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MISCELLANEOUS FIELD STUDIES
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PAMPHLET

MINERALOGICAL MAPS SHOWING DISTRIBUTION OF SELECTED ORE-RELATED MINERALS IN THE NONMAGNETIC, HEAVY-MINERAL-CONCENTRATE FRACTION OF STREAM SEDIMENT FROM THE MOUNT HAYES 1° x 3° QUADRANGLE, EASTERN ALASKA RANGE, ALASKA

By

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STUDIES RELATED TO AMRAP

The U.S. Geological Survey is required by ANILCA (Alaska National Interest Lands Conservation Act, Public Law 96-487, 1980) to survey certain Federal lands in Alaska to determine their mineral values, if any. Results from AMRAP (Alaska Mineral Resource Assessment Program) must be made available to the public and be submitted to the President and the Congress. This report presents results and some interpretation of the distribution or ore-related minerals in the heavy-mineral-concentrate fraction of stream-sediment samples collected in the Mount Hayes 1° x 3° quadrangle, Alaska. This is one of a series of reports that have been prepared for the quadrangle; other reports in this series include Curtin and others (1989) and Nokleberg and others (1990, 1991, 1992).

INTRODUCTION

Exploratory geochemical sampling was done in 1979, 1980, and 1981. The collection of composite samples of stream sediment or glacial debris was emphasized the first 2 years; the last year was spent collecting mineralized stream pebbles, float, and outcrop samples. The stream-sediment and heavy-mineral-concentrate samples were collected at 795 sites on tributary streams having drainage basins ranging from 1 to 5 mi^2 in area. The glacial debris samples were collected at 116 sites on tributary glaciers also having drainage basins ranging from 1 to 5 mi^2 in area. All of these samples were analyzed for 31 elements by six-step semiquantitative emission spectrography (Grimes and Marranzino, 1968). In addition, all samples were analyzed for zinc by an atomic absorption method (Ward and others, 1969). The spectrographic and chemical results are available in O'Leary and others (1982).

PREPARATION OF THE CONCENTRATE SAMPLES

The heavy-mineral-concentrate fraction of the stream-sediment samples (hereafter referred to as concentrate samples) was obtained at each site by wet-sieving active alluvium through a stainless-steel screen having a mesh opening of 2 mm into a 14-in. steel gold pan. The minus-2-mm material was panned to remove most of the quartz, feldspar, barren schist fragments, clay-size particles, and organic material. The composite glacial debris samples were collected by sieving detrital rock material and ice through the 2-mm screen into a gold pan and then panning to obtain the heavy-mineral fraction.

In the laboratory, the concentrate samples were air dried and then sieved through a 30-mesh (0.60-mm) sieve. The minus-30-mesh fraction was further separated using bromoform to remove the remaining lighter minerals having a specific gravity of 2.85 or less. Heavy-mineral fractions were extracted from the mineralized stream pebbles, float, and outcrop specimens by coarsely grinding the samples in a Braun pulverizer with the ceramic plates set 1 mm apart, panning the samples, and then separating the minerals using bromoform flotation and magnetic separation. A nonmagnetic fraction of each sample was obtained using a Frantz Isodynamic Separator at a coil setting equivalent to 0.7 ampere and track settings equivalent to 5° forward slope and 10° side tilt. By using this magnetic separation procedure, a relatively nonmagnetic fraction of each sample free of magnetic iron oxides, garnet, amphibole, pyroxene, epidote, and other high-iron silicates was obtained. Elimination of these minerals from the concentrate samples reduces the interference from variations in composition of non-ore-related minerals, permits easier spectrographic detection of ore-related elements, and facilitates visual identification of mineral grains.

The nonmagnetic heavy-mineral fraction was scanned visually using a binocular microscope and short-wave ultraviolet light to identify ore-related minerals. In most cases, the mineral grains could be identified from their physical properties, but X-ray diffraction was used to confirm some species. This visual examination is an important supplement to the spectrographic analyses because the particulate nature of this sample medium poses problems for both the sample preparer and the analyst. A 5-mg split of finely pulverized sample is normally used for the spectrographic analysis; however, malleable minerals such as native gold, silver, and copper may be poorly represented in the analyzed portion because of smearing out of the metals on the pulverizer components.

Another benefit of the visual examination is identifying artifacts such as bullet and solder fragments, wire, or other man-made contaminants. It is useful to be aware of these contaminants as they can give inflated values of some ore-related elements in the spectrographic results.

GEOLOGY

INTRODUCTION

The Mount Hayes quadrangle encompasses about 6,700 mi^2 of east-central Alaska. The main physiographic feature of the area is the eastern Alaska Range, which forms an arcuate wall of glacially sculptured high peaks and spectacular valley glaciers. Mount Hayes is the highest point in the quadrangle at 13,832 ft. The complex bedrock geology of the quadrangle is divided into two general areas by the Denali fault, a major northwest-trending geologic and geographic feature that bisects the quadrangle. The bedrock geology in the quadrangle is further subdivided into tectonostratigraphic terranes. The term "terrane" as used here in this report is defined as a fault-bounded geologic entity having a distinct geologic, stratigraphic, and structural history, all differing markedly from those of neighboring terranes (Jones and Silberling, 1979). Terranes are further divided into "subterranes," which consist of various fault-bounded but originally stratigraphically related parts of a terrane. For this report, a brief description of the geology for each terrane or subterrane is presented. The geology, mineral resource potential, and the lode mineral occurrences and deposits for each terrane or subterrane (Nokleberg and others, 1990, 1991) are reflected in the concentrate samples collected from streams draining these terranes. Our study shows specific ore-mineral "signatures" for each terrane.

Yukon-Tanana terrane

The most extensive bedrock unit north of the Denali fault is the Yukon-Tanana terrane (Jones and others, 1984). In this report the Yukon-Tanana terrane is subdivided, from north to south, into the Lake George, Macomb, Jarvis Creek Glacier, and Hayes Glacier subterranes (Aleinikoff and Nokleberg, 1985a; Nokleberg and Aleinikoff, 1985; Nokleberg, Aleinikoff, and Lange, 1986; Nokleberg and others, 1989) in order to emphasize their genetic relationships as various structural levels of the Yukon-Tanana terrane. These subterranes are interpreted as various levels of a complex and highly metamorphosed Devonian and Mississippian continental-margin igneous arc (Nokleberg and Aleinikoff, 1985; Nokleberg and others, 1989). Regional tilting toward the south near the Denali fault exposes the deeper, granitic levels of the igneous arc to the north, and the shallower, volcanic levels to the south.

Lake George subterrane

The Lake George subterrane (Aleinikoff and Nokleberg, 1985a, b; Nokleberg and Aleinikoff, 1985; Nokleberg and others, 1989) is in the northeastern part of the quadrangle and is composed of (1) multiply deformed, medium- to coarse-grained metasedimentary rocks consisting of muscovite-quartz-biotite-garnet schist and metaquartzite derived from quartz-rich to clay-rich shale and quartzite of Devonian or older age; (2) relatively younger Devonian, medium-grained, gneissose granodiorite and granite; and (3) Mississippian coarse-grained augen gneiss derived from granite and granodiorite. The metasedimentary rocks and metamorphosed plutonic rocks are ductilely deformed and regionally metamorphosed under conditions of the middle or upper amphibolite facies into mylonitic schist and mylonitic gneiss, and exhibit local retrogression to the lower greenschist facies (Nokleberg, Aleinikoff, and Lange, 1986; Nokleberg and others, 1989). The metamorphosed rocks are locally intruded by early Tertiary to Late Cretaceous diorite, granodiorite, and granite. These plutonic rocks are locally slightly to moderately schistose and are weakly metamorphosed at lower greenschist facies. Small areas of some plutons are extensively hydrothermally altered. The Lake George subterrane is bounded on the south by the Tanana River fault.

Macomb subterrane

The Macomb subterrane (Aleinikoff and Nokleberg, 1985a; Nokleberg and Aleinikoff, 1985) occurs south of the Lake George subterrane in the northeastern part of the quadrangle. The Macomb subterrane is composed of (1) older, multiply deformed, medium-grained, pelitic schist, calc-schist, and quartz-feldspar-biotite schist derived from shale, marl, and sandstone of Devonian or older age and (2) a suite of relatively younger, shallow-level, fine- to medium-grained, gneissose granite, granodiorite, quartz diorite, and diorite of Devonian age. The metasedimentary rocks and the metamorphosed plutonic rocks are ductilely deformed and regionally metamorphosed at epidote-amphibolite to upper greenschist facies into mylonitic gneiss and schist (Nokleberg, Aleinikoff, and Lange, 1986). The metasedimentary and metamorphosed plutonic rocks are intruded by younger and less deformed and metamorphosed early Tertiary to Late Cretaceous rocks ranging in composition from quartz diorite to granite. These younger plutonic rocks are locally weakly to moderately deformed and metamorphosed. The Macomb subterrane is bounded to the south by the Elting Creek fault.

Jarvis Creek Glacier subterrane

The Jarvis Creek Glacier subterrane (Aleinikoff and Nokleberg, 1985a; Nokleberg and Aleinikoff, 1985) occupies much of the northern part of the quadrangle, south of the Macomb subterrane. The Jarvis Creek Glacier subterrane consists of fine-grained, multiply deformed schist derived from Devonian or older sedimentary and volcanic rocks. This subterrane is subdivided into three major rock units: (1) a metasedimentary rocks unit rich in fine-grained metasedimentary rocks and containing minor metavolcanic rocks; (2) a metavolcanic rocks unit rich in fine-grained metavolcanic rocks and containing moderate amounts of fine-grained metasedimentary rocks; and (3) an areally restricted unit of gneissic granodiorite, diorite, and augen gneiss. The metasedimentary and metavolcanic rocks are almost totally recrystallized (Nokleberg, Aleinikoff, and Lange, 1986). The metasedimentary rocks consist of varying proportions of pelitic schist, quartzite, calc-schist, quartz-feldspar schist, and marble. Protoliths for these rocks include shale, quartz sandstone, marl, sandstone, volcanic graywacke, and limestone. The metavolcanic rocks consist of varying proportions of abundant metaandesite and meta-quartz-keratophyre, less abundant metadacite and metabasalt, and very sparse metarhyodacite. In the north-central part of the quadrangle at Donnelly Dome, the Jarvis Creek Glacier subterrane is intruded by intensely deformed and gneissose Devonian metagranodiorite and sparse augen gneiss derived from granite and granodiorite.

The Jarvis Creek Glacier subterrane is ductilely deformed and regionally metamorphosed mainly at greenschist facies into mylonitic schist, or locally phyllonite (Nokleberg, Aleinikoff, and Lange, 1986). Locally, large areas of upper greenschist facies and lower amphibolite facies metamorphism occur in the northern part of the Jarvis Creek Glacier subterrane in the area south of Granite Mountain and south of Donnelly Dome. The higher grade metamorphic minerals are progressively replaced by lower grade metamorphic minerals southward. The Jarvis Creek Glacier subterrane is locally intruded by small to large plutons of granite and granodiorite of early Tertiary to Late Cretaceous age mainly in the Granite Mountain, Molybdenum Ridge, and Buchanan Creek areas. In the central part of the Jarvis Creek Glacier subterrane is an intrusive complex of early Tertiary monzonite, alkali gabbro, lamprophyre, and quartz diorite, partly surrounded by a ring dike of granite. Local lamprophyre dikes also occur in the eastern part of the Jarvis Creek Glacier subterrane, and locally abundant gabbro, diabase, and metagabbro dikes also cut the metamorphic rocks of the Jarvis Creek Glacier subterrane. The Jarvis Creek Glacier subterrane is bounded to the south by the Hines Creek, Denali, and Mount Gakona faults.

Hayes Glacier subterrane

The Hayes Glacier subterrane (Aleinikoff and Nokleberg, 1985a; Nokleberg and Aleinikoff, 1985) occurs across the central part of the quadrangle, south of the Jarvis Creek Glacier subterrane. The Hayes Glacier subterrane consists of multiply deformed phyllite derived from Devonian or older sedimentary and volcanic rocks that can be subdivided into two major units: (1) a unit of metasedimentary rocks containing sparse metavolcanic rocks and (2) a unit of metavolcanic rocks containing moderate to substantial amounts of metasedimentary rocks. Rocks in both units are almost totally recrystallized and contain few to no relict minerals. The metasedimentary rocks in the eastern part of the quadrangle consist of varying proportions of pelitic phyllite, quartz-rich phyllite, quartz-feldspar phyllite, and minor calc-phyllite and marble derived from shale, chert, or, less likely, quartz siltstone, volcanic graywacke, marl, and limestone. In the western part of the quadrangle, the metasedimentary rocks unit consists predominantly of multiply deformed black to dark-gray pelitic schist, quartz-mica schist, and lesser quartzite and calc-schist derived from shale, quartz-siltstone and sandstone, and marble of pre-mid-Cretaceous age. The metavolcanic rocks consist of varying proportions of abundant metaandesite and metamorphosed quartz keratophyre, and sparse metadacite and metabasalt.

The Hayes Glacier subterrane is ductilely deformed and regionally metamorphosed at lower and middle greenschist facies into phyllonite and blastomylonite (Nokleberg, Aleinikoff, and Lange, 1986). In the eastern part of the quadrangle, southeast of the Robertson River, the Jarvis Creek Glacier and Hayes Glacier subterranes are intruded by an early Tertiary to Late Cretaceous granite pluton. In the western part of the quadrangle, the Hayes Glacier subterrane is intruded by the nonschistose granite pluton of Mount Hayes, of early Tertiary to Late Cretaceous age. The Hayes Glacier subterrane is also intruded by relatively older and locally abundant mid- or Late Cretaceous metagabbro and metadiabase dikes and sills. The Hayes Glacier subterrane also contains sparse, nonschistose lamprophyre dikes and one small alkali gabbro pluton of apparent early Tertiary age. The Hayes Glacier subterrane is bounded to the south by the Nenana Glacier and Denali faults.

Aurora Peak terrane

The Aurora Peak terrane (Nokleberg and others, 1985) occurs north of the Denali fault in the western part of the quadrangle. This terrane consists of (1) fine- to medium-grained and multiply deformed calc-schist, marble, quartzite, and pelitic schist of Silurian to Triassic age and (2) lesser amounts of regionally metamorphosed and deformed Late Cretaceous plutonic rocks consisting of gneissose quartz diorite, granodiorite, granite, and sparse amphibolite derived from gabbro and diorite. Protoliths for the metasedimentary rocks include marl, quartzite, and shale. The Aurora Peak terrane exhibits an older, upper amphibolite-facies metamorphism associated with mylonitic schist, and a younger, middle greenschist-facies metamorphism associated with blastomylonite (Nokleberg and others, 1985). The Aurora Peak terrane is intruded by weakly nonmetamorphosed Late to mid-Cretaceous gabbro plutons and dikes, and granodiorite and granite plutons. The Aurora Peak terrane is bounded to the south by the Denali fault.

Windy terrane

The Windy terrane (Jones and others, 1984, 1987; Nokleberg and others, 1985) is found within branches of the Denali fault (north of the Maclaren terrane and south of the Aurora Peak and Yukon-Tanana terranes), as well as in the southeast corner of the quadrangle. Unlike the adjacent terranes to the north and the south, the Windy terrane exhibits mainly sedimentary or volcanic textures and structures rather than metamorphic ones. Relict sedimentary structures include bedding, graded bedding, and crossbedding.

The Windy terrane is a structural composite of two assemblages. One assemblage consists of fault-bounded lenses of Cretaceous flysch and volcanic rocks. The flysch rocks consist of argillite, and weakly metamorphosed quartz-pebble siltstone, quartz sandstone, graywacke, and conglomerate. The volcanic rocks are mainly andesite and dacite. The other assemblage in the melange of the Windy terrane consists of small to large, fault-bounded lenses of limestone and marl of Silurian(?) and Devonian age.

The Windy terrane is singly deformed and has a weak schistosity that, along with parallel bedding, generally dips steeply and parallels the west-northwest-trending Denali fault. Locally, however, the terrane is intensely deformed—phyllonite and protomylonite are developed in narrow shear zones. The Windy terrane locally exhibits sparse incipient greenschist-facies metamorphism.

Maclaren terrane

The Maclaren terrane is present south of the Denali fault in the central and western parts of the quadrangle. The Maclaren terrane consists of two major lithic units: (1) the penetratively deformed and regionally metamorphosed granitic plutonic rocks of the East Susitna batholith to the north and (2) the schist and amphibolite, phyllite, and argillite and metagraywacke of the Maclaren Glacier metamorphic belt to the south (Nokleberg and others, 1982, 1985, 1989). The contact between the East Susitna batholith and the Maclaren Glacier metamorphic belt is a faulted intrusive contact named the Meteor Peak fault (Nokleberg and others, 1982, 1985).

East Susitna batholith

The East Susitna batholith consists principally of gneissic granitic rocks, migmatite, migmatitic schist, amphibolite, and quartzite. The gneissic granitic plutonic rocks are derived mainly from diorite and granodiorite, and to a lesser extent from granite. The granitic rocks locally grade into migmatite, migmatitic schist, and amphibolite. The amphibolite consists mainly of older, more intensely regionally metamorphosed and penetratively deformed gabbro and diorite and lesser high-grade, pelitic sedimentary rocks.

The East Susitna batholith is ductilely deformed and metamorphosed into mylonitic gneiss and schist under conditions of the upper amphibolite facies, with local retrograde metamorphism at conditions of the lower greenschist facies (Nokleberg and others, 1985). Small roof pendants of calc-schist, quartzite, and amphibolite are found in the batholith near the west edge of the quadrangle.

Maclaren Glacier metamorphic belt

The Maclaren Glacier metamorphic belt is a prograde, Barrovian-type metamorphic belt. From north to south, its principal lithic components are (1) schist and amphibolite, (2) phyllite, and (3) argillite and metagraywacke. The contacts between these three lithic parts of the terrane are generally faults with intense shearing and abrupt changes of metamorphic facies at each contact. The argillite and metagraywacke unit is composed predominantly of volcanic graywacke and siltstone, sparse andesite and basalt, and lesser calcareous and quartzose siltstone.

The metamorphic belt is ductilely deformed into protomylonite and phyllonite in the argillite and metagraywacke unit, phyllonite in the phyllite unit, and mylonitic schist in the schist and amphibolite unit.

The protolith for the sedimentary and volcanic rocks of the metamorphic belt is Late Jurassic or older in age. A minimum age for the protolith is indicated by intrusion of dikes of the Late Cretaceous and early Tertiary East Susitna batholith into the schist and amphibolite rocks of the metamorphic belt (Nokleberg and others, 1992).

Clearwater terrane

The Clearwater terrane (Jones and others, 1984; Nokleberg and others, 1982, 1985, 1989) occurs in the western part of the quadrangle as a narrow, fault-bounded lens along the Broxson Gulch thrust between the Maclaren and Wrangellia terranes. The Clearwater terrane consists of highly deformed chlorite schist, muscovite schist, schistose rhyodacite, Upper Triassic marble, and greenstone derived from pillow basalt. The Clearwater terrane is weakly deformed and metamorphosed at greenschist facies, and is locally intruded by a fault-bounded and weakly gneissose pluton of diorite and quartz diorite. The age of the pluton is assumed to be Jurassic and (or) Cretaceous.

Wrangellia terrane

The Wrangellia terrane (Jones and others, 1984, 1987; Nokleberg and others, 1982, 1985, 1989) occurs across the southern part of the quadrangle and is subdivided into the Slana River subterrane to the north and the Tangle subterrane to the south (Nokleberg and others, 1982, 1985, 1989). The Wrangellia terrane is weakly regionally metamorphosed at the lower greenschist facies (Nokleberg and others, 1985, 1989). Metamorphic minerals are generally sparse, and abundant relict minerals occur in most rocks. The Wrangellia terrane is locally intruded by weakly deformed to nonschistose, small- to moderate-size granite plutons of Mesozoic(?)

age (Nokleberg and others, 1992). These granitic plutons are discussed in the "Terrane of ultramafic and associated rocks" section.

Slana River subterrane

The Slana River subterrane consists mainly of upper Paleozoic island-arc rocks and disconformably overlying massive basalt flows of the Late Triassic Nikolai Greenstone, younger Mesozoic flysch, and Tertiary continental sedimentary and volcanic rocks. The upper Paleozoic island-arc rocks consist of andesite and dacite flows, volcanic graywacke and breccia, other epiclastic rocks, argillite, and limestone of the Pennsylvanian Tetelna Volcanics, Pennsylvanian and Permian Slana Spur Formation, and Permian Eagle Creek Formation. The Tetelna Volcanics and Slana Spur Formation are intruded by Permian hypabyssal dacite stocks, sills, and dikes, and granite. The Late Triassic Nikolai Greenstone consists of massive, subaerial, amygdaloidal basalt flows about 1,500 m thick. Locally extensive gabbro dikes and cumulate mafic and ultramafic sills intrude the Nikolai Greenstone and older rocks in the subterrane. Locally overlying the Nikolai Greenstone in the eastern part of the Slana River subterrane are Triassic limestone, Jurassic and Cretaceous argillite and graywacke of the Gravina-Nutzotin belt, and sparse deposits of Tertiary sandstone, conglomerate, and rhyolite to dacite tuff, breccia, and flows. The Slana River subterrane is bounded to the north by the Broxson Gulch thrust and the Denali fault and to the south by the Eureka Creek fault.

Tangle subterrane

Relative to the Slana River subterrane, the Tangle subterrane contains a thinner sequence of upper Paleozoic and Lower Triassic sedimentary and tuffaceous rocks, and a thicker sequence of the Nikolai Greenstone. The upper Paleozoic and Lower Triassic sedimentary rocks consist of aquagene tuff, dark-gray argillite, minor andesite tuff and flows, and very sparse light-gray limestone. The Nikolai Greenstone consists of a moderately thick basal member of pillow basalt, and a thick upper member of massive, subaerial, amygdaloidal flows. Sparse Upper Triassic marble overlies the Nikolai; younger Mesozoic sedimentary rocks are lacking in the Tangle subterrane. Extensive gabbro and cumulate mafic and ultramafic sills and plutons intrude the Nikolai Greenstone and older units and are discussed in the "Terrane of ultramafic and associated rocks" section.

Terrane of ultramafic and associated rocks

In the southeastern part of the quadrangle, a narrow terrane of ultramafic rocks and small areas of associated mafic and granitic rocks intrude the Nikolai Greenstone and older rocks in the Wrangellia terrane. The ultramafic, mafic, and granitic rocks represent part of a string of alpine peridotites that occur along or near the Denali fault (Richter and others, 1977; Nokleberg and others, 1982, 1985, 1989). The ultramafic rocks are chiefly dark-green serpentinized pyroxenite and peridotite, light-gray to green dunite, and dark-green schistose amphibolite and lighter colored hornblende-plagioclase gneiss derived from gabbro. Interlayered with the gneisses are rare thin lenses of light-green and gray marble and zones of dark-gray graphitic schist. The ultramafic rocks are interpreted as comagmatic with the basalts that formed the Nikolai Greenstone and may be Late Cretaceous in age (Nokleberg and others, 1992). The ultramafic and associated rocks are ductilely deformed and have been regionally metamorphosed twice.

The granitic rocks intruding the Wrangellia terrane are small- to moderate-size plutons that are locally hydrothermally altered. These granitic plutons are interpreted as being coeval and comagmatic with the Upper Jurassic and Lower Cretaceous flysch and volcanic rocks of the Gravina-Nutzotin belt and the marine and subaerial andesite volcanic flows and volcaniclastic rocks of the Lower Cretaceous Chisana Formation to the southeast in the Nabesna quadrangle (Richter, 1976). This suite of granitic plutons and coeval volcanic rocks is named the Gravina arc by Stanley and others (1990). Some granitic plutons in the Wrangellia terrane are petrographically identical to the Pennsylvanian granitic plutons and they could possibly be of late Paleozoic age (Nokleberg and others, 1992).

Gulkana River terrane

A part of the Gulkana River terrane—mapped previously in the Gulkana quadrangle (Nokleberg, Wade, and others, 1986)—is found in the south-central part of the Mount Hayes quadrangle, south of the Wrangellia terrane. The two terranes are separated by the Paxson Lake fault. In the Mount Hayes quadrangle, the Gulkana River terrane consists of massive to weakly schistose metamorphosed hornblende andesite. Samples of metaandesite were too low in zirconium to warrant U-Pb zircon isotopic analysis (Nokleberg and others, 1992). The Gulkana River terrane is correlative with the Haley Creek metamorphic assemblage of Plafker and others (1989) in the northern part of the Valdez quadrangle to the southeast, which contains similar late Paleozoic metamorphosed andesite and basalt flows.

KNOWN MINERAL OCCURRENCES

Known metalliferous lode and placer mineral occurrences, mineral deposits, prospects, and mines in the Mount Hayes quadrangle were studied and compiled as part of the geologic and mineral resource assessment investigations of the quadrangle.

LAKE GEORGE AND MACOMB SUBTERRANES

A minor mineral occurrence in bedrock of the Lake George subterrane is on the south shore of Lake George (T. 23 N., R. 5 E.), where a silicified, iron-stained pyrite-quartz-actinolite schist contains as much as 30 ppm tin (Nokleberg and others, 1991). The granitic rocks in the Lake George subterrane contain no known lode or placer occurrences.

In the Macomb subterrane, minor lode mineral occurrences associated with the granitic rocks occur in four areas: (1) a small area of gold-bearing (3.2 ppm) iron-stained quartz-biotite schist near a granitic dike and a small gold-bearing altered aplite dike, both on the north side of Elting Creek (T. 20 N., R. 16 E.); (2) a small area of gold-bearing (2.8 ppm) altered aplite dike (T. 19 N., R. 5 E.); and (3) two small areas of pyrite-bearing aplite or quartz monzonite containing silver (7 ppm) and lead (130 ppm) in T. 22 N., R. 7 E. (Nokleberg and others, 1991). A minor occurrence of pyroxene cumulate in T. 20 N., R. 6 E. is classified as a podiform chromite deposit type and contains >5,000 ppm chromium.

JARVIS CREEK GLACIER SUBTERRANE

The Jarvis Creek Glacier subterrane contains locally substantial mineral deposits and occurrences (Nokleberg and others, 1991). The major lode mineral deposits form two belts, a western belt west of the Delta River between the Hayes and McGinnis Glaciers (Tps. 14 and 15 S., Rs. 5, 6, and 8 E.) and an eastern belt in the area southeast of the West Fork of the Robertson River (Tps. 16, 17, and 18 N., Rs. 5, 6, and 7 E.). The deposits in the eastern belt are in the metavolcanic rocks unit and form about 15 small- to moderate-size Kuroko-type massive sulfide occurrences. The deposits in the western belt are in the greenstone and the metasedimentary rocks unit and form about five prospects and occurrences. Both the western and eastern belts share the same general mineralogy—disseminated to massive chalcopyrite, galena, sphalerite, pyrite, and pyrrhotite. Significant values of Ag, As, Au, and Sn are found in both belts; anomalous values of antimony are also found in the eastern belt. In both belts, the massive sulfide deposits occur discontinuously as irregularly shaped, generally fault bounded pods, lenses, and stringers. Preliminary studies of these deposits have been published by Nokleberg and Lange (1985) and Lange and others (1990). Field, petrographic, geochemical, and isotopic data suggest these deposits formed in a Devonian submarine island-arc environment, and were subsequently deformed in the mid-Cretaceous.

Other lode occurrences in the metasedimentary rocks unit of the Jarvis Creek Glacier subterrane are widely scattered in iron-stained schist disseminated with pyrite (some with quartz and veins) and accompanied by anomalous Ag, Au, Cu, Mo, Pb, and Zn. Gold- and base-metal quartz vein deposits in the Jarvis Creek Glacier subterrane are probably related to regional metamorphism and (or) to the intrusion of granitic plutons of Cretaceous age.

Anomalous silver and gold in samples of granodiorite with molybdenite are related to late Mesozoic and early Tertiary granitic rocks in three areas west of Molybdenum Ridge (T. 13 S., R. 6 E.). Gold is also found in the area in gravel placers downstream from the quartz monzonite of Granite Mountain (T. 13 S., R. 12 E.) and the granodiorite of Molybdenum Ridge.

HAYES GLACIER SUBTERRANE, AND WINDY AND AURORA PEAK TERRANES

The Hayes Glacier subterrane contains several bedrock mineral occurrences (Nokleberg and others, 1991). These mineral occurrences, located in T. 15 S., R. 6 E. and T. 16 N., R. 6 E., consist of three areas of altered quartz-mica-graphite schist with disseminated pyrite and quartz veins containing anomalous values of silver, gold, and molybdenum. A minor lode mineral occurrence in the Windy terrane in the southeastern part of the quadrangle is a small area of metamorphosed quartz–white mica graywacke that contains as much as 5,000 ppm arsenic. The mineral occurrences in the Hayes Glacier subterrane and the Windy terrane are probably either gold quartz vein or epithermal precious- and base-metal deposits that formed during regional metamorphism and (or) intrusion of Cretaceous granitic plutons. The Aurora Peak terrane contains no known lode or placer mineral occurrences.

MACLAREN AND CLEARWATER TERRANES, AND TERRANE OF ULTRAMAFIC AND ASSOCIATED ROCKS

The Maclaren Glacier metamorphic belt of the Maclaren terrane contains sparse bedrock mineral occurrences (Nokleberg and others, 1991). The mineral occurrences in the metasedimentary and metavolcanic rocks are (1) one small area of metaandesite in T. 19 S., R. 5 E. containing local bornite and malachite and significant values of silver and (2) three small areas of pyrite-bearing phyllite in T. 18 S., Rs. 4, 5, and 8 E. containing moderate values of silver and low values of zinc. The only minor lode mineral occurrence in, or related to, late Mesozoic or early Tertiary granitic rocks is a small area of plutonic porphyry containing pyrite, molybdenite, and chalcopyrite in quartz veins near, and in, altered quartz monzonite. A few small gold placer occurrences are found downstream from the metamorphic belt. The East Susitna batholith of the Maclaren terrane does not contain any known mineral deposits, prospects, or occurrences.

The Clearwater terrane contains only sparse mineral occurrences (Nokleberg and others, 1991). A lode mineral occurrence in T. 20 S., R. 4 E. is a small area of pyrite-bearing phyllite containing moderate values of copper. The single lode mineral occurrence in or near late Mesozoic or early Tertiary granitic rocks is in T. 20 S., R. 4 E., where a moderate-size area of iron-stained metadacite near a quartz diorite pluton contains pyrite, galena, malachite, and sphalerite. There are no known placer mineral deposits or occurrences in the Clearwater terrane.

Minor bedrock mineral occurrences in the terrane of ultramafic and associated rocks in the eastern part of the quadrangle are (1) hornblende-plagioclase gneiss containing disseminated pyrite, pyrrhotite, and chalcopyrite and (2) a podiform chromite deposit in alpine peridotite.

SLANA RIVER SUBTERRANE

The Slana River subterrane contains abundant mineral deposits and occurrences (Nokleberg and others, 1991). Most of the bedrock occurrences are related to igneous activity during late Paleozoic island-arc volcanism (Nokleberg and others, 1984). Nineteen small- to moderate-size dacite porphyry copper-gold-silver occurrences are located in the south-central and southeastern parts of the quadrangle, and contain disseminated to local small masses of chalcopyrite, bornite, malachite, and pyrite. Anomalous amounts of Ag, As, Au, Mo, and Sn are found associated with these occurrences.

Skarn prospects and occurrences are found hosted in marble interlayered with late Paleozoic metavolcanic rocks that are intruded by gabbro, diabase, and dacite. These skarn occurrences are in the south-central and southeastern parts of the quadrangle and consist of disseminated to local small masses of chalcopyrite and pyrite containing anomalous amounts of Ag, Au, Co, and Zn.

Small- to moderate-size prospects and occurrences of copper-silver quartz vein deposits occur in late Paleozoic metaandesite and metadacite and in the Late Triassic Nikolai Greenstone. These occurrences consist of disseminated and small masses of chalcopyrite, bornite, malachite, and azurite containing anomalous amounts of Ag, As, Au, Pb, and Zn. Nokleberg and others (1984) suggested that these mineral occurrences formed during low-grade regional metamorphism of the Wrangellia terrane in the mid-Cretaceous.

Small- to moderate-size occurrences of gabbroic nickel-copper deposits occur in late Paleozoic or Late Triassic gabbro, diabase, or cumulate ultramafic rocks. The minerals found in these occurrences are principally disseminated to massive pyrite and pyrrhotite, and minor chalcopyrite lenses and veins containing anomalous amounts of silver and gold.

Locally abundant occurrences of podiform chromite deposits are in mafic or ultramafic dikes and sills in the Late Triassic Nikolai Greenstone in the central and western parts of the subterrane. These occurrences are mostly of disseminated to small lenses and stringers of chromite that contain anomalous amounts of cobalt.

Other small bedrock mineral occurrences in the Slana River subterrane consist of (1) disseminated pyrite containing anomalous amounts of silver and gold in sheared, iron- or copper-stained volcanic, volcaniclastic, or argillite rocks and (2) chalcopyrite and galena containing anomalous amounts of silver in quartz veins in limestone. The occurrences are probably gold quartz veins or epithermal precious- and base-metal deposits that formed either during low-grade regional metamorphism of the Wrangellia terrane in the mid-Cretaceous, or during intrusion of Mesozoic granitic plutons. The major area of the various lode deposits described above collectively is found in T. 18 S., Rs. 6, 8, 9, 10, and 11 E.; T. 19 S., Rs. 5, 6, 9, 10, and 12 E.; and T. 20 S., Rs. 14, 15, and 16 E.

Gold placer deposits occur in the Slana River subterrane (Yeend, 1981; Nokleberg and others, 1991). Most of the placers occur downstream from Tertiary sedimentary rocks, upper Paleozoic island-arc rocks, or late Mesozoic and early Tertiary granitic rocks. Most of the major placers in the Mount Hayes quadrangle occur in the Slate Creek area (T. 20 S., R. 15 E.) in gravels eroded from fault-bounded lenses of Tertiary sedimentary rocks within the McCallum Creek–Slate Creek fault. A few of the placers occur in the Broxson Gulch (Tps. 18 and 19 S., R. 8 E.), Rainy Creek (T. 19 S., R. 10 E.), Eureka Creek (T. 19 S., Rs. 9 and 10 E.), and Delta River areas. In these areas, many of the Tertiary sedimentary source rocks also occur in fault-bounded lenses (Stout, 1976; Yeend, 1981).

TANGLE SUBTERRANE

The Tangle subterrane contains one lode mine (Kathleen Margaret) and abundant prospects and occurrences, mainly in the Late Triassic Nikolai Greenstone, or in mafic and ultramafic rocks that are probably comagmatic with the Nikolai (Nokleberg and others, 1991). The Kathleen Margaret mine, located in SW1/4 NE1/4 T. 19 S., R. 6 E., is a copper-silver quartz vein deposit containing disseminated and local masses of chalcopyrite, bornite, malachite, and azurite and anomalous amounts of gold. Other small copper-silver quartz vein occurrences are scattered within the Late Triassic Nikolai Greenstone. These deposits and occurrences may have formed during low-grade regional metamorphism of the Wrangellia terrane in the mid-Cretaceous (Nokleberg and others, 1984).

Chromite occurs in scattered occurrences within cumulate ultramafic rocks in the south-central and southwestern parts of the quadrangle and as disseminations in small lenses and stringers of podiform chromite containing anomalous amounts of nickel (Nokleberg and others, 1991).

Other lode mineral occurrences in the Tangle subterrane include (1) a skarn deposit in marble containing gold and malachite and anomalous silver and molybdenum; (2) argillite interbedded with metabasalt and containing anomalous silver; and (3) pyrite containing copper in sheared, serpentinized olivine cumulate rocks. Sparse gold placer occurrences are found in the Tangle subterrane mostly in gravels downstream from the Nikolai Greenstone. The major areas of the precious- and base-metal deposits of the Tangle subterrane are collectively found in T. 19 S., Rs. 6 and 7 E.; T. 20 S., R. 5 E.; T. 21 S., Rs. 9, 10, and 11 E.; and T. 22 S., R. 11 E.

MINERALOGY

For this study, 795 samples of concentrate were visually scanned for mineralogy using a binocular microscope. Following are the identified 14 ore-related minerals, their chemical formulas, and the number of site occurrences for each mineral: arsenopyrite, FeAsS (200); chalcopyrite, $CuFeS_2$ (376); galena, PbS (177); sphalerite, ZnS (35); pyrite, FeS_2 (180 sites where the volume percent is >50 percent of the nonmagnetic fraction); cinnabar, HgS (73); gold, Au (42); molybdenite, MoS_2 (16); powellite, Ca (Mo, W)O_4 (12); scheelite, $CaWO_4$ (101); cassiterite, SnO_2 (38); fluorite, CaF_2 (12); monazite, (Ce, La, Y, Th)PO_4 (89); and thorite, $ThSiO_4$ (21). The distribution of these minerals is shown on maps A-F, which also show the topography and tectonostratigraphic terranes of the Mount Hayes quadrangle.

DISTRIBUTION OF THE BASE-METAL SULFIDES

Well-defined mineral distribution patterns for the base-metal sulfides (chalcopyrite and arsenopyrite, map A; galena and sphalerite, map B; and pyrite, map C) crosscut the Mount Hayes quadrangle at a diagonal. Areas delineated by this band north of the Denali fault are underlain by metasedimentary and metavolcanic rocks of the Jarvis Creek Glacier and Hayes Glacier subterranes. Base-metal sulfides are also distributed in the metasedimentary rocks of both the Aurora Peak and Windy terranes. Areas delineated by sulfide-rich samples south of the Denali fault are underlain by the island-arc volcanic rocks of the Slana River subterrane (Nokleberg and others, 1985). Other less extensive zones yielding sulfide-rich samples are in areas underlain by the East Susitna batholith, in the Maclaren Glacier metamorphic belt, in the Clearwater terrane, in the Tangle subterrane, and in the terrane of ultramafic and associated rocks.

Jarvis Creek Glacier subterrane

Known Kuroko-type massive sulfide occurrences and epithermal base-metal quartz vein occurrences in the Jarvis Creek Glacier subterrane are reflected in the concentrate samples. Samples containing microscopically visible grains of arsenopyrite, chalcopyrite, pyrite, and galena target the known massive sulfide deposits between the Hayes and McGinnis Glaciers, and drainages between the West Fork of the Robertson River and the main stream of the Robertson River (T. 18 N., Rs. 5 and 6 E.; Nokleberg and others, 1990, 1991). The mineralogical data suggest that known sulfide deposits could extend to the west into T. 14 S., Rs. 4 and 5 E., and south of Mount Pillsbury (T. 16 S., R. 9 E.). The distribution of sphalerite in the concentrate samples suggests that zinc-sulfide occurrences may be located in bedrock of the Jarvis Creek Glacier subterrane west of Hayes Glacier (map B) as well.

A distribution of sulfide minerals in the concentrate samples probably reflects known occurrences of sulfide-bearing quartz veins and sulfide-bearing schist in the metasedimentary rocks unit of the Jarvis Creek Glacier subterrane. Quartz cobbles from streams that intersect the Richardson Highway from Ruby Creek southward to Miller Creek contain small inclusions of arsenopyrite, pyrite, galena, and sphalerite. Many samples in this area contain pyrite in excess of 50 percent by volume of the nonmagnetic concentrate (map C). This area may host undiscovered massive sulfide occurrences.

One of the more striking regional sulfide patterns outlines the known mineral occurrences of the Jarvis Creek watershed (Tps. 15 and 16 S., Rs. 10 and 11 E.). All of the known mineral occurrences in this watershed shown in Zehner and others (1985) are reflected in the concentrate samples, which, in most cases, contain greater than 50 percent by volume of pyrite.

Other watersheds that show geological and mineralogical characteristics similar to those of the Jarvis Creek watershed are July Creek, Gerstle River, Little Gerstle River, Johnson River, Castner Glacier, and Fels Glacier (Nokleberg and others, 1990, 1991).

Hayes Glacier subterrane

In the Hayes Glacier subterrane, the few known sulfide mineral occurrences are indicated in concentrate samples by the presence of sulfide minerals. The sulfide mineralogy of the samples is similar to that of samples from the Jarvis Creek Glacier subterrane. Virtually every sample contains chalcopyrite, many contain arsenopyrite, and some have galena and (or) sphalerite. A narrow trend of sphalerite-rich samples indicates possible zinc-sulfide occurrences in that part of the Hayes Glacier subterrane north of the Denali fault.

Much of the Hayes Glacier subterrane is underlain by high alpine glaciers. Consequently, the sampling of some medial moraines was used to obtain the concentrate samples. During the sampling of the Trident Glacier (T. 15 S., R. 7 E.), large cobbles of massive sulfides chiefly of pyrite, chalcopyrite, and arsenopyrite and little quartz were encountered on one of the more northwestern medial moraines. Stephens and others (1983) showed that the source of these massive-sulfide cobbles is from a gangue-free vein located near the periphery of a granitic plutonic complex that intrudes the Hayes Glacier subterrane in T. 15 S., R. 6 E. This vein may be part of a polymetallic vein occurrence associated with the granitic plutonic complex.

Windy terrane

The Windy terrane covers a small area of the Mount Hayes quadrangle; consequently, the concentrate samples may have included sediment contributions from adjacent mineralized terranes. Concentrate samples from the southeastern corner of the quadrangle contain chalcopyrite, pyrite, sphalerite, and galena whose sources may be the Windy terrane, but are more likely either the adjacent Slana River subterrane to the south or the adjacent Jarvis Creek Glacier subterrane to the north. Chalcopyrite found in one concentrate sample from T. 17 S., R. 9 E. (map A) may indicate an area of mineralized rock within the Windy terrane.

Aurora Peak terrane

The Aurora Peak terrane contains no known lode or placer mineral occurrences. However, 12 sulfide-rich concentrate samples suggest that this terrane could contain base-metal sulfide occurrences. Concentrate samples containing microscopically visible arsenopyrite and chalcopyrite come from the high alpine-glaciated areas of T. 16 S., R. 8 E. There is a possibility that some sulfide minerals are from a high ridge to the north underlain by the Hayes Glacier subterrane. Some samples are from streams restricted to the Aurora Peak terrane, which could indicate the presence of sulfide occurrences in those areas.

Macomb subterrane

The surficial deposits in the Macomb subterrane on Berry Creek (Tps. 15 and 16 S., R. 16 E.) contain large float boulders of pyritic schist containing as much as 25 percent by volume of base-metal sulfide minerals. However, extensive glacial deposits in the area preclude a precise determination of the origin of these sulfide-rich boulders. It is assumed that the arsenopyrite, galena, and sphalerite that occur in the concentrate samples from this area were derived from the schist boulders. Three concentrate samples from the Prospect Creek watershed (T. 16 S., R. 15 E.) contain arsenopyrite, pyrite, and galena. The common association of base-metal sulfide minerals in concentrate samples from Prospect Creek and Berry Creek suggests that sulfide occurrences may be in the area where these two watersheds merge. The size and economic significance of such a lode occurrence is uncertain, although the quantity and size of the sulfide-rich schist erratics on Berry Creek indicate a potentially moderate size occurrence.

Slana River subterrane

Sulfide-rich concentrate samples from the Slana River subterrane have sources in known mineral deposits and occurrences (Nokleberg and others, 1990, 1991) as well as from areas where deposits have not been noted. Most of the known sulfide-rich lode occurrences principally contain chalcopyrite, bornite, and pyrite. The copper-silver quartz vein deposits in the Paleozoic metavolcanic rocks and the Late Triassic Nikolai Greenstone yield galena and sphalerite in concentrate samples (map B).

Tangle subterrane

Concentrate samples containing chalcopyrite form a cluster in T. 19 S., R. 6 E (map A), which probably reflects the copper-rich ore body of the Kathleen Margaret mine, and perhaps similar undiscovered copper occurrences in the area. Although a major part of the Tangle subterrane contains known sulfide-rich mineral occurrences, concentrate samples are notably lacking in visible sulfides. Concentrate samples were also analyzed for copper, lead, and zinc, but none of these elements were found in anomalous concentrations (Curtin and others, 1989). However, anomalous concentrations of these elements were found in the minus-80-mesh stream-sediment samples (Curtin and others, 1989), suggesting that the search for other sulfide-rich mineral occurrences in the Tangle subterrane may best be accomplished using stream-sediment samples.

Maclaren and Clearwater terranes, and terrane of ultramafic and associated rocks

The Maclaren Glacier metamorphic belt of the Maclaren terrane contains a small area of known sulfide-rich mineral occurrences in metaandesite in T. 19 S., R. 5 E. Concentrate samples from this area contain chalcopyrite, arsenopyrite, pyrite, and galena. Likewise, three areas known to be underlain by pyrite-bearing phyllite in Tps. 18 and 19 S., Rs. 4, 5, and 8 E. yield visible pyrite, chalcopyrite, and arsenopyrite in concentrate samples. The East Susitna batholith of the Maclaren terrane contains no identified mineral occurrences, yet some concentrate samples from T. 17 S., Rs. 7 and 8 E. and T. 18 S., R. 5 E. contain chalcopyrite, arsenopyrite, and pyrite, suggesting that some areas of the batholith could contain sulfide minerals, possibly related to undiscovered polymetallic vein occurrences.

In the Clearwater terrane, several concentrate samples reflect the known mineral occurrences in pyrite-bearing phyllite and metadacite. Samples from this terrane contain chalcopyrite, sphalerite, pyrite, and galena.

The terrane of ultramafic and associated rocks in the eastern part of the quadrangle contains a minor occurrence of chalcopyrite in hornblende gneiss derived from metagabbro. Streams that drain the ultramafic terrane also drain the adjacent Hayes Glacier subterrane and the Slana River subterrane; consequently, the possible contribution of sulfide minerals to the stream sediment from the latter two terranes could be significant in assessing the mineral potential of the terrane of ultramafic and associated rocks on a reconnaissance scale of this size.

DISTRIBUTION OF GOLD AND CINNABAR

A well-defined mineral distribution pattern of gold and cinnabar in concentrate samples (map D) delineates a zone south of the Denali fault in the southern half of the Mount Hayes quadrangle. The area delineated by the gold and cinnabar is underlain by upper Paleozoic volcanic rocks, younger Mesozoic flysch, the Late Triassic Nikolai Greenstone and associated sedimentary rocks, and Tertiary continental sedimentary and volcanic rocks of the Wrangellia terrane (Nokleberg and others, 1985). Gold occurs in concentrate samples in the extreme western part of the quadrangle in a zone that includes the Clearwater terrane and the Maclaren terrane.

Concentrate samples containing gold and cinnabar also form a prominent cluster in the Slate Creek placer area (T. 20 S., R. 15 E.). The Slate Creek district has had gold production in excess of 100,000 ounces (Yeend, 1981) from a combination of alluvial and colluvial fan material with admixed drift. The gravel includes abundant well-rounded granitic boulders and cobbles, most likely derived from Tertiary conglomerate that caps the high hills north of the Slate Creek deposits. A conglomerate resembling the upland surface conglomerate is exposed in the vicinity of the placer mine in apparent fault contact with older rocks in the Slate Creek valley (Yeend, 1981). The immediate source of gold mined at Slate Creek and other properties in the area appears to be the upland surface conglomerate (Yeend, oral commun., 1985). The gold recovered from our concentrate samples has rounded edges and flattened worn surfaces, suggesting that it was recycled several times during weathering.

Concentrate samples from the Slate Creek mining district are also rich in cinnabar, although no lode sources are known and Yeend (1981) reported no cinnabar in his concentrate samples. The cinnabar seen in our microscope scans is bright and fresh looking, suggesting separate sources of the cinnabar and gold.

Placer gold deposits are known in Broxson Gulch (T. 18 S., R. 8 E.) and in areas to the east, in Rainy Creek (T. 19 S., R. 10 E.), and the Delta River. The placer deposit in Broxson Gulch is in an alluvial fan containing well-rounded boulders and cobbles of rock types typical of the previously discussed gold-bearing Tertiary(?) conglomerate (Yeend, 1981).

Rose (1965) suggested gold sources for deposits on Rainy Creek as either nearby copper-iron sulfide deposits or high gravels of Tertiary(?) age to the north. The gold recovered from concentrate samples taken from the Rainy Creek area has appearances of being recycled several times, suggesting that the source is from the Tertiary(?) gravels. Gold in samples from Little Clearwater Creek (Tps. 20 and 21 S., R. 5 E.) and a small tributary in the southeast corner of T. 19 S., R. 4 E. suggests a potential lode source in the area near the fault contact of the Clearwater terrane and the Tangle subterrane in the southwest corner of T. 19 S., R. 5 E.

North of the Denali fault, gold in the concentrate samples is generally derived from known placer gold deposits, but possibly also indicates some lode occurrences. For example, numerous gold flakes were recovered from a scheelite-rich concentrate sample collected in T. 14 S., R. 4 E. (map E), which suggests a possible gold skarn deposit upstream in a small tributary to the East Fork of the Little Delta River. The inferred skarn may either be in the Jarvis Creek Glacier subterrane or the Hayes Glacier subterrane, but the lack of sufficient time made further exploration of this area impossible.

Visible gold and corresponding anomalous gold values of at least 20 ppm (Curtin and others, 1989) occur in a cluster in the north-central part of the quadrangle in the general area of McCumber Creek (T. 14 S., R. 11 E.). Most of the concentrate samples containing gold also have scheelite, which suggests that the Jarvis Creek Glacier subterrane may host undiscovered skarn or polymetallic vein occurrences.

Several gold-bearing concentrate samples from streams that drain southwesterly from the area of the Granite Mountain pluton suggest a possibility of undiscovered precious-metal polymetallic vein occurrences in the area of the pluton.

Visible gold in a concentrate sample from the northeast corner of T. 14 S., R. 13 E. may have been derived from an unknown placer deposit in Tertiary sandstone and conglomerate that crops out in the area.

A single concentrate sample from Berry Creek (T. 15 S., R. 16 E.) has gold but could have one or more sources, either in the sulfide-rich Devonian metasedimentary rocks, or in the Devonian granitic rocks of the Macomb subterrane.

DISTRIBUTION OF MOLYBDENITE, POWELLITE, AND SCHEELITE

Molybdenite, powellite, and scheelite in concentrate samples are probably derived from molybdenum-tungsten mineralization in parts of the East Susitna batholith of the Maclaren terrane (map E). The distribution of these minerals and the distribution of anomalous molybdenum and tungsten (Curtin and others, 1989) delineates an area having known and inferred porphyry copper and molybdenum occurrences, and tungsten skarn occurrences (Nokleberg and others, 1990, 1991).

In the area of Meteor Peak (T. 17 S., R. 7 E.) the concentrate samples indicate that the Late Cretaceous and early Tertiary gneissose granitic rocks are molybdenite rich and may represent undiscovered porphyry molybdenum occurrences. The concentrate samples also indicate that the Early Cretaceous or older schist and amphibolite rocks in T. 17 S., R. 5 E. are tungsten rich.

The broadly distributed scheelite in concentrate samples from the Maclaren Glacier metamorphic belt of the Maclaren terrane and from the Clearwater terrane suggests that the metavolcanic and metasedimentary rocks probably contained disseminated tungsten in the original stratigraphic pile, but during greenschist and amphibolite metamorphism, a migrating metamorphic fluid phase may have leached the disseminated tungsten and deposited it as scheelite in metamorphic quartz veins. This correlation of anomalous tungsten and scheelite with the distribution of metavolcanic and metasedimentary rocks is seen in other parts of Alaska such as in the Upper Cretaceous Valdez Group of the Chugach terrane (Goldfarb and others, 1989).

Scheelite in samples from the Slate Creek district may be associated with the gold from the Tertiary(?) conglomerate that caps the high hills in the area. Elsewhere, to the northwest of the Slate Creek mining district in T. 20 S., Rs. 14 and 15 E., scheelite and molybdenite appear to be associated with the granitic rocks in the terrane of ultramafic and associated rocks.

A number of concentrate samples from streams draining granitic rocks in Tps. 15 and 16 S., Rs. 13 and 14 E. contain molybdenite, powellite, and scheelite. This area is also characterized geochemically by anomalous Ag, Bi, Cu, Pb, Sn, and Zn (Curtin and others, 1989). A porphyry tin environment in granitic rocks has been described in the area (Nokleberg and others, 1990).

The granitic rocks in the watersheds of Berry Creek and Bear Creek (T. 16 S., R. 16 E. and T. 20 N., R. 5 E.) are rich in molybdenite, powellite, and scheelite, as indicated in the concentrate samples. Curtin and others (1989) showed anomalous Cu, Pb, Mo, Sn, and Zn in the same area, inferred to be related to undiscovered porphyry tin and skarn occurrences (Nokleberg and others, 1990).

The granitic rocks of Granite Mountain in the north-central part of the quadrangle also yield concentrate samples containing molybdenite, powellite, and scheelite. In addition, Curtin and others (1989) showed anomalous Bi, Cu, Pb, Sb, and Sn within the same area. The distribution of anomalous metals outlines a zone of mineralization for undiscovered porphyry tin and porphyry copper-molybdenum occurrences (Nokleberg and others, 1990).

Scheelite also characterizes samples from areas of granitic rocks on Molybdenum Ridge, in the northwestern part of the quadrangle. Curtin and others (1989) showed anomalous Ag, Cu, Mo, Pb, Sb, Sn, and Zn in minus-80-mesh stream-sediment samples from this same area. The scheelite and associated high-metal values outline an area of inferred porphyry copper-molybdenum and copper-lead-zinc skarn, and porphyry tin occurrences (Nokleberg and others, 1990).

Many scheelite- and molybdenite-rich concentrate samples are spatially associated with granitic plutons in the various subterranes of the Yukon-Tanana terrane, but the Jarvis Creek Glacier subterrane is an exception. Widespread distribution of microscopically visible scheelite in concentrate samples within the Jarvis Creek Glacier subterrane shows no apparent association with granitic rocks. It appears that the tungsten for the scheelite was derived from the metavolcanic and metasedimentary pile during regional metamorphism and deposited in metamorphic quartz veins in scattered joint sets and shear zones.

DISTRIBUTION OF CASSITERITE, FLUORITE, MONAZITE, AND THORITE

Plutonic rocks north of the Denali fault are characterized by a suite of microscopically visible cassiterite, fluorite, monazite, and thorite (map F). These areas are also anomalous in Bi, Sb, Sn, and W in concentrate samples (Curtin and others, 1989). For example, in the area of Granite Mountain, the mineral suite of cassiterite, fluorite, monazite, and thorite suggests that the granite is a multiphased, highly fractionated rock and may contain deposits of tin and rare-earth elements of an undetermined grade and, therefore, an uncertain economic significance.

A granite ring dike between the July Creek and Gerstle Glacier watersheds in T. 16 S., R. 12 E. sheds cassiterite into nearby tributaries. However, a pluton body to the south of the ring dike does not appear to contain cassiterite as indicated by concentrate samples.

Granitic rocks of the Macomb subterrane also shed cassiterite, monazite, thorite, and fluorite into the streams. Fluorite content in some concentrate samples is as much as 40 percent by volume and is comprised of mostly pale-green to white cleavages; some cleavage fragments are tinged pale violet on the edges. This suite of minerals in conjunction with the abundance of fluorite suggests an environment favorable for unknown porphyry tin-type occurrences (Nokleberg and others, 1990). Monazite and thorite in the samples may indicate that the granitic rocks are enriched in rare-earth elements and thorium.

Concentrate samples from streams that drain the plutonic rocks just west of Molybdenum Ridge in the northwestern part of the quadrangle contain cassiterite and monazite. Curtin and others (1989) showed high concentrations of tin in concentrate samples and weakly to moderately anomalous concentrations of tin in stream-sediment samples from this area. The plutonic rocks of the Molybdenum Ridge area have the potential for undiscovered porphyry tin occurrences (Nokleberg and others, 1991).

South of the Denali fault, in the western part of the quadrangle, concentrate samples from streams draining the East Susitna batholith of the Maclaren terrane contain microscopically visible grains of monazite. It has been shown that the batholith is geochemically favorable for several types of mineral occurrences (Nokleberg and others, 1990). The presence of monazite in the concentrate samples may indicate thorium-rich, polymetallic vein occurrences in the batholith.

CONCLUSIONS

The distribution of ore-related minerals in heavy-mineral-concentrate samples indicates that the Mount Hayes quadrangle contains a diverse and widespread group of mineral occurrences. Most of the mineralogical data of concentrate samples indicate the known lode and placer mineral occurrences but also suggest five areas that may contain the potential for undiscovered metallic lode and placer deposits. These five areas include: (1) the north slope of Mount Giddings (T. 14 S., R. 4 E.), which may host gold skarn deposits in the Jarvis Creek Glacier subterrane; (2) the Mount Pillsbury area and the upper reaches of the Jarvis Creek watershed, which may host massive sulfide deposits in the Jarvis Creek Glacier subterrane; (3) granitic plutons in the Jarvis Creek Glacier subterrane and the Macomb subterrane, which may host tin-molybdenum porphyries and related tungsten skarn deposits; (4) granitic plutons of the Maclaren terrane, Jarvis Creek Glacier subterrane, and Macomb subterrane, which may host precious-metal and rare-earth deposits; and (5) granitic and metamorphic rocks in Granite Mountain, which may host precious-metal quartz veins in the Jarvis Creek Glacier subterrane.

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