U.S. DEPARTMENT OF THE INTERIOR
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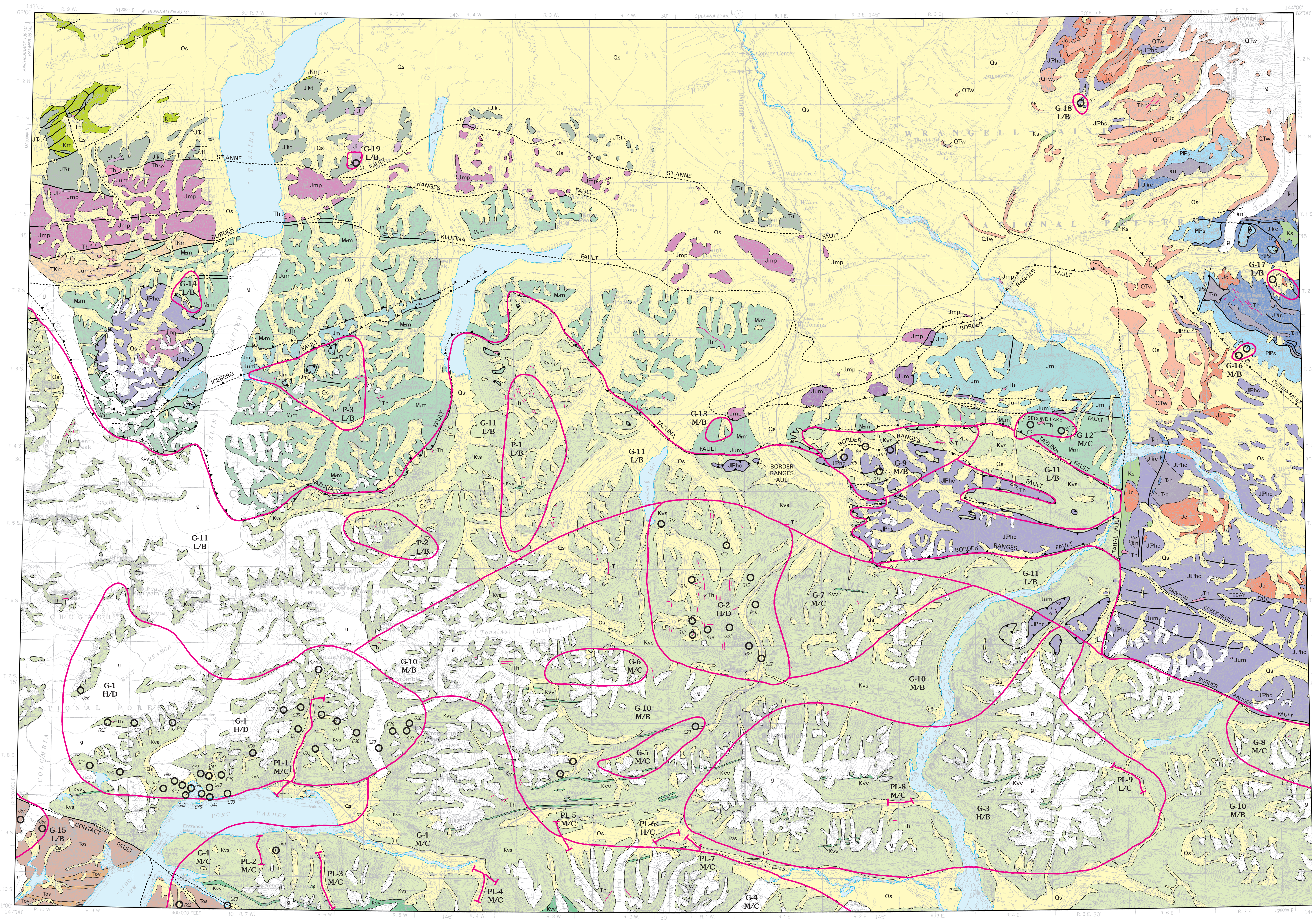
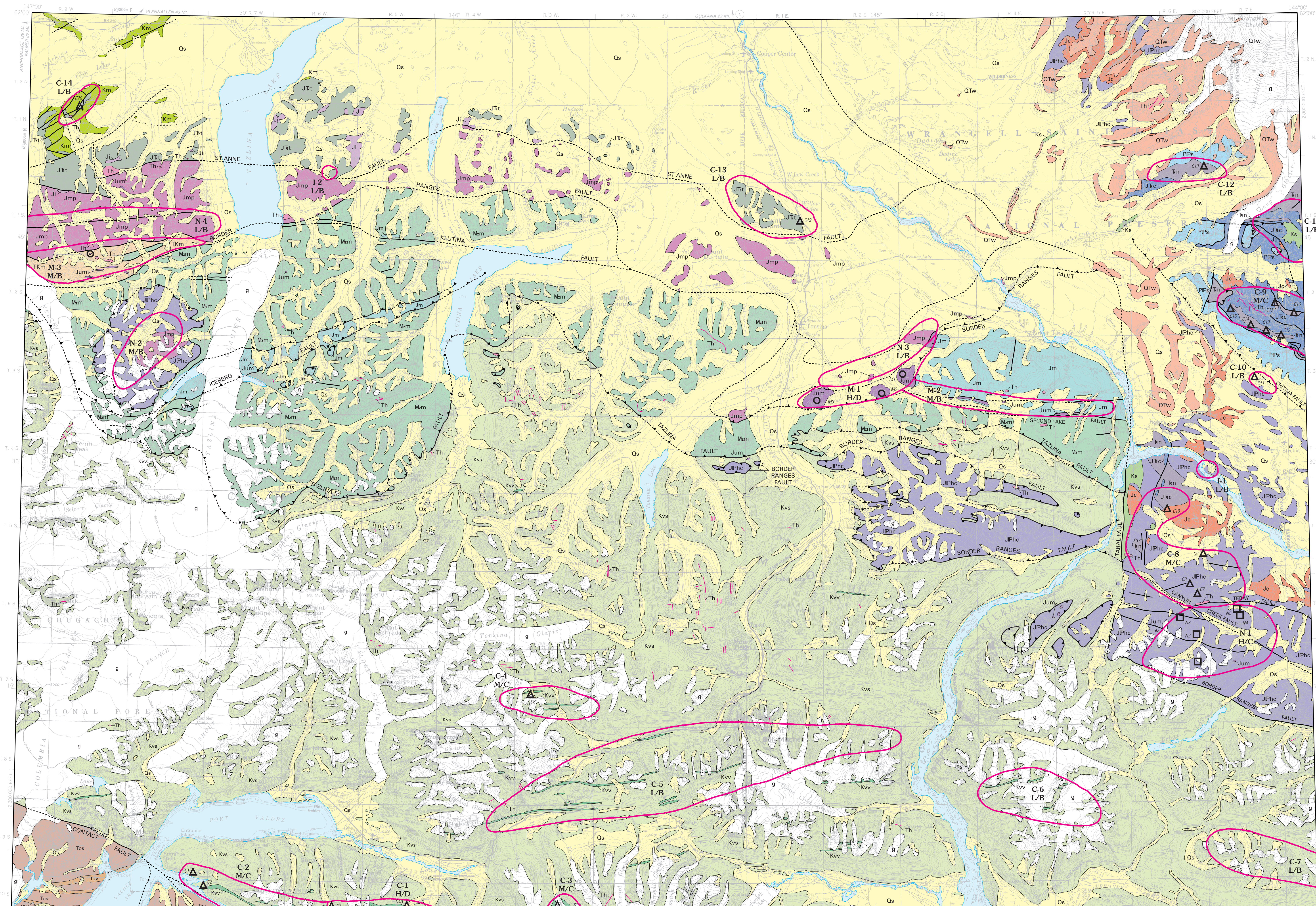
I–2652
Pamphlet accompanies map



MAP A. GEOLOGY AND AREAS OF POTENTIAL FOR PRECIOUS- AND BASE-METAL VEIN DEPOSITS AND FOR PRECIOUS-METAL PLACERS



Base from U.S. Geological Survey, 1960.
100,000-foot grid based on Alaska Coordinate System, zone 3.
10,000-meter Universal Transverse Mercator grid ticks, zone 6.
Universal Transverse Mercator Projection. 1927 North American Datum.

MAP B. GEOLOGY AND AREAS OF POTENTIAL FOR BASE AND FERROUS METALS IN VOLCANIC- AND INTRUSIVE-RELATED DEPOSITS

Geology modified from Winkler and others (1995)
Geology digitized by Nora Shew
Editing and digital cartography by Alessandro J. Donatich
Manuscript approved for publication July 9, 1998

SCALE 1:250 000

5 0 5 10 15 20 MILES

5 0 5 10 15 20 25 30 KILOMETERS

CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
1960 MAGNETIC DECLINATION AT SOUTH EDGE OF SHEET VARIES FROM 27°00' TO 28°00' EAST

EXPLANATION OF MINERAL RESOURCE POTENTIAL FOR MAP A

G-1 **Tracts favorable for undiscovered occurrences of mineral deposits of the specified types**—Number refers to tracts characterized in tables 2–5. **G**, low-sulfide gold-quartz veins (see table 2); **P**, polymetallic veins (see table 5)

PL-1 **Reach of drainage favorable for occurrences of placer deposits**—Number refers to stream listed in table 2

H/B **Levels of resource potential and certainty**—See "Relation between levels of resource potential and certainty" diagram on this sheet

G38 **Location of known occurrence of low-sulfide gold-quartz vein deposit**—Number refers to site listed in table 2

CORRELATION OF MAP UNITS FOR MAPS A AND B

ALL TERRANES
Surficial deposits

Qs — QUATERNARY

Plutonic rocks

Th — Eocene — TERTIARY

WRANGELLIA TERRANE
Sedimentary and volcanic rocks

QTw — Holocene to Miocene — QUATERNARY AND TERTIARY
Ks — Early Cretaceous — CRETACEOUS
JTRc — Late or Middle Jurassic to Late Triassic — JURASSIC AND TRIASSIC
TRn — Late and (or) Middle Triassic — TRIASSIC
PIPs — Early Permian and Pennsylvanian — PERMIAN AND PENNSYLVANIAN

Plutonic rocks

Jc — Late Jurassic — JURASSIC

Metamorphic rocks

JIPhc — Late Jurassic and Pennsylvanian and older(?) — JURASSIC AND PENNSYLVANIAN AND OLDER(?)

PENINSULAR TERRANE
Sedimentary and volcanic rocks

Km — Late and Early Cretaceous — CRETACEOUS
JTRt — Early Jurassic and Late Triassic(?) — JURASSIC AND TRIASSIC(?)

Plutonic rocks

Ji — Late Jurassic — JURASSIC
Jmp, Jum — Middle Jurassic and older(?) — JURASSIC AND OLDER(?)

CHUGACH TERRANE
Sedimentary and volcanic rocks

Kvv, Kvs, Mzm — Late Cretaceous — CRETACEOUS — MESOZOIC

Metamorphic rocks

TKm — TERTIARY OR CRETACEOUS
Jm — JURASSIC OR OLDER

PRINCE WILLIAM TERRANE
Sedimentary and volcanic rocks

Tov, Tos — Eocene and Paleocene — TERTIARY

DESCRIPTION OF MAP UNITS FOR MAPS A AND B

ALL TERRANES

Surficial deposits

Qs **Surficial deposits, undivided (Quaternary)**

Plutonic rocks

Th **Hypabyssal intrusive rocks (Eocene)**—Altered granite, granodiorite, or tonalite

WRANGELLIA TERRANE

Sedimentary and volcanic rocks

QTw **Wrangell Lava (Holocene to Miocene)**

Ks **Marine sedimentary rocks (Early Cretaceous)**—As mapped, consists of Berg Creek Formation and unnamed marine sedimentary rocks

JTRc **Marine clastic and carbonate rocks, undivided (Late or Middle Jurassic to Late Triassic)**—As mapped, consists of Kotsina Conglomerate (Middle or Late Jurassic), lower part of McCarthy Formation (Late Triassic), and Chitistone and Nizina Limestones (Late Triassic)

TRn **Nikolai Greenstone (Late and (or) Middle Triassic)**

PIPs **Skolai Group (Early Permian and Pennsylvanian)**

Plutonic rocks

Jc **Chitina Valley batholith (Late Jurassic)**

Metamorphic rocks

JIPhc **Haley Creek metamorphic assemblage (Late Jurassic and Pennsylvanian or older?)**—As mapped, consists of Uranatina River metaplutonic unit (Jurassic and Pennsylvanian) and Strelna Metamorphics of Plafker and others (1989a) (Early Pennsylvanian and older?)

PENINSULAR TERRANE

Sedimentary and volcanic rocks

Km **Matanuska Formation (Late and Early Cretaceous)**

JTRt **Talkeetna Formation (Early Jurassic and Late Triassic?)**

Plutonic rocks

Ji **Intrusive rocks (Late Jurassic)**—As mapped, consists of tonalite, granodiorite, and graphic granite

Jmp **Layered mafic plutonic rocks (Middle Jurassic and older?)**—As mapped, consists of the Nelchina River Gabbronorite (Middle Jurassic and older?), layered gabbro of the Tonsina ultramafic-mafic sequence, and layered quartz-bearing gabbro of Klanelneechena Creek

Jum **Ultramafic rocks (Middle Jurassic and older)**—As mapped, consists of harzburgite, dunite, and websterite of the Tonsina ultramafic-mafic sequence

CHUGACH TERRANE

Sedimentary and volcanic rocks

Valdez Group (Late Cretaceous)

Kvs **Sedimentary rocks**

Kvv **Mafic volcanic rocks**

Mzm **McHugh Complex (Mesozoic)**

Metamorphic rocks

TKm **Melange (Tertiary or Cretaceous)**

Jm **Greenschist and transitional blueschist facies metamorphic rocks (Jurassic or older)**—As mapped, consists of schist of Liberty Creek and schist of Iceberg Lake

PRINCE WILLIAM TERRANE

Sedimentary and volcanic rocks

Orca Group (Eocene and Paleocene)

Tos **Flyschoid sedimentary rocks**

Tov **Tholeiitic volcanic rocks**

g **Glaciers and superglacial moraine**

Contact—Approximately located. Dotted where concealed; queried where assumed

High-angle fault—Approximately located. Dotted where concealed; queried where assumed

Thrust fault—Approximately located. Sawteeth on upper plate. Dotted where concealed; queried where assumed

INCREASING LEVEL OF RESOURCE POTENTIAL →				
	U/A UNKNOWN POTENTIAL	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
		M/B MODERATE POTENTIAL	M/C MODERATE POTENTIAL	M/D MODERATE POTENTIAL
		L/B LOW POTENTIAL	L/C LOW POTENTIAL	L/D LOW POTENTIAL
				N/D NO POTENTIAL
	A	B	C	D
	INCREASING LEVEL OF CERTAINTY →			

RELATION BETWEEN LEVELS OF RESOURCE POTENTIAL AND CERTAINTY[1]

[1]Levels of certainty:
A Available information is not adequate for determination of the level of mineral resource potential.
B Available information only suggests the level of mineral resource potential.
C Available information gives a good indication of the level of mineral resource potential.
D Available information clearly defines the level of mineral resource potential.

EXPLANATION OF MINERAL RESOURCE POTENTIAL FOR MAP B

C-9 **Tracts favorable for undiscovered occurrences of mineral deposits of the specified types**—Number refers to tracts characterized in tables 2–5. **C**, massive sulfide deposits (see table 3); **M**, layered and podiform chromite deposits (see table 4); **N**, nickel-copper sulfide deposits (see table 4); **I**, porphyry copper-molybdenum deposits (see table 5)

H/B **Levels of resource potential and certainty**—See "Relation between levels of resource potential and certainty" diagram on this sheet

C16 **Location of known occurrence of massive sulfide deposit**—Number refers to site listed in table 3

M3 **Location of known occurrence of layered and podiform chromite deposit**—Number refers to site listed in table 4

N1 **Location of known occurrence of nickel-copper sulfide deposit**—Number refers to site listed in table 4

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MAPS SHOWING AREAS OF POTENTIAL FOR METALLIC MINERAL RESOURCES IN THE VALDEZ 1° x 3° QUADRANGLE, ALASKA

By
G.R. Winkler, R.J. Goldfarb, W.J. Pickthorn, and D.L. Campbell
1999

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FIGURES

TABLES

SUMMARY

Interpretation of geological, geochemical, geophysical, and mineral-deposit data has identified areas of metallic mineral-resource potential in the Valdez quadrangle, south-central Alaska, where undiscovered resources of precious, base, or ferrous metals are likely to occur. Nineteen areas, encompassing approximately 75 percent of the quadrangle, have potential for gold (±silver) in low-sulfide gold-quartz veins. Two areas underlain by rocks of the Valdez Group of the Chugach terrane (tracts G-1 and G-2) have mines with recorded production and have high potential for hosting additional gold resources; another area without mines (tract G-3) is presumed to have high potential also. Sixteen other areas underlain by the Valdez Group (tracts G-4 through G-19) are considered to have moderate or low potential. Three addtional areas in the Chugach terrane (tracts P-1 through P-3) have low potential for polymetallic veins, although no specific occurrences are known. Seven streams along the southern or eastern edges of the quadrangle have moderate potential for occurrences of placer gold (tracts PL-1 through PL-5 and PL-7 and PL-8), one stream (tract PL-6) has a high potential, and one stream (tract PL-9) has a low potential.

Several areas underlain by rocks of the Valdez Group also have potential for volcanogenic massive sulfide deposits. South of the town of Valdez, an area of high potential for copper resources (tract C-1) includes several mines near the head of Solomon Gulch that have recorded production and indicated reserves from Besshi-type deposits. Six other areas with moderate or low potential for the occurrence of Besshi- or Cyprus-type volcanogenic massive sulfide deposits have been identified within the Chugach terrane (tracts C-2 through C-7). North of the Border Ranges fault system, copper enrichments are known in several places in metavolcanic rocks of the southern margin of the Wrangellia terrane (tracts C-8 and C-10), the type Wrangellia terrane (tracts C-9, C-11, and C-12), and the Peninsular terrane (tracts C-13 and C-14). Tracts C-8 and C-9 have moderate potential for volcanogenic massive sulfide deposits; tracts C-10 through C-14 have low potential. Generally, these copper occurrences are small veins, pods, disseminations, and fracture coatings, either solitary or in closely spaced multiple occurrences. A few veins or pods are rich, but most contain only sparse or irregularly distributed metallic minerals. Although these copper deposits are likely to have formed syngenetically during Late Paleozoic or Early Jurassic arc-related submarine volcanism (deposits hosted by the Skolai Group or Talkeetna Formation, respectively), or during Late Triassic subaerial mafic volcanism (deposits hosted by the Nikolai Greenstone), a few deposits exhibit some hydrothermal remobilization. This may be related to Late Jurassic plutonism that produced numerous mesozonal intrusions known collectively as the Chitina Valley batholith. Along the eastern edge of the quadrangle near Copper Creek (tract C-9), a few small discordant lodes in the Upper Triassic Chitistone Limestone may be of the same type as the stratabound Kennecott-type deposits in the McCarthy quadrangle to the east.

Areas of potential for chromium and nickel resources are associated with mafic and ultramafic rocks in the Peninsular and southern margin of the Wrangellia terranes. In the Bernard Mountain area east of Tonsina, outcrops of layered dunite and tectonized harzburgite contain chromite-rich layers as much as several meters thick. Inferred total resources in this area of high potential (tract M-1) exceed 440,000 tons of ore at 5–11 percent Cr_2O_3, and constitute a significant resource of chromium. Several nearby areas of moderate potential for chromium and nickel resources in tectonized ultramafic bodies also have been identified (tract M-2), and a low potential exists for magmatic sulfide deposits enriched in nickel and copper in overlying layered gabbroic rocks (tract N-3). East of Tonsina in the Spirit Mountain area, a tract (N-1) has high potential for nickel and associated copper and platinum resources. At the Spirit Mountain prospect, massive and disseminated sulfide minerals occur in small mafic and ultramafic sills; the occurrences contain as much as 7.6 percent Ni. Inferred resources total about 6,500 tons averaging 0.7 percent Ni. In the northwestern part of the Valdez quadrangle, a moderate potential for chromium resources exists in an area south of the Border Ranges fault between Nelchina and Tazlina Glaciers (tract M-3). Areas of moderate and low potential for nickel resources, respectively, occur in nearby layered mafic intrusions along Klanelneechena Creek (tract N-2) and north of the Border Ranges fault (tract N-4).

INTRODUCTION

This report is one of a series of maps and reports produced as part of the U.S. Geological Survey's Alaska Mineral Resource Assessment Program (AMRAP) investigations of the geologic setting for metallic mineral resources in the Valdez 1° x 3° quadrangle, south-central Alaska. Other AMRAP products for the quadrangle summarize bedrock and surficial geology, geochronology, aeromagnetic and satellite imagery, and known mineral-resource occurrences, and provide the data from reconnaissance geochemical studies; references are provided in Winkler and others (1992), which also includes brief synopses of each product and related background investigations. The current report is principally based on information presented in earlier AMRAP reports, but also draws on addtional older sources of information on mineral-resource occurrences in the quadrangle. Many older sources are incomplete and do not provide sufficient information for accurate determination of mineral deposit types; however, these sources do provide valuable historic information on early exploration and production.

The purpose of this report is to delineate the boundaries of tracts that are considered to be favorable for the occurrence of undiscovered metallic mineral resources in the Valdez quadrangle, based on interpretation of available geological, geochemical, and geophysical data. The maps and accompanying text and tables synthesize information on known mines, prospects, and occurrences, mapped geologic units and structures, and geochemical and geophysical anomalies that may indicate metal concentrations. Two maps outline tracts with characteristics that favor the occurrences of specific types of mineral deposits: map A shows resource tracts for precious- and base-metal vein deposits and for gold placers; map B shows resource tracts for base and ferrous metals in volcanic- and intrusive-related deposits. In characterizing mineral deposit types, we generally follow the descriptive classifications of Cox and Singer (1986) or Bliss (1992). In the case of the Kennecott-type copper deposits, we follow the characteristics described by MacKevett and others (1997). This report should be used in conjunction with the report by Goldfarb and others (1995), which provides a concise summary of known mineral resources in the quadrangle and outlines areas of mineral-resource favorability based on the presence of geochemcally anomalous samples.

AREA DESCRIPTION

The Valdez quadrangle (fig. 1) includes an area of approximately 18,000 km^2 of south-central Alaska bounded by the 61° and 62° North parallels and by the 144° and 147° West meridans. Much of the quadrangle is mountainous: the central and southern parts are dominated by the rugged and glaciated Chugach Mountains and the northeastern part by the flanks of the lofty Wrangell Mountains, including much of the broad volcanic shield of Mt. Wrangell. The lowlands of the Copper River Basin occupy the northern part of the quadrangle. Transecting the lowlands and the Chugach Mountains from north to south is the Copper River, which is joined by a major tributary, the Chitina River, near the east-central edge of the quadrangle. Total relief in the quadrangle is 4,252 m from the summit of Mt. Wrangell in the northeast corner to sea level in Valdez Arm and Port Valdez in the southwest corner. The southwest corner is included within the Chugach National Forest and the area east of the Copper River is included within the Wrangell-St. Elias National Park and Preserve.

Road access to the Valdez quadrangle is limited. The Richardson Highway passes through the center of of the quadrangle from Copper Center to Valdez, and the Glenn Highway passes through the far northwestern corner. Valdez is the largest town in the quadrangle, with a 1990 population of 4,635. Copper Center is the only other town in the quadrangle; its 1990 population was 449. Parts of the east side of the quadrangle are accessible from the Edgerton Highway, which heads east from the Richardson Highway to the settlements of Kenney Lake, Lower Tonsina, and Chitina, and by the Chitina to McCarthy gravel road, which crosses the Copper River by a bridge at Chitina and extends eastward into the Wrangell-St. Elias National Park and Preserve. Port Valdez, the southern terminus of the trans-Alaska oil pipeline, is accessible by ship from Prince William Sound. The Valdez airport is served by commercial air service and there are numerous other air fields and bush airstrips in the quadrangle, most of them minimally improved and served only by charter operations. Widely scattered lakes, mostly in the Copper River Basin, may be reached by aircraft on floats. Due to the rugged, steep, glaciated terrain in much of the remainder of the quadrangle, it generally is accessible only on foot or by helicopter.

BACKGROUND STUDIES

GEOLOGIC MAPPING

The earliest published geologic observations covering parts of the Valdez quadrangle are from the late 1800's in reports from U.S. Army expeditions to explore the valleys of the Copper and Chitina Rivers. During the early 1900's, as exploration for mineral resources began to spread from Prince William Sound into the interior of Alaska, many reports included geologic observations or maps of local areas within the quadrangle. However, it was not until 1981, as part of AMRAP, that the first regional geologic map of the entire Valdez quadrangle (scale 1:250,000) was completed (Winkler and others, 1981b). Subsequently, as part of the USGS Trans-Alaska Crustal Transect (TACT) project, a more detailed geologic map of a north-south tier of quadrangles (scale 1:125,000) was completed in the vicinity of part of the Richardson Highway (Plafker and others, 1989a). Companion TACT reports provided tectonic (Plafker and others, 1989b) and structural (Nokleberg and others, 1989) syntheses, including detailed descriptions of the four lithotectonic terranes that make up the Valdez quadrangle—the Wrangellia, Peninsular, Chugach, and Prince William terranes (figs. 1, 2). Regional geologic mapping in the adjacent Anchorage 1° x 3° quadrangle (Winkler, 1992) clarified relations between terranes and characterized rocks at deep structural levels within the Peninsular terrane. These maps and studies provide integrated information regarding the geologic setting of the Valdez quadrangle; most of the subsequent descriptions of the quadrangle's geology are derived from these publications, and a simplified geologic map, also derived from them, is used as a base for maps A and B. A comprehensive bibliography of geologic investigations in the Valdez quadrangle is included in Winkler and others (1992).

GEOCHEMICAL STUDIES

Geochemical investigations in the Valdez quadrangle have derived analytical results primarily from reconnaissance stream-sediment and bedrock sampling, with more detailed results available for just a few areas. In a study of volcanogenic massive sulfide mineral deposits southeast of Valdez, Rose (1965) reported results of analyses for 18 sulfide-bearing rock samples and about 80 samples of stream sedment. Jasper (1967) collected 102 stream-sedment and panned-concentrates samples for analysis and visual examination from sites along

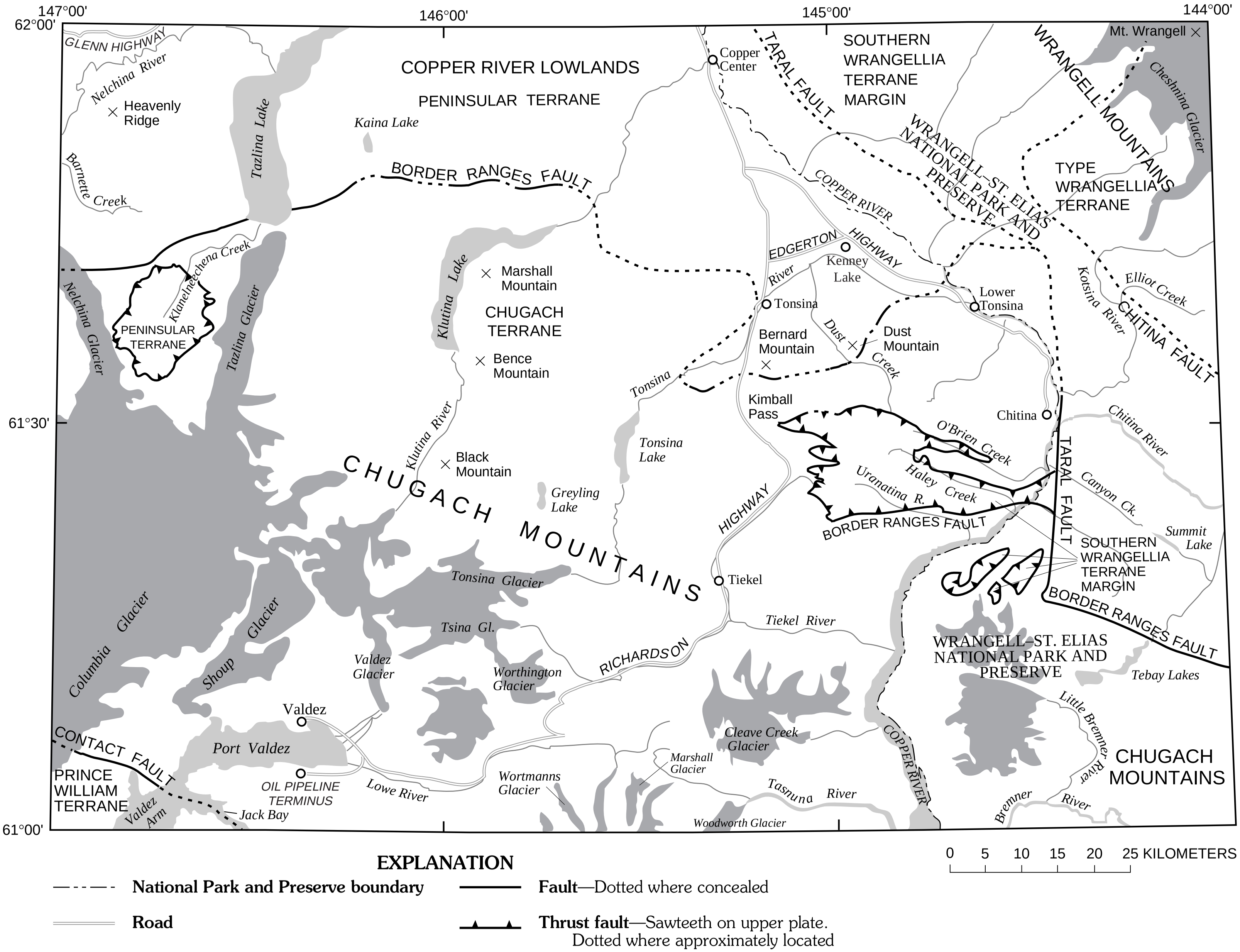
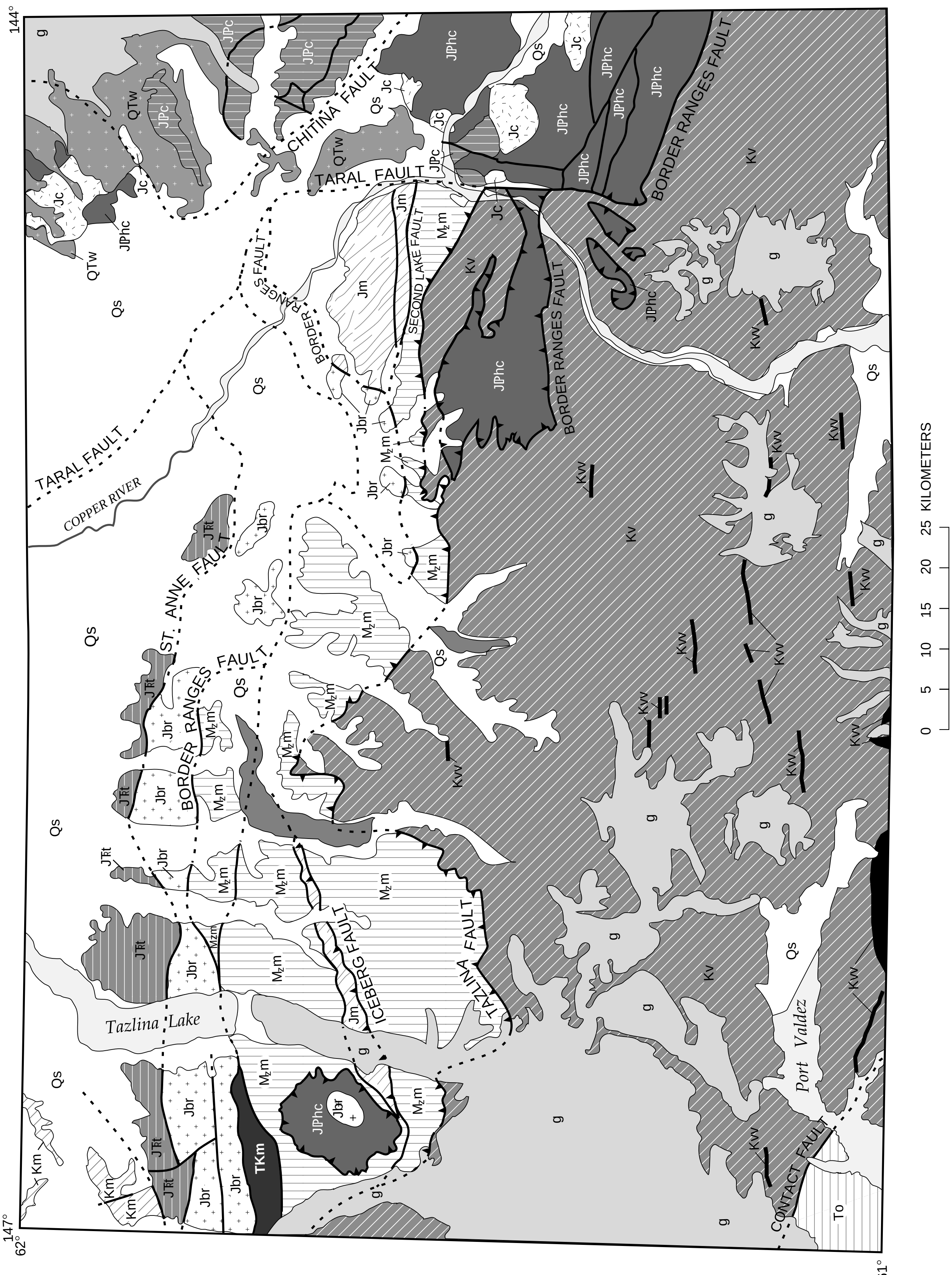


Figure 1. Major physiographic and cultural features and lithotectonic terranes of the Valdez 1°x3° quadrangle, Alaska. The quadrangle is underlain by rocks of the Wrangellia, Peninsular, Chugach, and Prince William terranes. The Wrangellia terrane is subdivided into the type Wrangellia terrane and the southern Wrangellia terrane margin.


144°
62°
147°
61°
TARAL FAULT
CHITINA FAULT
BORDER RANGES FAULT
SECOND LAKE FAULT
ST. ANNE FAULT
ICEBERG FAULT
TAZLINA FAULT
CONTACT FAULT
COPPER RIVER
Tazlina Lake
Port Valdez
0 5 10 15 20 25 KILOMETERS
Qs
QTw
JPc
JPhc
Jc
Jm
Jbr
Mzm
Kv
Kvv
g
TKm
Km
To

EXPLANATION

g — **Glaciers and superglacial moraine**

Qs — **Surficial deposits, undivided (Quaternary)**

WRANGELLIA TERRANE

QTw — **Wrangell Lava (Holocene to Miocene)**

Jc — **Chitina Valley batholith (Late Jurassic)**

JIPhc — **Haley Creek metamorphic assemblage (Late Jurassic and Pennsylvanian and older?)**

PENINSULAR TERRANE

Km — **Matanuska Formation (Cretaceous)**

Jbr — **Border Ranges ultramafic-mafic assemblage (Middle Jurassic)**

JTRt — **Talkeetna Formation (Early Jurassic and Late Triassic?)**

CHUGACH TERRANE

TKm — **Melange (Tertiary or Cretaceous)**

Valdez Group (Late Cretaceous)

Kv — **Sedimentary rocks**

Kvv — **Volcanic rocks**

MZm — **McHugh Complex (Mesozoic)**

Jm — **Greenschist and transitional blueschist facies metamorphic rocks (Jurassic or older)**—As mapped includes schist of Liberty Creek and schist of Iceberg Lake

PRINCE WILLIAM TERRANE

To — **Orca Group (Eocene and Paleocene)**—Flyschoid sedimentary and tholeiitic volcanic rocks

Contact

Fault—Dotted where approximately located

Thrust fault—Sawteeth on upper plate. Dotted where approximately located

Figure 2. Generalized geology of the Valdez 1°x3° quadrangle, Alaska. Modified from Winkler and others (1981b), Plafker and others (1989a, b), and Nokleberg and others (1989).

the Richardson and Edgerton Highways. Stream-sediment, lake-sediment, and water samples were collected from sites across most of the Valdez quadrangle by the Los Alamos National Laboratory for the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) program (Sharp and Hill, 1978; D'Andrea and others, 1981; Los Alamos National Laboratory, 1983). Detailed stream-sediment sampling in the vicinity of the Spirit Mountain nickel-copper prospect and stream-sediment and concentrate sampling around Bernard Mountain were performed by Herreid (1970) and Sutley and others (1990), respectively. Stream-sedment and concentrate samples were collected from 98 sites in the southern part of the quadrangle as part of the Chugach National Forest RARE II studies (Goldfarb and others, 1984). The most comprehensive geochemical study was conducted in conjunction with the AMRAP project, and included bedrock, stream-sediment, and heavy-mineral-concentrate sampling and analysis from throughout the quadrangle (Miller and others, 1982). Statistical analyses of all these data and descriptions of geochemical anomalies in the Valdez quadrangle were completed by Goldfarb and others (1995)—the principal source of geochemical interpretation for this report. Goldfarb and others (1995) delineated 31 areas defined by the presence of geochemical anomalies for various suites of elements that characterize particular mineral deposit types. Most of those areas are included within the tracts of mineral-resource potential described in later sections of this report.

GEOPHYSICAL STUDIES

Shallow crustal geophysical investigations of the Valdez quadrangle have been mostly reconnaissance in scope. Regional contouring of gravity data for the entire Valdez quadrangle is included in a 1:2,500,000-scale Bouguer gravity map of the State of Alaska (Barnes, 1977), and more detailed data have been collected, contoured, and interpreted for the southern one-third of the quadrangle in the area of Chugach National Forest (Barnes and Morin, 1990). During regional studies of the Copper River Basin, an aeromagnetic survey was flown over the northern part of the Valdez quadrangle in 1954 and 1955 (Andreason and others, 1958), and the remainder of the quadrangle was flown in 1978 in conjunction with the AMRAP project. From these two surveys, Case and others (1986) published an interpretation of the aeromagnetics for the entire quadrangle. Other interpretations of aeromagnetic data from parts of the quadrangle have been published separately (Andreason and others, 1964; Burns, 1982; Plafker and others, 1989b). Case and others (1986) found that the regional magnetic highs characteristically produced by particular bodies of rocks constituted indirect exploration guides for some types of mineral deposits—particularly in areas where bedrock is covered by unconsoldated deposits, glaciers, or bodies of water. For example, high-amplitude aeromagnetically postive features coincide with layered mafic and ultramafic igneous rocks that extend nearly the full width of the northern part of the quadrangle. These rocks locally host magmatic enrichments of nickel, chromium, copper, and platinum-group elements (see subsequent sections); even where the rocks are deeply covered, their presence is substantiated by the aeromagnetic data.

In the 1980's, geophysical investigations of the deep crustal structure of southern Alaska along the southern part of the TACT corridor provided abundant data on earthquake seismicity (Page and others, 1989), seismic reflection (Fisher and others, 1989) and refraction (Fuis and others, 1989), and aeromagnetic and gravity fields (Campbell, 1991). The combined data show that the upper crust beneath the Valdez quadrangle consists of sheets less than 10 km thick of rocks from the Chugach, Wrangellia, and Peninsular terranes underlain by north-dipping thrust faults. Undulating reflectors at depths between about 6 and 10 km are inferred by Fuis and Plafker (1991) to be tonalitic plutons, sources for the dikes and sills exposed in the Chugach terrane at the land surface above that apparently are concentrated in areas where low-sulfide gold-quartz vein deposits formed.

LANDSAT IMAGERY

As part of the AMRAP project, Landsat images of the Valdez quadrangle were evaluated to identify lineaments and circular and arcuate features as possible aids to locating mineral-resource occurrences. Although many linear, arcuate, and circular features were observed, there apparently is no consistent correlation between them and areas of known mineral occurrences (Le Compte, 1981) or areas thought to have potential.

MINES, PROSPECTS, AND MINERAL OCCURRENCES

Data from known mines, prospects, and mineral occurrences (fig. 3) were gathered from several compilations on mining and prospecting in the Valdez quadrangle, most notably Cobb (1979) and Jansons and others (1984). Cobb (1979) compiled all published references to mines, prospects, and mineral occurrences in the quadrangle, listing each by name with a brief synopsis of the geology and mining history, if available. Jansons and others (1984) compiled mineral occurrences in the Chugach National Forest, including the southern part of the Valdez quadrangle, and included contemporary information on mining claims filed with the Bureau of Land Management (BLM) and assessment studies by the former U.S. Bureau of Mines. Additional descriptions of mines and prospects in the Valdez quadrangle are found in Cobb and Matson (1972), MacKevett and Holloway (1977), and Winkler and others (1981a). The latter report also provided a preliminary analysis of general mineral deposit types in the quadrangle.

GEOLOGIC SETTING FOR MINERAL RESOURCES

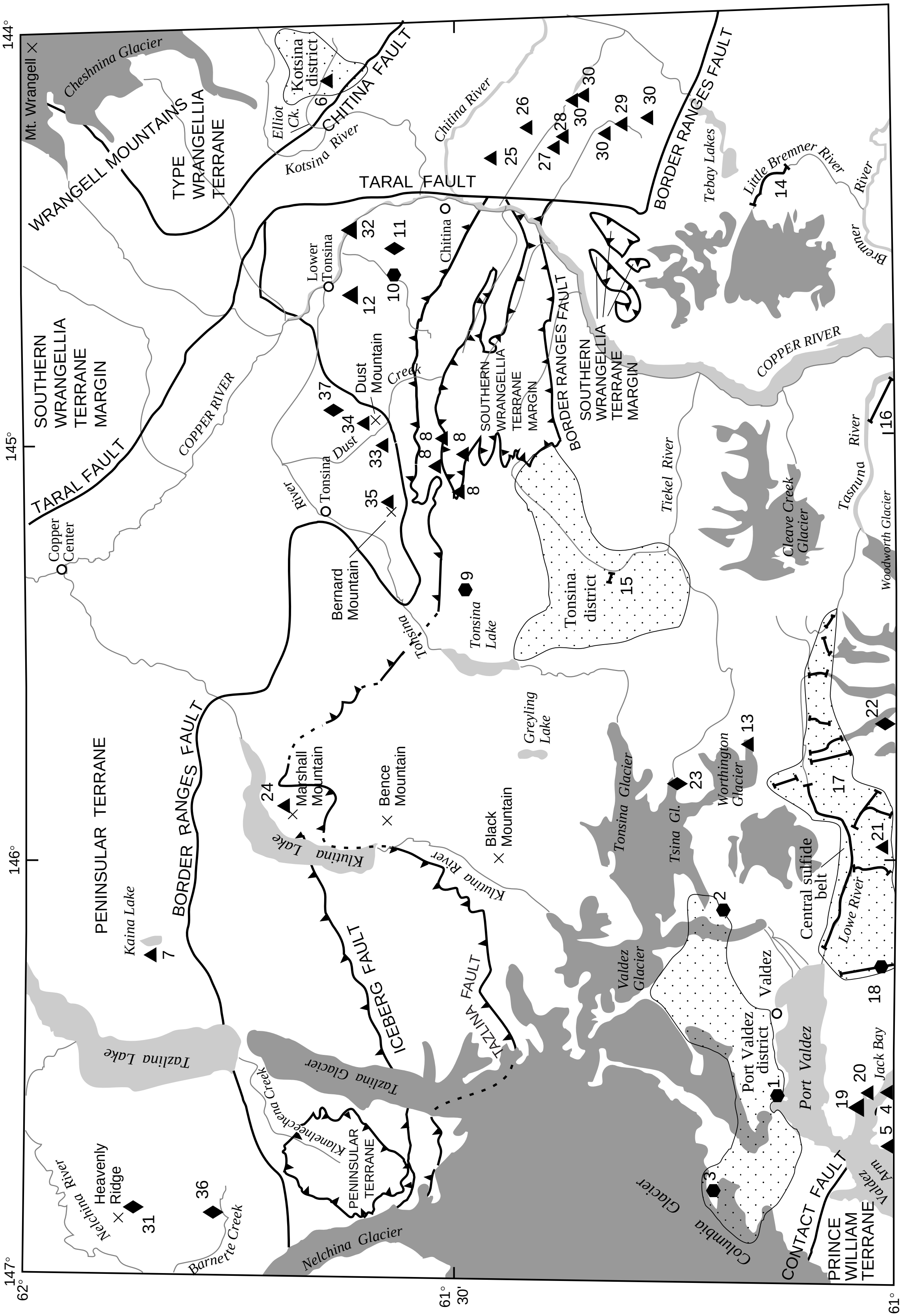
The Valdez quadrangle is underlain by four distinctive, fault-bounded lithotectonic terranes of contrasting stratigraphy, age, and structural and metamorphic style. Each terrane also has associated with it a characteristic suite of mineral commodities and types of mineral deposits. From north to south, the terranes are the Wrangellia, Peninsular, Chugach, and Prince William terranes (figs. 1, 2). The Wrangellia composite terrane, consisting of the late Paleozoic or older amalgam of the Wrangellia and Peninsular terranes (Plafker, 1987), was accreted to the south-central Alaska margin by mid-Cretaceous time (Csejtey and others, 1982; Hillhouse and Grommé, 1984). Accretion and underplating of the Chugach terrane against the backstop of the Wrangellia composite terrane probably occurred during much or all of Jurassic and Cretaceous time (Plafker, 1987; Plafker and others, 1989b, 1994), and the Prince William terrane was accreted by about 51 Ma (Plafker, 1987). Together the Chugach and Prince William terranes form the Southern Margin composite terrane (Plafker, 1990), one of the largest subduction-related accretionary complexes in the world (Plafker and others, 1994). Subsequent to accretion, all four terranes were intruded by Eocene felsic to intermediate dikes, sills, and small stocks. In the northeastern part of the quadrangle, Miocene and younger andesitic lavas were extruded on the Wrangellia terrane, and summit craters on the Mt. Wrangell shield volcano contain active fumaroles and also occasionally emit ash.

WRANGELLIA TERRANE

The Wrangellia terrane (Jones and others, 1977) underlies the northeastern part of the Valdez quadrangle and is bounded on the south by the Border Ranges fault system and on the west by the Taral fault (fig. 2). The Wrangellia terrane is divided into two distinct domains separated by the Chitina fault. The southern domain, called the southern Wrangellia terrane (Plafker and others, 1989b), consists of Early Pennsylvanian to Jurassic plutonic and andesitic island arc rocks and Early Pennsylvanian to Permian sedimentary and submarine volcanic rocks, all of which have been penetratively deformed and metamorphosed to greenschist to lower amphibolite facies. These metamorphic rocks, for which various names have been used locally, are grouped into the Haley Creek metamorphic assemblage. North of the Chitina fault are rocks of the type Wrangellia terrane: nearly unmetamorphosed Upper Paleozoic andesites and plutonic rocks and Mesozoic rift-fill tholeiitic basalts and shallow-marine calcareous and argillaceous sedimentary rocks. The most characteristic rocks of the type Wrangellia terrane are the Triassic Nikolai Greenstone and Chitistone Limestone—host rocks for numerous copper-rich mineral deposits, including the Kennecott-type (discussed below). The Upper Paleozoic rocks also host copper-rich volcanogenic deposits—occurrences that are much smaller than those hosted in the Mesozoic rocks that typify Wrangellia. Prior to accretion of the Chugach terrane along the southern margin of Wrangellia, Upper Jurassic quartz monzodiorite, quartz diorite, tonalite, and granodiorite of the Chitina Valley batholith intruded the Wrangellia terrane, remobilizing pre-existing copper deposits in the older rocks. The Jurassic plutons generally are intermediate to mafic in composition; although they locally are weakly enriched in molybdenum and copper, they apparently are eroded below the level at which mineralized porphyry systems might have existed. Unconformably overlying the Wrangellia rocks in the Valdez quadrangle are Holocene and Pleistocene flows and pyroclastic rocks of the Wrangell Lava, which are predominantly andesitic in composition, issued from the shield volcano of Mt. Wrangell (D.H. Richter, *in* Miller and Richter, 1994). No hydrothermal deposits are assocated with these Neogene volcanic rocks.

PENINSULAR TERRANE

Along the northern edge of the Valdez quadrangle, west of and separated from the Wrangellia terrane by the Taral fault and bounded on the south by the Border Ranges fault, is the Peninsular terrane (fig. 2). Within the quadrangle, the Peninsular terrane consists predominantly of the extrusive and intrusive phases of a Late Triassic to Middle Jurassic intraoceanic magmatic arc (Barker and Grantz, 1982; Burns, 1985; DeBari and Coleman, 1989). The extrusive rocks include bedded basaltic, andesitic, and dacitic tuffaceous rocks, flows, shallow intrusions, and volcanogenic sedimentary rocks of the Talkeetna Formation. Although rocks representing relatively shallow intrusive and extrusive levels of the Talkeetna magmatic arc are widely exposed, only a few small metal-bearing volcanogenic sulfide occurrences and associated hydrothermal veins and breccias are known to occur in this part of the quadrangle; no major porphyry systems have been discovered. The roots of the magmatic arc are exposed along the southern edge of the Peninsular terrane along the Border Ranges fault as a belt of mafic and ultramafic plutonic rocks, informally named the Border Ranges ultramafic-mafic assemblage (Hudson, 1983; Burns, 1985; DeBari and Coleman, 1989). The plutonic assemblage extends across the entire southern boundary of the Peninsular terrane and consists principally of layered gabbronorite, perdotite, and dunite. Magmatic enrichments of chromium, copper, nickel, and platinum-group elements are associated with the deep-seated ultramafic-mafic assemblage at several places. A klippe of metamorphosed Peninsular terrane, consisting of Jurassic amphibolite, orthogneiss, and layered gabbro, is found south of the Border Ranges fault in the Chugach terrane, between the Tazlina and Nelchina Glaciers (fig. 2). Cretaceous clastic sedimentary rocks deposited in a fore-arc basin, the Matanuska Formation, crop out in the extreme northwest corner of the quadrangle.



Mt. Wrangell
Cheshnina Glacier
WRANGELL MOUNTAINS
TYPE WRANGELLIA TERRANE
Kotsina district
CHITINA FAULT
Elliot Ck.
Kotsina River
Chitina River
TARAL FAULT
BORDER RANGES FAULT
Tebay Lakes
Little Bremner River
Bremner River
Lower Tonsina
Chitina
SOUTHERN WRANGELLIA TERRANE MARGIN
COPPER RIVER
Dust Mountain
Dust Creek
Tonsina River
Tonsina
Copper Center
Bernard Mountain
Tonsina Lake
Tonsina district
Tiekel River
Cleave Creek Glacier
Tasnuna River
Woodworth Glacier
25 KILOMETERS
0 5 10 15 20 25
PENINSULAR TERRANE
Kaina Lake
Marshall Mountain
Bence Mountain
Black Mountain
Greyling Lake
Klutina Lake
Klutina River
ICEBERG FAULT
TAZLINA FAULT
Tazlina Lake
Tazlina Glacier
Klanelneechena Creek
Tonsina Glacier
Tsina Gl.
Worthington Glacier
Central sulfide belt
Lowe River
Valdez Glacier
Valdez
Port Valdez district
Port Valdez
Jack Bay
Valdez Arm
Columbia Glacier
CONTACT FAULT
PRINCE WILLIAM TERRANE
Nelchina Glacier
Nelchina River
Heavenly Ridge
Barnette Creek
144°
145°
146°
147°
62°
61° 30'
61°

EXPLANATION

Mine—Identified by number

Prospect—Identified by number

Occurrence—Identified by number

Placer—Identified by number

Mining district—Area includes numerous mines and prospects

Glaciers and superglacial moraine

Fault—Approximately located

Thrust fault—Approximately located. Sawteeth on upper plate

Mines, prospects, and occurrences

1 Cliff mine
2 Ramsey-Rutherford mine
3 Gold King mine
4 Orion prospect
5 Curly-Kidney prospect
6 Benito Creek prospect
7 Kaina Lake prospect
8 Kimball Pass prospects
9 Quartz Creek mine
10 Opal mine
11 Fivemile Creek occurrence
12 Hundell Creek prospect
13 Worthington Glacier prospect
14 Little Bremner River placer
15 Boulder Creek placer
16 Tasnuna River placer
17 Unnamed placers in central sulfide belt.
18 Midas mine
19 Jack Bay copper prospect
20 Jack Bay prospect
21 Addison-Powell prospect
22 Wortmann Glacier occurrence
23 Tsina Glacier occurrence
24 Marshall Mountain prospect
25 Blackney prospect
26 Surprise prospect
27 Divide Creek prospect
28 Falls Creek prospect
29 Spirit Mountain prospect
30 Summit Lake prospects
31 Heavenly Ridge occurrence
32 Liberty Falls prospect
33 Sheep Hill prospect
34 Dust Mountain prospect
35 Bernard Mountain prospect
36 Barnette Creek occurrence
37 Scarp occurrence

Figure 3. Metallic mines, prospects, and occurrences in the Valdez 1°x3° quadrangle, Alaska. These mostly consist of small gold-bearing quartz veins. They also include placer gold; copper sulfide-dominant volcanogenic, magmatic, and Kennecott-type deposits; and podiform chromite mines, prospects and (or) occurrences.

CHUGACH TERRANE

The Chugach terrane, which forms most of the remaining southern two-thirds of the Valdez quadrangle, is separated from the Wrangellia and Peninsular terranes by the Border Ranges fault system. The Chugach terrane consists of three major fault-bounded sequences (fig. 2). From north to south, they include: (1) Jurassic and older greenschist and blueschist of the informally named schists of Liberty Creek and Iceberg Lake; (2) Upper Triassic to Lower Cretaceous melange and broken formation of the McHugh Complex; and (3) Upper Cretaceous flysch and oceanic basaltic rocks of the Valdez Group.

The schist of Liberty Creek forms a belt 28 km long along the northern margin of the Chugach terrane between Dust Creek and the Copper River. This unit is intensely deformed and consists of greenschist and minor blueschist. Relict textures and geochemistry suggest that it originally was an oceanic assemblage of basalt flows, breccias, and tuffs, and minor sedimentary rocks, which may have orignated as the subduction assemblage related to magmatism in the Talkeetna arc (Plafker and others, 1989b, 1994). A fault-bounded slab of greenschist and blueshist 40 km long by as much as 2 km wide (the schist of Iceberg Lake) is enclosed within the McHugh Complex along the Iceberg fault between Klutina Lake and Nelchina Glacier (Winkler and others, 1981b).

Faulted against the schist of Liberty Creek along the Second Lake fault or against the Border Ranges ultramafic-mafic assemblage along the Border Ranges fault is the McHugh Complex, a structurally-dismembered melange and broken formation composed predominantly of tholeiitic pillowed basalt and fragmental mafic volcanic rocks, with less abundant pelitic sedmentary rocks, radiolarian chert, and carbonate units. Locally, the McHugh Complex contains olistostromal blocks derived from the Wrangellia and Peninsular terranes, with which it now is tectonically juxtaposed. Rocks of the McHugh Complex generally are metamorphosed to prehnite-pumpellyite facies. They are interpreted to have formed by sedimentary and structural mixing of oceanic and arc-derived rocks during Jurassic and Cretaceous convergence between an oceanic plate and the southern margin of the Wrangellia-Peninsular composite terrane.

The third and most widespread unit of the Chugach terrane consists of flysch and tholeiitic basalt of the Upper Cretaceous Valdez Group. The flysch facies consists of an extremely thick and lithologically montonous sequence of interbedded argillite, siltstone, sandstone, and conglomeratic sandstone. The minor basalt facies, which is exposed principally along the southern edge of the quadrangle, consists of pillow basalt, pillow breccia, and aquagene mafic tuff. These metavolcanic rocks commonly contain lenses of massive to disseminated pyrite, pyrrhotite, chalcopyrite, cubanite, and sphalerite (Winkler and others, 1981a)—volcanogenic sulfide deposits of the Besshi- and Cyprus-types. In the Valdez quadrangle, the Valdez Group is highly deformed and regionally metamorphosed to greenschist facies. Metamorphic grade increases eastward, culminating in the Cordova and Bering Glacier 1° x 3° quadrangles in a schist and gneiss complex cored by migmatite and anatectic plutons. The metamorphism and plutonism are Eocene in age (Hudson and others, 1979; Hudson and Plafker, 1982) and occurred during accretion of the Valdez Group against the melange to the north. In the Valdez quadrangle, this regional high-temperature, low-pressure thermal event is manifested by felsic to intermediate dikes, sills, and plugs that are present throughout the Chugach terrane, but are particularly common in the Valdez Group. Mesothermal or low-sulfide gold-quartz veins are equally widespread in the greenschist facies metasedimentary rocks and are associated with the hypabyssal intrusions in many places in the Chugach terrane (Goldfarb and others, 1986; Goldfarb, 1989).

PRINCE WILLIAM TERRANE

Rocks of the Prince William terrane, which crop out in the southwest corner of the Valdez quadrangle, are a Paleogene accretionary assemblage, which has been strongly deformed and underplated against the Valdez Group along the Contact fault system (fig. 2). These Paleogene rocks, the Orca Group, consist principally of low-grade metamorphosed flysch—argillite, siltstone, and conglomerate—which were deposited in deep-sea fans adjacent to a convergent continental margin (Winkler and Plafker, 1993). Tholeiitic basalt, pillow breccia, and mnor mafic tuff commonly are interbedded with the sedimentary rocks. In the Valdez quadrangle, these mafic volcanic sequences are relatively thin, but to the south and southwest, in the Cordova and Seward quadrangles, they are voluminous and form—at Knight Island in western Prince William Sound—a complete ophiolitic sequence with sheeted dikes, intrusive gabbro, and sheared ultramafic rocks (Richter, 1965; Tysdal and Case, 1979; Nelson and others, 1985). At Rua Cove on Knight Island in the Seward quadrangle, and in the vicinity of Ellamar and Landlocked Bay in the Cordova quadrangle, the ophiolitic rocks and interbedded argillaceous sequences enclose volcanogenic massive sulfide deposits of the Cyprus- and Besshi-types, which have had large past production of copper and contain significant unmined resources (Nelson and others, 1984). No similar occurrences are known in rocks of the Orca Group in the Valdez quadrangle, however.

RESOURCE ASSESSMENT METHODS

This assessment reviews known metalliferous mineral deposits and evaluates the potential for undiscovered deposits by describing and classifying the types of mineral deposits present and delineating areas likely to contain additional undiscovered deposits of the classified types. Known and potential mineral deposits in the Valdez quadrangle are classified according to eight descriptive mineral deposit models, as shown on table 1. Most exploration and much small-scale mining took place in the Valdez

Table 1. *Classification of mineral deposit types for the Valdez 1° x 3° quadrangle, Alaska*

[Known mineral deposit types are those present in the quadrangle, which—in most cases—have been mined or thoroughly prospected. Postulated mineral deposit types are those that are not known to occur within the quadrangle, but for which geologic features or geochemical anomalies commonly associated with the deposit type are present]

KNOWN MINERAL DEPOSIT TYPES	
Vein deposits:	
	Low-sulfide, gold-quartz veins (precious-metal veins)
Massive sulfide deposits:	
	Volcanogenic massive sulfide deposits
	Kennecott-type deposits
Magmatic deposits:	
	Layered and podiform chromite deposits
	Nickel-copper sulfide deposits
Placer deposits:	
	Precious-metal placers
POSTULATED MINERAL DEPOSIT TYPES	
Vein deposits:	
	Polymetallic veins (base- and precious-metal veins)
Stockwork deposits:	
	Porphyry copper-molybdenum stockworks and veins

quadrangle between the late 1890's and circa 1920. For that time, the surface prospecting was relatively thorough, but little information was published, and production data seldom were made available. Reported descriptions of claims and operations are brief, imprecise, and qualitative. There has been no major mining and very little modern exploration in the quadrangle. Given these serious limitations in available information, our assignments of mineral deposit model types are tenuous and general. Nonetheless, we have identified tracts whose characteristics are favorable for additional occurrences of the eight types. Since our model types are so poorly constrained by available information, we do not make distinctions between less favorable (or "permissive") and more favorable (or "prospective") tracts, nor do we estimate numbers of undiscovered deposits. The tracts we delineate may be a hybrid of the "permissive" and "prospective" concepts, and with so little data, there is no rigorous way to distinguish them, nor to produce a quantitative estimation.

The resulting areas of mineral-resource potential are shown on maps A and B, and levels of resource potential and certainty are assigned to each of the tracts. All known occurrences within the mapped tracts are characterized on tables 2 through 5 (tables 2–5 begin on p. 26 of this pamphlet).

In our assignments, we conform to tradtional definitions of mineral-resource potential and certainty (Taylor and Steven, 1983). **High** mineral-resource potential exists where geologic, geochemical, and geophysical characteristics favorable for resource accumulation are known to be present, or where enough of these characteristics are present to give strong evidence that mineral concentration has taken place. (These conditions normally are met in tracts that enclose known mineral occurrences of the specified types.) **Moderate** mineral-resource potential exists where geologic, geochemical, or geophysical characteristics favorable for resource accumulation are known or can be reasonably inferred to be present, but where evidence of specific mineral concentration is less certain. **Low** mineral-resource potential exists in areas where geologic, geochemical, or geophysical characteristics permit deposits of a classified type to be present, but where no evidence of mineral concentration is present. The certainty of the assigned level is based on the availability and reliability of relevant information, which ranges from clearly defining the level of mineral-resource potential (certainty level **D**)—a condition met in very few cases in the Valdez quadrangle—to inadequate or unavailable information on potential mineral resources (level **A**). Intermediate levels of certainty, **C** and **B**, indicate that good or suggestive information, respectively, is available to assign a likelihood of mineral-resource occurrences. Implicit within our use of these defintions is the assumption that any occurrences that are found will conform to the sizes and grades of other known deposits of the classified type, where such a grade-tonnage model has been developed.

The following sections of the report discuss examples of each deposit type in the quadrangle, briefly elaborating characteristics that are likely to make nearby areas of the quadrangle prospective for additional as-yet undiscovered occurrences.

KNOWN MINERAL DEPOSIT TYPES

VEIN DEPOSITS

Low-sulfide gold-quartz veins (precious-metal veins) (table 2; map A)

Lode gold deposits are widespread in the Valdez quadrangle, with gold occurrences having been found in all four lithotectonic terranes (map A).

However, most gold occurrences are present in the lower to middle greenschist facies rocks of the Valdez Group. In quadrangles adjacent to the Valdez quadrangle, gold-producing districts also are located in Valdez Group rocks: the Girdwood district (Anchorage quadrangle) (Park, 1933); Port Wells, Hope-Sunrise, and Moose Pass districts (Seward quadrangle) (Johnson, 1914, 1915; Tuck, 1933); and Nuka Bay district (Seldovia quadrangle) (Richter, 1970). An estimated 132,400 ounces (oz) of gold have been produced from lode deposits in these quadrangles, including 61,646 oz from the Valdez quadrangle (Jansons and others, 1984). All known lode precious-metal production in the Valdez quadrangle has come from rocks of the Valdez Group, mostly from a few large gold-quartz vein systems mined near Valdez—the Cliff, Ramsey-Rutherford, and Gold King mines (Johnson, 1915). The Cliff mine (tract G-1, site G44) produced more than twice as much lode gold as any other mine in the Prince William Sound area—51,740 oz, as well as 8,153 oz Ag. In the Port Valdez district (fig. 3), the Ramsey-Rutherford (site G27) was second, having produced 5,375 oz Au and 1,194 oz Ag, and the Gold King (site G52) was third, having produced 1,997 oz Au and 187 oz Ag (Jansons and others, 1984, Appendix). Analyses of extensive chip and grab samples from these deposits during U.S. Geological Survey and U.S. Bureau of Mines investigations in the early 1980's (Goldfarb and others, 1984; Jansons and others, 1984) indicate that many veins average between 0.2–2.0 oz/ton Au and 0.2–1.0 oz/ton Ag; several properties in the Port Valdez district have between several hundred and several thousand tons of reserves (Jansons and others, 1984).

Within the Valdez Group rocks, gold-bearing quartz veins occur in shear zones and joints and as saddle reefs, in metasedimentary rocks and intermediate-composition dikes and stocks that have undergone brittle deformation. The veins commonly contain native gold, pyrite, arsenopyrite, chalcopyrite, sphalerite, galena, and occasionally stibnite or scheelite. Total sulfide content is low, generally only a few percent (Pickthorn, 1982; Goldfarb, 1989). Although these veins are as thick as several meters in many places, they seldom are continuous for more than 100 m and pinch and swell markedly along strike. In some occurrences, the veins may contain economic concentrations of silver, which, therefore, is a potential byproduct resource (Goldfarb and others, 1992). Nonmetallic gangue minerals are predominantly quartz, but include calcite, albite, chlorite, and limonite. Near-surface oxidation is present locally, but veins generally are not deeply weathered and oxidized enrichment zones are not typical. The gold is free-milling.

Gold-bearing quartz veins of the type found in rocks of the Valdez Group have commonly been refered to as orogenic metamorphic-hosted veins (Bohlke, 1982), low-sulfide gold-quartz veins (Berger, 1986), or mesothermal veins (Nesbitt and others, 1986). Examples of this deposit type include the Juneau gold belt in Alaska and the California Mother Lode (Goldfarb and others, 1997). However, the Juneau gold belt and the Mother Lode are spatially associated with major crustal lineaments, whereas the deposits in rocks of the Valdez Group do not exhibit such fundamental structural control. This absence of fluid-focussing crustal lineaments may explain the generally lower tonnages of deposits hosted by the Valdez Group, although their grades are relatively high.

The genesis of these mesothermal gold-bearing veins has engendered considerable debate. Mitchell (1979) first suggested a metamorphic dewatering model for vein formation in the Valdez Group; however, Mitchell and others (1981) and Silberman and others (1981) interpreted limited stable isotope and fluid inclusion data from the Hope-Sunrise district as indicating ore deposition by meteoric water at shallow depths. These authors estimated vein formation at temperatures of approximately 190° C and pressures of 1–25 bars, and classified these veins as epithermal deposits. Pickthorn (1982) and Pickthorn and Silberman (1984) suggested that initial fluids in veins in the Port Valdez district formed from metamorphic dewatering and that vein deposition occurred from a mixture of boiling metamorphic and meteoric fluids. Goldfarb and others (1986) interpreted fluid inclusion and stable isotope data for gold-bearing veins throughout the Valdez Group and determined that ore deposition was from a non-boiling fluid at temperatures of at least 210°–280° C and pressures of 1–1.5 bars. They related ore genesis to metamorphic devolatilization within deeper parts of an accretionary wedge, where the higher pressures and temperatures characterized a mesothermal, not epithermal, environment. The vertical extent of the gold-bearing veins, at least 2 km, by itself is suggestive of a mesothermal environment. In the Valdez district, limited K-Ar geochronologic data indicate that the regional metamorphic mineral assemblages, the vein mineral assemblages, and the minerals in discordant felsic dikes all span the same Eocene period of time, circa 53–47 Ma (Goldfarb and others, 1986; Plafker and others, 1989b), strongly suggestive of a common regional genesis. Haeussler and others (1995) suggested that subduction of an oceanic spreading center may have been the ultimate driving force for both magmatism and gold-related hydrothermal activity.

Within the Valdez quadrangle, magnetic and gravity data provide no direct indication of areas of gold mineralization within the Valdez Group or other rock units. In a few places, gold-bearing veins cut mafic metavolcanic rocks and are marked by weak gossans (map A, tract G-4); the metavolcanic rocks engender a weak positive aeromagnetic signature. However, most of the known gold-bearing deposits (table 2) are hosted by metasedimentary rocks and are located in areas of deep magnetic basement (5–10 km), varable magnetization, and shallow gravity gradients; thus, they cannot be associated directly with features responsible for the magnetic or gravity anomalies.

Geologic criteria are also of limited use in gold exploration in the Valdez quadrangle. The lack of major structural features associated with the occurrences and the fairly uniform metamorphic grade of the Valdez Group rocks do not allow for direct geologic targeting of favorable areas. Throughout the Valdez Group, however, there does appear to be a spatial relation between areas of felsic dikes and gold mineralization. This relation may indicate areas that were more prone to brittle deformation and (or) more conducive to dike and vein formation.

Geochemical data are the best indicators of areas favorable for the presence of gold-bearing quartz veins, but are nonetheless not everywhere reliable. For example, stream-sediment and panned-concentrate sampling in the Valdez quadrangle failed to delineate the Tonsina district (map A, tract G-2), where deposits within the Valdez Group have had known minor lode production. This probably is due to the very steep topography and active alpine glaciation in the district, and the small tonnage typical of the deposits.

Several tracts of high potential for lode-gold deposits in the Valdez Group have been identified (map A, tracts G-1 through G-3). Tract G-1, just north of the town of Valdez, is the Port Valdez district, an area approximately 45 km by 15 km with numerous mines, prospects, and occurrences. Most lode gold produced in the Valdez quadrangle was from this district (Nelson and others, 1984, table 2). Grab samples of vein quartz from the Alice (site G46), Cliff (G44), Little Giant (G32), and Millionaire (G35) mines contain as much as 5,000 parts per million (ppm) Au, 700 ppm Ag, 11,000 ppm As, as well as anomalous Bi, Cd, Cu, Hg, Pb, Sb, W, and Zn (Goldfarb, 1989). Stream-sediment and concentrate samples anomalous in Ag, Au, Co, Cu, Fe, Ni, or Pb (±As, Mo, Zn) also characterize this tract and expand the borders of the district to include new favorable ground to the northwest along Divider Mountain and Pandora Peak (Goldfarb and others, 1995). Jansons and others (1984) also reported the occurrence of a small gold-bearing quartz vein in the extension (site G56). Based on the existence of producing mines and the extent of geochemical anomalies, tract G-1 is assigned a high potential, certainty level D (H/D), for lode gold and associated silver resources in small quartz veins.

Tract G-2 (map A) is the Tonsina district, a 300-km^2 area just southeast of Tonsina Lake in the center of the quadrangle that also has been identified as having high potential, certainty level D (H/D), for lode gold resources. Although several mines in this district have recorded production, very few stream-sediment or concentrate samples were anomalous in elements, such as Ag, As, Au, Cu, Pb, and Zn, that are indicative of gold mineralization; the boundary of this tract is based principally on the presence of mines and prospects. Goldfarb and others (1995) speculated that this lack of geochemical anomalies may reflect either the presence of very fine grained gold in the source lodes or relatively limited outcrops of the gold-bearing quartz veins.

A large tract in the south-central Valdez quadrangle, centered around Cleave Creek Glacier and extending eastward across the Copper River (map A, tract G-3) has been identified as having a high potential, certainty level B (H/B), for undiscovered lode gold deposits, based on geochemical anomalies in stream-sediment and concentrate samples. Concentrate samples collected from near the toe of the Cleave Creek Glacier contain as much as 700 ppm Ag, >20,000 ppm As, and >1,000 ppm Au. Microscopically visible grains of native gold and sulfide minerals are relatively abundant in many of the samples (Goldfarb and others, 1995). East of the Copper River, concentrate samples contain anomalous gold but less commonly silver or arsenic. Although no mineral occurrences have been recognized in this tract, a placer gold prospect along the West Fork of the Little Bremner River was reported by Moffit (1914), and a quartz vein sampled by Miller and others (1982) contained 200 ppm As, 500 ppm Cu, and 150 ppm Ni. This tract also is underlain by metasedimentary rocks of the Valdez Group.

Tracts G-4 through G-8 (map A) also contain geochemical anomalies suggestive of areas of lode gold occurrences within the Valdez Group, and have been assigned a moderate potential, certainty level C (M/C). These tracts of resource potential are defined by anomalous concentrations of gold, commonly with silver, in analyses of stream-sediment and heavy-mineral-concentrate samples (Goldfarb and others, 1995). Tract G-4 along the southern edge of the quadrangle is an extensive belt enclosing anomalous gold and base-metal-bearing samples collected in an area of mixed metasedimentary and metavolcanic rocks. Although most mines and prospects in this tract are massive sulfide occurrences, several gold quartz veins have been explored. A vein sample from the Orion prospect (site G60), at the west end of the tract, contained 26,000 ppm As, 300 ppm Cd, 16 ppm Sb, and 5,200 ppm Zn (Goldfarb and others, 1995). Anomalous gold was detected in concentrate and stream-sediment samples from several sites in the tract. Several concentrate samples from below Sulphide Gulch and near Canyon Slough contained 700–1,000 ppm Au. A concentrate sample from the outwash of Marshall Glacier contained detectable gold, and is the only concentrate sample from the Valdez quadrangle that contained detectable antimony (500 ppm). Mcroscopic examination of these samples also detected visible gold (Goldfarb and others, 1995). Tracts G-5 through G-8 also are defined by samples containing anomalous gold and assocated indicator elements, such as Ag, As, Pb, Zn, and Cu (Goldfarb and others, 1992).

South of the settlement of Tonsina in the vicinity of Kimball Pass, several gold-bearing quartz veins have been prospected (MacKevett and Holloway, 1977), and stream-sediment samples from this tract (map A, tract G-9) contained 0.05–0.95 ppm Au (Miller and others, 1982). Quartz veins in windows of Valdez Group that are exposed between traces of the strongly folded Border Ranges fault are likely sources of this gold. This tract has been assigned a moderate potential, certainty level B (M/B), for gold resources. Based upon geochemical sampling and the presence of the scattered prospects, most of the southern part of outcrop areas of the Valdez Group (tract G-10) also has been assigned a moderate potential, certainty level B (M/B), for lode gold resources. Although samples from this tract contain little or no detectable gold, elements generally considered to be indicative of gold occurrences, such as Ag, As, Cu, Pb, W, and Zn, are commonly elevated in analyses (Miller and others, 1982). Because rocks of the Valdez Group are permissive for the formation of lode gold deposits, all the remainder of the Valdez Group (tract G-11) has been assigned a low potential, certainty level B (L/B), for containing undiscovered occurrences of lode gold.

Other indications of lode gold resources in the Chugach terrane occur in rocks of the McHugh Complex. Just west of Chitina, mines and prospects of the Opal group (map A, tract G-12, site G6) consist of several quartz veins less than 1 m thick that contain arsenopyrite, pyrite, galena, and sphalerite, and yield values of gold and silver (MacKevett and Holloway, 1977). Winkler and others (1981a) considered these veins to be cogenetic with small Eocene plutons. This tract is considered to have a moderate potential, certainty level C (M/C), for gold resources in quartz veins. Two other tracts underlain by rocks of the McHugh Complex have been identified by geochemical sampling as favorable for gold-bearing veins. Tract G-13, south of Tonsina, and tract G-14, along Klanelneechena Creek in the northwestern part of the quadrangle, yield concentrate samples with anomalous gold and other elements (Miller and others, 1982) suggestive of precious-metal mineralization. These tracts are assigned a moderate potential, certainty level B (M/B), and a low potential, certainty level B (L/B), respectively, for gold resources in small vein systems.

South of the Contact fault in rocks of the Orca Group, several sulfide-bearing quartz veins are present, indicating a possibility of potential lode gold resources (Winkler and others, 1981a; Nelson and others, 1984). Stream-sediment and concentrate samples that are weakly anomalous in Au (0.5 ppm), Ag, As, and Cu (Goldfarb and others, 1995) also may reflect the presence of gold-bearing quartz veins in this tract (map A, tract G-15). Elsewhere, rocks of the Orca Group generally lack gold-bearing quartz veins. The only known occurrences are in the McKinley Lake area of the Cordova quadrangle, where veins are proximal to a granitic stock (Goldfarb and others, 1992). Rocks of the Orca Group are geochemically similar to those of the Valdez Group, and, if exposed to low- to moderate-greenschist facies metamorphic conditions similar to the Valdez Group, may be favorable for formation of low-sulfide gold-quartz veins. Because of the lack of strong geochemical indicators, tract G-15 is considered to have low potential, certainty level B (L/B), for undiscovered lode gold occurrences.

Northeast of Chitina in the Wrangell Mountains, several gold-bearing quartz veins are present in low-grade metamorphic rocks of the Skolai Group (Wrangellia terrane). At Benito Creek (map A, tract G-16, site G5), a 1-m-thick quartz vein containing pyrite, arsenopyrite, chalcopyrite, tetrahedrite, and native gold was exposed for 200 m along strike. Although no production has been recorded, this vein was reputed to have contained beautiful gold-quartz specimens (Moffit, 1915; Moffit and Mertie, 1923). To the north, placer gold occurrences have been reported at the mouth of Copper Creek (tract G-17, site G3) (Winkler and others, 1981a), and one concentrate sample contained 5 ppm Au (Goldfarb and others, 1995). A Jurassic granodioritic pluton intrudes Triassic carbonate rocks nearby; unrecognized skarn mineralization is one possible source for the placer gold. Alternatively, several copper prospects near the headwaters have byproduct gold or silver (Moffit and Mertie, 1923), and also are possible sources. Other stream-sediment samples in this tract (G-17) contain anomalous antimony, an indicator of possible gold enrichment (Goldfarb and others, 1995). The Benito Creek area (G-16) is assigned a moderate potential, certainty level B (M/B), and the Copper Creek area (G-17) is assigned a low potential, certainty level B (L/B), for gold resources in low-sulfide quartz veins. North of these areas on the west flank of Mt. Wrangell, several bulldozer cuts have been made on lode gold claims in iron-stained talc schist and greenschist of the Haley Creek metamorphic assemblage (tract G-18). Apophyses of the Jurassic Chitina Valley batholith crop out nearby and may have induced the formation of small, weakly mineralized vein systems in the metamorphic rocks. Analyzed rock samples from this prospect contained no detectable gold, but did have as much as 5,000 ppm Ba and 5 ppm Ag (Miller and others, 1982). The tract is assigned a low potential, certainty level B (L/B), for precious-metal resources in small vein systems.

A lone occurrence of gold in rocks of the Peninsular terrane in the northwestern part of the Valdez quadrangle (map A, tract G-19) was reported by the U.S. Bureau of Mines (1980). Little is known about this location, except that several lode claims were staked along a contact between the Talkeetna Formation and a Jurassic intrusion (Winkler and others, 1981a). This tract has been assigned a low potential, certainty level B (L/B), for gold resources.

MASSIVE SULFIDE DEPOSITS

Volcanogenic massive sulfide deposits (table 3; map B)

The south-central part of the Valdez quadrangle is underlain by interbedded metasedimentary and mafic metavolcanic rocks of the Valdez Group. The metavolcanic rocks are interpreted as upper levels of oceanic basaltic crust, formed at a spreading center, with which sediments derived from a nearby continental margin magmatic arc were interlayered (Plafker and others, 1989b). A broad and generally gentle gravity high, termed the "Prince William Sound high" (Barnes and Morin, 1990), is associated with much of this area and is attributed to the relative abundance of metavolcanic rocks. The metavolcanic rocks are moderately magnetic, in marked contrast to the enclosing nonmagnetic metasedimentary rocks; thus, although they occur only in thin sequences, they impart a characteristic positive magnetic high on the regional aeromagnetic coverage (Case and others, 1986), and can be traced confidently beneath glaciers along the southern edge of the quadrangle.

Massive and semi-massive stratiform iron-copper-zinc sulfide deposits are present at scattered locations within, or proximal to, the mafic metavolcanic rocks (Crowe and others, 1992). The Midas mine (map B, tract C-1, site C3), the fourth largest copper producer in the Prince William Sound region and the largest copper producer in rocks of the Valdez Group, is located south of Valdez, as are several significant prospects (Winkler and others, 1981a). The two principal ore horizons at the Midas mine produced over 500 tons of Cu, and 2,569 oz Au and 15,157 oz Ag were produced as byproducts (Rose, 1965). Jansons and others (1984) estmated additional reserves of 62,000 tons grading 1.6 percent Cu. The ore bodies are hosted princpally in shear zones in metasedimentary rocks (Johnson, 1915), which are interbedded with tholeiitic basalt breccias and tuffs and tuffaceous sedimentary rocks. Ore at the Midas mine consisted principally of chalcopyrite, pyrite, pyrrhotite, sphalerite, and minor galena, and also contained as much as 0.42 oz/ton Ag and 0.062 oz/ton Au (Rose, 1965). These occurrences are classified either as Besshi-type massive sulfide deposits if the lodes are hosted by metasedimentary rocks or Cyprus-type if the lodes are in metavolcanic rocks (Nelson and Koski, 1987; Crowe and others, 1992).

Stream-sediment samples from near the southern margin of the quadrangle are seldom anomalous in elements indicative of nearby massive sulfide deposits, but panned-concentrate samples are consistently anomalous in Ag, As, Co, Cu, Fe, and Ni. Bi, Pb, and W also are anomalous at some sites (Goldfarb and others, 1995). Concordant lenses and disseminations of sulfide minerals, as well as discordant sulfide-bearing quartz veins in shear zones, are common in the metavolcanic rocks of this area. This trend of anomalous geochemical samples forms a northern extension of the informally named “Central Sulfide Belt” of the Cordova quadrangle immediately to the south (Goldfarb and others, 1992). The tract proximal to the Midas and Addison-Powell properties (map B, tract C-1) is assigned a high potential, certainty level D (H/D), for the occurrence of volcanogenic massive sulfide deposits with resources of copper and byproduct gold, silver, lead, or zinc. Eastward and westward extensions of the metavolcanic rocks and associated geochemical anomalies (tracts C-2 and C-3) are considered to have moderate potential, certainty level C (M/C), for volcanogenic massive sulfide deposits. Samples of sulfide-bearing metavolcanic rocks and veins near Wortmanns Glacier (tract C-3, site C5) are characterized by as much as 1.5 ppm Ag, 500 ppm Cr, 1,500 ppm Cu, 15 percent Fe, 7 percent Mg, 300 ppm Pb, and 7,000 ppm Zn (Miller and others, 1982).

Several other geochemically anomalous tracts associated with metavolcanic rocks of the Valdez Group have been identified. Winkler and others (1981a) described sulfide-bearing quartz veins and disseminated sulfide minerals in mafic metavolcanic rocks near the toe of Tsina Glacier (map B, tract C-4, site C6). This tract contains metavolcanic rocks similar to those in the vicinity of the Midas and Addison-Powell properties and is considered to have a moderate potential, certainty level C (M/C), for undiscovered resources of copper in volcanogenic massive sulfide deposits. In the south-central and southeastern parts of the quadrangle, anomalous geochemical samples and known occurrences of sulfide-bearing metavolcanic rocks (Goldfarb and others, 1995; Winkler and others, 1981a) define a discontinuous arc of tracts (C-5 through C-7) with low potential, certainty level B (L/B), for volcanogenic massive sulfide deposits.

Volcanogenic copper deposits of a different character occur in pre-Cretaceous rocks at many places north of the Border Ranges fault in the Valdez quadrangle. In the southern domain of Wrangellia, south of the Chitina fault, Pennsylvanian and Permian mafic flows and volcanclastic rocks host disseminated and massive sulfide deposits in at least four locations. The host rocks, weakly foliated greenstones of the Strelna Metamorphics, are interpreted to have formed in the early tholeiitic phase of a late Paleozoic intraoceanic arc, the Skolai arc (Richter and Jones, 1973). Just north of the Tebay fault along the east-central edge of the quadrangle (map B, tract C-8), copper- and iron-rich sulfide bodies are present at the Falls Creek, Divide Creek, Surprise Creek, and Blackney prospects (sites C7–C10, respectively) (Moffit, 1914; MacKevett and Holloway, 1977; Winkler and others, 1981a). Both the Blackney and Surprise Creek prospects occur near the margins of large Jurassic tonalite intrusions, which may account for both the brecciation and the hydrothermal alteration that characterize them. These prospects consist principally of veins of chalcopyrite and pyrite, and are much smaller than the volcanogenic deposits in the Prince William Sound region. Concentrate samples from tract C-8 generally contain 200–300 ppm Cu, and one sample from the headwaters of Taral Creek contained 10,000 ppm Cu and 5 ppm Ag (Goldfarb and others, 1995). This highly anomalous sample probably represents material weathered directly from the Blackney prospect, which contains a pyrite-chalcopyrite vein 0.5 m wide that extends for at least 60 m (Moffit, 1914). The tract is thought to have moderate potential, certainty level C (M/C), for undiscovered small copper lodes.

Records of the U.S. Bureau of Mines (1980) include a location of patented lode claims for copper in veins near Iron Creek (map B, tract C-10, site C11). We did not visit this site; host rocks for the prospect apparently are Upper Paleozoic metavolcanic rocks close to the concealed trace of the Chitina fault and also close to outcrops of Jurassic monzodiorite exposed in the canyon of the Kotsina River. Goldfarb and others (1995) did not show geochemical anomalies that might indicate nearby occurrences in this tract. The tract is considered to have low potential, certainty level B (L/B), for small copper lodes.

Another tract of moderate potential for volcanogenic copper deposits is present in rocks of the type Wrangellia terrane north of the Chitina fault (map B, tract C-9). In the Wrangell Mountains, east of the Kotsina River, numerous copper occurrences define the Kotsina district (Moffit and Mertie, 1923; Van Alstine and Black, 1946). The occurrences occupy complexly faulted and sheared zones in the Middle and Upper Triassic Nikolai Greenstone, and in the lowermost part of the overlying Upper Triassic Chitistone Limestone. The occurrences in the Nikolai Greenstone probably were generated by the same processes that formed the rich lodes in the Chitistone Limestone at the Kennecott mines to the east in the McCarthy quadrangle (MacKevett, 1976—see next section). However, since the greenstone clearly is the source of the copper and since most greenstone-hosted occurrences in the Valdez quadrangle are not proximal to lodes in the overlying carbonate rocks, they are described briefly here.

The Nikolai Greenstone was formed by voluminous, largely subaerial effusions of tholeitic basalt at low paleolatitudes (Hillhouse, 1977), either in a rift (Jones and others, 1977) or above an elongate mantle plume (Richards and others, 1991). The greenstone is intrinsically elevated in copper—geochemical analyses, formation-wide, average 155 ppm Cu (MacKevett and others, 1997). At the time of subaerial eruption, the copper probably was incorporated in a silicate mineral phase, then leached by low-temperature brines, which may have formed during and following deposition of the overlying Upper Triassic limestones (MacKevett and others, 1997). In the Valdez quadrangle, copper deposits in the Nikolai Greenstone generally consist of discordant veins and adjacent disseminations of bornite and chalcopyrite, with lesser pyrite, covellite, and enargite. Veins generally are thin and discontinuous, averaging about 5–10 cm wide and extending for only tens of meters laterally. Isolated masses of bornite and chalcopyrite as large as 0.5 m by 1.5 m have been found along some of the veins (Moffit and Mertie, 1923), but no large or high-grade deposits have been found and no tonnage or grade information has been published. In tract C-9, in the vicinity of Copper and Elliott Creeks, some deposits contain slightly elevated gold and silver values, as well as native copper (Moffit, 1915; Moffit and Mertie, 1923). Although underground workings in tract C-9 may total over 700 m, there is no record of production. Stream-sediment samples in the tract contain as much as 340 ppm Cu, and concentrate samples as much as 2,000 ppm Cu (Goldfarb and others, 1995). This tract is considered to have moderate potential, certainty level C (M/C), for undiscovered copper resources in small veins and lodes in the Nikolai Greenstone.

Tracts C-11 and C-12 (north of the Kotsina and Cheshnina Rivers, respectively) are geologically similar to tract C-9 and therefore permissive for the formation of volcanogenic copper resources in the Nikolai Greenstone. These tracts have been prospected, but generally lack geochemical anomalies that would be expected in the vicinity of volcanogenic deposits. They are considered to have low potential, certainty level B (L/B), for volcanogenic sulfide deposits.

Two tracts of low potential, certainty level B (L/B), for copper resources in disseminated volcanogenic deposits have been identified by geologic mapping in the Peninsular terrane. In the northwestern part of the quadrangle, the Heavenly Ridge prospect (map B, tract C-14, site C20) is a large iron-stained pyritic zone in Lower Jurassic volcanic and volcaniclastic rocks of the Talkeetna Formation. Newberry (1986) considered this occurrence to be a volcanogenic massive sulfide deposit. Although there is no recognized copper anomaly, the site may have some potential. An area similarly pyritized volcanic and volcaniclastic rocks of the Talkeetna Formation also occurs in the north-central part of the quadrangle at Willow Mountain (tract C-13, site C19), where weak iron- and copper-staining are distributed over a large area (Winkler and others, 1981a), and weak geochemical anomalies for copper and zinc have been reported (Miller and others, 1982).

Kennecott-type deposits (table 3; map B)

Within a few years after the discovery of the Bonanza lode near McCarthy in 1900, every outcrop of the contact between the Nikolai Greenstone and the Chitistone Limestone in the southern Wrangell Mountains—the stratgraphic interval in which the rich deposits of the Kennecott mines near McCarthy occur—had been prospected thoroughly (Mendenhall, 1905). Although numerous occurrences were noted in the Nikolai Greenstone throughout the region, the richest lodes were found to be confined to the lower part of the overlying Chitistone Limestone, principally in the vicinity of the Kennecott mines.

MacKevett and others (1997) provided a thorough descriptive and genetic model for stratabound copper deposits of the type occurring at the Kennecott mines in the McCarthy quadrangle about 60 km east of the eastern edge of the Valdez quadrangle. The following summary is abstracted from their definitive paper.

Following formation of the copper-enriched Nikolai Greenstone, carbonate sediments were deposited in a Late Triassic marine embayment upon the low-relief volcanic platform in an arid, near-equatorial environment, forming the Chitistone Limestone and overlying units. Local basins in the embayment contained sabkha-facies carbonate sediment rich in sulfates and organic matter, which became concentrated in evaporative brines. These brines circulated downward through joints and solution cavities into the underlying basalt. Subsequently, Late Jurassic and Early Cretaceous regional orogeny promoted further circulation of the brines, scavenging copper from the basalt and forming small early veins and disseminations in the basalt. When the circulating copper-rich brines migrated into solution fissures and breccias in the lower parts of the overlying carbonate rocks, however, they formed large and rich lodes, which are surrounded by envelopes of hydrothermal dolomite. In the McCarthy quadrangle to the east, where the carbonate sequence is thickest and the sabkha facies rocks are most extensive, enormous northeast-striking stratabound lodes (such as those at the Bonanza, Jumbo, Mother Lode, and Erie mines) form upward-tapering wedges as large as 580 m long, 50–60 m high, and 0.5–15 m wide at the base—the dimensions of the main Bonanza vein. This one ore body produced 720,000 tons of chalcocite-rich ore grading 13.44 percent copper; the ore also contained about 0.77 oz/ton silver. Somewhat smaller subparallel orebodies were spaced about 60 m apart, plunging northeastward essentially parallel to dips of the host Chitistone Limestone.

In the Valdez quadrangle, small bornite-chalcopyrite-malachite-pyrite veins are hosted in the Chitistone Limestone near its contact with the Nikolai Greenstone at the Swayze prospect on Elliott Creek (map B, tract C-9, site C12) and at the Ammann and Mullen prospects on Copper Creek (tract C-9, sites C16, C17, respectively). The mineralized veins apparently are continuations of sulfide-bearing veins in the underlying Nikolai Greenstone and do not widen into large lodes within the calcareous rocks (Moffit and Mertie, 1923). In 1943, reserves at the Mullen property were calculated to be about 1,300 tons at 1.55 percent copper (Van Alstine and Black, 1946)—a figure that is dwarfed by any of the known Kennecott-type deposits of the McCarthy area. Thin sequences of the Chitistone Limestone also overlie the Nikolai Greenstone on both the north and south sides of Elliott Creek. Although many copper-bearing veins have been prospected in the greenstone, none are known to extend upward into the limestone, nor are any independent lodes or veins known in outcrops of the Chitistone Limestone. In the Valdez quadrangle, the Chitistone apparently lacks the critical sabkha, organic-shale, and fetid-limestone facies of the lower member that are characteristic of the McCarthy area (Armstrong and MacKevett, 1982). Furthermore, the calcareous sequence in the Valdez quadrangle is one-tenth to one-third as thick as in the vicinity of the Kennecott mines (Moffit, 1938)—a thickness that is unlikely to generate a sufficient volume of copper-mobilizing brines to create large deposits, even if evaporite minerals had been present originally in the Chitistone in the Valdez quadrangle. Nonetheless, there is a slight possibility that small stratabound lodes of the Kennecott-type remain to be discovered in Upper Triassic carbonate rocks of the northeastern part of the Valdez quadrangle (map B, tracts C-9, C-11, C-12). A moderate potential, certainty level C (M/C), is assigned to tract C-9 because prospects are present, and a low potential, certainty level B (L/B), is assigned to tracts C-11 and C-12, which lack prospects.

Except for local occurrences of native copper in brecciated flow tops, amygdaloidal fillings, or rare disseminations, "volcanogenic" deposits hosted in the Nikolai Greenstone share several characteristics with Kennecott-type ores (MacKevett and others, 1997). Curiously, however, no Nikolai-hosted deposits are known within about 10 km of the main Kennecott mines. Most deposits in the Nikolai, like those in the overlying carbonate rocks, follow northeast-trending structures and contain minerals with low sulfur/copper ratios, but generally form only small veins of short lengths. Wallrock alteration adjacent to veins, unless there are nearby plutons, is negligible. Silberman and others (1980) presented compelling evidence that Nikolai-hosted veins formed at the same time and in equilibrium with regional metamorphism of the Nikolai at about 112±11 Ma. [That terrane-wide metamorphism is presumed to have resulted from the accretion of the Wrangellia composite terrane to the Alaskan continental margin.] Presumably, formation of the Nikolai veins constituted an early phase of a continuum that led to much richer and more voluminous copper deposition in more favorable superjacent carbonate host rocks. Thus, it is possible that some Nikolai-hosted veins represent feeders for Kennecott-type deposits. Whether the deposits are hosted in greenstone or carbonate rocks, however, the presence of volcanic rocks enriched in copper was critical for ultimate genesis of the deposits.

MAGMATIC DEPOSITS

Layered and podiform chromite deposits (table 4; map B)

Several areas of chromium occurrences are found associated with layered mafic and ultramafic plutons along the Border Ranges fault in the Valdez quadrangle. The rocks are part of the Border Ranges mafic-ultramafic assemblage (Hudson, 1983), which exposes deep, primitive levels of the Peninsular terrane, formed as a Late Triassic–Middle Jurassic intraoceanic island arc (Burns, 1985). The Bernard Mountain (map B, tract M-1, site M3), Sheep Hill (or Dust Mountain/West) (site M2), and Dust Mountain (site M1) prospects southeast of Tonsina, are located on conspicuous, tectonized and cumulate ultramafic bodies within a belt 40 km long and as wide as 4 km that contains discontinuous outcrops of strongly deformed dunite, pyroxenite, peridotite, and garnet-bearing layered gabbronorite separated by glacial valleys. This belt is called the Tonsina ultramafic-mafic sequence (Winkler and others, 1981a; Plafker and others, 1989b). Regional aeromagnetic data show that the sequence is continuous beneath the Quaternary cover and dips north to northwest toward a concealed contact with the Nelchina River gabbronorite, which makes up the rest of the Border Ranges mafic-ultramafic assemblage (Case and others, 1986).

At a prospect on the south side of Bernard Mountain (site M3), chromite occurs as sporadic pods and contorted masses 1–15 cm thick and 15–75 cm long in a tectonized harzburgite (Newberry, 1986). This prospect contains an estimated 5,000–15,000 tons at 5 percent Cr_2O_3, with a Cr:Fe ratio of 2.5 (Newberry, 1986, table 2). In contrast, at a prospect on the north side of Bernard Mountain, eight chromitite-rich bands 0.3–1.5 m thick are exposed in a 300-m-wide zone in cumulate dunite. This prospect contains an estimated 100,000–200,000 tons at 11 percent Cr_2O_3, and the Cr:Fe ratio is more favorable at 3.0 (Newberry, 1986, table 2). Foley and Barker (1985, table 1) identfied a total resource of 343,000 tons at 5 percent Cr_2O_3 at deposits at the southwest end of the mountain with Cr:Fe ratios from 1.9 to 2.6. These deposits apparently are in cumulate dunite (Newberry, 1986, figs. 11–12). Foley and Barker (1985) noted numerous additional small chromite occurrences on Bernard Mountain. Inasmuch as the large deformed ultramafic body crops out over a 2 km by 3.5 km area (Hoffman, 1974), other unevaluated chromite occurrences are likely.

At Sheep Hill ("Dust Mountain" of Newberry, 1986—map B, site M2), two poorly exposed chromite-bearing zones in cumulate dunite occur on the west and east sides of the hill, but are separated by about 1,000 m of barren perdotite. According to Newberry (1986, table 2), layers 0.6–1.6 m thick and at least 15–25 m long in these zones contain an estimated 3,000–10,000 tons at 7 percent Cr_2O_3 with Cr:Fe at 1.2. Foley and Barker (1985, table 2) indicate that these deposits contain >26,000 tons at 5 percent Cr_2O_3 with Cr:Fe at 1.9.

According to Berg and Cobb (1967), a prospect at Dust Mountain (east of Dust Creek—map B, site M1), exposes a massive body of chromite as much as 3 m thick and 25 m long, apparently in tectonized harzburgite (Newberry, 1986). Berg and Cobb (1967) reported hand samples assaying as high as 57 percent Cr_2O_3, with a range in Cr:Fe ratio in the chromite of 1.20–3.06. In contrast, Foley and Barker (1985) and Newberry (1986) reported only low-grade zones of disseminated or thinly banded chromite on Dust Mountain, with bulk samples containing only 2.6 percent Cr_2O_3 with Cr:Fe at 1.1. Foley and Barker (1985) reported that samples of dunite from Dust Mountain are more magnetic than from Bernard Mountain and Sheep Hill. They speculated that lower Cr:Fe ratios at Dust Mountain may reflect increased magnetite and decreased chromite in the spinel mineral fraction.

Anomalous concentrations of Ni (1,000–5,000 ppm), Co (150–200 ppm), Cu (1,000 ppm), and platinum-group elements have been detected at the Bernard Mountain, Sheep Hill, and Dust Mountain sites (Mulligan, 1974; MacKevett and Holloway, 1977; Miller and others, 1982), both in dunite and in associated peridotite or pyroxenite layers. The platinum-group element contents of chromite concentrates are as much as 3.4 ppm at Dust Mountain, 1.0 ppm at Sheep Hill, and 1.7 ppm at Bernard Mountain (Foley and others, 1987, 1989). At Dust Mountain, one chromite-rich segregation contained 10.5 ppm Pd and 7.9 ppm Pt and chrome spinel bands in pyroxenite also contain as much as 610 ppb Au (Foley and others, 1987). Stream-sediment samples are anomalous in Cr (as much as 5,000 ppm), Ni (as much as 1,000 ppm), and Fe (as much as 15 percent), and clearly define this area of chromite occurrences (Goldfarb and others, 1995). Tract M-1 is assigned a high potential, certainty level D (H/D), for chromite-enriched magmatic deposits and likely also contains byproduct platinum-group elements. Magmatic sulfide minerals, pyrite, marcasite, chalcopyrite, and lesser pentlandite occur in overlying garnet-bearing gabbronorite (or "granulite") layers. Selected rock samples from near benchmark "Scarp," at the northeast end of tract M-1, contain 2–6 percent sulfide minerals (Newberry, 1986).

There are two additional areas of anomalous chromium: (1) a tract extending eastward from the Bernard Mountain–Dust Mountain area along the Second Lake fault (tract M-2); and (2) at the northwest edge of the quadrangle just east of Nelchina Glacier (tract M-3). Although these occurrences are located within areas of melange (McHugh Complex or younger melange unit), the source of the chromium is considered to be structural slabs of serpentinized ultramafic rocks of the Peninsular terrane that have been brought up along the faults and incorporated in melange in the fault zones (Winkler and others, 1981b). Some rock samples from tract M-3 contain >5,000 ppm Cr and as much as 1,000 ppm Ni (Goldfarb and others, 1995). Tracts M-2 and M-3 are assigned a moderate potential, certainty level B (M/B), for undiscovered resources of chromium and associated nickel in magmatic deposits.

Nickel-copper sulfide deposits (table 4; map B)

Several nickel-copper sulfide prospects are located between the Tebay and Border Ranges faults at the eastern edge of the Valdez quadrangle. These prospects are located on small mafic and ultramafic sills in metamorphosed schist and limestone of the Strelna Metamorphics of the southern Wrangellia terrane (Winkler and others, 1981b; Plafker and others, 1989b). The deposits are magmatic in origin and consist of massive and disseminated sulfide minerals—pyrite, pyrrhotite, pentlandite, chalcopyrite, bravoite, and sphalerite—in the mafic and ultramafic intrusions. Hand samples of massive sulfide minerals have contained as much as 7.61 percent Ni, 1.56 percent Cu, 0.18 percent Co, and 2 oz/ton Ag (Overbeck, 1920; Kingston and Miller, 1945; Herreid, 1970); geochemical analyses show as much as 15 ppm Ag, 2,000 ppm Co, >20,000 ppm Cu, >5,000 ppm Ni, and 0.4 ppm Au (Goldfarb and others, 1995). Associated sulfide-bearing quartz veins contain >10,000 ppm As, 3,000 ppm Cu, >5,000 ppm Ni, and 7.0 ppm Pd, and an ultramafic rock sample contains 50 ppb Pt (Miller and others, 1982). Estimates of inferred resources at the Spirit Mountain prospect (map B, tract N-1, site N2) are 6,500 tons of material averaging 0.7 percent Ni and 0.5 percent Cu (Cornwall, 1968). Tract N-1 is assigned a high potential, certainty level C (H/C), for undiscovered copper and nickel resources in small magmatic sulfide deposits.

Several other areas considered to have potential for magmatic copper-nickel resources have been identified in rocks of the Peninsular terrane. In the northwestern corner of the quadrangle, stream-sediment samples collected from Klanelneechena Creek and tributaries,which are underlain by a klippe of layered gabbro and ultramafic rocks, were anomalous in Fe, Co, Cu, Cr, or V—the values for Co, 150 ppm, and Cu, 300 ppm, were the highest reached for stream-sediment samples in the quadrangle (Goldfarb and others, 1995). This tract, N-2, is assigned a moderate potential, certainty level B (M/B), for magmatic nickel-copper resources. Two other anomalous tracts in gabbroic rocks of the Peninsular terrane, N-3 east of Tonsina and N-4 in the northwest corner of the quadrangle, also have been identified by geochemical sampling. Layered gabbronorite of the Tonsina ultramafic-mafic sequence in the vicinity of the "Scarp" benchmark, tract N-3, contained as much as 1,000 ppm Ni and 1,000 ppm Cu in rock samples with visible pyrite, marcasite, and chalcopyrite (Newberry, 1986; Goldfarb and others, 1995). In the Barnette Creek tract, N-4, a sulfide-bearing mafic dike in the Nelchina River gabbronorite contains as much as 15 percent Fe, 10 percent Mg, 5 ppm Ag, 1,000 ppm Co, 1,500 ppm Cr, 28,000 ppm Cu, 3,000 ppm Ni, and 0.55 ppm Au (Miller and others, 1982). Newberry (1986) described layers in the Barnette Creek area, at a relatively high stratigraphic level within the 4,000-m-thick Nelchina River gabbronorite, that contained from 2 to 7 percent interstitial sulfide minerals, principally pyrrhotite and chalcopyrite, but with minor pentlandite as well. His analyses of sulfide-bearing rock showed anomalous Cu (2 percent) and Ni (240 ppm), but insignificant amounts of Au, Pt, and Pd. Intersttial grains of sulfide minerals, chiefly pyrrhotite, and possibly chalcopyrite and pyrite, are disseminated in layered gabbronorite of the Border Ranges ultramafic-mafic assemblage in many places; slightly elevated concentrations locally characterize gossans. Inasmuch as gold and platinum-group elements are enriched in magmatic sulfide layers in layered mafic-ultramafic plutonic complexes elsewhere in the world, Newberry (1986) speculated that such enriched horizons might occur stratigraphically lower in the Nelchina River gabbronorite. No such occurrences have been located downsection to the south, but the terrane is rugged and very difficult to explore; prospecting has been minimal. Tracts N-3 and N-4 are both considered to have low potential, certainty level B (L/B), for undiscovered copper and nickel occurrences, with possible byproduct resources of gold or platinum-group elements.

PLACER DEPOSITS

Precious-metal placers (table 2; map A)

Approximately one-half of the gold produced from the Valdez and adjacent Seward, Anchorage, and Cordova 1° x 3° quadrangles has been from placer deposits (Nelson and others, 1984). However, almost all of this placer gold production was from the Girdwood district and from districts on the Kenai Peninsula (Tysdal, 1978), not from placers in the Valdez quadrangle. Much of the Valdez quadrangle is characterized by very steep topography and active alpine glaciation. Unlike the fluviatile environments of the placer districts at Girdwood and on the Kenai Peninsula, the predominantly fluvioglacial environments of the Valdez quadrangle are generally unfavorable for the development of economic placer deposits. In areas underlain by rocks of the Valdez Group, most drainages near known lode gold mines also were placered, but generally the deposits were low-grade and the gold was very fine (Winkler and others, 1981a). In the Chugach National Forest, an investigation of potential placer gold resources was carried out by the U.S. Bureau of Mines (Jansons and others, 1984). Of 20 sites examined, 7 with gold values ranging from 0.0023 to 0.028 oz/yd^3 were considered to have moderate potential, certainty level C (M/C), for development. On map A and table 2 these are: Tasnuna River (PL-7), Cleave Creek (PL-8), Bench Creek (PL-5), Brown Creek (PL-4), Solomon Gulch (PL-3), Salmon Creek (PL-2), and Mineral Creek (PL-1). One site, Marshall Glacier (PL-6), tested at 0.14 oz/yd^3, and was considered by the U.S. Bureau of Mines to have high potential, certainty level C (H/C), for development (Jansons and others, 1984). Gold-bearing placers were identified in the early 1900's on the Little Bremner River just downstream from its unnamed source glacier (site PL-9) in a relatively inaccessible basin where quartz veins with anomalous gold values also were discovered (Moffit, 1914). A short distance to the west near the headwaters of Dewey Creek, which drains to the Copper River from the same unnamed glacier, gold-bearing placers also occur (Miller and others, 1982). This short, steep drainage apparently was not prospected during the early 1900's. In the Little Bremner drainage, prospecting was thorough, but values were low. The prospectors soon moved eastward to richer placers discovered on Golconda Creek in the McCarthy quadrangle. Site PL-9 is given a low potential, certainty level C (L/C), for unworked resources of precious-metal placers.

Because rocks of the Valdez Group are permissive as bedrock sources for gold in placers, all drainages (exclusive of sites PL-1 to PL-9) underlain by rocks of the Valdez Group are considered to have a low potential, certainty level B (L/B), for undiscovered resources of placer gold. In areas outside of Valdez Group bedrock, all drainages underlain by bedrock areas with anomalous gold values also are considered to have a low potential, certainty level B (L/B), for undiscovered resources of placer gold.

POSTULATED MINERAL DEPOSIT TYPES

VEIN DEPOSITS

Polymetallic veins (base- and precious-metal veins) (table 5; map A)

According to generally accepted models (Cox and Singer, 1986), polymetallic veins can be distinguished from low-sulfide gold-bearing quartz veins by their greater content of sulfide minerals and by their inclusion of a broader suite of base and ferrous metals in addition to the typical precious metals. In polymetallic veins, Zn, Cu, and Pb values will be significantly higher, and Fe and Mn generally also will be much higher than in typical precious-metal veins. Because of the increased presence of base and ferrous metals, weathering of polymetallic veins typically produces gossans. In the steep, rapidly eroding terrane of southern Alaska, however, where oxidation zones generally are thin (if present at all), even weak gossans seldom form over polymetallic veins. Inasmuch as the geochemical signature of polymetallic veins includes metals that also are anomalous in many precious-metal veins, the two vein types really may represent a continuum. The presence of felsic dikes in the vicinity of both types of geochemical signatures in the Valdez quadrangle also supports the inferred genetic link between low-sulfide gold-bearing quartz veins and polymetallic veins.

Three tracts in the Valdez quadrangle (map A, tracts P-1 through P-3) are considered to have potential for polymetallic vein deposits, based on geochemical sampling. No occurrences are known presently. In two tracts south of Klutina Lake (P-1 and P-2), heavy-mineral-concentrate and stream-sediment samples contained anomalous amounts of Ag, Fe, As, Cu, Mo, Pb, W, or Zn, including several of the highest values reported in the quadrangle (Goldfarb and others, 1995). These tracts are underlain by metasedimentary rocks of the Valdez Group. Minor intercalated metavolcanic rocks and abundant felsic dikes also are present. The third tract (P-3) is east of the Tazlina Glacier and is underlain by rocks of the McHugh Complex. Concentrate and sediment samples contained anomalous Zn and Sb, and less commonly Ag, Mg, Co, Ni, Cu, Cr, or Ti. Goldfarb and others (1995) suggested that these suites of elements possibly indicate polymetallic veins in source rocks for the sediment. All three tracts are assigned a low potential, certainty level B (L/B), for the occurrence of undiscovered polymetallic veins.

STOCKWORK DEPOSITS

Porphyry copper-molybdenum stockworks and veins (table 5; map B)

Two sulfide-bearing occurrences assocated with plutons have been prospected in the last 30 years in the Valdez quadrangle. In the east-central part of the quadrangle near the mouth of the Chitina River (map B, tract I-1), disseminations and small clots of chalcopyrite and molybdenite have been found in an Upper Jurassic biotite granodiorite pluton near its contact with greenstone of the Strelna Metamorphics; the occurrence was tentatively considered to be a porphyry system by MacKevett and Holloway (1977). However, stockwork quartz veining and alteration that might be indicative of extensive hydrothermal alteration are notably lacking (Winkler and others, 1981a). In the northwestern part of the quadrangle, sulfide-bearing quartz veins occur in iron-stained, brecciated Talkeetna Formation near its contact with a small Jurassic or Eocene pluton (tract I-2), but the veining and gossan are only very local. Analyses of stream-sediment samples from drainages in the adjacent area have some minor enrichments in molybdenum, copper, and zinc (Miller and others, 1982). Although we regard undiscovered porphyry-related deposits as unlikely, we assign a low potential, certainty level B (L/B), to tracts of small extent that include both of these occurrences.

REFERENCES CITED

Andreason, G.E., Dempsey, W.J., Henderson, J.R., and Gilbert, F.P., 1958, Aeromagnetic map of the Copper River Basin, Alaska: U.S. Geological Survey Geophysical Investigations Map GP–156, scale 1:125,000.

Andreason, G.E., Grantz, Arthur, Zietz, Isidore, and Barnes, D.F., 1964, Geologic interpretation of magnetic and gravity data in the Copper River Basin, Alaska: U.S. Geological Survey Professional Paper 316–H, p. 135–153.

Armstrong, A.K., and MacKevett, E.M., Jr., 1982, Stratigraphy and diagenetic history of the lower part of the Triassic Chitistone Limestone, Alaska: U.S. Geological Survey Professional Paper 1212–A, 26 p.

Barker, Fred, and Grantz, Arthur, 1982, Talkeetna Formation in the southeastern Talkeetna Mountains, southern Alaska—An Early Jurassic andesitic island arc: Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 147.

Barnes, D.F., 1977, Bouguer gravity map of Alaska: U.S. Geological Survey Geophysical Investigations Map GP–913, scale 1:2,500,000.

Barnes, D.F., and Morin, R.L., 1990, Gravity contour map and interpretation of gravity data for the Chugach National Forest, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF–1645–F, scale 1:250,000.

Berg, H.C., and Cobb, E.H., 1967, Metalliferous lode deposits of Alaska: U.S. Geological Survey Bulletin 1246, 254 p.

Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.

Bliss, J.D., editor, 1992, Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, 168 p.

Bohlke, J.K., 1982, Orogenic (metamorphic-hosted) gold-quartz veins, *in* Erickson, R.L., ed., Characteristics of mineral deposit occurrences: U.S. Geological Survey Open-File Report 82–795, p. 62–67.

Brooks, A.H., 1912, Gold deposits near Valdez: U.S. Geological Survey Bulletin 520–D, p. 108–130.

———1922, The Alaskan mining industry in 1920: U.S. Geological Survey Bulletin 722–A, p. 7–67.

Burns, L.E., 1982, Analysis of gravity and magnetic anomalies over a layered gabbro complex, Chugach Range, Alaska: U.S. Geological Survey Open-File Report 82–460, 96 p.

———1985, The Border Ranges ultramafic and mafic complex, south-central Alaska—Cumulate fractionates of island arc volcanics:

Canadian Journal of Earth Sciences, v. 22, p. 1020–1038.
Campbell, D.L., 1991, Gravity and magnetic models of profiles near Richardson Highway, southern Alaska, *in* Guidebook to Field Trip T104: International Geological Congress, 28th, p. 69–74.
Case, J.E., Burns, L.E., and Winkler, G.R., 1986, Maps showing aeromagnetic survey and geologic interpretation of the Valdez quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF–1714, 2 sheets, scale 1:250,000.
Cobb, E.H., 1979, Summary of references to mineral occurrences (other than mineral fuels and construction materials) in the Valdez quadrangle, Alaska: U.S. Geologcal Survey Open-File Report 79–1241, 166 p.
Cobb, E.H., and Matson, N.A., Jr., 1972, Metallic mineral resources map of the Valdez quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF–438, scale 1:250,000.
Cornwall, H.R., 1968, Nickel deposits of North America: U.S. Geological Survey Bulletin 1223, 62 p.
Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.
Crowe, W.E., Nelson, S.W., Shanks, W.C., Brown, P.E., and Valley, J.W., 1992, Geology and geochemistry of volcanogenic massive sulfide deposits and related igneous rocks, Prince William Sound, south-central Alaska: Economic Geology, v. 86, p. 1722–1746.
Csejtey, Béla, Jr., Cox, D.P., Evarts, R.C., Stricker, G.D., and Foster, H.L., 1982, The Denali fault system and the Cretaceous accretionary development of southern Alaska: Journal of Geophysical Research, v. 87, p. 3741–3754.
D'Andrea, R.F., Garcia, S.R., and numerous others, 1981, Uranium hydrogeochemical and stream sediment reconnaissance of the Valdez MTMS quadrangle, Alaska: Grand Junction, Colo., Bendix Field Engineering Corporation Report GJBX 90 (81), 65 p.
DeBari, S.M., and Coleman, R.G., 1989, Examnation of the deep levels of an island arc—Evidence from the Tonsina ultramafic-mafic assemblage, Tonsina, Alaska: Journal of Geophysical Research, v. 94, p. 4373–4391.
Fisher, M.A., Brocher, T.M., Nokleberg, W.J., Plafker, George, and Smith, G.L., 1989, Seismic reflection images of the crust of the northern part of the Chugach terrane, Alaska—Results of a survey for the trans-Alaska crustal transect: Journal of Geophysical Research, no. B4, p. 4424–4440.
Foley, J.Y., and Barker, J.C., 1985, Chromite deposits along the Border Ranges fault, southern Alaska—Part 1, Field investigations and descriptions of chromite deposits: U.S. Bureau of Mines Information Circular 8990, 58 p.
Foley, J.Y., Burns, L.E., Schneider, C.L., and Forbes, R.B., 1989, Preliminary report of platinum-group element occurrences in Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 89–20, 32 p.
Foley, J.Y., Mardock, C.L., and Dahlin, D.C., 1987, Platinum-group elements in the Tonsina ultramafic complex, southern Alaska, *in* Vassiliou, A.H., Hausen, D.M., and Carson, D.J.T., eds., Process mineralogy VII—Applications to mineral benefciation technology and mineral exploration, with special emphasis on carbonaceous gold ores: The Metallurgical Socety, Inc., p. 165–195.
Fuis, G.S., Ambos, E.L., Mooney, W.D., Christensen, N.L., and Geist, Eric, 1989, Crustal structure of accreted terranes in southern Alaska, Chugach Mountains, and Copper River basin from seismic refraction results: Journal of Geophysical Research, v. 96, no. B3, p. 4187–4227.
Fuis, G.S., and Plafker, George, 1991, Evolution of deep structure along the trans-Alaska crustal transect, Chugach Mountains and Copper River Basin, southern Alaska: Journal of Geophysical Research, v. 96, no. B3, p. 4229–4253.
Goldfarb, R.J., 1989, Genesis of lode-gold deposits of the southern Alaska Cordillera: Boulder, Colo., University of Colorado Ph.D. dissertation, 437 p.
Goldfarb, R.J., Borden, J.C., and Winkler, G.R., 1995, Geochemical survey of the Valdez 1° x 3° quadrangle, south-central Alaska: U.S. Geological Survey Bulletin 2084, 77 p., 1 sheet, scale 1:250,000.
Goldfarb, R.J., Case, J.E., Plafker, George, and Winkler, G.R., 1992, Maps showing areas of potential for mineral resources in the Cordova and Middleton Island 1° x 3° quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF–2190, scale 1:250,000.
Goldfarb, R.J., Leach, D.L., Miller, M.L., and Pickthorn, W.J., 1986, Geology, metamorphic setting, and genetic constraints of epigenetic lode-gold mineralization within the Cretaceous Valdez Group, south-central Alaska, *in* Keppie, J.D., Boyle, R.W., and Haynes, S.J., eds., Turbidite-hosted gold deposits: Geological Association of Canada Special Paper 32, p. 87–105.
Goldfarb, R.J., Miller, L.D., Leach, D.L., and Snee, L.W., 1997, Gold deposits in metamorphic rocks of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral deposits of Alaska: Littleton, Colo., Economic Geology Monograph 9, p. 151–190.
Goldfarb, R.J., Nelson, S.W., Dumoulin, J.A., and Miller, M.L., 1984, Data report and statistical summary for samples of moraine and stream sediment, nonmagnetic heavy mineral concentrate, and rock samples from Chugach National

Forest, Alaska: U.S. Geological Survey Open-File Report 84–355, 466 p.
Haeussler, P.J., Bradley, D.C., Goldfarb, R.J., Snee, L.W., and Taylor, C.D., 1995, Link between ridge subduction and gold mineralization in southern Alaska: Geology, v. 23, p. 995–998.
Herreid, Gordon, 1970, Geology of the Spirit Mountain nickel-copper prospect and surrounding area: Alaska Division of Mines and Geology Geologic Report 40, 19 p.
Hillhouse, J.W., 1977, Paleomagnetism of the Triassic Nikolai Greenstone, McCarthy quadrangle, Alaska: Canadian Journal of Earth Sciences, v. 14, no. 11, p. 2578–2592.
Hillhouse, J.W., and Grommé, C.S., 1984, Northward displacement and accretion of Wrangellia—New paleomagnetic evidence from Alaska: Journal of Geophysical Research, v. 89, p. 4461–4467.
Hoffman, B.L., 1974, Geology of the Bernard Mountain area, Tonsina, Alaska: Fairbanks, Alaska, University of Alaska MS thesis, 68 p.
Hudson, Travis, 1983, Calc-alkaline plutonism along the Pacific rim of southern Alaska, *in* Roddick, J.A., ed., Circum-Pacific plutonic terranes: Geological Society of America Memoir 159, p. 159–170.
Hudson, Travis, and Plafker, George, 1982, Paleogene metamorphism of an accretionary flysch terrane, eastern Gulf of Alaska: Geological Society of America Bulletin, v. 93, p. 1280–1290.
Hudson, Travis, Plafker, George, and Peterman, Z.E., 1979, Paleogene anatexis along the Gulf of Alaska margin: Geology, v. 7, p. 573–577.
Jansons, Uldis, Hoekzema, R.B., Kurtak, J.M., and Fechner, S.A., 1984, Mineral occurrences in the Chugach National Forest, south-central Alaska: U.S. Bureau of Mines Mineral Lands Assessment Report MLA 5–84, 218 p., 2 sheets, scale 1:250,000.
Jasper, M.W., 1967, Geochemical investigations along the Valdez to Chitina Highway in south-central Alaska, 1966: Alaska Divsion of Mines and Geology Geochemical Report 15, 19 p.
Johnson, B.L., 1914, Mining on Prince William Sound: U.S. Geological Survey Bulletin 592–G, p. 237–243.
———1915, The gold and copper deposits of the Port Valdez district, Alaska: U.S. Geological Survey Bulletin 622–E, p. 140–188.
———1916, Mining on Prince William Sound: U.S. Geological Survey Bulletin 642–D, p. 137–145.
———1918, Mining on Prince William Sound: U.S. Geological Survey Bulletin 662–C, p. 183–192.
———1919a, Mining on Prince William Sound: U.S. Geological Survey Bulletin 692–C, p. 143–151.
———1919b, Mineral resources of Jack Bay district and vicinity, Prince William Sound: U.S. Geological Survey Bulletin 692–C, p. 153–173.
Jones, D.L., Silberling, N.J., and Hillhouse, J., 1977, Wrangellia—A displaced terrane in northwestern North America: Canadian Journal of Earth Sciences, v. 14, p. 2565–2577.
Kingston, Jack, and Miller, D.J., 1945, Nickel-copper prospects near Spirit Mountain, Copper River region, Alaska: U.S. Geological Survey Bulletin 943–C, p. 49–57.
Le Compte, J.L., 1981, Map showing interpretation of Landsat imagery of the Valdez 1° x 3° quadrangle, southern Alaska: U.S. Geological Survey Open-File Report 80–892–F, scale 1:250,000.
Los Alamos National Laboratory, 1983, The geochemical atlas of Alaska: Grand Junction, Colo., Bendix Field Engineering Corporation Report GJBX–32 (83), 57 p.
MacKevett, E.M., Jr., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF–733–B, scale 1:250,000.
MacKevett, E.M., Jr., Cox, D.P., Potter, R.W., II, and Silberman, M.L., 1997, Kennecott-type deposits in the Wrangell Mountains, Alaska—High-grade ores near a basalt limestone contact, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral deposits of Alaska: Littleton, Colo., Economic Geology Monograph 9, p. 66–89.
MacKevett, E.M., Jr., and Holloway, C.D., 1977, Table describing metalliferous and selected nonmetalliferous mineral deposits in eastern southern Alaska: U.S. Geological Survey Open-File Report 77–169–A, 99 p.
Mendenhall, W.C., 1905, Geology of the Copper River region, Alaska: U.S. Geological Survey Professional Paper 41, 133 p.
Miller, R.J., Winkler, G.R., O'Leary, R.M., and Cooley, E.F., 1982, Analyses of rock, stream-sediment, and heavy-mineral-concentrate samples from the Valdez quadrangle, Alaska: U.S. Geological Survey Open-File Report 82–451, 224 p., 2 sheets, scale 1:250,000.
Miller, T.P., and Richter, D.H., 1994, Quaternary volcanism in the Alaska Peninsula and Wrangell Mountains, Alaska, *in* Plafker, George, and Berg, H.C., eds., The geology of Alaska: Boulder, Colo., Geological Society of America, The Geology of North America, v. G–1, p.759–779.
Mitchell, P.A., 1979, Geology of the Hope-Sunrise (gold) mining district, north-central Kenai Peninsula, Alaska: Stanford, Calif., Stanford University M.S. thesis, 123 p.
Mitchell, P.A., Silberman, M.L., and O'Neil, J.R., 1981, Genesis of gold vein mineralization in an Upper Cretaceous turbidite sequence, Hope-Sunrise district, southern Alaska: U.S. Geological Survey Open-File Report 81–103, 18 p.
Moffit, F.H., 1914, Geology of the Hanagita-Bremner region, Alaska: U.S. Geological Survey Bulletin 576, 56 p.
———1915, Mineral deposits of the Kotsina-Kuskulana district, with notes on mining in Chitina

Valley: U.S. Geological Survey Bulletin 622, p. 103–117.
———1918, Mining in the lower Copper River Basin: U.S. Geological Survey Bulletin 662, p. 155–182.
———1935, Geology of the Tonsina district, Alaska: U.S. Geological Survey Bulletin 866, 38 p.
———1938, Geology of the Chitina Valley and adjacent area, Alaska: U.S. Geological Survey Bulletin 894, 137 p.
Moffit, F.H., 1954, Geology of the Prince Willaim Sound region, Alaska: U.S. Geological Survey Bulletin 989–E, p. 225–310.
Moffit, F.H., and Fellows, R.E., 1950, Copper deposits of the Prince William Sound region, Alaska: U.S. Geological Survey Bulletin 963–B, p. 47–80.
Moffit, F.H., and Mertie, J.B., 1923, The Kotsina-Kuskulana district, Alaska: U.S. Geological Survey Bulletin 745, 149 p.
Mulligan, J.J., 1974, Mineral resources of the trans-Alaska pipeline corridor: U.S. Bureau of Mines Information Circular 8626, 24 p.
Nelson, S.W., Dumoulin, J.A., and Miller, M.L., 1985, Geologic map of the Chugach National Forest, south-central Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF–1645–B, 16 p., 1 sheet, scale 1:250,000.
Nelson, S.W., and Koski, R.A., 1987, The Midas mine—A stratiform Fe-Cu-Zn-Pb sulfide deposit in late Cretaceous turbidite near Valdez, Alaska: Geological Society of America Abstracts with Programs, v. 19, no. 6, p. 436.
Nelson, S.W., Miller, M.L., Barnes, D.F., Dumoulin, J.A., Goldfarb, R.J., Koski, R.A., Mull, C.G., Pickthorn, W.J., Jansons, Uldis, Hoekzema, R.B., Kurtak, J.M., and Fechner, S.A., 1984, Mineral resource potential map of the Chugach National Forest, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF–1645–A, 24 p., scale 1:250,000.
Nesbitt, B.E., Murowchich, J.B., and Muelenbachs, Karl, 1986, Dual origin of lode-gold deposits in the Canadian Cordillera: Geology, v. 14, p. 506–509.
Newberry, R.J., 1986, Mineral resources of the northcentral Chugach Mountains, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 86–23, 44 p.
Nokleberg, W.J., Plafker, George, Lull, J.S., Wallace, W.K., and Winkler, G.R., 1989, Structural analysis of the southern Peninsular, southern Wrangellia, and northern Chugach terranes along the trans-Alaska crustal transect, northern Chugach Mountains, Alaska: Journal of Geophyscal Research, v. 94, no. B4, p. 4297–4320.
Overbeck, R.M., 1920, Nickel deposits in the lower Copper River valley: U.S. Geologcal Survey Bulletin 712, p. 91–98.
Page, R.A., Stephens, C.D., and Lahr, J.C., 1989, Seismicity of the Wrangell and Aleutian Wadati-Benioff zones and the North American plate along the trans-Alaska crustal transect, Chugach Mountain and Copper River Basin, southern Alaska: Journal of Geophysical Research, v. 94, no. B11, p. 16059–16082.
Park, C.F., 1933, The Girdwood district, Alaska: U.S. Geological Survyey Bulletin 849–G, p. 381–424.
Pickthorn, W.J., 1982, Stable isotope and fluid inclusion study of the Port Valdez district, southern Alaska: Los Angeles, Calif., University of California M.S. thesis, 66 p.
Pickthorn, W.J., and Silberman, M.L., 1984, Structural relations and fluid-inclusion data for mineralized and nonmineralized veins in the Port Valdez gold district, Valdez quadrangle, southern Alaska, *in* Coonrad, W.L., and Elliott, R.L., eds., The United States Geological Survey in Alaska—Accomplishments during 1981: U.S. Geological Survey Circular 868, p. 86–89.
Plafker, George, 1987, Regional geology and petroleum potential of the northern Gulf of Alaska continental margin, *in* Scholl, D.W., Grantz, Arthur, and Vedder, J.G., eds., Geology and resource potential of the continental margin of western North America and adjacent ocean basins: Houston, Tex., Circum-Pacific Council for Energy and Mineral Resources, Earth Scence Series 6, p. 229–268.
———1990, Regional geology and tectonic evolution of Alaska and adjacent parts of the northeast Pacific Ocean margin—Proceedings of the Pacific Rim Congress 90: Queensland, Australia, Australasian Insttute of of Mining and Metallurgy, p. 841–853.
Plafker, George, Lull, J.S., Nokleberg, W.J., Pessel, G.H., Wallace, W.K., ,and Winkler, G.R., 1989a, Geologic map of the Valdez A-4, B-3, B-4, C-3, C-4, and D-4 quadrangles, northern Chugach Mountains and southern Copper River Basin, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I–2164, scale 1:125,000.
Plafker, George, Moore, J.C., and Winkler, G.R., 1994, Geology of the southern Alaskan margin, *in* Plafker, George, and Berg, H.C., eds., The geology of Alaska: Boulder, Colo., Geological Society of America, The Geology of North America, v. G–1, p. 389–449.
Plafker, George, Nokleberg, W.J., and Lull, J.S., 1989b, Bedrock geology and tectonic evolution of the Wrangellia, Peninsular, and Chugach terranes along the trans-Alaska crustal transect in the northern Chugach Mountains and southern Copper River Basin, Alaska: Journal of Geophyscal Research, v. 94, no. B4, p. 4255–4295.
Richards, M.A., Jones, D.L., Duncan, D.A., and DePaolo, D.J., 1991, A mantle plume initation model for the formation of Wrangellia and other oceanic flood basalt plateaus: Science, v. 254, p. 263–267.
Richter, D.H., 1965, Geology and mineral deposits of central Knight Island, Prince William Sound,

Alaska: Alaska Division of Mines and Minerals Geologic Report 16, 37 p.
———1970, Geology and lode-gold deposits of the Nuka Bay area, Kenai Peninsula, Alaska: U.S. Geological Survey Professional Paper 625–G, 16 p.
Richter, D.H., and Jones, D.L., 1973, Structure and stratigraphy of the eastern Alaska Range, Alaska, *in* Arctic geology: Amercan Association of Petroleum Geologists Memoir 19, p. 408–420.
Rose, A.W., 1965, Geology and mineralization of the Midas mine and Sulphide Gulch areas near Valdez, Alaska: Alaska Division of Mines and Minerals Geologic Report 15, 21 p.
Sharp, R.R., and Hill, D.E., 1978, Uranium concentration in stream waters and sediments from selected sites in the eastern Seward Peninsula, Koyukuk, and Charley River areas, and across south-central Alaska: Los Alamos Scientific Laboratory Informal Report LA–6649–MS, 125 p.
Silberman, M.L., MacKevett, E.M., Jr., Connor, C.L., and Matthews, Alan, 1980, Metallogenic and tectonic significance of oxygen isotope data and whole-rock K-Ar ages of the Nikolai Greenstone, McCarthy quadrangle, Alaska, *in* Silberman, M.L., Field, C.W., and Berry, A.L., eds., Proceedings of the symposium on mineral deposits of the Pacific Northwest: U.S. Geological Survey Open-File Report 81–355, p. 52–73.
Silberman, M.L., Mitchell, P.A., and O'Neil, J.R., 1981, Isotopic data bearing on the origin and age of epithermal lode gold deposits in the Hope-Sunrise mining district, northern Kenai Peninsula, Alaska, *in* Albert, N.R.D., and Hudson, Travis, eds., The United States Geological Survey in Alaska—Accomplishments during 1979: U.S. Geological Survey Circular 823–B, p. B81–B84.
Smith, P.S., 1930, Mineral industry of Alaska in 1927: U.S. Geological Survey Bulletin 810, p. 1–64.
———1937, Mineral industry of Alaska in 1935: U.S. Geological Survey Bulletin 880–A, p. 1–95.
———1939, Mineral industry of Alaska in 1937: U.S. Geological Survey Bulletin 910–A, p. 1–113.
Sutley, S.J., Goldfarb, R.J., O'Leary, R.M., and Tripp, R.B., 1990, A comparison of geochemical exploration techniques and sample media in accretionary continental margins—An example from the Pacific Border Ranges, southern Alaska, U.S.A.: Journal of Geochemical Exploration, v. 37, p. 255–275.
Taylor, R.B., and Steven, T.A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, p. 1268–1270.
Tuck, Ralph, 1933, The Moose Pass–Hope district, Kenai Peninsula: U.S. Geological Survey Bulletin 849–I, p. 469–530.
Tysdal, R.G., 1978, Map showing placer deposits of the Seward and Blying Sound quadrangles, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF–880–B, scale 1:250,000.
Tysdal, R.G., and Case, J.E., 1979, Geologic map of the Seward and Blying Sound quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigations Map I–1150, 12 p., scale 1:250,000.
U.S. Bureau of Mines, 1980, Valdez 1:125,000 quadrangle map overlay showing mineral deposit locations, principal minerals, and number and type of claims: U.S. Bureau of Mines Open-File Report, August 1980, scale 1:250,000.
Van Alstine, R.E., and Black, R.F., 1946, Copper deposits of the Kotsina-Kuskulana district, Alaska: U.S. Geological Survey Bulletin 947–G, p. 121–141.
Winkler, G.R., compiler, 1992, Geologic map, cross sections, and summary geochronology of the Anchorage quadrangle, southern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I–2283, scale 1:250,000.
Winkler, G.R., Goldfarb, R.J., and Borden, J.C., 1995, Map showing geology and geochemically anomalous areas, Valdez 1° x 3° quadrangle, south-central Alaska, *in* Goldfarb, R.J., Borden, J.C., and Winkler, G.R., Geochemical survey of the Valdez 1° x 3° quadrangle, south-central Alaska: U.S. Geological Survey Bulletin 2084, 77 p., 1 sheet, scale 1:250,000.
Winkler, G.R., Goldfarb, R.J., Pickthorn, W.J., and Plafker, George, 1992, The Alaska Mineral Resource Assessment Program—Background information to accompany geologic and mineral-resource maps of the Valdez quadrangle, south-central Alaska: U.S. Geological Survey Circular 1087, 25 p.
Winkler, G.R., Miller, R.J., MacKevett, E.M., Jr., and Holloway, C.D., 1981a, Map and summary table describing mineral deposits in the Valdez quadrangle, southern Alaska: U.S. Geological Survey Open-File Report 80–892–B, 2 sheets, scale 1:250,000.
Winkler, G.R., and Plafker, George, 1993, Geologic map and cross sections of the Cordova and Middleton Island quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I–1984, scale 1:250,000.
Winkler, G.R., Silberman, M.L., Grantz, Arthur, Miller, R.J., and MacKevett, E.M., Jr., 1981b, Geologic map and summary geochronology of the Valdez quadrangle, southern Alaska: U.S. Geological Survey Open-File Report 80–892–A, 2 sheets, scale 1:250,000.

Table 2. *Characteristics of tracts favorable for low-sulfide gold-quartz veins and drainages favorable for precious-metal placers in the Valdez 1° x 3° quadrangle, Alaska*

Table 2. *Characteristics of tracts favorable for low-sulfide gold-quartz veins and drainages favorable for precious-metal placers in the Valdez 1° x 3° quadrangle, Alaska—CONTINUED*

[*Rating=level of potential (H, M, L)/level of certainty (A, B, C, D)—see definitions in text. **Delineating criteria=1, presence of quartz veining; 2, presence of greenschist-facies metamorphism; 3, proximity to felsic plutons; 4, presence of discordant linear structures; 5, presence of mines and prospects; 6, permissive geochemical anomalies; 7, presence of gold-bearing placers.]

Tract No.	Rating*	Delineating criteria**	Host rocks	Controlling structures	Associated intrusive rocks	Commodities present	Geochemical anomalies present	Geophysical features	Site no./Names	Location T., R.	Principal references
				LOW-SULFIDE GOLD-QUARTZ VEINS (MAP A)					LOW-SULFIDE GOLD-QUARTZ VEINS (MAP A)—CONTINUED		
G-1	H/D	1, 2, 3, 4, 5, 6, 7.	Upper Cretaceous Valdez Group.	Extensional faults, shear zones, and joints related to post-metamorphic uplift.	Hypabyssal Eocene felsic dikes and plugs.	Au, Ag	Ag, As, Au, Ba, Bi, Cd, Co, Cu, Fe, Mo, Ni, Pb, Sb, W, Zn.	None noted	G26	T8S, R5W	U.S. Bureau of Mines (1980)
									G27/Ramsey-Rutherford	T8S, R5W	Johnson (1915), Moffit (1954)
									G28/Pinochle	T8S, R5W	Johnson (1915)
									G29/Rose Johnson	T8S, R5W	Johnson (1915)
									G30/Valdez Bonanza, Ibex, Valdez	T8S, R6W	Brooks (1912), Brooks (1922), Johnson (1915)
									G31/Ethel, Blue Ribbon	T7S, R6W	Brooks (1912), Johnson (1915), Smith (1930)
									G32/Mountain View, July, Little Giant, Mountain King, Rose, Star.	T7S, R6W	Johnson (1915), Smith (1937)
									G33/Alaskan	T8S, R6W	Johnson (1915)
									G34/Quitsch	T7S, R6W	Johnson (1915
									G35/Hercules, Chesna, Monte Carlo, Sunshine, Slide, Millionaire.	T7S, R6W	Brooks (1912), Johnson (1915), Johnson (1919a).
									G36/Forty-Five, High Grade	T8S, R6W	Johnson (1915)
									G37/Big Four	T7S, R7W	Johnson (1915), Smith (1937)
									G38/McCallum	T8S, R7W	Johnson (1916), Johnson (1918)
									G39/Alaska Gold Hill	T8S, R7W	Johnson (1919a)
									G40/Owl/Thompson-Ford	T8S, R7W	Johnson (1915)
									G41/Guthrie and Belloli	T8S, R7W	Johnson (1915)
									G42/Bunker Hill, Seacoast Mining Co.	T8S, R8W	Johnson (1915)
									G43/Cube	T8S, R7W	Johnson (1915), Johnson (1919a)
									G44/Cliff	T9S, R8W	Johnson (1915), Moffit (1954)
									G45/Gold Bluff, Sealey-Davis	T8S, R8W	Johnson (1915)
									G46/Alice	T8S, R8W	Johnson (1915)
									G47/IXL, Shoup Bay Mining Co., Silver Gem, Spanish.	T8S, R8W	Brooks (1912), Johnson (1915)
									G48/Palmer	T8S, R8W	Brooks (1912)
									G49/Bluebird, Whistler	T8S, R8W	Brooks (1912), Johnson (1915)
									G50/Big Four, Hecla	T8S, R8W	Brooks (1912)
									G51/Cameron-Johnson, Minnie, Olson, Rambler.	T8S, R8W	Johnson (1912), Johnson (1918)
									G52/Gold King	T8S, R8W	Johnson (1915)
									G53/Bessie Williams	T8S, R9W	Johnson (1915)
									G54/National, Mayfield	T8s, R9W	Johnson (1915), Johnson (1916)
									G55/Rough and Tough, Ruff and Tuff, Thompson.	T8S, R9W	Smith (1939)
									G56/Divider Mountain	T7S, R9W	Jansons and others (1984)
G-2	H/D	1, 2, 3, 4, 5, 7.	Ditto	Ditto	Ditto	Au, Ag	Ag, As, Au, Cu, Fe, Pb.	None noted	G12	T5S, R2W	U.S. Bureau of Mines (1980)
									G13/Quartz Creek	T5S, R1W	Moffit (1918)
									G14/Telluride, Wetzler	T6S, R1W	Moffit (1918), Moffit (1935)
									G15/Squaw Creek	T6S, R1E	U.S. Bureau of Mines (1980)
									G16/Tiekel	T6S, R1E	MacKevett and Holloway (1977)
									G17/Glacier Creek	T6S, R1W	U.S. Bureau of Mines (1980)
									G18/Knowles	T6S, R1W	Moffit (1935)
									G19/Eagle	T6S, R1W	Moffit (1935)
									G20/Ross	T6S, R1W	Moffit (1935)
									G21/Portland	T7S, R1E	Moffit (1918)
									G22/Reis	T7S, R1E	Moffit (1918)
G-3	H/B	1, 2, 3, 4, 6, 7.	Ditto	Extensional faults, shear zones, and joints.	Ditto	Au, Ag	Ag, As, Au, B, Be, Co, Cu, Ni, Sn, W, Zn.	None noted	None noted		
G-4	M/C	1, 2, 3, 4, 5, 6, 7.	Ditto	Extensional faults, shear zones, and joints related to post-metamorphic uplift.	Hypabyssal Eocene felsic dikes and plugs.	Au, Ag (±Cu, Pb, Zn).	Ag, As, Au, B, Ba, Bi, Cd, Co, Cu, Fe, Mn, Mo, Ni, Pb, Sb, V, W.	Positive aeromagnetic anomalies over areas of mafic metavolcanic rocks.	G59/Curly Kidney	T10S, R8W	Johnson (1919b)
									G60/Orion	T10S, R7W	Johnson (1919b)
									G61/Patten Mining Co., Golden, Happy Days.	T9S, R7W	Johnson (1919b), Mulligan (1974)

Table 2. *Characteristics of tracts favorable for low-sulfide gold-quartz veins and drainages favorable for precious-metal placers in the Valdez 1° x 3° quadrangle, Alaska—CONTINUED*

Table 2. *Characteristics of tracts favorable for low-sulfide gold-quartz veins and drainages favorable for precious-metal placers in the Valdez 1° x 3° quadrangle, Alaska—CONTINUED*

Tract No.	Rating*	Delineating criteria**	Host rocks	Controlling structures	Associated intrusive rocks	Commodities present	Geochemical anomalies present	Geophysical features	Site no./Names	Location T., R.	Principal references
				LOW-SULFIDE GOLD-QUARTZ VEINS (MAP A)—CONTINUED							
G-5	M/C	1, 2, 3, 4, 5, 6.	Upper Cretaceous Valdez Group.	Extensional faults, shear zones, and joints related to post-metamorphic uplift.	Hypabyssal Eocene felsic dikes and plugs.	Au, Ag	Au, Zn	None noted	G23/Townsend and Holland	T8S, R1W	Moffit (1935)
G-6	M/C	1, 2, 3, 4, 6	Ditto	Ditto	Ditto	Au, Ag	Ag, As, Au, Cu	None noted	None noted	T7S, R3W	This report
G-7	M/C	1, 2, 3, 4, 6, 7?.	Ditto	Ditto	Ditto	Au, Ag	Ag, Au, Cu, Fe, Mn, Pb, W, Zn.	None noted	None noted	T6S, R2E	Goldfarb and others (1995)
G-8	M/C	1, 2, 3, 4, 6.	Ditto	Ditto	Ditto	Au, Ag	Ag, Au, Cr, Fe, Mo, W.	None noted	None noted	T8S, R7E	Goldfarb and others (1995)
G-9	M/B	1, 2, 3, 4, 5, 6.	Ditto	Ditto	Ditto	Au, Ag	Ag, Au, Ba, Co, Cr, Cu, Zn.	None noted	G8/Kimball Pass	T4S, R2E	U.S. Bureau of Mines (1980), Goldfarb and others (1995).
									G9/Kimball Pass East	T4S, R2E	U.S. Bureau of Mines (1980), Goldfarb and others (1995).
									G10	T4S, R2E	U.S. Bureau of Mines (1980), Goldfarb and others (1995).
									G11	T4S, R2E	U.S. Bureau of Mines (1980), Goldfarb and others (1995).
G-10	M/B	1, 2, 3, 4, 5, 6, 7.	Ditto	Extensional faults, shear zones, and joints related to uplift.	Ditto	Au, Ag	None noted	None noted	G24/Worthington Glacier G25	T8S, R3W T8S, R3E	U.S. Bureau of Mines (1980) U.S. Bureau of Mines (1980)
G-11	L/B	1, 2, 3, 4	Ditto	Extensional faults, joints.	Eocene felsic plutons.	Au?	None noted	None noted	None noted		Goldfarb and others (1995)
G-12	M/C	1, 3, 4, 5, 6.	Mesozoic McHugh Complex and Eocene tonalite.	Extensional faults, shear zones, and joints.	Eocene tonalite stock and aplite dikes.	Au	Ag, As, Au, Cu, Pb, Zn.	None noted	G6/Opal, Tiger Mining Co. G7/Fivemile Creek	T4S, R4E T1S, R5E	MacKevett and Holloway (1977) Berg and Cobb (1967)
G-13	M/B	6	Mesozoic McHugh Complex.	No data	None noted	Au	Au, W	None noted	None noted	T4S, R1W	Goldfarb and others (1995)
G-14	L/B	6	Ditto	No data	Eocene felsic dikes	Au	Au, B, Co, Cr, Ni	None noted	None noted	T2S, R8W	Goldfarb and others (1995)
G-15	L/B	1, 5, 6, 7?	Orca Group	No data	None noted	Au	Ag, As, Au, Cu	None noted	G57/Columbia Glacier West G58/Columbia Glacier East	T9S, R10W T9S, R10W	U.S. Bureau of Mines (1980) U.S. Bureau of Mines (1980)
G-16	M/B	1, 2, 5, 6, 7	Skolai Group	Joints and shear zones.	Microdiorite dikes (Jurassic?).	Au	Ag, As, Au, Cu, Fe.	None noted	G4/Loraine Creek G5/Benito Creek	T3S, R7E T3S, R7E	U.S. Bureau of Mines (1980) Moffit and Mertie (1923)
G-17	L/B	1?, 5, 7	Jurassic granodiorite.	No data	Jurassic granodiorite.	Au	Cu	None noted	G3/Copper Creek	T2S, R7E	U.S. Bureau of Mines (1980)
G-18	L/B	5, 6	Strelna Metamorphics.	No data	Jurassic granodiorite.	Au?	Ba, Cu, Fe	None noted	G2/Chetaslina River	T2N, R5E	U.S. Bureau of Mines (1980)
G-19	L/B	1?, 5	Talkeetna Formation.	No data	Jurassic granodiorite.	Au?	None noted	None noted	G1/Kaina Lake	T1N, R6W	U.S. Bureau of Mines (1980)

Table 2. *Characteristics of tracts favorable for low-sulfide gold-quartz veins and drainages favorable for precious-metal placers in the Valdez 1° x 3° quadrangle, Alaska—CONTINUED*

Table 2. *Characteristics of tracts favorable for low-sulfide gold-quartz veins and drainages favorable for precious-metal placers in the Valdez 1° x 3° quadrangle, Alaska—CONTINUED*

Tract No.	Rating*	Delineating criteria**	Host rocks	Controlling structures	Associated intrusive rocks	Commodities present	Geochemical anomalies present	Geophysical features	Site no./Names	Location T., R.	Principal references
PRECIOUS-METAL PLACERS (MAP A)—CONTINUED											
PL-1	M/C					Au	Ag, As, Au, Co, Cu, Pb, Zn.		Mineral Creek	T8S, R6W	Jansons and others (1984), Goldfarb and others (1995).
PL-2	M/C					Au	Ag, As, B, Pb		Salmon Creek	T9S, R7W	Jansons and others (1984), Goldfarb and others (1995).
PL-3	M/C					Au	As, Co, Cr, Cu, Ni		Solomon Gulch	T9S, R6W	Jansons and others (1984), Goldfarb and others (1995).
PL-4	M/C					Au	Ag, As, Au, Ba, Bi, Co, Cu, Mn, Pb.		Browns Creek	T20S, R4W	Jansons and others (1984), Goldfarb and others (1995).
PL-5	M/C					Au	Ag, As, Bi, Co, Cu, Mn, Pb.		Bench Creek	T9S, R3W	Jansons and others (1984), Goldfarb and others (1995).
PL-6	H/C					Au	Ag, As, Au, Co, Cu, Mn, Pb.		Marshall Glacier	T9S, R2W	Jansons and others (1984), Goldfarb and others (1995).
PL-7	M/C					Au	Ag, As, Au, B, Bi, Co, Cu, Mn, Pb, Sb.		Tasnuna River	T10S, R3E	Jansons and others (1984), Goldfarb and others (1995).
PL-8	M/C					Au	Ag, As, Au, B, Bi, Co, Cu, Mn, Pb, W, Zn.		Cleave Creek	T9S, R2E	Moffit (1914), Jansons and others (1984), Golfarb and others (1995).
PL-9	L/C					Au	Ag, Au, Cu, Pb		Little Bremner River	T8S, R5E	Moffit (1914), Jansons and others (1984), Goldfarb and others (1995).

Table 3. *Characteristics of tracts favorable for massive sulfide deposits in the Valdez 1° x 3° quadrangle, Alaska*

Table 3. *Characteristics of tracts favorable for massive sulfide deposits in the Valdez 1° x 3° quadrangle, Alaska—CONTINUED*

[*Rating=level of potential (H, M, L)/level of certainty (A, B, C, D)—see definitions in text. **Delineating criteria=1, presence of mafic volcanic or metavolcanic rocks; 2, presence of calcareous sedimentary rocks; 3, presence of stratiform or stratabound copper (±iron-zinc) sulfide minerals; 4, presence of mines or prospects; 5, permissive geochemical anomalies; 6, presence of northeast- or northwest-trending steep fault or breccia zones.]

Tract No.	Rating*	Delineating criteria**	Host rocks	Controlling structures	Associated intrusive rocks	Commodities present	Geochemical anomalies present	Geophysical features	Site no./Names	Location T., R.	Principal references
					VOLCANOGENIC DEPOSITS (MAP B)				VOLCANOGENIC DEPOSITS (MAP B)—CONTINUED		
C-1	H/D	1,3,4,5	Upper Cretaceous Valdez Group.	Shearing mostly parallel to layering.	Mafic sills	Cu, Au, Ag, Zn.	Ag, As, Au, B, Bi, Co, Cr, Cu, Fe, Mn, Ni, W.	Positive aeromagnetic highs located over mafic igneous rocks.	C3/Midas, All American C4A, B/Addison-Powell, Sulphide Gulch.	T10S, R6W T10S, R5W	Johnson (1915), Moffit and Fellows (1950), Rose (1965), Crowe and others (1992). Johnson (1916), Moffit and Fellows (1950), Rose (1965).
C-2	M/C	1,3,4	Ditto	Discordant shears.	Ditto	Cu, Zn	Ag, As, Cr, Cu, Fe, Pb, Zn.	Ditto	C1/Jack Bay (1) C2/Jack Bay (2)	T9S, R8W T9S, R8W	Johnson (1919b), Moffit and Fellows (1950) Johnson (1919b), Moffit and Fellows (1950)
C-3	M/C	1,3,5	Ditto	Discordant quartz veins.	Ditto	Cu	Ag, As, Co, Cr, Cu, Fe, Pb, W, Zn.	Ditto	C5/Wortmanns Glacier	T10S, R3W	Winkler and others (1981a), Goldfarb and others (1995).
C-4	M/C	1,3,5	Ditto	Ditto	Ditto	Cu	Ag, As, Cu, Fe, Pb, Zn.	None noted	C6/Tsina Glacier	T7S, R3W	Winkler and others (1981a)
C-5	L/B	1,5	Ditto	Ditto	None noted	Cu	Ag, As, Au, Cr, Cu, Fe, Mn, Pb, W, Zn.	None noted	None noted	T8S, R1E	Goldfarb and others (1995)
C-6	L/B	1,5	Ditto	Ditto	None noted	Cu	As, Au, Cu, Mn	None noted	None noted	T8S, R4E	Goldfarb and others (1995)
C-7	L/B	5	Ditto	Ditto	None noted	Cu	Ag, Co, Cu, Fe, Mn, Pb, Zn.	None noted	None noted	T9S, R7E	Goldfarb and others (1995)
C-8	M/C	1,2,3,4, 5,6.	Strelna Metamorphics.	Fractures, joints.	Jurassic tonalite	Cu	Ag, B, Co, Cu	None noted	C7/Falls Creek C8/Divide Creek C9/Surprise Creek C10/Blackney	T6S, R6E T6S, R6E T5S, R6E T5S, R6E	Moffit (1914), Goldfarb and others (1995) Moffit (1914) Moffit (1914) Moffit (1914), Goldfarb and others (1995)
C-9	M/C	1,2,4,5, 6.	Upper Triassic Nikolai Greenstone near contact with overlying Upper Triassic Chitistone Limestone.	Shear zones, faults, and fractures.	Porphyritic dikes near greenstone/ limestone contacts.	Cu	B, Cu, V, Zn	None noted	C12/Copper Queen, Copper King, Mineral King, Swayze. C13/Curtis, Goodyear, Elizabeth, Henry Prather, Lizzie G., Louise, Marie Antoinette, Mary Ellen, Marmot. C14/Lawton, Leland, Albert Johnson, Guthrie, Cliff, Fog, Elliott Creek. C15/Chance C16/Blue Bird, Bunker Hill, Forget-Me-Not, Montana Boy. C17/Mullen, Cave, Mountain Sheep, Peacock.	T3S, R8E T2S, R7E T2S, R7E T2S, R7E T2S, R8E T2S, R7E	Moffit and Mertie (1923) Moffit (1915), Moffit and Mertie (1923) Mendenhall (1905), Moffit and Mertie (1923) Moffit and Mertie (1923) Moffit and Mertie (1923), Van Alstine and Black (1946). Moffit and Mertie (1923), Van Alstine and Black (1946).
C-10	L/B	1,4	Strelna Metamorphics?.	No data	No data	Cu?	None noted	None noted	C11/Iron Creek	T3S, R7E	U.S. Bureau of Mines (1980)
C-11	L/B	1,2	Nikolai Greenstone/ Chitistone Limestone.	No data	None noted	Cu?	None noted	None noted	None noted	T1S, R7E	This report
C-12	L/C	1,2,4,5?	Nikolai Greenstone.	No data	None noted	Cu?	Cu, Fe	None noted	C18/Cheshnina River	T1N, R6E	U.S. Bureau of Mines (1980)
C-13	L/B	1,5	Talkeetna Formation.	No data	Jurassic gabbro	Cu?	Cu, Fe, Zn	None noted	C19/Willow Mountain	T1S, R1E	Berg and Cobb (1967), MacKevett and Holloway (1977).
C-14	L/B	1,4,5	Talkeetna Formation.	Shear zones and breccia zones.	None noted	Cu?	Ag, As, Ba, Zn	None noted	C20/Heavenly Ridge	T1N, R9W	Winkler and others (1981a), Newberry (1986)

Table 3. *Characteristics of tracts favorable for massive sulfide deposits in the Valdez 1° x 3° quadrangle, Alaska—CONTINUED*

Table 3. *Characteristics of tracts favorable for massive sulfide deposits in the Valdez 1° x 3° quadrangle, Alaska—CONTINUED*

Tract No.	Rating*	Delineating criteria**	Host rocks	Controlling structures	Associated intrusive rocks	Commodities present	Geochemical anomalies present	Geophysical features	Site no./Names	Location T., R.	Principal references
KENNECOTT-TYPE DEPOSITS (MAP B)								KENNECOTT-TYPE DEPOSITS (MAP B)—CONTINUED			
C-9	M/C	1, 2, 3, 4, 5, 6.	Chitistone Limestone near contact with underlying Nikolai Greenstone.	Shear zones, fractures, and breccias.	Porphyritic dikes near greenstone/ limestone contacts.	Cu	Au, B, Cu, V, Zn	None noted	C12/Swayze	T3S, R8E	Moffit and Mertie (1923), Van Alstine and Black (1946).
									C16/Ammann	T2S, R8E	Moffit and Mertie (1923), Van Alstine and Black (1946).
									C17/Mullen, Cave	T2S, R7E	Moffit and Mertie (1923), Van Alstine and Black (1946).
C-11	L/B	1,2	Ditto	None noted	None noted	None noted	None noted	None noted	None noted	T1S, R7E	This report
C-12	L/B	1,2	Ditto	None noted	None noted	None noted	None noted	None noted	None noted	T1N, R6E	This report

Table 4. *Characteristics of tracts favorable for magmatic deposits in the Valdez 1° x 3° quadrangle, Alaska*

Table 4. *Characteristics of tracts favorable for magmatic deposits in the Valdez 1° x 3° quadrangle, Alaska—CONTINUED*

[*Rating=level of potential (H, M, L)/level of certainty (A, B, C, D)—see definitions in text. **Delineating criteria=1, presence of ultramafic or mafic intrusive igneous rocks; 2, presence of igneous layering; 3, presence of sulfide or oxide minerals; 4, presence of mines or prospects; 5, permissive geochemical anomalies.]

Tract No.	Rating*	Delineating criteria**	Host rocks	Controlling structures	Associated intrusive rocks	Commodities present	Geochemical anomalies present	Geophysical features	Site no./Names	Location T., R.	Principal references
			LAYERED AND PODIFORM CHROMITE DEPOSITS (MAP B)								
M-1	H/D	1, 2, 3, 4, 5.	Tonsina ultramafic and mafic sequence.	Mineralogic and tectonic layers.	Layered dunite, clinopyroxenite, and peridotite.	Cr (platinum-group elements).	Co, Cr, Cu, Fe, Ni, Pd, Pt.	Pronounced positive aeromagnetic anomalies.	M1/Dust Mountain M2/Sheep Hill M3/Bernard Mountain	T3S, R3E T3S, R2E T3S, R1E	Foley and Barker (1985), Newberry (1986) Foley and Barker (1985), Newberry (1986) Hoffman (1974), Foley and Barker (1985), Newberry (1986).
M-2	M/B	1, 2, 3, 5	Serpentinized ultramafic rocks.	Ditto	Ditto	Cr	Cr, Cu, Ni, V	Ditto	None noted	T3S, R4E	Goldfarb and others (1995)
M-3	M/B	1, 2, 3, 4, 5.	Ditto	Ditto	Ditto	Cr	Co, Cr, Cu, Fe, Ni, V.	Ditto	M4/Barnette Creek	T1S, R9W	Winkler and others (1981a), Newberry (1986)
			NICKEL-COPPER SULFIDE DEPOSITS (MAP B)								
N-1	H/C	1,34,5	Ultramafic and mafic sills, discordant quartz veins.	None noted	Foliated Jurassic quartz diorite plutons, Tertiary monzonite plugs.	Ni, Cu (Co, Ag, platinum-group elements).	Ag, As, Au, B, Co, Cr, Cu, Fe, Ni, Pb, Pd, Pt, Zn.	Local, high-amplitude positive aero-magnetic anomalies.	N1/Summit Lake N2/Spirit Mountain N3/Summit Lake N4/Summit Lake N5/Summit Lake	T7S, R6E T6S, R6E T6S, R6E T6S, R7E T6S, R7E"	MacKevett and Holloway (1977), U.S. Bureau of Mines (1980). Kingston and Miller (1945), Herreid (1970) MacKevett and Holloway (1977) U.S. Bureau of Mines (1980) U.S. Bureau of Mines (1980)
N-2	M/B	1, 2, 3, 5	Serpentinized ultramafic rocks; amphi-bolite-grade metamorphic rocks.	No data	Layered gabbronorite.	Ni?, Cu?	Ag, B, Co, Cr, Cu, Fe, Mg, Ni, V.	Pronounced positive aeromagnetic anomaly.	None noted	T3S, R8W	Goldfarb and others (1995)
N-3	L/B	1, 2, 3, 4, 5.	Tonsina ultramafic and mafic sequence.	Mineralogic layers.	Layered gabbronorite.	Ni, Cu platinum-group elements.	Co, Cr, Cu, Fe, Mg, Ni, Pd, Pt.	Ditto	None noted	T3S, R3E	Newberry (1986), Goldfarb and others (1995)
N-4	L/B	1, 2, 3, 4, 5.	Nelchina River Gabbronorite.	Mineralogic layers.	Tertiary? felsic plugs and dikes.	Ni, Cu	Ag, Au, Co, Cr, Cu, Fe, Mg, Ni, V.	Ditto	None noted	T1S, R9W	Newberry (1986), Goldfarb and others (1995)

Table 5. *Characteristics of tracts favorable for polymetallic vein deposits and permissive for porphyry copper-molybdenum deposits in the Valdez 1° x 3° quadrangle, Alaska*

Table 5. *Characteristics of tracts favorable for polymetallic vein deposits and permissive for porphyry copper-molybdenum deposits in the Valdez 1° x 3° quadrangle, Alaska—CONTINUED*

[*Rating=level of potential (H, M, L)/level of certainty (A, B, C, D)—see definitions in text. **Delineating criteria=1, presence of quartz veining; 2, presence of discordant linear structures; 3, proximity to felsic to intermediate plutons; 4, presence of permissive geochemical anomalies; 7, presence of sulfide minerals.]

Tract No.	Rating*	Delineating criteria**	Host rocks	Controlling structures	Associated intrusive rocks	Commodities present	Geochemical anomalies present	Geophysical features	Site no./Names	Location T., R.	Principal references
					POLYMETALLIC VEINS (MAP A)				POLYMETALLIC VEINS (MAP A)—CONTINUED		
P-1	L/B	2,3,4	Upper Cretaceous Valdez Group.	No data	Felsic dikes and plugs.	No data	Ag, As, Au, Cu, Fe, Mo, Pb, W, Zn.	None noted	None noted	T4S, R3W	Goldfarb and others (1995)
P-2	L/B	2,3,4	Ditto	Ditto	Ditto	No data	Ditto	Ditto	None noted	T5S, R5W	Goldfarb and others (1995)
P-3	L/B	2,3,4	Mesozoic McHugh Complex.	Ditto	Ditto	No data	Ag, Co, Cr, Cu, Mg, Sb, Ti, Zn.	Ditto	None noted	T3S, R6W	Goldfarb and others (1995)
				PORPHYRY COPPER-MOLYBDENUM STOCKWORKS AND VEINS (MAP B)					PORPHYRY COPPER-MOLYBDENUM STOCKWORKS AND VEINS (MAP B)—CONTINUED		
I-1	L/B	3,4,5	Jurassic granodiorite.	Ditto	Jurassic granodiorite.	Cu, Mo	Cu, Mo	None noted	None noted	T4S, R6E	MacKevett and Holloway (1977)
I-2	L/B	1,3,4,5	Lower Jurassic Talkeetna Formation.	Ditto	Jurassic granodiorite.	No data	Co, Mo, V	Ditto	None noted	T1N, R6W	Goldfarb and others (1995)