent iron, and copiously iron-stained oxidized lodes, are of exploration interest as possible indicators of deposits of other metals.

Lead

Deposits that contain lead as their major commodity are not known in the quadrangle. The main lead occurrences are galena-bearing polymetallic base-metal lodes, typically veins, as at the Harrais (2), Nikolai Butte (58), and O'Hara (59) prospects, and locality (165), where lead is ancillary to either zinc or copper. Galena is a minor to rare accessory in some gold-bearing quartz veins and in a few other deposits.

Manganese

Secondary manganese minerals, generally accompanied by more abundant secondary iron minerals, are dispersed in oxidized parts of many of the lodes. The largest detected concentration of manganese, greater than 5,000 ppm, represents an altered zone accompanied by base metals and silver (165).

Mercury

Mercury is exceedingly rare in the quadrangle. Its only known occurrences are the cinnabar reported in Dan Creek (57) placer concentrates (Moffit and Capps, 1911, p. 99) and traces of cinnabar in oxidized ore at the Bonanza mine (89) (L. H. Green, oral commun., 1971).

Molybdenum

The molybdenum sulfide, molybdenite, is moderately abundant; in a few places, is of potential significance, mainly as a byproduct. The richest molybdenite deposits are associated with upper Tertiary, mainly granodiorite, plutons where they form copper-molybdenum or molybdenum porphyries or quartz veins that probably are genetically related to the porphyries. Most of these deposits are in a granodiorite mass that is exposed in the rugged mountainous terrain of Tps. 5, 6, and 7 S., Rs. 19 and 20 E., a region of extremely difficult access. Consequently, the deposits are mainly evident in abundant mineralized boulders on moraines of glaciers that head in the granodiorite upland. The molybdenum porphyries, such as (30-(2)) and (35), consist of networks of molybdenite-rich quartz veinlets in the granodiorite. They carry some pyrite, minor to trace amounts of copper and silver, and, rarely, traces of tungsten or bismuth. The Tertiary copper-molybdenum porphyries consist mainly of disseminated sulfides in the granodiorite as in samples (30-(3)) and (31). They are characterized by chalcopyrite exceeding molybdenite and generally more abundant pyrite and silver than their molybdenum porphyry counterparts. Molybdenite-bearing quartz veins related to the Tertiary granodiorite, for example (32, 35, 44), typically are less than 20 cm thick; a few attain thicknesses of almost a metre. Molybdenite, mainly confined to vein selvages, is their dominant sulfide mineral.

The Porphyry Mountain prospect (77) explored a discontinuous irregular quartz vein that cuts Tertiary granodiorite and dacite. The vein contains some molybdenite, mainly localized along vein selvages, and minor amounts of gold.

The copper porphyries in Jurassic granitic rocks, as at (5), (129), (137), (178), and most of their related quartz veins contain only minor or subordinate amounts of molybdenum. Molybdenum is a significant resource in at least two of the porphyry deposits in Cretaceous granitic rocks in the Nabesna quadrangle (Richter and others, 1975); by analogy, correlative Cretaceous intrusive rocks in the northeastern part of the McCarthy quadrangle are regarded as sites favorable for molybdenum deposits. However, our few analyses of these rocks and their altered zones, for example (150), revealed only small amounts of molybdenum. Several of the quartz-rich veins that cut diverse rocks in the southern part of the quadrangle are hosts for small qauntities of molybdenum.

Nickel

Nickel is an unimportant minor element in a few of the veins and altered zones, such as (86), but its only significant concentrations are in serpentinized ultramafic rocks along the northern flank of the Chugach Mountains. These alpine-type ultramafic rocks were tectonically emplaced in metamorphosed Skolai Group (upper Paleozoic) terrane north of, but near, the Border Ranges fault. They form sheared masses at localities (20, 21, 41, 42) that contain chromite and disseminated sulfides, chiefly pyrrhotite. Samples representative of these masses contained 2,000-3,000 ppm nickel. The serpentinized ultramafic rocks are in geologic settings analogous to those for larger correlative ultramafic masses west of the quadrangle that contain chromium, nickel, copper, and platinum-group element resources. These correlative ultramafic rocks include one at the Spirit Mountain nickel-copper prospect (Herreid, 1970; Kingston and Miller, 1945), another ultramafic complex near Spirit Mountain, and the Bernard Mountain ultramafic assemblage (Hoffman, 1974), all in nearby parts of the Valdez quadrangle.

Thorough minerals-oriented exploration of the virtually unprospected ultramafics and their environs in the McCarthy quadrangle might discover significant deposits in the known serpentinized masses, or, less likely, in mineralized ultramafics not found during our investigations.

Platinum group elements

None of our samples were analyzed for platinum-group elements. The most likely, and probably only, host for platinum-group elements is the ultramafic rocks discussed under "Nickel." These rocks are inferred to have contents of platinum-group elements similar to those in correlative ultramafics in nearby parts of the Valdez quadrangle. Our ultramafic rock samples from the Valdez quadrangle contained 0.005 to 0.070 ppm platinum and 0.005 to 7 ppm palladium.

Tin

Only one anomalous concentration of tin was detected, 100 ppm in a sample of an altered dike that cuts upper Paleozoic quartz monzonite at locality (34).

Titanium

Titanium occurs widely in many of the rocks, lodes, and placers; no important concentrations were found. The titanium mierals identified include ilmenite and titaniferous magnetite, mainly as minor accessories in mafic igneous rocks; sphene, widely but sparsely distributed in various rocks; leucoxene, as a local alteration product; and rare rutile. Some Cretaceous conglomerates and coarse sandstones and a few placer deposits have local concentrations of heavy titanium minerals.

Tungsten

Tungsten is associated with stibnite-rich veins that cut the Nizina Limestone (50). An analyzed sample from these veins disclosed 7,000 ppm tungsten, probably incorporated in scheelite. The only other tungsten detected was trace amounts in a sample of mineralized Tertiary granodiorite (31).

Vanadium

Although many of the rocks, in particular mafic varieties, and a few lodes contain vanadium, no markedly anomalous concentrations were detected. Most of the vanadium probably is geochemically affiliated with iron in iron-rich minerals.

Zinc

The best zinc deposits are the polymetallic base-metal lodes at the O'Hara (59), Harrais (2), and Nikolai Butte (58) prospects and at localities (60) and (165). These lodes, except for the Nikolai Butte prospects, which are mainly for copper, are characterized by the abundance or dominance of sphalerite in their ore mineral assemblages. The sphalerite typically is associated with lesser amounts of galena, and in some deposits, with minor to abundant copper minerals, chiefly chalcopyrite. Secondary zinc minerals occur in some of the altered and oxidized lodes such as the altered vein at (165). Most of the zinc lodes carry minor amounts of silver and cadmium. The lodes form veins, disseminations, and small podlike masses localized in marble and schist in the upper Paleozoic Skolai Group or in Triassic Nikolai Greenstone and Chitistone Limestone. Some of the deposits are rich, and despite apparently being too small for exploitation under current conditions, none have been sufficiently explored to preclude the possibility that some may actually be large enough to support small-scale mining, particularly in the future.
Several other deposits contain minor amounts of sphalerite. Among these are: a dike with disseminated sulfides (14), and altered copper-bearing quartz vein that cuts upper Tertiary granodiorite (61), the Silver Star prospect (176), local disseminated sulfides in the Nikolai Greenstone (125), and gold-bearing lodes at the Yellowband (5) and nearby prospects.

NONMETALLIC COMMODITIES

The quadrangle contains large resources of limestone, sand, gravel, rock suitable for various industrial and construction purposes, and some dolomite. Its known resources of other nonmetallic commodities are minor or negligible. Such resources include small deposits of barite and phosphate rock and possibly the magnetite of previously described contact-metamorphic deposits, which may have a remote potential for minor industrial uses, such as ballast. The principal nonmetallic resources are commodities whose utilization depends largely on their proximity to urban or industrial centers and on their high-volume production and low transportation costs. Unless the region undergoes socioeconomic changes not anticipated at this time, it is not likely that nonmetallic commodities will be exploited except on a small-scale provincial basis.

Barite

Barium was detected in amounts greater than 5,000 ppm in two barite-bearing lodes (86) and (178). It is doubtful if either deposit is large enough or rich enough to stimulate economic interest. Except for minor occurrences in a few other lodes and in some placer concentrates, barite was not found elsewhere in the quadrangle.

Carbonate Rocks

Carbonate rocks of the quadrangle include abundant limestone and marble and some dolomite, rocks suitable for many of the numerous industrial uses of carbonate rocks. The carbonate rocks are best represented by the belt of Chitistone and Nizina Limestones along the southern flank of the Wrangells, the marble-rich Kaskawulsh Group, and, to lesser extent, by Permian limestone and marble. Limestone occurs in several other formations, but typically, such limestone forms beds that are too thin or too contaminated by detrital minerals to merit serious economic consideration.

The carbonate rocks have physical and chemical properties that reflect their diverse modes of formation and subsequent geologic histories. Some, such as the Nizina Limestone, contain locally abundant chert; others large components of detrital or metamorphic minerals or siliceous fossils; and a few are in structural settings that would inhibit mining. Limestone with high calcium carbonate content occurs in large volume. Dolomite and dolomitic limestone are best developed in the stratigraphically lowermost 100 m of the Chitistone and are minor constituents of some of the other carbonate rocks.

Chemical analyses of the limestones--excluding those that are markedly dolomitic--are summarized as follows:

		Weight percent			
		CaO	MgO	CO_2	Other oxides (mainly SiO_2)
Chitistone Limestone (9 samples)	Range	51.0-55.1	0.2-3.1	41.5-44.2	0.9-5.7
	Mean	53.6	0.8	42.8	2.6
Nizina Limestone (10 samples)	Range	46.3-54.7	0.4-3.3	49.4-43.9	0.9-11.0
	Mean	52.0	1.4	41.8	4.9
McCarthy Formation (lower member) (9 samples)	Range	26.0-52.4	0.3-2.3	20.8-41.9	4.9-51.8
	Mean	38.8	0.9	30.9	26.7
(Upper member) (3 samples)	Range	27.3-38.2	0.4-2.5	20.2-30.3	29.0-52.1
	Mean	31.9	1.7	24.4	42.6
Permian Limestone (2 samples)	Range	52.5-54.3	0.4-0.5	40.6-42.5	4.5-4.7
	Mean	53.4	0.5	41.5	4.6
Permian Marble (3 samples)	Range	47.4-54.6	0.4-4.7	37.9-43.1	1.9-10.0
	Mean	50.3	2.7	41.1	5.8
Marble, Kaskawulsh Group of Kindle (1953) (1 sample)		54.0	1.1	44.0	0.9
Lower Cretaceous Limestone (2 samples)	Range	38.1-51.0	0.3-1.3	29.6-40.5	8.1-31.0
	Mean	44.6	0.8	35.1	19.6
Shaly Limestone from Frederika Formation (Tertiary) (1 sample)		49.9	2.5	42.2	5.4

Analyses by U.S. Geological Survey; analysts: Lowell Artis, S. D. Botts, Floyd Brown, Gillison Chloe, Paul Elmore, J. L. Glenn, J. Kelsey, Herbert Kirschenbaum, Hezekiah Smith, and Dennis Taylor.

The most extensive and purest carbonate rocks are in remote, rugged, and (or) exceptionally scenic regions. High costs of transportation, development, and mining and critical environmental considerations are strong deterrents to their exploitation.

Phosphate Rock

Some impure cherts and spiculites in the upper member of the McCarthy Formation are weakly phosphatic. These silica-rich aphanitic rocks contain minor amounts of calcium fluorapatite and associated carbonaceous debris. Although phosphate-bearing rocks are widespread in the provenance of the upper member, mainly in T. 4 S., Rs. 14, 15 E., they are lean. The maximum P_2O_5 contents detected are between 1 and 2 percent. Consequently, they have negligible economic significance.

Sand, Gravel, and Rock

Sand, gravel, and rock occur widely in the quadrangle and have had limited local use in road building and similar construction endeavors. Sand, gravel, and boulders are voluminous constituents of the extensive alluvial, glaciofluvial, and glacial deposits, and the bedrock formations could furnish a large variety of industrial rock. These commodities are in ample supply for any foreseen local demand, but because of high transportation costs and their general local availability elsewhere, it is not likely that they will be exported from the region. Deposits of sand, gravel, or rock amenable to highly specialized uses, such as high-silica sand, are not known in the quadrangle.

ENERGY RESOURCES

No significant concentrations or markedly favorable indications of energy resources are known in the quadrangle. Information relevant to the few minor occurrences of energy commodities and to areas with rocks or geologic settings favorable for energy resources is given under (a) coal, (b) geothermal energy, (c) nuclear fuels, and (d) petroleum.

Coal

Sparse thin seams of lignite, generally less than 0.5 m thick and 200 m long, occur in the Tertiary Frederika Formation. The Frederika documents local subaerial sedimentation, mainly in intermontane basins, that preceded or accompanied early stages of Wrangell Lava volcanism. The lignite deposits are best developed in T. 2 S., R. 18 E. and T. 3 S., Rs. 17, 18 E., but their small size, erratic distribution, and remoteness preclude commercial development. Carbonaceous, locally lignitized, plant debris is sparsely distributed in some Cretaceous rocks of the Matanuska-Wrangell sequence.

Geothermal Energy

The potential for geothermal energy is strongly related to Wrangell Lava volcanism. The Wrangell Lava forms an extensive calcalkaline volcanic province characterized by differentiated rocks of diverse, but mainly andesitic and dacitic, composition. Within the quadrangle, its lava flows, tephra, and subordinate intrusive phases dominate the lofty crestal areas of the Wrangell Mountains and underlie large tracts northeast of the range. Although these rocks mainly represent older (Tertiary) activity, intermittent Wrangell Lava volcanism continued well into the Quaternary by the evidence of the 1400-1500 year old White River ash (Stuiver, Borns, and Denton, 1964). This ash, whose source is in the eastern part of the quadrangle (Lerbekmo and Campbell, 1969), represents the youngest known volcanic activity. According to T. P. Miller (oral commun., 1975), favorable volcanigenic geothermal areas are generally associated with felsic volcanic centers less than 0.5 m. y. old. The source area for the White River ash qualifies as favorable on the basis of such parameters. Smith and Shaw (1975, p. 67, 74) provide data on the White River volcanic system, which they likewise consider as having possible geothermal potential. They (p. 67, 74) give geothermal information for some Wrangell Mountain volcanic systems west of the quadrangle. Other similarly young felsic volcanic centers have not been identified in the quadrangle, but some may exist in remote, largely icebound summit areas of the range. Developing the potential geothermal resources would evoke strong objections on environmental grounds and costs would be high, probably prohibitive.

Nuclear Fuels

No uranium or thorium minerals were found. Weakly anomalous radioactivity was detected in a sample of phosphate-bearing chert from the lower member of the McCarthy Formation, but efforts to isolate and identify the radioactivity source were unsuccessful. According to Walter Holmes (oral commun., 1967), who prospected for uranium in the quadrangle, parts of the Frederika Formation emit weakly anomalous radioactivity. However, we failed to detect any radioactivity anomalies in the Frederika.

Most of our samples were routinely scanned for radioactivity anomalies, and several field areas were checked with Geiger or scintillation counters. Although these investigations were not sufficiently broad or thorough to constitute a detailed radiometric survey, the results, taken together with other geologic data, imply that the quadrangle has a low potential for uranium and thorium. Conversely, by analogy with known uranium deposits elsewhere, several rock units or geologic settings within the McCarthy are favorable for uranium. Among these are: (a) Quaternary glaciofluvial deposits, extensively developed in the Chitina and its main tributary valleys, and in some areas west of the quadrangle, intercalated with local Wrangell Lava flows; (b) the Frederika Formation, which contains abundant clastic sedimentary rocks, some lignite and other carbonaceous rocks, and intercalated lava flows and sills; (c) the phosphate-bearing chert and spiculite of the upper member of the McCarthy Formation; and (d) some granitic rocks, in particular silica-poor phases of the upper Paleozoic plutons.

Petroleum

No petroleum resources are known in the quadrangle, and the potential for them is poor. With the exception of unconsolidated Quaternary sedimentary deposits and some parts of the Frederika Formation, most of the rocks are well indurated and have low porosities and permeabilities. Numerous petroleum company geologists have examined parts of the area. They mainly focused on detailed studies of the Matanuska-Wrangell and some other sedimentary sequences in order to accrue data pertinent to regional stratigraphic correlations and interpretations. The Chitistone and Nizina Limestones, in many places fetid when freshly broken, and carbonaceous parts of the McCarthy Formation are generally regarded as possible source rocks for petroleum. These rocks were strongly deformed during the Upper Jurassic and Lower Cretaceous regional orogeny; and if they did contain petroleum, it probably migrated to distal regions. No reservoir rocks favorable as hosts for the conjecturally migrated petroleum are known. Some post-orogenic rocks, such as parts of the Frederika and possibly local zones in Upper Cretaceous parts of the Matanuska-Wrangell sequence, may be favorable reservoir rocks, but they show no evidence of petroleum.

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[1] In this report, "Kennecott" pertains to the mines, mining company, ore deposits, and related topics, and "Kennicott" to geographic and geologic features. The rationale for the dual spelling and usage is as follows: the mining company was named for the Kennicott Glacier, which was named by Rohn (1900 literature) for Robert Kennicott, a pioneer surveyor; somehow, probably inadvertently, an "e" was substituted for the "i" in the company name.

[2] Numbers in the parentheses correspond to map numbers on the map and table.