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Metallogeny and Major Mineral Deposits of Alaska

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S.G.S.

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PREFACE

This report is a preliminary version of a chapter for the volume on Alaskan geology for the Decade of North American Geology (DNAG) by the Geological Society of America. This report is based on recent unpublished data on metalliferous mineral deposits of Alaska, and on recent and older published articles and summaries of Alaskan mineral deposits and regional geology. The unpublished data were contributed by mineral deposit and regional geologists in private industry, universities, the U.S. Geological Survey, the Alaska Division of Geological and Geophysical Surveys, the U.S. Bureau of Mines, and the authors. Data were also obtained for classification of metalliferous mineral deposits from mineral deposit geologists in the U.S. Geological Survey. The 54 contributors who gave freely of their data, with affiliations at the time of contribution, are:

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INTRODUCTION AND PURPOSE

Alaska is commonly regarded as one of the frontiers of North America for the discovery of metalliferous mineral deposits. A recurring theme in the history of the state has been "rushes" or "stampedes" to sites of newly discovered deposits. Since about 1965, private mining companies have undertaken much exploration for lode and placer mineral deposits. During the same period, because of the considerable interest in federal lands in Alaska and the establishment of new national parks, wildlife refuges, and native corporations, extensive studies of mineral deposits and of the mineral resource potential of Alaska have been conducted by the U.S. Geological Survey, the U.S. Bureau of Mines, and the Alaska Division of Geological and Geophysical Surveys. These studies have resulted in abundant new information on Alaskan mineral deposits. In the same period, substantial new geologic mapping has also been completed with the help of new logistical and technical tools. One result of the geologic mapping and associated geologic studies is the recognition of numerous fault-bounded assemblages of rocks designated as tectonostratigraphic terranes. Proponents of this concept suggest that most of Alaska consists of a collage of such terranes (Jones and others, 1987; Monger and Berg, 1987).

The purpose of this report is to summarize the local geology, geologic setting, and metallogenesis of the major metalliferous lode deposits and placer districts of Alaska. The term "major mineral deposit" is defined as a mine, mineral deposit with known reserve, prospect, or occurrence that the authors judged significant for any given geographic region. This report is based primarily on unpublished data, and only secondarily on published articles concerning metalliferous mineral deposits and geology of Alaska. The unpublished data were contributed by mineral-deposits geologists in private industry, universities, the U.S. Geological Survey, the Alaska Division of Geological and Geophysical Surveys, the U.S. Bureau of Mines, and by the authors. Contributors are listed on the title page.

The regional metallogenesis and the major metalliferous lode deposits and placer districts are described in the following text. Locations of the lode deposits and placer districts are plotted on Plates 1 and 2. To facilitate use of these maps, the characteristics of the lode deposits are summarized in Table 1 (Plate 1), and the characteristics of the placer districts are summarized in Table 2 (Plate 2). The classification of lode mineral and placer deposits is summarized in Appendix 1. The lithotectonic terrane maps of Jones and others (1987) and Monger and others (1987) are used as the geologic underlay for Map 1 on Plate 1. More detailed, tabular descriptions of metalliferous lode deposits and placer districts of Alaska are published in a USGS Bulletin titled "Significant Metalliferous Lode Deposits and Placer Districts of Alaska" by Nokleberg and others (1987). The following abbreviations or terms are used in this report: PGE - Platinum group elements; REE - rare-earth elements; and tonne - metric ton.

PREVIOUS STUDIES

Since 1964, several statewide and regional summaries of Alaskan metalliferous lode and placer deposits have been published by the U.S. Geological Survey (USGS), and the Alaska Division of Geological and Geophysical Surveys (ADGGS). In 1964, the USGS published a map of placer gold occurrences in Alaska (Cobb, 1964); subsequently, they published a statewide summary of metalliferous lode deposits (Berg and Cobb, 1967) and a summary of

Alaskan placer deposits (Cobb, 1973). In 1976 and 1977, the USGS published a series of regional tables, maps, and references for metalliferous deposits. These regional reports cover the Brooks Range (Grybeck, 1977), the Seward Peninsula (Hudson and others, 1977), central Alaska (Eberlein and others, 1977), and southern Alaska (MacKevett and Holloway, 1977a, b). In 1981, the USGS published a report on all known mines, prospects, deposits, and occurrences in southeastern Alaska (Berg and others, 1981), and in 1982 a series of regional mineral-terrane maps of Alaska, prepared by C.C. Hawley and Associates, showing the location, size, and type of major metalliferous mineral deposits, was published by the Arctic Environmental Information and Data Center (AEIDC, 1982). In 1981 and 1984, the USGS published reports summarizing the regional geology, metallogenesis, and mineral resources of southeastern Alaska (Berg and others, 1981; Berg, 1984). In recent years, a yearly listing of Alaskan lode and placer deposits has been published by the Alaska Division of Geological and Geophysical Surveys; the listing for 1985 is by Bundtzen and others (1986).

CLASSIFICATION OF MINERAL DEPOSITS

Metalliferous deposits discussed in this report are classified into 29 lode deposit and 4 placer deposit models or types, listed below and described in Appendix 1. For simplicity, some types are grouped under one heading. This classification was derived mainly from the mineral-deposit models developed by Erickson (1982), Cox (1983a, b), Cox and Singer (1986), and other works listed in Appendix 1. Of the 29 types of lode and placer deposits, four were newly formulated for this study: metamorphosed sulfide, Cu-Ag quartz vein, and felsic-plutonic U lode deposits, and placer Sn deposits. The lode-deposit types are listed below, in order from those at or near the surface, such as stratiform deposits, to those formed at deeper levels, such as zoned mafic-ultramafic and podiform chromite deposits.

Lode Deposit Types

Kuroko massive sulfide deposit.
Besshi massive sulfide deposit.
Cyprus massive sulfide deposit.
Sedimentary exhalative Zn-Pb deposit.
Kipushi Cu-Pb-Zn (carbonate-hosted Cu) deposit.
Metamorphosed sulfide deposit.
Bedded barite deposit.
Sandstone U deposit.
Basaltic Cu deposit.
Hot spring Hg deposit.
Epithermal vein deposit.

Low-sulfide Au quartz vein deposit (abbreviated to Au quartz vein deposit).
Cu-Ag quartz vein deposit.
Polymetallic vein deposit.
Sb-Au vein deposit.
Sn greisen, Sn vein, and Sn skarn deposits.
Cu-Zn-Pb (± Au, Ag), W, and Fe (± Au) skarn deposits.
Porphyry Cu-Mo, porphyry Cu, and porphyry Mo deposit.
Felsic plutonic U deposit.
Gabbroic Ni-Cu deposit.
Zoned mafic-ultramafic Cr-Pt (± Cu, Ni, Co, Ti or Fe) deposit.

Podiform chromite deposit.
Serpentine-hosted asbestos deposit.

Placer Deposit Types

Placer Au deposit.
Placer Sn deposit.
Placer PGE-Au deposit.
Shoreline placer Ti deposit.

Each mineral deposit described in this report is classified into one of the above types. For a few lode deposits, lack of data precludes classification into a specific type. For these, a brief description of the deposit is enclosed in parentheses under the column labeled "Type" in Table 1.

LODE DEPOSITS - BROOKS RANGE

The northwestern Brooks Range contains several sedimentary exhalative Zn-Pb, one bedded barite, several podiform chromite, one Kipushi Cu-Pb-Zn, and various vein deposits. The southern flank of the central Brooks Range contains an extensive suite of major Kuroko massive sulfide deposits and one major carbonate-hosted Kipushi Cu-Pb-Zn deposit. The central Brooks Range contains a suite of of moderate-size polymetallic vein, Au quartz vein, Sb-Au vein, porphyry Cu and Mo, and Cu-Pb-Zn and Sn skarn deposits. The northeastern Brooks Range contains a cluster of Pb-Zn skarn, polymetallic vein, and porphyry Mo deposits. Mineral deposits in the Brooks Range and Seward Peninsula are further summarized by Einaudi and Hitzman (1986).

Stratiform Zn-Pb-Ag and and Barite Deposits, Northwestern Brooks Range

The northwestern Brooks Range contains a belt of large sedimentary exhalative Zn-Pb-Ag and bedded barite deposits that extend along strike for more than 200 km (Plate 1, Table 1). The larger Zn-Pb-Ag deposits are at Lik which contains an estimated 25 million tonnes of ore, and at Red Dog Creek (described below), which contains an estimated 85 million tonnes of ore and ranks within the largest 20 percent of known deposits of this type. Both deposits have high values of Zn, Pb, and Ag (Table 1). A somewhat similar deposit occurs at Drenchwater Creek (described below) in both sedimentary and volcaniclastic rocks (Table 1). The Nimiuktuk bedded barite deposit contains an estimated 1.5 million tonnes of barite (Table 1). Substantial potential exists for finding additional deposits in the northwestern Brooks Range (Nokleberg and Winkler, 1982; Lange and others, 1985).

The sedimentary exhalative Zn-Pb-Ag and bedded barite deposits occur in a tectonically disrupted and strongly folded assemblage of Mississippian and Pennsylvanian chert, shale, limestone turbidite, minor tuff, and sparse intermediate to silicic volcanic rocks, mainly keratophyres, named the Kuna Formation by Mull and others (1982). The Kuna Formation forms the basal unit of the Kagvik sequence of Churkin and others (1979) and the Kagvik terrane of Jones and others (1987) (Plate 1). This unit, and younger late Paleozoic and early Meosozic cherts and shales are interpreted either as a deep-water, allochthonous oceanic assemblage (Churkin and others, 1979; Nokleberg and Winkler, 1982; Lange and others, 1985) or as an assemblage deposited in an intracratonic basin (Mull and others, 1982; Mayfield and others, 1983).

Depending upon interpretation of stratigraphy, the sedimentary exhalative Zn-Pb-Ag and bedded barite deposits are interpreted to have formed either in an incipient submarine, continental-margin arc or in the early stages of a long-lived, sediment-starved, epicontinental basin.

Red Dog Creek Zn-Pb-Ag Deposit

By Joseph T. Plahuta, Loren E. Young, J. S. Modene

The Red Dog Creek deposit is a major, black-shale-hosted Zn-Pb-Ag deposit of submarine exhalative origin (Moore and others, 1986). The deposit occurs within a complexly deformed, northeast-trending belt of thrust slices. A Mesozoic compressional event greatly foreshortened the original basin and produced a thick stack of folded and internally imbricated thrust plates (Fig. 1A). The deposit is hosted by black, fine-grained siliceous shales, by cherts, and by medium-grained limestone turbidities of the Mississippian and Pennsylvanian Kuna Formation. The formation is informally subdivided into an upper, ore-bearing Ikalukrok unit and a lower, more calcareous Kivalina unit, which forms the stratigraphic footwall to the deposit (Fig. 1B).

The sulfide deposits occur in two areas, the main deposit is partially bisected by Red Dog Creek, and the smaller Hilltop deposit caps a hill about 800 m to the south. Drilling on the main deposit indicates the presence of 85 million tonnes of ore grading 17.1% Zn, 5.0% Pb, and 82 g/t Ag. The main deposit trends north-northwest and forms a nearly flat-lying lens 1,600 m long and 150 to 975 m wide (Fig. 1). Depth to the top of the ore varies from zero to 60 m. The Hilltop deposit occurs in a flat-lying klippe as much as 90 m thick, 850 m long, and 600 m wide. Both deposits occur in five stacked thrust plates (Fig. 1A) within a regionally telescoped sequence and they are separated from the footwall units by a major fault zone. Two of the thrust plates contain significant sulfide deposits, and are separated by tectonic slivers of barren units. The deposits are structurally underlain by the Cretaceous Okpikruak Formation (Fig. 1B).

The deposits are intercalated, stratiform lenses composed of varying proportions of fine-grained sphalerite, galena, pyrite, marcasite, quartz, and barite. The dominant gangue is quartz. Local concentrations of fossil worm tubes, analogous to modern occurrences along the East Pacific Rise, are thought to represent vent-related life zones. Minor amounts of low-grade sulfides occur as beds and veins in the enclosing shales, especially near the base of the deposit, where the veins form a feeder system. In these areas, the veins are as much as 1 m thick and contain medium- to coarse-grained sulfides, as well as wall rock inclusions. Barite-rich lenses, attaining thicknesses greater than 45 m, are most common as a cap to the deposit and locally extend upward into the Siksikpuk Formation.

The deposits are classified as submarine exhalative deposits that formed in the early stages of a long-lived starved epicontinental basin (Moore and others, 1986). Alternatively, Lange and others (1985) suggest the deposit formed in an incipient submarine island-arc or submarine continental-margin-arc environment. The mineralizing event took place episodically for 25 to 30 m.y., concurrent with tectonic instability in the basin. Small, spatially associated igneous intrusions of possible Mississippian age provide evidence for locally elevated heat flow. Although the source of the metals is speculative, underlying Devonian fluvial-deltaic rocks may have provided a basin aquifer through which the mineralizing fluids moved before exhalation on the sea floor. Structurally adjacent parts of the Upper Devonian Noatak

Sandstone contain vein and disseminated sulfides that may be coeval with the Red Dog Creek deposit.

Drenchwater Creek Zn-Pb-Ag Deposit

The Drenchwater Creek deposit consists of sphalerite, galena, pyrite, marcasite, and sparse barite in a zone about 1,830 m long and as much as 45 m wide (Nokleberg and Winkler, 1982; Lange and others, 1985). The sulfides occur both in disseminations and in massive layers in deep-water marine chert, shale, tuff, tuffaceous sandstone, and keratophyre and andesite flows and sills of Mississippian age. The rocks constitute the oldest part of the Kagvik sequence which in this area occurs in the lowest structural plate in a belt of thrust faults that strike east-west and dip gently south.

The sulfides occur in hydrothermally altered chert and shale and in adjacent volcaniclastic rocks. Fragments of fine-grained feldspar, pumice lapilli, and mafic volcanic rocks are commonly replaced by aggregates of kaolinite, montmorillonite, sericite, chlorite, actinolite, barite, calcite, quartz, fluorite, and prehnite. Local sulfide-bearing quartz-rich exhalite is associated with the volcanic and volcaniclastic rocks. The sulfides and barite form disseminations, massive sphalerite-rich layers or more rarely, quartz-sulfide veins that crosscut cleavage paralleling axial planes of south-dipping, north-verging folds. The veins represent minor, post-deformational transport and deposition of metals. Selected samples contain more than 1% Zn, 2% Pb, 150 g/t Ag, and 500 g/t Cd. The deposits are interpreted as having formed from metal-laden hydrothermal fluids discharged onto a deep-ocean floor during submarine eruptions occurring in an incipient submarine continental margin-arc or island-arc environment.

Chromite Deposits, Northwestern Brooks Range

The southern flank of the northwestern Brooks Range contains a belt of deposits at Iyikrok Mountain, Avan, Misheguk Mountain, and Siniktanneyak Mountain (Table 1, Plate 1) classified as podiform chromite deposits (J.A. Albers in Cox and Singer, 1986). The deposits consist mainly of disseminated to fine-grained, discontinous chromite layers and pods in complexly faulted, serpentinized dunite and harzburgite tectonite (Table 1, Plate 1). The largest deposit, at Avan, contains an estimated 285,000 to 600,000 tonnes of chromite (Foley and others, in press) and is thus an extremely large deposit. The dunite and harzburgite tectonite are part of the Misheguk igneous sequence of pillow basalt (locally intensely serpentinized), gabbro, chert, and minor limestone that is interpreted as a dismembered ophiolite (Roeder and Mull, 1978; Zimmerman and Soustek, 1979; Nelson and Nelson, 1982). This sequence is named the Misheguk Mountain allochthon by Mayfield and others, 1983), part of the Angayuchum terrane (Plate 1). The sedimentary rocks range in age from Mississippian to Jurassic; the mafic volcanic rocks range in age from Devonian to Triassic. The age of the ultramafic rocks is Jurassic or older. The ultramafic and mafic rocks occur in a series of klippen that are thrust over mainly Paleozoic and Mesozoic sedimentary rocks of the Arctic Alaska terrane to the north (Plate 1).

Sulfide Vein Deposits, Northwestern Brooks Range

The eastern part of the northwestern Brooks Range contains a belt of sulfide vein deposits at Story Creek, Whoopee Creek, Frost, and Omar (Table 1, Plate 1). They generally consist of sphalerite and galena with quartz and minor carbonate gangue in veins and fractures that are found in the Mississippian Kayak Shale of the Endicott Group at the Story Creek and Whoopee Creek deposits, and in dolomite and limestone of the Baird Group at Frost. The veins and fractures occur in linear zones from 1.5 to 3 km long and that cross tightly folded strata, indicating an epigenetic origin (Inyo F. Ellersieck and Jeanine M. Schmidt, written commun., 1985). No tonnage and grade data are available. Insufficient data preclude assignment of these deposits to a specific mineral deposit type. The Omar deposit (Table 1) consists of disseminated to massive chalcopyrite and other sulfides in veinlets, stringers, and blebs in brecciated Ordovician to Devonian dolomite and limestone of the Baird Group (Folger and Schmidt, 1986), and it is classified as a Kipushi Cu-Pb-Zn deposit (Table 1). The Endicott Group which hosts the Story Creek and Whoopee Creek deposits, forms part of the Brooks Range allochton (Mayfield and others, 1983) and is part of the Endicott Mountains subterrane (Plate 1). The Baird Group, which hosts the Frost deposit, forms part of the Kelly River allochthon (Mayfield and others, 1983) and is part of the Delong Mountains subterranes (Plate 1).

Massive Sulfide Deposits, Southern Brooks Range

An extensive belt of major Kuroko massive sulfide deposits and one Kipushi Cu-Pb-Zn deposit occurs along an east-west trend for about 260 km along the southern flank of the Brooks Range (Plate 1). The largest deposits are in the Ambler district (Hitzman and others, 1986) at Arctic, which contains an estimated 32 million tonnes of ore, and at Ruby Creek, which contains an estimated 91 million tonnes of ore averaging 1.2% Cu (Table 1). Other Kuroko massive sulfide deposits in the belt are at Smucker, BT, Jerri Creek, Roosevelt Creek, and Michigan Creek (Table 1, Plate 1) (Hitzman and others, 1982). The Ann deposit in the southern Brooks Range may be either a polymetallic vein or a metamorphosed sulfide deposit (Table 1).

The Kuroko massive sulfide deposits occur in or adjacent to submarine mafic and felsic metavolcanic rocks and associated carbonate, pelitic, and graphitic metasedimentary rocks of the Devonian and Mississippian Ambler sequence (Hitzman and others, 1982, 1986). The Ambler sequence, along with the Beaver Creek Phyllite, Bornite Marble, Mauneluk Schist, and Anirak Schist, forms the informally named "schist belt" of the southern Brooks Range (Hitzman and others, 1982). The Ambler sequence is generally multiply deformed and exhibits metamorphism of both greenschist and blueschist facies (Hitzman and others, 1982). The deposits occur within the Ambler sequence, which forms the southern part of the Hammond subterrane (Plate 1). Most workers in the southern Brooks range favor an origin of continental-margin rifting rather than an island-arc for the Kuroko massive sulfide deposits. The Ruby Creek deposit, classified as a Kipushi Cu-Pb-Zn deposit, is genetically related to Devonian submarine volcanism (See section by M.W. Hitzman, below). Bernstein and Cox (1986) stress the significance of carrolite and the Cu-Ge sulfide renierite in the Ruby Creek deposit as a link to the dolomite-hosted deposits at Kipushi and Zaire (Cox and Singer, 1986).

Smucker Zn-Pb-Ag Deposit
by Charles M. Rubin

The Smucker deposit is the westernmost of the Kuroko massive sulfide deposits of the Ambler sequence. The deposit occurs on the limb of a recumbent, asymmetric antiform that plunges gently northwest. The stratiform sulfide horizon extends at least 1,000 m along strike and occurs structurally below quartz-muscovite schist and above quartz-graphite phyllite members of the Ambler sequence. The sulfide horizon consists of banded, fine- to medium-grained pyrite, sphalerite, galena, chalcopyrite, and minor owyheeite in a gangue of quartz, calcite, and pyrite. Hydrothermal alteration, sulfide stockworks, or sulfide veins are not observed. Grades of the major massive sulfide horizons range from 1 to 5% Pb, 5 to 10% Zn, and 103 to 343 g/t Ag with minor Au.

The deposit occurs in a Late Devonian, polydeformed sequence of mafic and felsic metavolcanic and metasedimentary rocks exhibitng mainly greenschist facies metamorphism. The mafic and felsic metavolcanic rocks consist of quartz-muscovite schist, quartz-feldspar-muscovite schist, quartz-chlorite-calcite phyllite, and porphyroblastic quartz-K-feldspar-muscovite schist. The interlayered metasedimentary rocks consist of quartz-muscovite-chlorite phyllite, quartz-graphite phyllite, calcite-mica schist, and marble. The host rocks probably are derived from a bimodal calcic to calc-alkalic volcanic suite, interlayered with impure clastic and carbonate sedimentary rocks. The host rocks strike west-northwest, dip moderately south, and have been deformed into tight to isoclinal folds overturned to the south. Interpretations of regional stratigraphy are obscured by intense deformation and transposition of bedding into foliation. The deposit is interpreted to have formed either along a Late Devonian epicratonic rift margin or or in a pull-apart basin.

Arctic Zn-Cu-Ag Deposit

By Jeanine Schmidt

The Arctic deposit is the largest of the belt of volcanogenic (Kuroko) massive sulfide deposits in the Ambler sequence along the southern flank of the Brooks Range (Schmidt, 1983, 1986) (Fig. 2, Plate 1, Table 1). The deposit occurs in a sequence of metamorphosed basaltic and rhyolitic volcanic rocks, volcaniclastic and minor plutonic rocks, and pelitic, carbonaceous, and calcareous sedimentary rocks. The main deposit is interlayered with graphitic schists between two metarhyolite porphyries which are interpreted as submarine ash-flow tuffs (Fig. 2).

Minor sufides occur at two horizons above the main deposit which consists of semi-massive or less commonly massive sulfides in multiple lenses, each as much as 15 m thick, over a vertical interval of 6 to 80 m. The main deposit has an areal extent of about 900 by 1,050 m and is estimated to contain 32 million tonnes grading 4.0% Cu, 5.5% Zn, 1.0% Pb, 51.4 g/t Ag, and 0.65 g/t Au (Sichermann and others, 1976). The sulfides are mainly chalcopyrite and sphalerite, with less pyrite, pyrrhotite, galena, tetrahedrite, and arsenopyrite and traces of bornite, magnetite, and hematite. The sulfides are slightly to strongly zoned laterally, with pyrrhotite and arsenopyrite more abundant in the central and northwestern parts of the deposit and bornite more abundant in the southeast. Gangue minerals are also zoned, with calcite and dolomite dominant in the southeast, barite most abundant in the center, and quartz and minor phyllosilicates micas throughout. Minor sulfides occur at two horizons above the main deposit.

A sequence of laterally and vertically zoned, altered rocks is thickest in the southeastern part of the deposit and thins rapidly westward. Magnesian chlorite-rich altered rock is limited to the footwall of the main deposit. Enveloping the sulfide lenses is a zone of mixed alteration of barian fluorphlogopite, talc, barite, barian phengite, quartz, calcite, and magnesian chlorite. Irregularly overlying the main deposit are thinly laminated altered rocks consisting of pyrite, calcite, and phengite. All types of alterations are thickest in a zone trending north-northeast on the southeast side of the deposit, coincident with the high-Cu areas indicated by metal zoning.

Documented chemical changes in the host rocks adjacent to the main deposit have been an overall decrease in Na, K, and Si, a decrease of Al in the talc-rich zones, and an increase in Mg, Ba, F, Fe, Mg/Fe, and total volatiles in all types of alteration. The majority of the sulfides are interpreted to have been deposited in flat-lying areas and slopes 150 to 450 m from a topographically higher, linear vent area. An elongate zone with high Cu, low Ag and Pb, and the most intense alteration, is interpreted to be the fluid vent area that was probably fault controlled and active during short-lived Devonian and Mississippian rifting along a continental margin.

Ruby Creek Cu Deposit
By Murray W. Hitzman

The Ruby Creek deposit occurs on the north flank of the Cosmos Hills in the west-central part of the Ambler district (Figs. 3, 4; Plate 1, Table 1) (Hitzman and others, 1982). The deposit consists of disseminated to massive chalcopyrite, bornite, chalcocite, pyrite, and local sphalerite. Local sparse galena, pyrrhotite, marcasite, carrollite, cuprite, and renierite also are present. The deposit contains an estimated 91 million tonnes averaging 1.2% Cu, with 454,000 tonnes grading up to 4% Cu (Runnells, 1969). The deposit occurs in brecciated and intensely folded and faulted dolomite and limestone of the Devonian Bornite Marble (Hitzman and others, 1982),a unit that is about 1,000 m thick.

The deposit is interpreted to have formed along a rifted continental margin in the Late Devonian (Hitzman, 1986). The deposit occurs along a fault controlled(?) margin of a carbonate bank adjacent to a shale-filled graben. The carbonates were deposited as an intertidal bank with scattered organic mounds and a bioherm barrier at the basin edge; this carbonate bank is stratigraphically approximately equivalent to the bimodal metavolcanic rocks and metasedimentary rocks of the Ambler sequence, which contains volcanogenic massive sulfide deposits and which crops out about 15 km to the north. Paleogeographic reconstructions indicate that the Ruby Creek area and volcanogenic massive sulfide deposits in the Ambler sequence were located on opposite sides of a major shale-filled graben.

Mineralized hydrothermal dolostone bodies are recognized in biohermal and backreef facies of the Cosmos Hills along 10 km of the paleobasin margin (Hitzman and others, 1982). The overall trend of these bodies is parallel to the fault-controlled(?) margin of the basin, although several bodies formed along second-order structures. Clasts of hydrothermal dolostone are present in synsedimentary breccia, indicating mineralization occurred concurrently with sedimentation. Pb-Pb ages from galena in the deposit have yielded concordant Late Devonian ages (Rob Kirkham, written commun., 1979).

The Ruby Creek hydrothermal dolostone body displays evidence of three major hydrothermal dolomitizing events (Hitzman, 1986). The first two events, A and B, formed a roughly dome-shaped body about 450 m thick and 1,000 m by 1,500 m in lateral extent. Alteration was locally controlled by stratigraphy, pure clean limestone beds were most easily dolomitized. Less permeable argillaceous and highly carbonaceous limestones have been generally less altered. In the upper part of the system, these beds channeled fluids, while at the base, such beds were altered to zones of ferroan dolomite and (or) siderite and chlorite.

The first alteration event produced the A-dolostone, consisting of ferroan dolomite near the base of the carbonate section grading upward to magnesian dolomite in the upper part of the section (Fig. 4). The second hydrothermal event produced the B-dolostone, which cuts A-dolostone along irregular solution fronts and locally caused in-situ brecciation. Deep in the system, B-dolostone contains pyrite, chlorite, pyrrhotite, trace chalcopyrite and cymrite, and sphalerite. Late-B zones, defined by lenses of poorly ferroan dolomite and calcite in stratigraphic traps, often contain nearly massive pyrite and lesser sphalerite. The final hydrothermal event resulted in brittle fracturing of the dolostone body and production of C veins. The C veins are vertically zoned from mildly ferroan dolomite veins containing sparse pyrite deep in the system, to dolomite veins containing chalcopyrite and minor calcite in the central portion of the system, to dolomite-calcite veins containing subsidiary sphalerite and chalcopyrite on the outer fringes of the system. High-grade ore containing bornite, chalcocite, chalcopyrite, carrollite, and sphalerite formed where fracturing of the body allowed solutions access to the late B-massive pyrite zones. Copper sulfides replace the late-B pyrite; carrollite formed where the solutions forming the C veins interacted with the late-B cobaltiferous pyrite.

Sun Zn-Pb-Cu-Ag Deposit
By Christopher D. Maars

The Sun deposit occurs in the easternmost part of the belt of Kuroko massive sulfide deposits in the Ambler district (Plate 1, Table 1). The deposit consists of massive sulfides in at least three separate zoned horizons. The sulfides are sphalerite, chalcopyrite, galena, and argentiferous tetrahedrite. Gangue minerals are pyrite, arsenopyrite, and barite. The upper sulfide horizon is rich in Zn, Pb, and Ag, the middle horizon is rich in Cu, and the lower horizon is rich in Cu and Zn. Grades average 1 to 4% Pb, 6 to 12% Zn, 0.5 to 2% Cu, and 685 to 1,030 g/t Ag. Individual quartz-barite beds contain as much as 690 to 1,030 g/t Ag.

The deposit is hosted in metarhyolite, muscovite-quartz-feldspar schist, micaceous calc-schist, marble, and greenstone of the Devonian and Mississippian Ambler sequence, which strikes northeast and dips moderately southeast (Fig. 4). Most of the deposit is hosted in felsic or graphitic schist. Thin concordant layers of sulfides occur in the metarhyolite. Most of the metarhyolite is siliceous, light-colored, weakly schistose, and sparsely porphyritic. Small- and large-scale isoclinal folds are present in both host rocks and sulfide layers. The deposit is interpreted to have formed during Devonian and Mississippian submarine volcanism.

Vein, Skarn, and Porphyry Deposits, Central Brooks Range

To the north of the Ambler sequence in the central Brooks Range is a long belt of vein, skarn, and porphyry deposits with an east-west strike length of about 240 km (Table 1, Plate 1). At Mt. Igikpak and Arrigetch Peaks, the major deposits are polymetallic quartz veins with base-metal sulfides, Sn skarns with disseminated cassiterite and base-metal sulfides, and Cu-Pb-Zn skarns with disseminated Fe sulfides, and base-metal sulfides. At Sukapak Mountain, Sb-Au quartz vein deposits occur with sparse disseminated stibnite, cinnabar, and gold. At Victor and nearby areas, a porphyry Cu deposit contains veinlet and disseminated chalcopyrite and other base-metal sulfides in Devonian granodiorite porphyry, along with an adjacent Cu skarn deposit with interstitial bornite, chalcopyrite, and other base metal sulfides. At Geroe Creek, veinlet, stockwork, and disseminated molybdenite occur in a Devonian granite, and are classified as a porphyry Cu-Mo deposit. In the Chandalar district, gold and sparse sulfides occur in Au quartz vein deposits in a zone about 4.0 km wide and 1.6 km long. In 1981, the Mikado Squaw mine in the Chandalar district contained an estimated 11,000 tonnes grading 75 g/t Au (Dillon, 1982). The Chandalar district contains an estimated 45,000 tonnes grading 80 g/t Au (Dillon, 1982).

These deposits are in a structurally complex and polymetamorphosed assemblage of Devonian or older carbonate rocks, including the Silurian and Devonian Skagit Limestone, calc-schist, quartz-mica schist, and quartzite, that is intruded by Proterozoic and Late Devonian gneissic granitic rocks and is part of the Hammond subterrane (Plate 1). The Devonian gneissic granitic rocks and their related mineral deposits form an east-west-striking belt in the central part of the metasedimentary rocks. U-Pb zircon isotopic ages indicate that the Devonian gneissic granitic rocks intruded about 30 to 40 m.y. after the eruption of the submarine volcanic rocks that host the massive sulfide deposits in the Ambler district to the south (Newberry and others, 1986). The polymetallic vein deposits, Cu and Sn skarns, and porphyry deposits are interpreted as having formed during intrusion of the Devonian and older gneissic granitic rocks in a continental-margin subduction zone (Newberry and others, 1986). The Au quartz and Sb-Au quartz vein deposits are interpreted as being related to much later Mesozoic greenschist to amphibolite facies regional metamorphism of the metasedimentary and gneissic granitic rocks.

Skarn, Vein, and Porphyry Deposits, Northeastern Brooks Range

A cluster of skarn, vein, and porphyry deposits is present in the northeastern Brooks Range in an area that has mostly been withdrawn from mineral exploration (Table 1, Plate 1). The major deposits are: (1) at Esotuk Glacier, a Pb-Zn skarn with disseminated galena and spalerite, and a fluorite vein; (2) at Porcupine Lake, tetrahedrite, enargite, and fluorite in veins and as replacements in a polymetallic vein(?); (3) at Romanzof Mountains, disseminated galena, sphalerite, and chalcopyrite and base-metal sulfides in quartz veins in a Devonian(?) granite, which classified as a superposed porphyry Cu and polymetallic vein deposit, and a Pb-Zn skarn with galena and sphalerite; (4) at Bear Mountain, a molybdenite- and wolframite-bearing Tertiary rhyolite porphyry stock, classified as a porphyry Mo deposit (Barker and Schwainbank, 1986); and (5) at Galena Creek, disseminated galena and sphalerite in a polymetallic vein. No tonnage and grade estimates are available, and none of the deposits has been developed or produced. The paucity of deposits in the northeastern Brooks Range most likely reflects the limited geological exploration of the area.

The mineral deposits in the northeastern Brooks Range occur in a variety of host rocks. The skarn deposit at Esotuk Glacier is in Devonian or older marble and calc-schist intruded by Devonian gneissose granite. The polymetallic vein deposit at Porcupine Lake occurs in silicified tuffaceous limestone of the Mississippian and Pennsylvanian Lisburne(?) Group. The porphyry Cu, polymetallic vein, and skarn deposits at Romanzof Mountains are in Devonian(?) granite and Precambrian marble and calc-schist of the Neruokpuk Quartzite intruded by the Silurian or Early Devonian Okpilak (granite) batholith. The porphyry Mo deposit at Bear Mountain occurs in molybdenite-wolframite-bearing Tertiary rhyolite porphyry stock intruding the Neroukpuk(?) Quartzite. The polymetallic vein deposit at Galena Creek is in metasedimentary rocks and greenstone of the Neruokpuk(?) Quartzite. The metasedimentary rocks of the Neruokpuk(?) Quartzite and the younger late Paleozoic and Mesozoic sedimentary rocks in the region are part of the North Slope subterrane (Plate 1).

LODE DEPOSITS - SEWARD PENINSULA

The Seward Peninsula contains a variety of lode deposits (Table 1, Plate 1): (1) Sn-W vein, Sn skarn, and Sn greisen deposits; (2) polymetallic vein and porphyry deposits; (3) Au quartz vein deposits; (4) a felsic plutonic U and a sandstone U deposit; and (5) a metamorphosed sulfide deposit. The first three groups include most of the deposits in the region. The larger Sn lode deposits are mainly in the northwestern part of the peninsula; smaller Sn deposits occur elsewhere. The polymetallic and Au quartz vein deposits occur mainly in the southeastern and eastern parts of the peninsula (Plate 1). Felsic plutonic U, sandstone U, and metamorphosed sulfide deposits occur in the eastern part of the peninsula (Plate 1).

Sn Vein, Skarn, and Greisen Deposits

Sn lode deposits in the Seward Peninsula consist of Sn vein deposits at Cape Mountain and Potato Mountain, a Sn skarn deposit at Ear Mountain, Sn-W skarn and greisen deposits at Lost River, and a Sn greisen deposit at Kougarok. These deposits are often referred to as the Cretaceous tin province of the Seward Peninsula. The Sn vein deposits at Cape and Potato Mountains consist of cassiterite, pyrite, and a variety of other minerals, generally as disseminations in the margins or dikes of Cretaceous granite or in veins and veinlets in Precambrian or early Paleozoic metasedimentary rocks. The Sn skarn deposits at Lost River and Ear Mountain occur in Paleozoic limestone intruded by Late Cretaceous granite. The Sn greisen deposit at Kougarok occurs in steep pipes of greisenized Late Cretaceous granite. The larger Sn lode deposits occur at Lost River and Kougarok.

Lost River Sn-W Deposits

The Lost River deposits occur in vein skarn, greisen, and solution breccia near and along the upper margin of a Late Cretaceous granitic stock (Table 1, Plate 1) (Sainsbury, 1969; Dobson, 1982; Donald Grybeck, written commun., 1984). The stock intrudes a thick sequence of argillaceous limestone of the Ordovician Port Clarence Limestone of former usage, part of the York terrane (Plate 1). Early-stage andradite-idocrase skarn, and later fluorite-magnetite-idocrase vein skarns are altered to chlorite-carbonate assemblages that formed contemporaneously with greisen formation and cassiterite deposition. Locally abundant beryllium concentrations occur in fluorite-white mica veins, some containing diaspore, chrysoberyl, and tourmaline. These veins are probably associated with the early stages of granite intrusion. The major ore minerals in the skarns and greisen are cassiterite and wolframite, with lesser stannite, galena, sphalerite, pyrite, chalcopyrite, arsenopyrite, and molybdenite and a wide variety of contact metasomatic and alteration minerals. Most of the production was from the Cassiterite dike, a near-vertical granite dike extensively altered to greisen. Several small Sn deposits occur nearby, at or in the Tin Creek Granite; various polymetallic veins and skarns occur near the adjacent Brooks Mountain Granite.

Kougarok Sn Deposit
By Christopher C. Puchner

The Kougarok deposit (Table 1, Plate 1) consists of tin and tantalum-niobium concentrations in granitic dikes, sills, and plugs and in schist adjacent to the granitic rocks (Puchner, 1986). Rb-Sr and K-Ar age determinations indicate a Late Cretaceous age for the granitic rocks, which probably are coeval with other tin-bearing granitic rocks of the Seward Peninsula (Hudson and Arth, 1983). The tin deposits occur in four geologic settings: (1) in steep cylindrical pipes of greisen formed in granite; (2) in greisen formed in dikes; (3) in greisen formed along the roof zone of granitic sills; and (4) as stockwork veinlets in adjacent schist. Tin occurs dominantly as disseminated cassiterite in quartz-tourmaline-topaz greisen. Sn grades range from 0.1 to 15% Sn and average approximately 0.5% Sn. Ta-Nb deposits are confined to the roof greisens. Tantalite-columbite occurs as disseminated grains in quartz-white mica greisen beneath and (or) adjacent to tin-bearing quartz-tourmaline greisen. Grades range from 0.01 to 0.03% for both Ta and Nb. The wall rocks are part of the Nome Group (Sainsbury, 1972).

Polymetallic Vein and Porphyry Deposits

Sparse sulfide vein deposits, classified as polymetallic vein deposits, and one porphyry Mo deposit occur in the Seward Peninsula, mainly in the eastern part (Plate 1). The polymetallic vein deposits are at Serpentine Hot Springs, Omilak, Independence, and Quartz Creek, and the porphyry Mo deposit is at Windy Creek (Table 1). The polymetallic vein deposits consist of veins, stringers, and disseminations of pyrite and base-metal sulfide in: (1) Paleozoic(?) marble and quartz-mica schists, part of the Nome Group or mixed unit of Till (1984) in an area intruded by Cretaceous granitic plutons for all but the Quartz Creek deposit; and (2) altered andesite and granite of Jurassic or Cretaceous age for the Quartz Creek deposit. The porphyry Mo deposit at Windy Creek consists of veins and stringers of quartz, Fe sulfides, molybdenite, galena, and sphalerite in the hornblende granite of the Cretaceous(?) Windy Creek pluton. The pluton intrudes early Paleozoic mafic schist and marble of the Nome Group (or mixed unit of Till, 1984), part of the Seward terrane (Plate 1).

Au Quartz Vein Deposits

The Seward Peninsula contains numerous Au quartz vein deposits, prospects, and one mine. The larger deposits are in the Nome district aty Daniels Creek (Bluff), and at Big Hurrah (Table 1, Plate 1) (Gamble and others, 1985). Some of the areas produced minor gold; only the Big Hurrah Mine in the Solomon River area has recorded production. Most of the deposits consist of gold and sparse sulfide minerals in narrow quartz veins emplaced along fault zones in low-grade metamorphic rocks, mainly in the mixed unit of metasedimentary rocks and mafic schist of the Nome Group. The quartz veins cut the generally shallowly dipping metamorphic foliation. In addition to quartz, the veins typically contain minor carbonate and albite or oligoclase. Native gold is accompanied by sparse arsenopyrite and lesser pyrite. Total sulfide content is usually only a few percent. The origin of the Au vein deposits is not clear. The discordance of the veins with metamorphic foliations, the preliminary oxygen isotope and fluid inclusion data, similarities to other occurrences in metamorphic rocks, and the total absence of known or suspected intrusives near the veins indicate that the gold deposits formed from fluids that equilibrated with the sedimentary and (or) volcanic protoliths of the

Nome Group under greenschist- or amphibolite-facies conditions and then moved upward during a later, post-kinematic part of the event to deposit the vein minerals (Gamble and others, 1985). A Late Jurassic or Early Cretaceous age of metamorphism and vein formation seems likely (Gamble and others, 1985).

Big Hurrah Au Deposit

By Bruce M. Gamble

The Big Hurrah Au deposit consists of four major quartz veins, and zones of ribbon quartz, from 1 to 5 m thick and a few hundred m long, formed mainly of quartz with lesser amounts of plagioclase and carbonate minerals and accessory gold, scheelite, arsenopyrite, and pyrite (Gamble and others, 1985, Read and Meinert, 1986). The veins are localized along faults that parallel major regional faults and strike northwest and mostly dip steeply southwest. The veins commonly have a ribbon structure caused by the presence of graphite- or carbon-coated fractures and (or) inclusions of wall rock that parallel the veins. The veins occur in a graphitic quartz-rich schist that contains variable but small amounts of chlorite and (or) sericite. An estimated 155,500 g of gold has been recovered, mostly between 1903 and 1907, with some production in the 1940's and early 1950's (J. Orr, written commun., 1954). Several mining companies have drilled the deposit since then; recent assays show 25 to 65 g/t Au (Gamble and others, 1985). years. The schists hosting the veins are part of the Nome Group (mixed unit of Till, 1984), which forms part of the Seward terrane (Plate 1).

Other smaller Au quartz vein deposits on the Seward Peninsula share some similarities with the Big Hurrah deposit. The similarities are low sulfide-mineral concentration, fault localization, and confinement to low-grade, greenschist facies metamorphic rocks. However, the dissimilarities are smaller widths, more limited strike continuity, lower grades, occurrence in other lithologies and commonly contain a wider variety of minerals, including contain plagioclase, siderite, ferroan dolomite(?), arsenopyrite, minor pyrite, and locally stibnite.

U and Metamorphosed Sulfide Deposits

A felsic plutonic U deposit occurs at Eagle Creek and a sandstone U deposit occurs at Death Valley, both in the eastern part of the Seward Peninsula (Table 1, Plate 1). The felsic plutonic deposit consists of diseminated U-, Th-, and REE-minerals along the margins of alkaline dikes intruded into a Cretaceous granite pluton and adjacent wall rocks (Miller, 1976; Miller and Bunker, 1976). The Death Valley sandstone U deposit consists of mainly metaautinite in Paleocene sandstone along the margin of a Tertiary sedimentary basin (Dickinson and Cunningham, 1984). The U is interpreted as having been transported by groundwater from Cretaceous granitic plutons to the west.

A metamorphosed sulfide deposit occurs at Hannum Creek in the northeastern part of the Seward Peninsula (Table 1, Plate 1). The deposit consists of blebs, stringers, massive boulders, and disseminations of base-metal sulfides and barite parallel to layering in Paleozoic quartz-mica schist and marble, part of the Nome Group (mixed unit of Till, 1984). The deposit is interpreted as a metamorphosed laminated exhalite, possibly a former sedimentary exhalative Zn-Pb deposit (J.A. Briskey, written commun., 1985).

LODE DEPOSITS - WEST-CENTRAL ALASKA

West-central Alaska contains a variety of lode deposits. The southwestern Kuskokwim Mountains contain an Sb-Hg vein deposit, a zoned mafic-ultramafic Fe-Ti deposit, and a hot-spring Hg deposit. The central Kuskokwim Mountains contain a complex and extensive suite of Au quartz vein, Sb-Au vein, polymetallic vein, epithermal vein, hot spring Hg, Cu and Fe skarn, and felsic plutonic U deposits, and a carbonate-hosted sulfide deposit. The northeastern Kuskokwim Mountains contains several podiform chromite deposits in thin discontinuous thrust sheets of ultramafic and related rocks. The west-central Yukon-Koyukuk basin contains a suite of polymetallic vein and porphyry Mo and Cu deposits. The northern and eastern Yukon-Koyukuk basin contains suites of felsic plutonic U, polymetallic and epithermal vein, and W skarn deposits and a suite of podiform chromite and serpentinite-hosted asbestos deposits in thin discontinuous thrust sheets of ultramafic and related rocks. Vein, Zoned Mafic-Ultramafic, and Hot Spring Deposits,

Southwestern Kuskokwim Mountains

A Sb-Hg vein deposit at Kagati Lake, a zoned mafic-ultramafic deposit at Kemuk Mountain, and a hot spring Hg deposit at Cinnabar Creek occur in the Kuskokwim Mountains (Table 1, Plate 1). The Katagi Lake Sb-Hg deposit consists of stibnite, cinnabar, and quartz veinlets along joint surfaces in a Late Cretaceous monzonite and granodiorite stock intruding Lower Cretaceous volcaniclastic rocks and andesite of the late Paleozoic and Mesozoic Gemuk Group (Sainsbury and MacKevett, 1965). The Kemuk Mountain Fe-Ti deposit consists of a buried titaniferous magnetite deposit in a crudely-zoned pyroxenite (Humble Oil and Refining Company, written commun., 1958), and is estimated to contain 2.2 billion tonnes grading 15 to 17% Fe and 2 to 3% TiO_2. The Cinnabar Creek Hg deposit consists of stibnite and cinnabar in shear zones, disseminations, and veinlets in or near silica-carbonate dikes in argillite and other clastic rocks of the Gemuk Group (Sainsbury and MacKevett, 1965), part of the Togiak terrane (Plate 1).

Vein, Hot Spring, Skarn, and U Deposits, Central Kuskokwim Mountains Region

A wide variety of magmatism-related lode deposits occur in the central Kuskokwim Mountains region (Table 1, Plate 1). The major deposits are an epithermal vein deposit at Taylor Mountains; hot spring Hg deposits at Red Devil (described below), DeCoursey Mountain, and White Mountain (described below); a Sb-Au vein deposit at Snow Gulch; polymetallic vein deposits at Fortyseven Creek, Mission Creek, Owhat, Chicken Mountain, Golden Horn, Malemut, Granite, Broken Shovel, Cirque, Tolstoi, Independence, Candle, and Win-Won; a Cu-Au-Ag-Bi skarn deposit at Nixon Fork (described below); an Fe skarn deposit at Medfra; and a felsic plutonic U deposit at Sischu Creek. Most of the polymetallic vein and related deposits occur in the Flat and Innoko districts (described below).

The magmatism-related deposits are associated mainly with Late Cretaceous and early Tertiary granite, granodiorite, monzonite, and lesser gabbro that intrude an extensive suite of Cretaceous graywacke, argillite, basaltic to rhyolite volcanic flows, tuffs, and breccias of the Kuskokwim Group (Cady and others, 1955). Two unique deposits in the area are the Reef Ridge carbonate-hosted sulfide deposit. and the Sischu Creek felsic plutonic U deposit (Table 1, Plate 1). The Reef Ridge deposit consists mainly of stringers of sphalerite and minor galena in hydrothermal breccia in Silurian and Devonian carbonate rocks. The minimum strike length of the sulfides is 2,000 m and the width is as much as 15 m. The felsic plutonic U deposit consists of strongly radioactive U- and Th-rich porphyritic sanidine rhyolite and quartz porphyry flows in belts as much as several km wide and long that are associated with Late Cretaceous volcanic piles and granitic stocks and plugs.

Red Devil Hg Deposit

The Red Devil deposit consists of cinnabar and stibnite in about twenty plunging chimneylike bodies located along intersections of two altered basalt dikes in a wrench fault zone (Herreid, 1962; MacKevett and Berg, 1963. H. R. Beckwith, written commun., 1965) (Table 1, Plate 1). The ore bodies are vertically zoned, with nearly pure cinnabar at the surface, and increasing proportions of stibnite at depth. At 200 m below the surface mainly stibnite and quartz occur with a trace of cinnabar. The Red Devil mine has been the largest producer of mercury in Alaska, its production of 34,745 flasks accounting for about 80 percent of the state's production from 1942 through 1974 (Bundtzen and others, 1985). It is the largest and best exposed deposit of at least 15 known in the Kuskokwim mercury belt extending 400 km northeast from Dillingham to the Upper Innoko River. The Red Devil deposit and others in the belt are hosted in the flysch of the Kuskokwim Group, a turbiditic to fluvial clastic sedimentary sequence interpreted by Bundtzen and Gilbert (1983) to have been deposited in an elongate structural trough in the mid- and Late Cretaceous.

The Red Devil and nearby deposits at Barometer, Parks, and Rhyolite are interpreted to have been deposited by ascending hydrothermal fluids, carrying Hg- and Sb-bearing solutions into epithermal conditions (Sainsbury and MacKevett, 1965). The sulfides were probably deposited when the fluids reached near-surface groundwater in hot-spring conduits. The Red Devil deposit is similar to other flysch-hosted deposits, in California, Spain, and the U.S.S.R., where mercury in eugeosynclinal sedimentary rocks is mobilized into high-level, structurally controlled deposits by igneous activity. The abundant 60 to 70 Ma plutons, dike swarms, and volcanic rocks prevalent in the area (Bundtzen and Gilbert, 1983) might be the heat sources to mobilize mercury.

Flat and Innoko Districts

By Thomas K. Bundtzen

The Flat district contains an extensive suite of polymetallic and lesser Sb-Au vein deposits at Chicken Mountain, Golden Horn, Broken Shovel, Granite, and Malemute, and the Innoko district contains an equally extensive suite of polymetallic vein deposits, locally rich in Sn, at Cirque, Tolstoi, Independence, and Win-Won, (Table 1, Plate 1) (Bundtzen and Laird, 1982, 1983a, b, c; Bundtzen and Gilbert, 1983; Bundtzen and others, 1985).

The Chicken Mountain Au deposit (Table 1) consists of veinlets with arsenopyrite, scheelite, cinnabar, gold, and stibnite. The veinlets are hosted in an intensely hydrothermally altered zone in the southern part of the Chicken pluton (monzonite-gabbro) of Chicken Mountain. Pervasive sericitic alteration occurs in a northeast-trending area of about 250 by 600 m.

The Golden Horn Au-Ag-Sb deposit (Table 1) consists of veins of stibnite, cinnabar, scheelite, sphalerite, Pb-Sb sulfosalts, and chalcopyrite in a gangue of quartz, tourmaline, and calcite in a shear zone 30 m wide and 3 km long on the eastern side of the Otter Creek pluton (monzonite). Stibnite and cinnabar locally crosscut other sulfides. The veins occur in irregularly distributed quartz-filled shear zones at or near the contact of the pluton with Cretaceous clastic rocks. Sb-Hg veins crosscut older sulfides but are not directly associated with Au-As-W zones. The deposit has produced 479 tonnes grading 174 g/t Au and 171 g/t Ag.

The Broken Shovel Ag-Pb-Sb deposit (Table 1) consists of tourmaline, quartz, arsenopyrite, and sulfosalts in veins in the central part of the Cretaceous Moose Creek pluton (monzonite). The veins vary from 1 to 3 m wide, and occur in a sericite-tourmaline alteration zone about 300 by 400 m. The deposit contains an estimated 13,600 tonnes grading 178 g/t Ag, 0.15% Pb, and 0.15% Sb.

The Cirque and Tolstoi Cu-Ag-Sn deposits (Table 1) consist of chalcopyrite, tetrahedrite, pyrite, arsenopyrite, and scheelite in a gangue of tourmaline, axinite, and quartz localized along faults or in tourmaline phyllic alteration in altered monzonite and capped by altered olivine basalt. The two deposits, which exhibit characteristics of both polymetallic vein and porphyry Cu deposits, are associated with zoned, multiphase plutons ranging in composition from olivine gabbro to monzonite. The plutons and associated volcanic fields have alkalic affinities and show strong differentiation trends. The more promising deposits are in high cupolas or structural conduits of the most differentiated, felsic phases of the plutons.

The Independence Au deposit (Table 1) consists of quartz fissure fillings with gold, pyrite, and arsenopyrite in an altered dacite to rhyolite dike. The dike is part of the 60-km-long Yankee dike swarm. The deposit has been explored through several hundred m of underground workings and has produced 1,773 g of Au from 113 tonnes of ore. The Candle deposit consists of cinnabar, arsenopyrite, and quartz in stockworks in a Late Cretaceous sericitized monzonite near the intrusive contact with overlying altered olivine basalt. The Win-Won Sn-Ag deposit (Table 1) consists of chalcopyrite in numerous enechelon quartz veinlets, from 10 to 20 cm wide, in a well-developed quartz stockwork in hornfels on the northeast margin of the Cloudy Mountains volcanic field and related plutonic complex.

White Mountain Hg Deposit

By Brian K. Jones

The White Mountain deposit consists of cinnabar in three zones between Ordovician limestone and shale of the Nixon Fork sequence (Sainsbury and MacKevett, 1965). The zones occur in a belt about 1 km wide and 3 km long on the northwest side of the Farewell fault. In the southern zone, cinnabar forms thin crystalline coatings in brecciated dolomite, coatings on breccia surfaces, and irregular veinlets. In the central zone, irregular lenses of cinnabar occur in silicified limestone and dolomite. In the northern zone, rich cinnabar lenses occur on both sides of a major fault between shale and limestone. The largest massive cinnabar lens is 350 m long and 10 to 15 cm thick. Local cinnabar also occurs in dolomitized limestone with small, karst-like solution caverns. The gangue minerals in the cinnabar lenses are mainly dolomite, chalcedony, calcite, dickite, and limonite. The deposit was mined mainly from 1964 to 1974 and produced about 3,500 flasks. Chip samples of the cinnabar zones contain from 5 to 30% cinnabar. The overall features of this deposit and the nearby Mary Margaret and Peggy Barbara deposits, including a sulfur-mercury spring, indicate low-temperature deposition of mercury in a hot-spring environment along structural conduits associated with the Farewell fault.

Nixon Fork-Medfra District

The Nixon Fork-Medfra district contains several Cu-Au skarn deposits from Nixon Fork to Medfra and a dolomitic Fe-skarn deposit at Medfra (Table 1, Plate 1). The Cu-Au skarns consist of gold, chalcopyrite, pyrite, bornite, and Bi in skarn bodies that form irregular replacements in recrystallized Ordovician limestone of the Telsitna Formation near a Late Cretaceous monzonite (Martin, 1921; Brown, 1926; Jasper, 1961; Herreid, 1966; Patton and others, 1984) and in roof pendants overlying the pluton. Gangue minerals are diopside, andradite garnet, plagioclase, actinolite, epidote, and apatite. The skarns occur mainly in fractures from 1 to 4 m wide, 50 m long, and usually within 40 m of the pluton. A few skarns occur in roof pendants overlying the pluton, and several skarn bodies occur in fault-controlled veinlets away from the main trend of skarns. Local groundwater alteraton produced extensive oxidized skarn containing limonite, quartz, malachite, pyrite, and gold, and phyllic or argillic clay mineral alteration, which also occurs in the pluton, is typical of many Cu skarn deposits (Cox and Singer, 1986).

Skarns in the area have produced about 1.24 to 1.87 million g of Au and undisclosed amounts of Cu, Ag, and Bi. Individual skarn bodies in the area contain up to 113 g/t Au and 1.5 to 2% Cu. Most ore was mined from areas of secondary enrichment. Lower grade sulfide-rich ore occurs at depths greater than 60 m.

The Medfra Fe skarn deposit consists of magnetite and very minor chalcopyrite and sphalerite in epidote and garnet skarn. The deposit contains an estimated 11,600 m^3 grading 85% Fe_2O_3 with traces of Cu and Au (Patton and others, 1984).

Chromite Deposits, Tozitna and Innoko Areas

Several podiform chromite deposits occur in a series of intensely deformed ultramafic and associated rocks that form small, discontinuous thrust slices in the Tozitna and Innoko areas. The larger deposits are at Mount Hurst and Kaiyuh Hills (Table 1, Plate 1). The thrust slices are too small to show on Plate 1. The Mount Hurst deposit (Table 1) consists of banded chrome spinel in dunite layers in wehrlite (Chapman and others, 1982; Roberts, 1984). The largest chromite band strikes north-south, and varies from 10 to 800 cm thickness over a strike length of 10 m. Grab samples contain from 22 to 62.2% Cr_2O_3. The Kaiyuh Hills deposit consists of bands and disseminations of chromite from 1 cm to 1 m thick in fresh or serpentinized dunite (Loney and Himmelberg, 1984; Foley and others, 1985) and contains an estimated 15,400 to 33,500 tonnes Cr2O3. The ultramafic rocks at the two deposits consist of dunite, wehrlite, harzburgite, lherzolite, and clinopyroxenite. Associated with the ultramafic rocks are chert, basalt, and carbonate. The ultramafic rocks and associate rocks are interpreted as part of a complexly deformed and dismembered ophiolite of Jurassic(?) age (Loney and Himmelberg, 1984).

Vein and Porphyry Deposits, West-Central Yukon-Koyukuk Basin

The major deposits in the west-central Yukon-Koyukuk basin are a porphyry Mo deposit at McLeod, a combined polymetallic vein and porphyry Cu deposit at Illinois Creek, and polymetallic vein deposits at Perseverance (described below), Beaver Creek, and Quartz Creek (Table 1, Plate 1). The porphyry Mo deposit at McLeod consists of platy aggregates of molybdenite in quartz veinlets in the altered core of a Late Cretaceous or early Tertiary granite porphyry stock that intrudes mid-Cretaceous graywackes (Harold Noyes, written commun., 1984). At Illinois Creek, the combined polymetallic vein and porphyry Cu deposit consists of galena-sphalerite veins along a contact of altered Cretaceous granite porphyry against schist, and propylitically altered Cretaceous granitic plutons containing chalcopyrite, galena, and precious metals (Thomas K. Bundtzen, written commun., 1984; William W. Patton, written commun., 1985). The granitic rocks intrude early Paleozoic or older greenschist, quartzite, and orthogneiss, part of the Ruby terrane (Plate 1). The Quartz Creek deposit consists of disseminated sulfides in a zone as much as 8 km wide and more than 29 km long in altered andesite and granite of Jurassic or Cretaceous age.

Perseverance and Beaver Creek Pb-Ag-Zn Deposits

By Brian K. Jones

The Perseverance Pb-Ag-Sb deposit (Table 1) consists of veins of coarse-grained galena, tetrahedrite, and traces of jamesonite, in a gangue of dolomite and minor quartz, that crosscut bedding and schistosity of enclosing early Paleozoic or older chlorite-mica schists of the Ruby terrane (Plate 1). Oxidized zones in the veins contain cerussite, azurite, malachite, and stibconite(?). The deposit has produced about 231 tonnes grading 73% Pb and 124 g/t Ag.

The Beaver Creek Ag-Pb-Zn deposit (Table 1) consists of a zone of highly oxidized limonite, goethite, argentiferous galena, quartz, and sphalerite. The zone exhibits local surface occurrences of massive galena and limonite-cerussite gossan. The zone is about 300 m long and varies from 2.5 to 5 m thick; it is parallel to or crosscuts layering in enclosing schists of the Ruby terrane. The Beaver Creek deposit contains an estimated 13,600 tonnes grading 103 g/t Ag, 0.8% Zn, and 0.5% Cu, and an additional 19,100 tonnes tons grading 26.1 g/t Ag, 4.2% Pb, 0.16% Zn, and 0.2% Cu.

U Deposits, Northern Yukon-Koyukuk Basin

A suite of felsic plutonic U deposits occurs in Purcell district of the northwestern Yukon River Region at Wheeler Creek, Clear Creak, and Zanes Hills (Table 1, Plate 1) (Miller and Elliott, 1969; Miller, 1976; Jones, 1977). These deposits are part of a belt of U and Th deposits associated with a mid- and Late Cretaceous alkaline intrusive belt extending about 300 km from Hughes on the Koyukuk River to the Darby Mountains on the Seward Peninsula. The plutonic rocks vary from calc-alkaline to K-rich alkalic granitic rocks that intrude a sequence of andesitic flows, tuffs, breccia, agglomerate, conglomerate, tuffaceous graywacke, and mudstone with local intercalations of Early Cretaceous limestone, part of the Koyukuk terrane (Plate 1).

The Wheeler Creek deposit consists of uranothorite and gummite in altered, small, smoky, quartz-rich veinlets, and in altered areas in a Late Cretaceous alaskite. The deposit is about 500 m long and 50 m wide. Grab samples contain as much as 0.0125% U. The Clear Creek deposit consists of uraniferous nepheline syenite and bostonite dikes in Early Cretaceous andesite. The dikes occur within the contact aureole of the Late Cretaceous monzonite to granodiorite of the Zane Hills and contain as much as 0.04% U, and 0.055% Th. The Zane Hills deposit consists of uranothorite, betafite, uraninite, thorite, and allanite in veinlets in a foliated monzonite border phase, locally grading to syenite, of the Late Cretaceous monzonite to granodiorite pluton of Zane Hills. Selected samples contain as much as 0.027% Th.

Asbestos and Chromite deposits, Northern and Eastern Flanks of Yukon-Koyukuk Basin
By Jeffery Y. Foley

Several serpentinite-hosted asbestos deposits and a podiform chromite deposit occur along the eastern flanks of the Yukon-Koyukuk basin at Asbestos Mountain, Caribou Mountain, Lower Kanuti River, and Holonada (Table 1, Plate 1). The Asbestos Mountain deposit consists of serpentinite with veins of cross- and slip-fiber tremolite and chrysotile in a klippe of ultramafic rocks. The larger podiform chromite deposits at Caribou Mountain and Holonada consist of bands of massive chromite and chromohercynite in layers as much as 3 m thick and 130 m long. The Caribou Mountain deposit contains an estimated 2,270 tonnes, and the Holonada deposit contains as much as 24,900 tonnes (Foley and McDermott, 1983; Foley and others, 1984). One layer at Caribou Mountain is at least 25 m long and contains 7.5% Cr_2O_3. The average grade at Holonada is 20 Cr_2O_3. The asbestos and chromite deposits are in complexly faulted dunite layers associated with harzburgite, abundant pillow basalt, locally intensely serpenitinized gabbro, chert, and minor limestone of Permian through Jurassic age, all interpreted as a dismembered ophiolite (Zimmerman and Soustek, 1979; Nelson and Nelson, 1982; Loney and Himmelberg, 1985a, b), part of the Amgayuchum terrane (Plate 1).

Vein and Skarn Deposits, Eastern Yukon-Koyukuk Basin

A major polymetallic or epithermal vein deposit occurs at Upper Kanuti River, and a W skarn deposit occurs at Bonanza Creek (Table 1, Plate 1). The Upper Kanuti River Pb-Ag deposit consists of disseminated pyrite, galena, and sphalerite in an extensive gossan zone in a silicified rhyolite unit that may be a dike intruding a Cretaceous pluton (Patton and Miller, 1970). The Bonanza Creek W-Ag deposit consists of scheelite, chalcopyrite, and pyrrhotite in skarn adjacent to a Late Cretaceous granite pluton intruding the early Paleozoic or older pelitic schist, quartzite, and marble (Clautice, 1980) of the Ruby terrane (Plate 1).

LODE DEPOSITS - EAST-CENTRAL ALASKA

East-central Alaska contains a variety of lode deposits. The Manley and Livengood area contains polymetallic vein, Sb-Au vein, Mn-Ag vein, Hg vein, felsic plutonic U, Sn greisen, and Sn vein deposits. The northern and central parts of the Yukon-Tanana Upland contains suites of Sb-Au vein, Au-quartz vein, polymetallic vein, W skarn, and porphyry Cu-Mo deposits, a Au-As vein deposit, and a Sn greisen deposit. The Manley and Livengood area also contains a serpentinite-hosted asbestos deposit and a minor Pt deposit in thrust sheets of ultramafic and associated rocks. The northern Alaska Range contains an extensive district of polymetallic and Sb-Au vein and Kuroko massive sulfide deposits.

Vein and U Deposits, Manley and Livengood Region, Northwest Yukon-Tanana Upland

The major lode deposits in the Manley area are a polymetallic vein deposit at Hot Springs Dome, a Mn-Ag vein at Avnet, and a Sb-Au vein deposit at Sawtooth Mountain (Table 1, Plate 1). The Hot Springs Dome Au-Ag-Pb deposit consists of veins in shear zones with galena, limonite, siderite, copper, chalcopyrite, and Fe sulfides in Jurassic and Cretaceous flysch intruded by early Tertiary granite. The Avnet Mn-Ag deposit consists of irregular masses of psilomelane in thin vein quartz cutting lower and middle Paleozoic chert, quartzite, limestone, dolomite, and greenstone. The Sawtooth Mountain Sb-Au deposit consists of massive stibnite in a vertical cylinder about 3 m in diameter in flysch near a Cretaceous granite. The Triassic rocks, along with Upper Jurassic and Cretaceous quartzite, graywacke, and argillite, and volcanic conglomerate, all complexly deformed, form part of the Manley terrane (Plate 1). The Paleozoic rocks at the Avnet deposit are part of the Baldry terrane (Plate 1).

Major lode deposits in the Livengood area include Sb-Au and Au quartz vein deposits at Gertrude Creek, Griffen, and Ruth Creek, and the Hudson Cinnabar Hg vein deposit (Table 1, Plate 1). The Gertrude Creek, Griffen, and Ruth Creek Au deposits consist of quartz stringers as much as 8 cm wide with pyrite, stibnite, and base metal sulfides in altered Cretaceous monzonite and silica-carbonate rock. The Hudson Cinnnabar deposit consists of cinnabar in disseminations and quartz veins in altered early Tertiary granite dikes and plutons. The wall rocks in the Livengood area consist of a highly folded and weakly metamorphosed sequence of the Ordovician Livengood Dome Chert and overlying Silurian and Devonian dolomite, chert, volcanic rocks, serpentinite, shale, sandstone, and minor limestone and form part of the Livengood terrane (Plate 1).

To the northeast, a felsic plutonic U deposit occurs at Roy Creek, and a Sn greisen and Sn vein deposit occurs at Lime Peak (Table 1, Plate 1). The plutonic rocks hosting the deposits in both areas intrude a sequence of weakly deformed, quartz-rich sandstone, grit, shale, and slate, locally with probable Early Cambrian fossils, informally named the Wickersham grit unit, forming part of the Wickersham terrane (Plate 1).

Roy Creek U-Th Deposit
By P. Jeffrey Burton

The Roy Creek (formerly Mount Prindle) deposit contains a varied suite of U, Th, and REE minerals, phosphates, carbonates, and oxides, including allanite, bastnaesite, britholite, monazite, neodymian phosphate(?), thorianite, thorite, uranite, and xenotime. These minerals occur in steeply dipping quartz fissure veins that locally pinch and swell. Hematitic alteration and leaching of magnetite from the wall rocks occurred during vein formation. The veins are hosted in a small alkaline intrusive complex consisting of Cretaceous syenite and granite. The major rock units are porphyritic biotite aegirine-augite syenite, aeririne-augite syenite, porphyritic biotite augite syenite, and alkali granite, with minor magnetite-biotite-aegirine-augite lamprophyre dikes. The alkaline complex intrudes the Cambrian Wickersham grit unit.

Lime Peak Sn Deposit
By P. Jeffrey Burton and W. David Menzie

The Lime Peak deposit consists of areas of veinlets, breccia zones, and pods of black tourmaline and areas of chlorite, sericite, green tourmaline, and quartz alteration in an early Tertiary hypabyssal, peraluminous, biotite granite pluton (Menzie and others, 1983; Burton and others, 1985). The pluton is cut by numerous felsic and minor intermediate dikes. The areas of veinlets, breccia zones, and tourmaline pods are suggestive of deuteric alteration, whereas the areas of chlorite, sericite, and quartz are probably the result of hydrothermal alteration. Anomalous high values of Sn and associated Ag, B, Bi, Mo, Pb, and Zn occur in rock samples from and around the pluton. Very rare fluorite, topaz, pyrite, chalcopyrite, and molybdenite occur in the altered areas. Grab samples contain as much as 0.16% Sn, 0.1% Zn, 0.5% Cu, 0.2% Pb, and 14 g/t Ag. Cassiterite occurs in stream sediments in the surrounding area. The deposit is classified as either a Sn greisen or Sn vein deposit.

The granitic pluton varies from older, coarse-grained equigranular biotite granite to younger porphyritic biotite granite with a fine-grained groundmass. Local miarolitic cavitites are present, and the pluton has a K-Ar age of 56.7 Ma. Epizonal emplacement of the pluton is implied by a wide contact metamorphic aureole, abundant miarolitic cavities, porphyritic textures, and abundant veins. The pluton intrudes the lower part of the Cambrian Wickersham grit unit.

Vein, Skarn, Sn Greisen, and Porphyry Deposits, Northern and Eastern Yukon-Tanana Upland

The major lode mineral deposits in the northern and eastern Yukon-Tanana Upland are (Table 1, Plate 1): Sb-Au vein deposits at Dempsey Pup and Scrafford; Au-quartz vein deposits at Table Mountain, Democrat, and Purdy; polymetallic vein deposits at Cleary Summit, Ester Dome, Blue Lead, Tibbs Creek, and Gray Lead; W skarn deposits at Salcha River and Gilmore Dome; porphyry Cu-Mo deposits at Mosquito, Asarco, Bluff, and Taurus (described below); a Au-As vein deposit at Miller House; a Sn greisen deposit at Ketchem Dome; a serpentinite-hosted asbestos at Slate Creek (described below); and a podiform chromite deposit at Eagle C3. The deposits at Scrafford, Cleary Summit, Gilmore Dome, Ester Dome, and Democrat are in the Fairbanks district, one of the major mining areas in Alaska.

The northern and eastern part of the Yukon-Tanana Upland is underlain by multiply metamorphosed and penetratively deformed Devonian and older quartz-mica schist and gneiss, quartzite, quartz-rich grit, gneissic plutonic rocks, metavolcanic rocks, marble, and calc-schist that are intruded by Cretaceous and early Tertiary granitic plutons (Foster and others, this volume). The marble locally contains Devonian fossils, and parts of the gneissic plutonic rocks are dated as Devonian and Mississippian by U-Pb zircon isotopic studies. These metamorphic rocks are part of the Yukon-Tanana terrane (Plate 1).

The polymetallic and Sb-Au vein deposits are probably related to either greenschist facies regional metamorphism and (or) intrusion of Cretaceous and early Tertiary granitic plutons. The Au quartz vein deposits are interpreted as being related to a widespread regional metamorphic and deformational event that culminated with intrusion of Cretaceous granitic plutons, dikes, and sills. The porphyry and skarn deposits are related to an extensive suite of discontinuous early Tertiary granitic plutons and related igneous rocks. The porphyry deposits occur at the western end of a broad belt of similar deposits extending from the Dawson Range in western Canada into eastern Alaska (Hollister, 1978).

Fairbanks District

By Thomas E. Smith and Paul A. Metz

The Fairbanks district is one of the major mining areas in Alaska, with numerous lode and placer mines in an area of approximately 2,000 km^2. Since the discovery of gold placers in 1902, the district has produced 236 million g of placer gold and 7.8 million g of lode gold, nearly 25 percent of Alaska's production. The deposits were first described by Prindle and Katz (1913) and subsequently by Smith (1913), Chapin (1914, 1919), Mertie (1918), and Hill (1933). Hill (1933) first noted the close spatial relationship of placer and lode deposits.

The Fairbanks district is underlain by three metamorphosed stratigraphic sequences, in thrust contact, which are intruded by various granitic plutons, dikes, and sills (Fig. 5) (Smith and others, 1981; Forbes and Weber, 1982). The Fairbanks schist unit of Bundtzen (1982), the lowest sequence of late Precambrian or early Paleozoic age, consists dominantly of quartzite and muscovite-quartz schist, metamorphosed at conditions of the greenschist facies. Within the Fairbanks schist unit is a succession known as the Cleary sequence which is a 120 to 240 m thick and consists of felsic schist, laminated white micaceous quartzite, chlorite-actinolite greenstone, graphitic schist, minor metavolcanic rocks, calc-schist, and marble. The Cleary sequence hosts most of the lode deposits in the district and is present upstream from the major placer districts (Smith and others, 1981); it is believed to have a volcanogenic origin. (2) Structurally above the Fairbanks schist unit is the Chena River sequence, consisting of banded amphibolite, tremolite marble, garnet-muscovite schist, biotite schist, calc-schist, and metachert, metamorphosed at conditions of the lower amphibolite facies (Forbes and Weber, 1982). (3) In the northern part of the district, the Fairbanks schist is structurally overlain by the Chatanika sequence, consisting of garnet-pyroxene eclogite, garnet amphibolite, quartzite, marble, and pelitic schist.

Granitic rocks in the district include a hornblende granodiorite pluton near Pedro Dome, a younger, multiphase porphyritic quartz monzonite to granodiorite pluton at Gilmore Dome, and numerous small plutons or hypabyssal bodies and dikes of felsic or intermediate composition. Field relations indicate mesozonal emplacement; K-Ar and Rb-Sr isotopic ages range from 91 to 93 Ma (Late Cretaceous). Chemical, mineralogical, and isotopic criteria indicate that the porphyritic quartz monzonite may be an S-type granite, whereas the hornblende granodiorite displays features of both S- and I-type granite.

Two major deformations occurred in the district. The earlier resulted in synmetamorphic, overturned to recumbent, subisoclinal, northeast-verging folds with wavelengths of about 300 m. The later deformation refolded these structures into broad, northeast-trending open folds that control the distribution of major rock types (Fig. 5A). Local minor structures, including shears and crush zones typically cluster in northeast- and north-northeast-trending sets, both of which have a close spatial and genetic relationship to the discordant Au, Sb, and As lode deposits in the district. Northeast-trending faults typically show reverse offset and southerly dips.

The district contains 188 lode gold deposits, of which 65 have produced an estimated 8.7 million g Au with average grades ranging from 9.6 to 79 g/t (Thomas, 1973). The deposits are concentrated in the Cleary Summit, Ester Dome, Scrafford, and Gilmore Dome areas (Fig. 5) (Table 1, Plate 1). The lode deposits consist of five groups (Metz and Halls, 1981): (1) Stratabound volcanogenic(?) deposits with intergrown As, Zn, Sb, Pb, and Cu sulfides, gold, and scheelite in conformable lenses parallel to layering in metavolcanic rocks of the Cleary sequence; (2) Pb-sulphosalt quartz sulfide veins with argentiferous galena, sphalerite, chalcopyrite, stibnite, arsenopyrite, and gold in Cretaceous granitic plutons; (3) Skarn deposits, mostly as replacements of calcareous layers of the Cleary sequence, with scheelite in prograde hedenbergite pyroxene and subcalcite garnet skarn and retrograde hornblende-quartz-calcite metasomatic mineral assemblages in calc-schist and marble adjacent to Cretaceous granitic plutons at Gilmore and Pedro Domes (Allegro, 1984); (4) Polymetallic gold-sulfide quartz vein deposits within and crosscutting the Cleary sequence; and (5) stibnite gash veins and fracture fillings in axial plane shears in metavolcanic rocks of the Cleary sequence.

Field observations and chemical data lead to the following model of ore ore genesis: (1) Precambrian or early Paleozoic bimodal submarine volcanism in a rift environment, along with formation of volcaniclastic rocks and exhalites enriched in Au, Sb, As, and W; (2) regional polymetamorphism and deformation resulting in mobilization of metals into veins; (3) emplacement of post-tectonic Cretaceous granitic plutons, possibly during anatexis, with concurrent skarn formation and continued mobilization of metals in veins at favorable sites within the Cleary sequence (Smith and others, 1981).

Taurus Cu-Mo Deposit

By E. R. Chipp

The Taurus porphyry Cu-Mo deposit is the best known of three porphyry deposits that are present about 11 to 22 km west of the Canadian border in the Yukon-Tanana Upland; the other deposits are at East Taurus and Bluff (Table 1, Plate 1). The Taurus deposit consists of sparse disseminated Cu and Mo sulfides and pervasive pyrite in altered areas of an early Tertiary granite porphyry and disseminated pyrite in associated volcanic rocks. The sulfides occur in three settings: (1) chalcopyrite, molybdenite, and pyrite in veinlets of quartz and sericite; quartz and sericite with accessory biotite and orthoclase; quartz, magnetite and anhydrite; and clay, fluorite, and zeolite; (2) sparse concentrations of Cu and Mo sulfides associated with potassic alteration in the magnetite-rich core of the granite porphyry; and (3) higher concentrations of Cu and Mo sulfides associated with phyllic alteration in the periphery of the granite porphyry. Propyllitic alteration is minor in the core but is extensive in the periphery of the granite porphyry. Intense sericitic alteration occurs in gneiss along the southern and eastern contacts of the granite porphyry; these areas have very low concentrations of sulfides which formed mostly through supergene processes.

A late hypogene alteration phase containing montmorillonite, fluorite, calcite, and zeolite is present locally within northeast-trending fractures and may be associated with regional tourmaline-quartz alteration. Supergene alteration defined by abundant clay minerals and limonite has occurred in all parts of the deposit to at least 30 m below the surface. Cu enrichment due to surficial oxidation and redeposition near the former water table is detectable but not significant. Chalcocite is the principal sulfide replacing chalcopyrite and coating pyrite for 30 m below the leached cap. Approximately

450 million tonnes grading 0.5% Cu and 0.07% MoS_2 are present. One drill hole, 120 m long, grades 0.104% MoS_2, indicating molybdenum may be more important at depth.

The granitic plutons at Taurus and at nearby porphyry deposits and the associated felsic tuffs and breccias are spatially related to the east-west-trending McCord Creek fault. Fault intersections and flexures apparently controlled emplacement of porphyries and intrusive breccias. The porphyries intrude multiply deformed and metamorphosed Devonian or older sedimentary and volcanic rocks and Devonian and Mississippian gneissic granitic rocks of the Yukon-Tanana Upland (Foster and others, this volume). Biotite from the granite porphyry at Taurus yields a K-Ar age of 57.0 Ma (T.K. Bundtzen, written commun., 1985). Local small stocks of Mesozoic(?) granodiorite also occur in the area. The porphyry deposits are interpreted as having formed during hydrothermal alteration of magnetite-rich granite porphyry, probably within a backarc environment.

Asbestos and Pt Deposits, Eastern Yukon-Tanana Upland

Asbestos and Pt deposits also occur in the eastern Yukon-Tanana Upland, where they consist of a large serpentinite-hosted asbestos deposit at Fortymile (described below) and a Pt deposit in ultramafic rocks at Eagle C-3 (Table 1, Plate 1). The Eagle C-3 deposit consists of high PGE values in biotite pyroxenite in a small ultramafic body (Table 1). These deposits are in discontinuous remnants of thrust sheets of ultramafic and associated rocks that are structurally above the Yukon-Tanana terrane (Plate 1). Many of the thrust sheets are too small to depict on Plate 1. The thrust sheets consist of serpentinized harzburgite and associated ultramafic rocks, gabbro, pillow basalt, and local Permian chert, all of which may be part of a severely dismembered ophiolite (Foster and others, this volume). These scattered, isolated thrust sheets of ultramafic and related rocks are part of the Seventymile terrane (Plate 1).

Fortymile Asbestos Deposit
By Robert K. Rogers

The Fortymile area contains numerous fairly small bodies of ultramafic rocks near the Tintina fault, eleven of which contain concentrations of chrysotile asbestos (Table 1). The ultramafic rocks adjacent to the fault consist of partially serpentinized harzburgite and dunite, whereas those as much as 64 km south of the fault are completely serpentinized. The deposit in the Slate Creek area consists of antigorite with minor clinochrysotile, chrysotile, magnetite, brucite, and magnesite in completely serpentinized harzburgite and dunite. The serpentine probably replaced magnesium-rich olivine, minor orthopyroxene, and rare clinopyroxene. The chrysotile asbestos is present in zones of fracturing near centers of thicker serpentinite, primarily as cross-fiber chrysotile in randomly oriented veins about 0.5 to 1 cm thick. The veins contain alternating zones of chrysotile and magnetite and commonly exhibit magnetite selvages. Some chrysotile is altered to antigorite. The chrysotile veins appear to be the result of fracture filling from fluids migrating through fractures, or possibly from relatively immobile fluids dissolving and reprecipitating serpentine within a small area. Three of the ultramafic bodies in the Slate Creek area are estimated to contain 58 million tonnes averaging 6.4% chrysotile fiber.

The harzburgite and dunite hosting the deposits is in tabular tectonic lenses that range from 60 to 150 m thick as much as 800 m long. The serpentinite is generally massive; zones of intense shearing are common near contacts. The serpentinite is commonly altered near contacts and fault zones. Calcite, dolomite, magnesite, cryptocrystalline quartz, and limonite-goethite replace serpentine, and they appear to have formed during reaction of serpentinite with CO_2-rich meteoric water. The Fortymile asbestos deposit is interpreted as a low-temperature replacement deposit formed during alteration of the harzburgite.

Vein and Massive Sulfide Deposits, Northern Alaska Range Region

The major lode deposits in the northern Alaska Range include (Table 1, Plate 1): (1) an extensive district of polymetallic and Sb-Au vein deposits in the Kantishna District (described below) at Slate Creek, Eagles Den, Quigley Ridge, Banjo, Spruce Creek, and Stampede; and (2) an extensive suite of massive sulfide deposits at Liberty Bell, Sheep Creek, Anderson Mountain, WTF, Red Mountain, Miyaoka, Hayes Glacier, McGinnis Glacier, and in the Delta district. The massive sulfide deposits extend for 350 km along strike on the northern flank of the Alaska Range (Plate 1), and constitute one of the longer belts of massive sulfide deposits in Alaska. Deposits in this belt have been discovered mainly within the last 10 years. Potential exists for the discovery of additional deposits.

Both the vein and massive sulfide deposits occur in Devonian or older polymetamorphosed, polydeformed, submarine metavolcanic rocks, pelitic schists, calc-schist, and marble, with few or no gneissic granitic rocks (Aleinikoff and Nokleberg, 1985; Nokleberg and Aleinikoff, 1985). This assemblage is interpreted as the upper structural and stratigraphic level of the Yukon-Tanana terrane (Nokleberg and Aleinikoff, 1985). Metamorphic grade ranges from amphibolite facies at depth to greenschist facies at higher levels (Nokleberg and Aleinikoff, 1985; Nokleberg and others, 1986). Locally abundant Cretaceous(?) gabbro to diorite dikes and sills crosscut schistosity and foliation in the sequence. Structurally overlying these older rocks are the singly metamorphosed and deformed metasedimentary and metavolcanic rocks of the Precambrian or Paleozoic Keevy Peak Formation and Mississippian(?) Totlanika Schist (Wahrhafitg, 1968; Gilbert and Bundtzen, 1979). The massive sulfide deposits are classified as Kuroko massive sulfide deposits that formed during Devonian submarine volcanism. The polymetallic vein and Sb-Au deposits in northern Alaska Range are probably formed during Cretaceous regional metamorphism and (or) during intrusion of somewhat younger Late Cretaceous or early Tertiary dike swarms.

Kantishna District

By Thomas K. Bundtzen

The Kantishna district contains an extensive suite of polymetallic and Sb-Au vein deposits at Slate Creek, Quigley Ridge, Banjo, Spruce Creek, Eagle Den, and Stampede (Table 1, Plate 1). Most of the deposits are in the middle Paleozoic or older metamorphosed volcanic and sedimentary rocks of the Spruce Creek sequence (Bundtzen, 1981), which is correlated by some workers with the Cleary sequence in the Fairbanks district (Bundtzen and Smith, 1986).

Most of the vein deposits occur as crosscutting quartz-carbonate-sulfide veins and are structurally controlled within a northeast-trending fault zone, 60 km long, extending from Slate Creek to Stampede. Mineralization occurred before, during, and after fault-zone movement, as illustrated by both crushed and undeformed ore shoots in the same vein system. The vein faults range from 30 to 500 m long and from a few cm to 9 m wide; they occur in various lithologies but are best developed in brittle rocks such as quartzite or metaigneous rocks. The vein deposits consist of Ag-Au-Sb-Pb-Zn quartz-carbonate-sulfide veins subdivided into the following three types: (1) polymetallic vein deposits composed of quartz, arsenopyrite, pyrite, gold, and scheelite; (2) polymetallic vein deposits composed of galena, sphalerite, tetrahedrite, pyrite, and chalcopyrite, often with silver, lead, and antimony sulfosalts; and (3) Sb-Au vein deposits composed of stibnite and quartz, largely free of other sulfides.

The Quigley Ridge deposit consists of type 2 veins and contains an estimated 381,000 tonnes grading 1,337 g/t Ag, 4.8 g/t Au, 6.4% Pb, and 2.3% Zn. The Banjo deposit consists of type 1 veins and contains an estimated 159,000 tonnes grading 13.4 g/t Au, 123 g/t Ag, and 1.5% combined Pb, Zn, and Sb. The Spruce Creek deposit also consists of type 1 veins and contains an estimated 77,000 tonnes grading 2.4 g/t Au, 276 g/t Ag, and 2.5% combined Pb, Zn, and Sb. The deposits at Slate Creek, Last Chance, and Stampede consist of type 3 veins and together contain an estimated 507,000 tonnes grading 11.9% Sb with minor Ag and Zn.

Textures indicate that arsenopyrite and pyrite formed early; base-metal sulfides, such as sphalerite, chalcopyrite, galena, and silver sulfides, and tetrahedrite formed next; and Sb minerals such as boulangerite, jamesonite, and stibnite formed late (Bundtzen, 1981). The highest Ag and Au values are in type 2 veins and occur in tetrahedrite, polybasite, pyrargyrite, and pearceite. The Kantishna vein deposits were probably formed during hydraulic fracturing of the metalliferous host rocks of the Spruce Creek sequence. Metals were leached from the volcanic and sedimentary rocks and were transported by hydrothermal fluids into structural conduits. The heat engine was probably either mid-Cretaceous regional greenschist facies metamorphism or plutonism or the emplacement of younger Late Cretaceous or early Tertiary dike swarms.

Liberty Bell and Sheep Creek Massive Sulfide Deposits, Bonnifield District

By Thomas K. Bundtzen

Two small massive sulfide deposits occur at Liberty Bell and Sheep Creek in the Bonnifield district (Table 1, Plate 1). Both are hosted in the volcanic and sedimentary rocks of the Precambrian or Paleozoic Keevy Peak Formation and the Mississippian(?) Totatlanika Schist. Both deposits illustrate diversity in texture, geometry, and metal content.

The Liberty Bell massive sulfide deposit consists of arsenopyrite, pyrite, pyrrhotite, chalcopyrite, and bismuthinite lenses and disseminations that occur parallel to layering in tuffaceous schist. The deposit has a maximum thickness of 10 m and a strike length of 200 m; it contains an estimated 91,000 tonnes grading 10% As, 2% Cu, and 34 g/t Au. The deposit is adjacent to a metamorphosed Paleozoic(?) plug that is probably coeval with the tuff protolith of the schist. The Liberty Bell deposit resembles the Langdal, Renstrom, and Boliden arsenic and precious metal massive sulfide deposits of north-central Sweden, which are interpreted as a Proterozoic example of a Kuroko massive sulfide district.

About 20 km south of the Liberty Bell deposit on the opposite limb of a major syncline, the Sheep Creek massive sulfide deposit consists of sphalerite, galena, pyrite and stannite in massive lenses in phyllite and metaconglomerate. The lenses are in a zone about 330 m long and are localized in the nose of an overturned anticline near the contact between the volcanic-rock-rich Totalanika Schist and the sedimentary-rock-rich Keevy Peak Formation. Selected samples average 11% combined Zn and Pb, 10 g/t Ag; local zones as much as 1 m thick average 1% Sn.

Anderson Mountain Massive Sulfide Deposit, Bonnifield District

By Curtis J. Freeman

The Anderson Mountain massive sulfide deposit is also in the Bonnifield district (Table 1, Plate 1); it consists of massive sulfide layers with pyrite, chalcopyrite, galena, sphalerite, enargite, and arsenopyrite in a gangue of quartz, sericite, chlorite, calcite, barite, and siderite. The massive sulfides contain recoverable Cu, Pb, Zn, and Ag, along with anomalous Hg, As, Sb, W, Sn, and Ba. Thicknesses of the sulfide layers range from 0.6 to 3 m; grades range from 0.5 to 19% Cu, a trace to 5% Pb, a trace to 22% Zn, and a trace to 170 g/t Ag. The sulfide-rich layers occur in metamorphosed marine tuffaceous rhyolite with lithic interbeds. The deposit is slightly discordant with respect to the host horizon and appears to rest on an irregular paleosurface in the stratigraphic footwall. Metal concentrations in the stratigraphic package indicate episodic mineralization, with a rather slow beginning, a peak of metal deposition, and subsequent tapering. The lower contacts of the sulfide layers are sharp whereas the upper contacts are irregular and have variable grade and geometry; the upper contacts are locally dome-shaped. Lateral and vertical metal-ratio trends indicate deposition near, but not at, an exhalative center.

The tuffaceous rhyolite and lithic interbeds hosting the deposit are part of the Moose Creek Member of the Mississippian(?) Totatlanika Schist. The wallrocks beneath the deposit are mainly black carbonaceous shale and calcareous shale. The wallrocks above the deposit are mainly massive to pyroclastic basalt interbedded with lenses of thin black shale. Low-grade greenschist facies metamorphism has altered the host rocks but has not destroyed relict sedimentary textures. Relict crossbedding, scours, and rare shellly fossils indicate marine deposition. The host units strike northeast, dip moderately southeast, and are dissected by numerous small high-angle faults.

WTF and Red Mountain Zn-Pb-Cu-Ag Deposits

By D. R. Gaard

The WTF and Red Mountain deposits (Table 1, Plate 1) consist of massive pyrite, sphalerite, galena, and chalcopyrite in a quartz-rich gangue. Local alterations consist of intense silicification and talc formation. The deposits contain an estimated 1.12 million tonnes grading 0.15% Cu, 3.5% Pb, 7.9% Zn, 270 g/t Ag, and 1.9 g/t Au. The deposits occur on either side of a large east-west-trending asymmetric syncline, with the Red Mountain deposit on the south limb and the WTF deposit on the north limb (Fig. 6).

The deposits are in the upper part of the Mystic Creek Member of the Mississippian(?) Totatlanika Schist, near the contact with the overlying Sheep Creek Member. The Red Mountain deposit occurs within several silica-exhalite horizons in a sequence of metamorphosed dacitic to rhyolitic crystal tuff, lapilli tuff, minor flows, and metasedimentary rocks. The southern exhalite horizon at Red Mountain consists of sphalerite and coarse pyrite in a black chlorite schist; the northern exhalite horizon at Red Mountain, about 90 to 120 m thick, contains pyrite-rich massive sulfide with Cu, Zn, Pb, and Ag and several massive pyrite horizons. The ore-grade massive sulfides at Red Mountain are fine grained and finely to coarsely laminated. Local deformation of the deposit is illustrated by sparse sulfide augen in the massive sulfide layers.

The WTF deposit consists of a fairly thin but areally extensive pyrite-rich massive sulfide, generally less than 3 m thick, containing Ag, Zn, Pb, and Au. The sulfides are fine grained and finely to coarsely laminated. High Ag values are related to local tetrahedrite inclusions in galena. The quartz gangue content increases to the west along with decreasing Pb/Zn ratio, and decrease in Ag. Synsedimentary pyrite gradually decreases from 10 to 20% to 2 to 5% in the black schist above the massive sulfide.

The thick massive sulfide deposit at Red Mountain and the thinner deposit at WTF are interpreted as coeval proximal and distal deposits, respectively. The deposits are interpreted to have formed from a hydrothermal cell at a waning submarine volcanic center. Sulfidic exhalations precipitated the podiform massive sulfides at Red Mountain, whereas an extensive euxinic basin caused precipitation of the distal WTF deposit from fumarole-derived brines that originated near Red Mountain.

Miyaoka, Hayes Glacier, and McGinnis Glacier Cu-Pb-Ag-Au Deposits

By Ian M. Lange and Warren J. Nokleberg

To the east, a suite of Kuroko massive sulfide deposits occurs at Miyaoka, Hayes Glacier, and McGinnis Glacier (Table 1, Plate 1). The deposits consist of disseminated grains to massive lenses and pods of Fe-sulfides, chalcopyrite, and sphalerite in a gangue of quartz, chlorite, epidote, biotite, and actinolite (Nokleberg and Lange, 1985). The more extensive deposit at McGinnis Glacier consists of sulfide pods and lenses as much as 1 m thick that occur discontinuously in a zone as much as 15 m thick and 2 km long. The sulfides are in an intensely deformed, interfoliated marine sequence of Devonian or older metavolcanic and metasedimentary rocks (Aleinikoff and Nokleberg, 1985). The host rocks show evidence of two periods of metamorphism, an older of amphibolite facies and a younger of greenchist facies. The deposits probably formed in a submarine island-arc setting.

Delta District

By Clint R. Nauman and Steven R. Newkirk

The Delta district deposits occur at the eastern end of the belt of massive sulfide deposits in eastern part of the northern Alaska Range (Plate 1) (Nauman and others, 1980). The district comprises an area of approximately 1,000 km^2 and contains numerous stratiform, transposed stratiform, and lesser replacement-type massive sulfide deposits within a thick sequence of metavolcanic and metasedimentary rocks metamorphosed at conditions of the greenschist facies.

The base metal deposits in the Delta district occur in four regional trends, the DD, DW, Trio, and PP-LZ trends. The central DD and DW trends contain massive sulfides in lenses and sheets, respectively. The DD South massive sulfide deposit, hosted in metavolcanic rocks, contains 1.5 million tonnes of brecciated and weakly banded pyrrhotite, pyrite, and Cu, Pb, and Zn sulfides with average grades of 1% Cu, 8% combined Pb and Zn, 62 g/t Ag, and 2 g/t Au within a lens at most 545 m long, 212 m wide, and 15 m thick in the central portion. The DD North deposit, another lens-like body, located about 1.6 km away along strike, contains similar copper and gold grades but is relatively depleted in Pb and Zn. To the northwest and southeast for several km along strike, thin beds of Pb-, Zn-and Ag-rich massive sulfides crop out in pelitic and tuffaceous metasedimentary rock layers.

In contrast to the DD deposits, the nearby tuff-hosted DW-LP deposit is composed of a laterally extensive, but structurally segmented, sheet-like massive pyrite bed containing in excess of 18 million tonnes of fairly low grade material that is at least 606 m long, 3 to 15 m thick, and extends 1,500 m downdip. Typical grades range from 0.3 to 0.7% Cu, 1 to 3% Pb, 3 to 6% Zn, 34.3 to 109 g/t Ag, and 1 to 3.4 g/t Au. The deposits in the outlying Trio and PP-LZ trends are generally closely associated with calcareous and carbonaceous metasedimentary rocks that flank the central volcanic axis of the district, where the DD and DW trends occur. These deposits are relatively enriched in Pb, Zn, and Ag, and consist of both stratiform and replacement massive sulfide deposits discontinuously present in a zone as much as 40 km long.

The sulfide deposits of the Delta district occur in the here informally named Delta schist unit of the Yukon-Tanana terrane. This unit consists of a northwest-trending axis of Devonian metavolcanic rocks (Aleinikoff and Nokleberg, 1985) flanked to the north by metamorphosed shallow marine sedimentary rocks, and to the south by metamorphosed deeper marine sedimentary rocks (Nauman and others, 1980). The metavolcanic rocks, which host most of the major base and precious metal deposits, are derived from a volcanic suite varying in composition from spilite to keratophyre. Integral to this suite are numerous synvolcanic tholeiitic greenstone sills that are too thin to show on Figure 7. The greenstone sills are interpreted as being spatially related to the massive sulfide bodies and genetically related to the effusive volcanic suite. Hydrothermal fluid flow probably focused around the sills, producing overlapping stages of chloritization, silicification, sericitization, pyritization, and Pb-Ag-Au mineralization. The abundance and variety of sulfide deposits in the Delta district apparently resulted from evolving hydrothermal activity accompanying prolonged injection of syndepositional tholeiite sills into near-surface volcanic and sedimentary debris in a marginal rift environment.

LODE DEPOSITS - ALEUTIAN ISLANDS AND ALASKA PENINSULA

The Aleutian Islands and Alaska Peninsula contain a limited variety of lode deposits. The Aleutian Islands and southwest Alaska Peninsula contain an extensive suite of epithermal and polymetallic vein and porphyry Cu and Mo deposits. The northeast Alaska Peninsula contains suites of Cu-Zn-Au and Fe skarn, polymetallic vein, and porphyry Cu deposits, and one epithermal vein deposit.

Vein and Porphyry Deposits, Aleutian Islands and Southwestern Alaska Peninsula

Numerous epithermal and polymetallic vein and porphyry Cu and Cu-Mo deposits occur in the Aleutian Islands and southwestern Alaska Peninsula (Table 1, Plate 1). They consist of: (1) epithermal vein deposits at Canoe Bay, Aquilla, Apollo-Sitka, Shumagin, San Diego Bay, Kuy, and Fog Lake; (2) polymetallic vein deposits at Sedanka, Warner Bay, Cathedral Creek, and Kilokak Creek; and (3) porphyry Cu and Mo deposits at Pyramid, Kawisgag, Mallard Duck Bay, Bee Creek, Rex, and Mike. The epithermal vein deposits generally consist of quartz-vein systems and silicified zones containing gold and lesser sulfides in Tertiary andesite and dacite and in lesser rhyodacite and rhyolite flows and breccias. The polymetallic vein deposits generally consist of base-metal sulfides in quartz veins and in disseminations in Tertiary diorite, granodiorite, and andesite and dacite stocks, and in andesite and dacite flows, and in volcanic sandstone intruded by stocks and dikes. The porphyry Cu and Mo deposits commonly consist of disseminated chalcopyrite and (or) molybdenite and pyrite in altered areas in or near Tertiary or Quaternary andesite, dacite, and rhyodacite stocks, often along joints or in stockworks.

The epithermal and polymetallic vein and porphyry deposits are along a linear belt more than 800 km long (Plate 1). This belt is intepreted as being related to hydrothermal and epithermal activity associated with the late-magmatic stages of Tertiary and Quaternary hypabyssal plutonic and associated volcanic centers. These centers are along part of the Aleutian arc, one of the classic igneous arcs along the rim of the Pacific Ocean. The arc is composed mainly of early Tertiary to Holocene andesite to dacite flows, tuff, and intrusive and extrusive breccia; hypabyssal diorite and quartz diorite and small silicic stocks, dikes, and sills; and volcanic graywackes, shale, and lahars (Burk, 1965; Beikman, 1980; Wilson, 1985). Extensive late Tertiary and Quaternary volcanoes and associated volcanic and volcaniclastic rocks form major parts of the arc and dominate the landscape.

Underlying the southwestern Alaska Peninsula, almost as far west as Cold Bay, is the older bedrock, designated as part of the Peninsular terrane (Plate 1) (the so called Alaska Peninsula terrane of Wilson and others, 1985). The older bedrock is locally extensively intruded by the Jurassic, Cretaceous, and early Tertiary Alaska-Aleutian Range batholith (Reed and Lanphere, 1973). The Eocene and earliest Miocene volcanic and hypabyssal rocks deposited on, and intruded into this older bedrock, constitute part of the so called Meshik arc of Wilson (1985). The major deposits in the southwestern Alaska Peninsula are the Apollo-Sitka, Shumagin, and Aquila Au-Ag epithermal vein deposits and the Pyramid porphyry Cu deposit.

Apollo-Sitka Au-Ag Deposit

The Apollo-Sitka deposit consists of quartz-carbonate veins and silicified zones with gold, galena, sphalerite, chalcopyrite, tetrahedrite, native copper, and trace tellurides(?) (Brown, 1947; Alaska Mines and Geology, 1983; Eakins and others, 1985). Much of the gold is disseminated in sulfides. The veins and zones occur in a series of at least eight strongly-developed, northeast-striking fracture systems. The veins extend for several thousand m along the surface and to at least 360 m below the surface; they range from a few cm to about 7 m wide. The higher-grade parts of the deposit occupy tensional flexures in the fracture systems. Abundant comb structure and euhedral crystal druses indicate that the veins formed at shallow depths. The fracture systems containing the veins are south of the Unga caldera system. The veins are hosted in propylitically altered, shale, tuff, and intermediate to felsic volcanic rocks of probable late Tertiary age. From 1894 to 1906, the deposit produced about 3.33 million g of Au from 435,000 tonnes of ore grading 242 g/t Ag and 7.9 g/t Au. Most of the native gold ore was mined during this period. The gold in the remaining part of deposit is associated with Zn and Pb. Extensive recent exploration has resulted in delineation of an estimated additional 163,000 tonnes with one area grading as much as 7.3 g/t Au, 240 g/t Ag, 15% Zn, and 1% Pb.

Pyramid Cu-Mo Deposit

By Gary Anderson and Thomas K. Bundtzen

The Pyramid deposit consists of disseminated molybdenite in Fe-stained dacite porphyry stock and dikes of late Tertiary age (Table 1, Plate 1) (Armstrong and others, 1976; Hollister, 1978; Wilson and Cox, 1983). A zonal alteration pattern is present, with a core of secondary biotite and about 3 to 10% magnetite grading outward to an envelope of quartz-sericite alteration. Fractures adjacent to the stock are filled with sericite. Local extensive oxidation and supergene enrichment occurs in a blanket as much as about 100 m thick with secondary chalcocite and covellite. The stock intrudes Upper Cretaceous and lower Miocene fine-grained clastic rocks, which are contact metamorphosed adjacent to the stock. The deposit is centered on a 3 km^2 area within the stock and contains an estimated of 113 million tonnes grading 0.4% Cu, 0.05% Mo, and a trace of Au.

The Pyramid deposit is the best known of a series of large-tonnage, low-grade porphyry Cu and Mo deposits in the Alaska Peninsula. The Pyramid Bee Creek, Rex, and Warner Bay porphyry Cu deposits (Plate 1) occupy a transitional zone between the parts of the magmatic arc underlain by oceanic crust to the southwest and continental crust to the northeast. Some of the deposits are Mo-rich and contain anomalous concentrations of Bi, Sn, and W that may be characteristic of continental margin deposits (Wilson and Cox, 1983).

Vein, Skarn, and Porphyry Deposits, Northeastern Alaska Peninsula

A few skarn and porphyry deposits occur in the northeastern Alaska Peninsula (Table 1, Plate 1) and consist of: (1) Cu-Au and Cu-Zn skarn deposits at Crevice Creek and Glacier Fork; (2) Fe skarn deposits at Kasna Creek and Magnetite Island; (3) an epithermal(?) vein deposit at the Johnson Prospect; and (4) polymetallic vein deposits at Kijik River and Bonanza Hills. The Cu-Au and Cu-Zn skarn deposits generally consist of epidote-garnet skarn in limestone or marble, with disseminations and layers of chalcopyrite, sphalerite, and pyrrhotite, in areas where Jurassic(?) granodiorite and granite intrude calcareous sedimentary rocks. The Fe skarn deposits generally consist of magnetite skarn in dolomite or marble with lesser garnet, amphibole, and local chalcopyrite. The Fe skarns occur in areas where Jurassic(?) quartz diorite and tonalite intrude the calcareous sedimentary rocks. The polymetallic vein deposits generally consist of disseminated sulfides in altered Tertiary dacite porphyry or of base metal sulfides in veins in metamorphosed dacite flows and sandstone near hypabyssal granite.

These deposits occur in bedrock consisting of marine sedimentary rocks of the Upper Triassic Kamishak Formation, Lower Triassic marble, and the volcanic and volcaniclastic rocks of the Early Jurassic Talkeetna Formation of the Peninsula terrane (Plate 1) (so-called Alaska Peninsula terrane of Wilson and others, 1985) that are intruded by Jurassic, Cretaceous, and early Tertiary dacite porphyry, small stocks, and large granitic plutons of the Alaska-Aleutian Range batholith. The major deposit is the Johnson Prospect.

Johnson Au-Zn Prospect
By Carl I. Steefel

The Johnson deposit consists of a quartz stockwork of quartz-sulfide veins with chalcopyrite, pyrite, sphalerite, galena, and gold. The veins also contain chlorite, sericite, anyhydrite, and barite alteration minerals. Along a few m of drill core, grades range from 20.6 to 41.2 g/t Au, 9.4 to 24.8% Zn and average 2% Pb. The stockwork veins occur in a discordant pipelike body of silicified volcanic rocks. The deposit is hosted in volcaniclastic, pyroclastic, and volcanic rocks, part of the Portage Creek Agglomerate Member of the Lower Jurassic Talkeetna Formation. Near the deposits, the Talkeetna Formation is intruded by Late Jurassic quartz diorite and granite of the Alaska-Aleutian Range batholith. This deposit is an epithermal vein(?) deposit, and is interpreted as having formed during replacement and alteration associated with the late magmatic stage of nearby Jurassic plutons.

LODE DEPOSITS - SOUTHERN ALASKA

Southern Alaska contains a large variety of lode deposits. The southwestern Alaska Range contains a suite of Cu-Pb-Zn skarn, polymetallic vein, Sn greisen and vein, and porphyry Cu-Au and Mo vein deposits, a Besshi massive sulfide deposit, and a gabbroic Ni-Cu(?) deposit. The central and eastern Alaska Range and the Wrangell Mountains contain a suite of Cu-Ag and Fe skarn, polymetallic vein, and porphyry Cu and Cu-Mo deposits, and a suite of Cu-Ag quartz vein, basaltic Cu, and Besshi massive sulfide deposits. The Talkeetna Mountains contain a suite of Au quartz vein deposits, and a suite of podiform chromite deposits is present on Kodiak Island, the Kenai Peninsula, and the northern Chugach Mountains. The southern Chugach Mountains, southeast Kenai Peininsula, and Kodiak Island contain an extensive suite of Au quartz vein deposits, and the Prince William Sound district contains an extensive suite of Besshi and Cyprus massive sulfide deposits.

Skarn, Vein, and Massive Sulfide Deposits, Southwestern Alaska Range

Major lode deposits in the southwestern and western Alaska Range consist of several Ag-Pb-Zn-Cu skarn deposits in the Farewell district at Bowser Creek, Rat Fork, Sheep Creek, and Tin Creek; a gabbroic Ni-Cu deposit at Chip Loy; and a Besshi massive sulfide deposit at Shellebarger Pass.

Farewell District
By Thomas K. Bundtzen

Major Cu-Ag-Pb-Zn skarn deposits occur at Bowser Creek, Rat Fork, Sheep Creek, and Tin Creek, and a Ni-Co deposit occurs at Chip Loy in the Farewell district in a 500 km^2 area of the southwestern Alaska Range (Table 1, Plate 1). The Bowser Creek Ag-Pb skarn deposit consists of pyrrhotite, sphalerite, galena, and chalcopyrite in a hedenbergite-johannsenite endoskarn in marble adjacent to an early Tertiary felsic dike (Szumigala, 1985). Local fissures in marble adjacent to skarn contain Ag-rich galena and pyrrhotite. The deposit is estimated to contain as much as 272,000 tonnes with 10% Pb and Zn and 100 g/t Ag. The Tin Creek skarn deposit consists of pyroxene-rich skarn with abundant sphalerite and minor chalcopyrite and garnet skarn with chalcopyrite and minor sphalerite. Local abundant gangue epidote and amphibole also occur in the skarns (Szumigala, 1985). The pyroxene skarn is distal to, and the garnet skarn is proximal, to an extensive Tertiary granodiorite dike swarm. The Chip-Loy Ni-Co deposit, classified as a gabbroic Ni-Cu deposit, consists of massive to disseminated pyrrhotite, bravoite, and chalcopyrite along a steeply dipping contact between diabase and shale (Herreid, 1966; W.S. Roberts, oral commun., 1985).

Lode deposits in the Farewell district are generally centered at or near plutons 1 to 5 km^2 in size and related igneous breccias of early and (or) middle Tertiary plutons of the Alaska-Aleutian Range batholith. The base-metal skarn deposits are typical of low-temperature fracture-controlled zinc-lead skarns. The deposits occur either as skarns in lower and middle Paleozoic deep-water carbonate rocks or shale or as stockwork veinlet zones in fine-grained plutons. These stratified wall rocks are part of the Dillinger terrane (Plate 1).

Shellebarger Pass Massive Sulfide Deposit

The Shellebarger Pass deposit consists of a very fine-grained mixture of mainly pyrite and marcasite with lesser sphalerite, chalcopyrite, galena, and pyrrhotite in a gangue of siderite, calcite, quartz, and dolomite (Reed and Eberlein, 1972). The sulfides occur in at least six individual bodies in carbonate-rich beds and as fracture fillings, mainly in chert and siltstone. The sulfides are hosted in Triassic or Jurassic chert, dolomite, siltstone, shale, volcanic graywacke, conglomerate, aquagene tuff, pillow basalt, agglomerate, and breccia. The highest chalcopyrite concentrations are in basal parts of the deposits. Minor sphalerite is present in or near hanging wall zones. The main sulfide bodies may be proximal to basaltic flow fronts. Hydrothermal alteration is extensive occurs in the foot wall but rare to absent in the hanging wall. The deposit contains an estimated several hundred thousand tonnes of unknown grade. Selected samples contain as much as 5% Cu and average 2% Cu and 1% Zn. The host rocks are part of the Mystic terrane (Plate 1).

Polymetallic Vein, Sn Greisen and Vein, and Porphyry Deposits, Western Alaska Range

The major lode deposits in the western Alaska Range are (Table 1, Plate 1): Sn greisen(?) and vein deposits at Boulder Creek, Coal Creek (described below), and Ohio Creek; several polymetallic vein deposits at Partin Creek, Ready Cash, and Nim and Nimbus (described below); and porphyry Mo, Cu-Mo, and Cu-Au at Miss Molly, Treasure Creek, and Golden Zone.

The Sn greisen(?) and vein deposit at Boulder Creek (Purkeypile) consists of cassiterite and sulfides in fracture fillings in metasedimentary rocks near a Tertiary biotite granite (Conwell, 1977), and the Sn greisen and vein deposit at Ohio Creek consists of muscovite-tourmaline greisen and quartz arsenopyrite veins in a Tertiary granite stock (Table 1). The polymetallic vein deposits at Partin Creek and Ready Cash consist of Fe and base metal sulfides in veinlets and disseminations in Triassic basalt and marble. The porphyry Mo deposit at Miss Molly consists of quartz veins with molybdenite, pyrite, and local fluorite in a Tertiary(?) granite stock intruding Jurassic and Cretaceous flysch. (Fernette and Cleveland, 1984). The porphyry Cu-Mo deposits at Treasure Creek consist of disseminated molybdenite and other base-metal sulfides in a silicified and sheared Tertiary granite stock intruding Cretaceous flysch (Csejtey and Miller, 1978).

These magmatism-related deposits occur in the northeastern part of the Aleutian-Alaska Range batholith, mainly in the lower Tertiary McKinley sequence of granite and granodiorite plutons (Reed and Lanphere, 1973; Lanphere and Reed, 1985). In the western part of the area, the plutons intrude highly folded and thrusted Devonian mafic and ultramafic rocks, Devonian argillite and graywacke, Mississippian chert, Permian through Triassic volcanic and marine sedimentary rocks, and Jurassic argillite and sandstone, part of the Chulitna terrane (Plate 1). In the eastern part of the area, the plutons intrude highly deformed, deep marine, partly volcaniclastic, flyschoid graywacke and argillite and minor amounts of chert, limestone, and conglomerate, mainly Late Jurassic and Early Cretaceous age, part of the Kahiltna terrane (Plate 1).

Coal Creek Sn Deposit
By Gregory Thurow and J. Dean Warner

The Coal Creek Sn greisen(?) and Sn vein system consists of (1) sporadic grains and local concentrations of cassiterite in a sheeted vein system and minor disseminations of cassiterite in and above the apical dome of an early Tertiary granite intruding older, related granite; and (2) cassiterite in thin quartz-topaz-sulfide veinlets, 1 to 3 mm wide, that postdate alteration and stockwork veinlets. The veins vary from a hairline to 1 cm in width, are nearly vertical, and attain a density of 10 veins per m in the most intensely fractured zones. Vein sulfides include arsenopyrite, pyrite, pyrrhotite, and sphalerite. Granite adjacent to the veins is pervasively altered to quartz, tourmaline, topaz, sericite, and minor fluorite. The granite intrudes contact metamorphosed Devonian argillite, graywacke, and minor limestone. The deposit contains an estimated 5 million tonnes grading 0.28% Sn and 0.5% Cu.

Golden Zone Au Deposit
By Charles C. Hawley

The Golden Zone deposit consists of veins and mineralized shear zones, porphyry Au deposits, a breccia pipe, and skarn deposits, classified as parts of a complex polymetalliv vein and associated Au-Ag breccia pipe. The breccia pipe contains arsenopyrite and siliceous breccia occur. The pipe is in the center of a quartz diorite porphyry stock; both pipe and stock plunge steeply east-northeast and are barely unroofed. The pipe enlarges from about 75-m diameter at the surface to about 100 m diameter at the 180-m level and probably continues to enlarge at depth and then splits into feeder zones. Veins in the breccia pipe range from a few cm of massive sulfide to sulfide-bearing shear zones more than 15 m across containing numerous sulfide zones. The breccia pipe may have formed during hydrothermal stoping and collapse of the quartz diorite, guided by northeast- and northwest-trending conjugate faults. The porphyry contains a network of hairline fractures and distinct fissures filled with arsenopyrite, pyrite, chalcopyrite, and quartz. The contact between the pipe and porphyry is sharp. The porphyry is dated at 68.0 Ma (Swainbank and others, 1977). The deposit has produced 49,000 g of Au, 268,000 g of Ag, and 19 tonnes of Cu. The deposit contains an estimated 5 million tonnes grading 4 g/t Au, along with minor Cu and Ag.

Nim and Nimbus Cu-Ag-Au Deposits
By Richard C. Swainbank

The Nim deposit consists of: (1) Veinlets and disseminations of pyrite, chalcopyrite, molybdenite, and arsenopyrite in contact metamorphic rocks and in intrusive breccia; (2) veins and disseminations of arsenopyrite, molybdenite, chalcopyrite, and chalcocite in an early Tertiary granite porphyry and in peripheral rhyolite dikes; and (3) disseminated arsenopyrite, molybdenite, chalcopyrite, and pyrite in rhyolite porphyry and quartz porphyry dikes. Grab samples contain as much as 2% Cu, 137 g/t Ag, and 13 g/t Au. The deposit is in a zone about 0.5 km wide and 2 km long in Jurassic(?) clastic sedimentary rocks. The Nimbus deposit consists of a lens of massive arsenopyrite, pyrite, and sphalerite 1 to 2 m thick and 10 m long in a brecciated felsic dike in a strand of the Upper Chulitna fault.

Basaltic Cu, Massive Sulfide, Vein, Skarn, and Porphyry Deposits, Central and Eastern Alaska Range and Wrangell Mountains

The central and eastern Alaska Range and Wrangell Mountains contain a complex variety of large and small lode deposits. The largest and best known are the Cu deposits of the Kennecott district, which produced about 544 million kg Cu and 280 million g Ag from about 1913 to 1938, and the Nabesna mine, which produced about 1.66 million g Au from about 1931 to 1940. Major porphyry Cu-Mo deposits are at Orange Hill and Bond Creek, Horsfeld, and Carl Creek. Other major lode deposits are (Table 1, Plate 1): (1) Basaltic Cu deposits at Westover, Nelson, and Erickson; (2) Cu-Au-Ag skarn deposits at Zackly, Rainy Creek, and Midas; (3) Fe skarn deposits at Nabesna and Rambler; (4) Cu-Ag quartz vein deposits at Kathleen-Margaret, Nugget Creek, and Nikolai; (5) porphyry Cu deposits at Rainbow Mountain, Slate Creek, Chistochina, Baultoff, and Carl Creek; (6) a porphyry Cu-Mo deposit at London and Cape; (7) a polymetallic vein deposit at Nabesna Glacier; (8) a Besshi massive sulfide deposit at Denali; and (9) a dunitic Ni-Cu deposit at Fish Lake.

These deposits occur in a complex stratigraphic assemblage of late Paleozoic island-arc volcanic and sedimentary rocks, metabasalt of the Triassic Nikolai Greenstone, Upper Triassic and Lower Jurassic limestone and calcareous argillite, and Upper Jurassic and Lower Cretaceous volcanic rocks and flysch of the Gravina-Nutzotin sequence, part of the Wrangellia terrane (Nokleberg and others, 1985) (Plate 1). The older part of this assemblage is intruded by late Paleozoic hypabyssal plutons, and the entire assemblage is intruded by Jurassic and Cretaceous granitic plutons (Richter, 1975; MacKevett, 1978; Nokleberg and others, 1985). The metallogenesis and tectonic history of this part of the Wrangellia terrane is summarized Nokleberg and others (1984) and Nokleberg and Lange (1985).

Zackly Cu-Au Deposit
By Rainer J. Newberry and Clint R. Nauman

The Zackly Cu-Au skarn deposit (Table 1, Plate 1) consists of disseminated chalcopyrite, bornite, pyrite, and gold in a zone of andradite garnet-pyroxene skarn and sulfide bodies in Late Triassic marble adjacent to albitized Cretaceous quartz monzondiorite. The zone is about 650 m long and 30 m wide. Gold occurs only in skarn, with higher Au grades mainly in a supergene(?) assemblage of malachite, limonite, chalcedony, and native Cu. Gold occurs only in skarn. A general zoning occurs from the pluton to skarn and consists of: (1) brown garnet with chalcopyrite; (2) green garnet with bornite and chalcopyrite; and (3) clinopyroxene and wollastonite; and (4) marble with magnetite and bornite. The deposit contains an estimated 1.25 million tonnes grading 1.6% Cu and 6 g/t Au.

Denali Cu-Ag, Kathleen-Margaret Cu, Rainy Creek Cu-Ag, and Rainbow Mountain Cu Deposits

The Denali Cu-Ag deposit (Table 1, Plate 1) consists of stratiform bodies of very fine grained and thin-layered chalcopyrite and minor pyrite in thin-bedded, shaley, cabonaceous, and calcareous argillite enclosed in the Upper Triassic Nikolai Greenstone in a zone as much as 166 m long and 9 m wide (Stevens, 1971, Seraphim, 1975). The sulfides are typically rhythmically layered. The argillite and greenstone are locally moderately folded and are metamorphosed at the lower greenschist facies. The deposit is classified as a Besshi(?) massive sulfide deposit, although it differs from Besshi deposits in having a very low Fe sulfide content. The deposit was most likely that formed in a reducing or euxinic marine basin created by abundant organic matter and sulfate reducing bacteria in a submarine volcanic environment.

The Kathleen-Margaret Cu-Ag vein deposit (Table 1, Plate 1) consists of a series of quartz veins, as much as 140 m long and 3 m wide, with disseminated to locally massive chalcopyrite, bornite, and malachite (MacKevett, 1965) in the Upper Triassic Nikolai Greenstone. The deposit is interpreted to have formed during the waning stages of Cretaceous(?) greenschist-facies metamorphism and weak deformation of the Nikolai Greenstone (Nokleberg and others, 1984).

The Rainy Creek Cu-Ag skarn deposit (Table 1, Plate 1) consists of disseminated to small masses of chalcopyrite, bornite, minor sphalerite, galena, magnetite, secondary Cu-minerals, and sparse gold in a zone of garnet-pyroxene skarn. The skarns are in a belt about 10 km long and as much as 5 km wide and are hosted in faulted lenses of marble adjacent to late Paleozoic(?) metagabbro, metadiabase, and metaandesite to metadacite that form small hypabyssal intrusions, dikes, and sills (Nokleberg and others, 1984).

The Rainbow Mountain porphyry Cu deposit (Table 1) consists of a discontinuous zone of subvolcanic porphyry intrusions that contain disseminated grains and small masses of chalcopyrite and pyrite and minor sphalerite and galena. The subvolcanic porphyry intrusions are in a zone about 6 km long along strike and as much as 1 km wide; they occur as small hypabyssal plutons, dikes, and sills, are hydrothermally altered, and intrude late Paleozoic metaandesite to metadacite submarine volcanic and sedimentary rocks (Nokleberg and others, 1985). The Rainy Creek Cu-Ag skarn and the Rainbow Mountain porphyry Cu deposits are probably magmatism-related deposits formed during late Paleozoic island arc volcanism (Nokleberg and others, 1984).

Nabesna and Rambler Au Deposits

By Rainer J. Newberry and Thomas K. Bundtzen

The Nabesna and Rambler Fe-Au skarn deposits consist of gold skarns formed in massive oxide and massive sulfide bodies that at Nabesna consist chiefly of pyrite and magnetite with minor chalcopyrite, galena, sphalerite, arsenopyrite, and gold. At the Rambler deposit, the sulfide bodies consist of massive auriferous pyrrhotite and pyrite that crosscut previously formed skarn. The gold skarns are characteristically zoned with separate skarn, magnetite, and sulfide-silica bodies. The skarn and magnetite are usually poor in sulfide and gold. The gold-rich sulfide-silica bodies overlie the highest level magnetite bodies in pipelike or mantolike replacements of marble between skarn and monzodiorite. In some cases, high-magnetite and high-sulfide bodies occur independently in marble near skarn. The Nabesna skarns are vertically zoned, with idocrase and pyroxene at depth and garnet, epidote, and magnetite towards the top. Crosscutting relations indicate that magnetite bodies are younger than skarn and high silica-bodies. Both deposits occur near the contact between monzodiorite and limestone. At Nabesna, the monzodiorite stock is exposed over a 2 km^2 area and contains sporadic albite-quartz-pyrite alteration. The monzodiorite has K-Ar hornblende and biotite ages of 109 and 114 Ma respectively. The Nabesna deposit produced about 1.66 million g Au with minor Cu and Ag (Wayland, 1943; Richter and others, 1975). The Rambler deposit contains an estimated 18,000 tonnes grading 34.3 g/t Au.

Orange Hill and Bond Creek Cu-Mo Deposits

The Orange Hill and Bond Creek deposits consist of pyrite, chalcopyrite, and minor molybdenite in potassic and sericitic quartz veins and disseminations (Richter and others, 1975). The deposits are hosted in the Cretaceous Nabesna pluton, a complex intrusion of quartz diorite and granodiorite intruded in turn by slightly younger granite porphyry. Most of the deposits consist of quartz-biotite-chalcopyrite-pyrite-anhydrite veinlets and quartz-sericite-pyrite veins that are localized in altered granite porphyry dikes (Rainer J. Newberry, written commun., 1985). Widespread, late-stage chlorite-sericite-epidote alteration is present within the Nabesna pluton. The main occurrences of altered rock occupy an area 1 by 3 km at Orange Hill and an area 2 by 3 km at the Bond Creek deposit. Associated skarn deposits consist of andradite garnet, pyroxene, pyrite, chalcopyrite, bornite, magnetite, massive pyrrhotite, pyrite, chalcopyrite, and sphalerite. The Nabesna pluton intrudes rocks as young as the Jurassic and Cretaceous flysch of the Gravina-Nutzotin belt. The Orange Hill deposit contains an estimated 320 million tonnes grading 0.35% Cu. The Bond Creek deposit contains an estimated 500 million tonnes grading 0.3% Cu.

Kennecott District

The Kennecott district includes the Bonanza, Jumbo, Erie, Mother Lode, and Green Butte mines (Table 1, Plate 1). The deposits are localized in the lower, largely dolomitic parts of the Upper Triassic Chitistone Limestone, generally less than 100 m above the disconformably underlying Middle and (or) Upper Triassic Nikolai Greenstone (Fig. 8) (Bateman and McLaughlin, 1920; MacKevett, 1976; Armstrong and MacKevett, 1982). The major masses of ore are mainly irregular massive bodies of Cu-sulfides. The largest known ore body at Jumbo was about 110 m high, as much as 18.5 m wide and extended 460 m along plunge. The principal Cu-sulfide minerals are chalcocite and covellite, with lesser enargite, bornite, chalcopyrite, luzonite, and pyrite. Tennantite, galena, and sphalerite are extremely rare. Secondary malachite and azurite also are present locally. About 544 million kg Cu, and 279 million g Ag were produced from 4.4 million tonnes of ore from about 1913 to 1938. More than 96 km of underground workings were developed. The basaltic Cu deposits in the Kennecott district are interpreted by Armstrong and MacKevett (1982) as having formed through derivation of Cu from the underlying Nikolai Greenstone, and deposition by oxygenated groundwater along dolomitic sabhka interfaces and as open-space fillings in fossil karsts in the lower part of the overlying Chitistone Limestone. The age of deposition is interpreted to be Late Triassic with possible later remobilization.

Willow Creek District, Talkeetna Mountains

Au quartz vein deposits in the Willow Creek district (Table 1, Plate 1) consist of a series of quartz veins with pyrite, chalcopyrite, magnetite, and gold, and minor arsenopyrite, sphalerite, tetrahedrite, and galena (Ray, 1954). Average grade ranges from about 17.2 to 68.6 g/t Au. About 18.4 million g gold were produced from 1909 to 1950. The veins average about 0.3 to 1 mm thick, are locally as much as 2 m thick, and occupy east-northeast- and north-south-striking shear zones as much as 7 m wide. Wallrock alteration along the veins consists of sericite, pyrite, carbonate, and chlorite. Clay-rich fault gouge is locally abundant along the margins of the veins and shear zones. The veins are in and along the margin of the early Tertiary granitic rocks of the Talkeetna Mountains batholith and locally also in adjacent mica schist. The main part of the district, which includes several mines and many prospects, occupies an area about 12.8 km long and 6.2 km wide along the southern margin of the batholith. Underground workings are estimated to total several thousand m. Nearly continuous mining and development has occurred from about 1909 to the present.

Chromite and Ni-Cu Deposits, Kodiak Island, Kenai Peninsula, and Northern Chugach Mountains

A belt of podiform chromite deposits occurs in southern Alaska on northern Kodiak Island, on the Kenai Peninsula, and along the northern flank of the Chugach Mountains at Halibut Bay, Claim Point, Red Mountain (described below), and Bernard and Dust Mountains (Table 1, Plate 1). A gabbroic Ni-Cu deposit occurs at Spirit Mountain. The podiform chromite deposits are present along a strike distance of over 425 km (Plate 1) in the Jurassic or older, informally named Border Ranges ultramafic and mafic complex of Burns (1984), a belt of ultramafic tectonites and cumulate gabbros and norites that extend for 1,000 km in southern Alaska around the great oroclinal warp of southern Alaska, adjacent to and north of the Border Ranges fault system (MacKevett and Plafker, 1974; Burns, 1985). The ultramafic and mafic rocks are interpreted as the roots to a Jurassic island arc (Burns, 1985; Plafker and others, 1985), and they form the southern margin of the Peninsular terrane (Plate 1). At the eastern end of the belt of podiform chromite deposits is a minor gabbroic Ni-Cu deposit at Spirit Mountain (Table 1, Plate 1). This deposit consists of Fe sulfides, pentlandite, chalcopyrite, and minor bravoite and sphalerite in small lenses and disseminations in serpentinized ultramafic rocks in gabbro sills that intrude late Palezoic limestone, tuff, and chert. The ultramafic and mafic rocks at this deposit may be part of the distal, eastern end of the Border Ranges ultramafic and mafic complex.

Red Mountain Chromite Deposit

The Red Mountain deposit consists of layers and lenses of chromite as much as a few hundred m long and 60 m wide in areas as long as several hundred m. (Guild, 1942). The major chromite layer is about 190 m long and up to 0.3 m wide. The chromite layers are in Middle Jurassic or older layered dunite tectonite with minor lesser wehrlite and clinopyroxenite; the ultramafic rocks are locally extensively serpentinized. The deposit contains an estimated 87,000 tonnes averaging 25 to 43% Cr_2O_3, including nearly 2.0 million tonnes in the informally named Turner stringer zone (Foley and others, 1985). Approximately 36,700 tonnes of high-grade chromite ore was produced from six layers in the deposit. The ultramafic and associated rocks at Red Mountain may be cumulate igneous rocks that formed in the basal parts of an island arc, with subsequent penetrative deformation and high-grade metamorphism (Burns, 1984). Sporadic exploration and development has occurred from about 1919 to the present. To the south, the ultramafic rocks are faulted against the metagraywacke and argillite of the Valdez Group of the Chugach terrane.

Au Vein Deposits, Kodiak Island, Southeast Kenai Peninsula, and Southern Chugach Mountains

An areally extensive suite of Au quartz vein deposits of small tonnage but locally high grade is present on Kodiak Island, on the southeast Kenai Peninsula, and in the southern Chugach Mountains (Table 1, Plate 1). The major deposits include the Alaska Oracle, Chalet Mountain, Cliff, Crown Point, Gilpatrick, Gold Kings, Granite, Jewel, Kenai-Alaska, Lucky Strike, Mineral King, Monarch, and those in the Nuka Bay district at Nualaska, Lost Creek, Alaska Hills, and Ramsay-Rutherford.

On the mainland, the Au quartz vein and massive sulfide deposits occur in the Upper Cretaceous Valdez Group, which consists of complexly folded and weakly metamorphosed metagraywacke and argillite, locally interleaved with pillow basalt, basaltic tuff, and mafic plutons (Winkler and others, 1981a, b). Undeformed, narrow, early Tertiary granodiorite and diorite dikes and plutons locally intrude the highly deformed Valdez Group. The lithologically similar, but less metamorphosed Kodiak Formation hosts Au quartz vein deposits on Kodiak Island. The Valdez Group and Kodiak Formation are parts of a flysch sequence deposited on oceanic crust (Plafker and others, 1985), and form the southern part of the Chugach terrane (Plate 1).

The Au quartz vein deposits are generally small, but high grade; most mines contain a maximum of a few hundred m of underground workings. The largest deposit, at Cliff, produced about 1.6 million g Au. The gold typically occurs in quartz and minor carbonate fissure veins with minor pyrite, pyrrhotite, arsenopyrite, chalcopyrite, galena, stibnite, and sphalerite. Sulfides compose at the most a few percent of the veins. The veins range up to several hundred m long and a few m wide, with average grades from 34.3 to 64.8 g/t Au. The veins generally occur in metagraywacke and argillite and less often in early Tertiary diorite and granodiorite dikes.

The Au quartz vein deposits generally occur in the younger of two generations of quartz fissure veins in the Valdez Group (Richter, 1970; Goldfarb and others, 1986). The older and mostly barren veins are generally subparallel to the dominant schistosity and parallel axial planes of minor and major folds. Their strike varies from northwest in the east to northeast in the west. The younger veins, locally gold bearing, occur in a series of tensional cross joints or fractures that are normal to the older quartz veins and the parallel structures. The strike of the younger set of quartz veins also varies from northwest in the eastern part of the region to northeast in the western part of the region. Both sets of quartz veins generally dip steeply to vertically. The Au quartz vein deposits of the Chugach terrane probably formed during a widespread hydrothermal event that occurred in the waning stage of an early Tertiary period of low-grade greenschist facies regional metamorphism, intense deformation, and granitic plutonism (Goldfarb and others, 1986).

Massive Sulfide Deposits, Prince William Sound District, Chugach Mountains

Besshi and Cyprus massive sulfide deposits are present in the Prince William Sound district along the eastern and northern margins of the Gulf of Alaska at Beatson, Copper Bullion, Ellamar, Fidalgo-Alaska, Knight Island, Latouche, Midas, Pandora, Standard Copper, and Threeman (Table 1, Plate 1). The Midas deposit occurs to the north, in the southern part of the Valdez Group; the other deposits are in the Orca Group. Most of the deposits are classified as sediment-hosted Besshi massive sulfide deposits; the basalt-hosted deposits at Knight Island, Rua Cove, Standard Copper, and Threeman are classified as Cyprus massive sulfide deposits (Table 1). The Orca Group that hosts most of the deposits consists of a strongly deformed, thick assemblage of Paleocene and Eocene(?) graywacke, argillite, minor conglomerate, pillow basalt, basaltic tuff, sills, and dikes (Winkler and Plafker, 1981), part of the Prince William terrane (Plate 1). A few gabbro plutons and locally abundant younger, early Tertiary diorite, granodiorite, and granite dikes and plutons intrude the Orca Group. The plutonic rocks are in part intensely deformed.

Midas Cu-Ag-Au Deposit
By Steven H. Nelson

The Midas deposit consists of disseminated to massive, stratiform chalcopyrite, pyrite, pyrrhotite, sphalerite, and minor galena in a folded, lens-shaped body as much as 7 m thick and 300 m long (Moffit and Fellows, 1950; Rose, 1965; Jansons and others, 1984). Margins of the ore body exhibit post-depositional shearing. Pillars in the main stope show sulfide layers and folds that are parallel to beds and folds in the host sedimentary rocks. The ore body occurs in highly deformed phyllite and metagraywacke of the Upper Cretaceous Valdez Group. Volcanic rocks have not been recognized in the mine, but they crop out within a few hundred m of the ore body in the footwall. Unmineralized to weakly mineralized quartz stockwork in the footwall could be the feeder system for the main ore body. Pyrite is generally crystalline and usually subhedral, and is enclosed in a matrix of younger chalcopyrite, sphalerite, pyrrhotite, and quartz. Siliceous (chert?) beds are restricted to layers within the ore body. The deposit, classified as a Besshi massive sulfide deposit, produced 1.54 million kg Cu, 471,000 g Ag, and 78,900 g Au from 44,800 tonnes of ore, making it the fourth largest producer of Cu in the Prince William Sound district. The deposit contains an estimated 56,200 tonnes of ore grading 1.6% Cu.

Latouche and Beatson Cu-Ag Deposits

The Latouche and Beatson deposits consist of two large and several small deposits in a zone of massive sulfide lenses and disseminations (Johnson, 1915; Jansons and others, 1984). The sulfides are mainly pyrite and pyrrhotite with minor chalcopyrite, cubanite, sphalerite, galena, silver, and gold. The common gangue minerals are quartz, sericite, and ankerite. The two deposits collectively produced more than 84.4 million kg Cu from about 4.5 million tonnes of ore grading about 1.7% Cu and 9.3 g/t Ag. The deposits are in a zone as much as 120 m thick and 300 m long along strike. The deposits occur in a fault zone adjacent to metagraywacke and argillite and are classified as Besshi massive sulfide deposits.

LODE DEPOSITS - SOUTHEASTERN ALASKA

Southeastern Alaska contains varied and complex geology. Sedimentary and volcanic rocks range in age from Ordovician to Holocene and were intruded and deformed through a wide span of time. Most, but not all, of the intrusion, metamorphism, and deformation occurred in the Mesozoic and Cenozoic. In this paper, southeastern Alaska is divided into three north-northwest-trending regions, the Coast Mountains region, central southeastern Alaska, and coastal southeastern Alaska (Plate 1). The Coast Mountains region consists of the informally named Coast plutonic-metamorphic complex of Brew and Ford (1984a, b), which is approximately equivalent, from east to west, to part of the Stikinia, terraneto all of the Tracy Arm and Taku terranes, and to part of the Gravina-Nutzotin belt (Monger and Berg, 1987). Central southeastern Alaska consists of the Alexander belt (Brew and others, 1984), which is approximately equivalent to the Alexander terrane (Monger and Berg, 1987). Coastal southeastern Alaska consists of the Kelp Bay Group and similar unnamed rocks, part of the Wrangellia terrane (Monger and Berg, 1987), and the Sitka Graywacke and similar unnamed rocks, part of the Chugach terrane (Monger and Berg, 1987).

Corresponding to the complex geology of the region are a complex variety of lode deposits. The Coast Mountains region contains extensive suites of Au quartz vein, metamorphosed sulfide, and zoned mafic-ultramafic deposits, a suite of Fe skarn and porphyry Mo deposits, and a Besshi massive sulfide deposit. Central southeastern Alaska contains extensive suites of Kuroko massive sulfide and bedded barite deposits, metamorphosed sulfide deposits, Cu-Zn-Au-Ag and Fe skarn and porphyry Cu deposits, Au quartz vein deposits, zoned mafic-ultramafic deposits, a gabbroic Ni-Cu deposit, and a felsic plutonic U and a sandstone U deposit. Coastal southeastern Alaska contains suites of Au quartz vein and gabbroic Ni-Cu deposits and a basaltic Cu deposit.

Coast Mountains Region

The major lode deposits in the Coast Mountains region are: (1) Au quartz vein deposits; (2) metamorphosed sulfide deposits; (3) a Besshi massive sulfide deposit; (4) am Fe skarn deposit; (5) a zoned mafic-ultramafic deposit; and (6) a porphyry Mo deposit.

Au Vein Deposits, Coast Mountains Region

Au quartz vein deposits are present in the Coast Mountains Region at Jualin, Kensington, Alaska-Juneau, Treadwell, Sumdum Chief, Riverside, Gold Standard, Sea Level, and Goldstream (Table 1, Plate 1). These deposits are widespread and occur along a strike length of 300 km (Plate 1). Most deposits are in the Juneau gold belt to the north, but a few are in an unnamed cluster to the south (Plate 1). In the Juneau gold belt, the deposits mostly occur in the western metamorphic zone, west of the foliated tonalite of the informally named Coast plutonic-metamorphic complex of Brew and Ford (1984a, b), mainly in metasedimentary and metavolcanic rocks of the Taku terrane (Jualin, Kensington, Alaska-Juneau, Sumdum Chief, and Sea Level deposits). A lesser number are in flysch of the Gravina-Nutzotin belt (Treadwell, Gold Standard, and Goldstream deposits) (Berg and others, 1972; Monger and Berg, 1987) (Plate 1). The deposit at Riverside is in the eastern metamorphic zone of the Coast plutonic-metamorphic complex, part of the Stikinia terrane (Plate 1).

Substantial gold has been produced from these deposits: 108 million g from the Alaska-Juneau, 90.1 million g from the Treadwell, and 746,000 g each of Au and Ag from the Sumdum Chief. The Au quartz vein deposits in the western part of the Coast Mountains region, west of the foliated tonalite sill, probably formed during low-grade regional metamorphism and subsequent intrusion of intermediate and felsic postdeformational Tertiary plutons. Fluid inclusion studies at the Alaska-Juneau deposit indicate that the gold was deposited from deep-seated hydrothermal fluids in fault zones at temperatures greater than 230 ^{o}C and pressures exceeding 1.5 kilobars, and that its deposition was accompanied by intense alteration and hydrofracturing of the host rocks (Goldfarb and others, 1986).

Alaska-Juneau Au Deposit

The Alaska-Juneau deposit (Table 1, Plate 1) consists of quartz-calcite veins, a few cm to 1 m thick, with sparse gold, pyrite, pyrrhotite, arsenopyrite, galena, sphalerite, chalcopyrite, and silver (Spencer, 1906; Twenhofel, 1952; Wayland, 1960; Herreid, 1962). The sulfide minerals also are present in adjacent, altered metamorphic rocks. The vein system is about 5.6 km long and as much as 600 m wide and consists of a series of semiparallel quartz-carbonate stringers in phyllite and schist near the contact between the Upper Triassic Perseverance Slate, and amphibolite derived from late(?) Mesozoic gabbro dikes and sills, the Gastineau Volcanic Group of Permian and (or) Late Triassic age. The deposit produced about 108 million g Au, 59.1 million g Ag, and 21.8 million kg Pb from about 80.3 million tonnes of ore. The mine contains a few hundred m of underground workings.

Treadwell Au Deposit

The Treadwell deposit consists of an extensive system of quartz and quartz-calcite replacements and veins with gold, pyrite, magnetite, molybdenite, chalcopyrite, galena, sphalerite, and tetrahedrite (Spencer, 1905; Buddington and Chapin, 1929; Twenhofel, 1952). The replacements and veins are in a shattered and altered granitic sill in slate and greenstone. Minor amounts of disseminated gold and sulfides occur in slate inclusions in the sill and in adjacent wallrock. The sill system is at least 1,100 m long and extends from a few hundred m above sea level to almost 1,000 m below the surface of the Gastineau Channel. About 101 million g Au was produced from 25 million tonnes of ore.

Sumdum Chief Au Deposit

The Sumdum Chief deposit consists of two quartz-calcite fissure veins with gold, auriferous pyrite, galena, sphalerite, chalcopyrite, and arsenopyrite (Spencer, 1906; Brew and Grybeck, 1984; Kimball and others, 1984). Gold is distributed unevenly and occurs mainly in pockets where small veins intersect large veins. The veins are as much as 6 m thick, and are in Paleozoic or Mesozoic graphitic slate and marble. About 746,000 g each of Au and Ag was produced.

Metamorphosed Sulfide Deposits, Coast Mountains Region

Metamorphosed sulfide deposits are present in the Coast Mountains region at Sweetheart Ridge, Sumdum (described below), Groundhog Basin, Alamo, Mahoney, Moth Bay, Reliance, and Red River (Table 1, Plate 1). The metamorphosed sulfide deposits are widespread and occur along a strike length of about 300 km (Plate 1). The deposits consist of stratabound, massive to disseminated sulfides hosted in moderately to highly metamorphosed and deformed volcanic and sedimentary rocks. Original or primary features of the deposits have been so obscured by metamorphism and deformation as to preclude classification into a more specific deposit type. Some of the deposits may be metamorphosed Kuroko massive sulfide deposits, as indicated by high Pb and Ag values and the presence of metamorphosed felsic volcanic rocks. All but one of the deposits are in the western metamorphic zone of the informally named Coast plutonic-metamorphic complex of Brew and Ford (1984a, b), west of the foliated tonalite sill, in the Taku terrane (Plate 1). The Red River deposit is in the central part of the informally named Coast plutonic-metamorphic complex in the Tracy Arm terrane (Plate 1).

Substantial amounts of Cu, Pb, Zn, and Ag are present in these deposits. The Groundhog Basin deposit, which contains an estimated several hundred thousand tonnes grading 8% Zn, 1.5% Pb, and 51.5 g/t Ag (Table 1), consists of disseminated to massive pyrrhotite, sphalerite, subordinate magnetite, galena, pyrite, and traces of chalcopyrite in several tabular or lenticular zones as much as 1 m thick in late Paleozoic or Mesozoic calc-silicate gneiss, quartz-feldspar gneiss, and hornblende gneiss. The Moth Bay deposit contains an estimated 90,700 tonnes grading 7.5% Zn and 1% Cu and an additional estimated 181,400 tonnes grading 4.5% Zn and 0.75% Cu. This deposit consists of discontinuous lenses and layers of massive pyrite, pyrrhotite, minor chalcopyrite, and minor galena in late Paleozoic or Mesozoic muscovite-quartz-calcite schist, minor pelitic schist, and quartz-feldspar schist.

Sumdum Cu-Zn-Ag Deposit

The Sumdum deposit consists of massive lenses and disseminations of pyrrhotite, pyrite, chalcopyrite, sphalerite, and lesser bornite, malachite, azurite, and galena in zones as much as 15 m wide (MacKevett and Blake, 1963; Brew and Grybeck, 1984; Kimball and others, 1984). The zones occur in metasedimentary schist and gneiss, mainly parallel to layering along the crest and flanks of isoclinal folds, but also in crosscutting veins and fault breccia. On the assumption that the deposit continues under the Sumdum Glacier, it is estimated to contain 24.2 million tonnes grading 0.57% Cu, 0.37% Zn, and 10.3 to 103 g/t Ag (Table 1).

Massive Sulfide, Skarn, Zoned Mafic-Ultramafic, and Porphyry Deposits, Coast Mountains Region

Four other lode deposit types occur in the Coast Mountains region: (1) A Besshi massive sulfide deposit is present at Yakima occurs quartz-calcite-sericite schist of the Gravina-Nutzotin belt and consists of disseminated pyrite and minor galena and sphalerite in a zone 1,600 m long and 90 m wide. (2) An Fe skarn deposit at North Bradfield Canal occurs in marble and paragneiss intruded by Tertiary granite of the informally named Coast plutonic-metamorphic complex of Brew and Ford (1984a, b). This deposit consists of 11 magnetite-chalcopyrite skarn bodies that form crudely stratabound lenses in marble and paragneiss. The skarn bodies are reported to be as much as 106 m long and 12 m thick. (3) A zoned mafic-ultramafic deposit is present at Union Bay (described below) in a zoned Cretaceous ultramafic pluton intruding the Gravina-Nutzotin belt. (4) A porphyry Mo deposit at Quartz Hill (described below) occurs in an Oligocene or Miocene granite porphyry intruding the central granitic belt of the Coast plutonic-metamorphic complex. The Quartz Hill deposit is regarded as a world-class Mo porphyry deposit (Eakins and others, 1985).

Union Bay Fe-Ti Deposit

The Union Bay zoned mafic-ultramafic deposit is in dunite and consists of disseminated magnetite and chromite in small, discontinuous stringers of as much as a few cm long (Ruckmick and Noble, 1959). The dunite forms a pipe and lopolith in the center of the concentrically zoned Union Bay ultramafic pluton that intrudes the Late Jurassic and Early Cretaceous flysch of the Gravina-Nutzotin belt. A shell of peridotite encloses the dunite, and the peridotite is in turn enclosed by pyroxenite and hornblende pyroxenite that forms the periphery of the pluton. The deposit contains an estimated one billion tonnes grading 18 to 20% Fe. Selected samples average 0.093 g/t Pt and 0.20 g/t Pd. The ultramafic pluton at Union Bay is one of a series of mafic-ultramafic plutons, of probable 100 to 110 Ma, that intrude along the length of southeastern Alaska from Klukwan to Duke island (Brew and Ford, 1984a, b).

Quartz Hill Mo Deposit
By P.R. Smith and J.E. Stephens

The Quartz Hill porphyry Mo deposit, 70 km east of Ketchikan, Alaska, contains one of the world's largest concentrations of molybdenite. This large tonnage deposit occurs in the hypabyssal late Oligocene or early Miocene intrusive complex of the informally named Quartz Hill stock. The stock is roughly ovoid in shape, approximately 5 km long by 3 km wide, and displays discordant contacts with the surrounding paragneiss and plutonic rocks of the informally named Coast plutonic-metamorphic complex of Brew and Ford (1984a, b) (Fig. 9). The stock is composed of a complex suite of four distinct phases. The principal rock unit, the Quartz Hill granite body, is the oldest and most prominant phase, and covers more than 75% of the surface area. The Quartz Hill granite body has been intruded by younger porphyritic quartz latite, younger granite, and dikes of quartz feldspar porphyry. Intrusive breccias are associated with some of the younger units. All of the rock units are similar in chemistry and mineralogy and consist of quartz, K-feldspar, sodic plagioclase, and minor biotite. Biotite from the Quartz Hill granite body has been dated at 26.9 Ma (Hudson and others, 1979).

The molybdenum deposit occurs predominantly in the informally named Quartz Hill stock and is tabular to slightly concave upward. The surface dimensions are about 2,800 by 1,500 m, and the deposit extends to a depth of 370 to 500 m (Fig. 9). Two relatively high-grade zones occur, the Quartz Hill zone, south of the Stephens fault, and the Bear Meadow zone, north of the Stephens fault. The deposit, as determined from nearly 61,000 m of drill core, contains an estimated 1.7 billion tonnes grading 0.136% MoS_2, using a cutoff grade of 0.070% MoS_2. Within the deposit, a high-grade zone contains approximately 440 million tonnes grading 0.219% MoS_2 using a cutoff grade of 0.15% MoS_2.

Molybdenite and pyrite are the major sulfides and occur with or without quartz in randomly oriented veinlets forming a pervasive and well-developed stockwork. The molybdenite is in fine grains that range from 0.008 to 0.09 mm in diameter. Other sulfides, including galena, sphalerite, and chalcopyrite, are present locally. Concentrations of Cu, Pb, Zn, Au, and Ag are at or near background values, both within and peripheral to the deposit. Hydrothermal alteration of the stock is widespread and generally of weak to moderate intensity. Silicic, potassic, phyllic, argillic, and propylitic alterations are identified, but their recognition is complicated by overprinting as a result of multiple intrusion and associated hydrothermal events.

Central Southeastern Alaska

The major lode deposits in central southeastern Alaska are (Table 1, Plate 1): (1) Kuroko massive sulfide deposits at Glacier Creek, Orange Point, Greens Creek, Pyrola, Kupreanof Island, Helen S., Zarembo Island, Khayyam, Niblack, Barrier Islands, and Driest Point; (2) metamorphosed sulfide deposits at Cornwallis, Copper City, and Moonshine; (3) bedded barite deposits at Castle Island and Lime Point; (4) polymetallic vein deposits at Nunatak, Coronation Island, and Bay View; (5) Au quartz-vein deposits at Reid Inlet, Dawson, and Golden Fleece; (6) Cu-Zn-Au skarn deposits at Kupreanof Mountain and in the Jumbo district; (7) a Cu-Fe skarn deposit at Kasaan Peninsula; (8) a porphyry Cu deposit at Margerie Glacier; (9) a gabbroic Ni-Cu deposit at Funter Bay; (10) zoned mafic-ultramafic deposits at Klukwan, Salt Chuck, and Duke Island; (11) felsic plutonic U deposits at William Henry Bay, Salmon Bay, and Bokan Mountain; and (12) a sandstone U deposit at Port Camden.

These lode deposits are hosted in three main groups of rocks in central southeastern Alaska: (1) The Paleozoic and early Mesozoic metasedimentary, metavolcanic, and metaplutonic rocks of the Alexander belt (Brew and others, 1984); (2) various Mesozoic and early Tertiary plutonic rocks; and (3) Tertiary sandstone. The Alexander belt, which is approximately equivalent to the Alexander terrane (Plate 1), consists mainly of Ordovician or older (?) carbonate rocks, carbonaceous flysch, chert, terrigenous and marine clastic rocks; Ordovician to Triassic metamorphosed basaltic to silicic flows and related volcaniclastic rocks; and Ordovician and Silurian diorite and trondhjemite. The younger plutonic rocks hosting, or associated with some lode deposits in the Alexander belt consist of Jurassic granite, Cretaceous granodiorite, Mesozoic (mainly Cretaceous) pyroxenite, gabbro-norite, and gabbro, and Tertiary granite, granite porphyry, and felsic dikes.

Massive Sulfide and Barite Deposits, Central Southeastern Alaska

Kuroko massive sulfide deposits occur at Glacier Creek, Orange Point, Greens Creek (described below), Pyrola, Kupreanof Island, Helen S., Zarembo Island, Khayyam (described below), Niblack, Barrier Islands, and Driest Point in central southeastern Alaska (Table 1, Plate 1). The smaller deposits consist of disseminated to massive Fe sulfides and base-metal sulfides in lenses and layers as much as about 25 m wide and 170 m long in Ordovician, Silurian, Permian(?), and Triassic felsic to intermediate flows, tuff, and volcaniclastic rocks, interlayered with limestone, slate, chert, and lesser greenstone, all part of the Alexander belt (Table 1). These deposits are spread over 300 km along the strike length of the Alexander belt.

Substantial amounts Cu, Pb, Zn, Ag, and Au occur in or have been produced from the Kuroko massive sulfide deposits in central southeastern Alaska (Table 1). The Glacier Creek deposit contains an estimated minimum 680,000 tonnes grading as much as 3% combined Cu and Zn and as much as 45% $BaSO_4$. The Greens Creek deposit contains an estimated 3.6 million tonnes grading 8% Zn, 2.7% Pb, 0.4% Cu, 360 g/t Ag, and 3.4 g/t Au. The Khayyam deposit produced about 6.4 million kg Cu, 40,100 g Au, and 53,300 g Ag from 205,000 tonnes of ore. The Niblack deposit produced about 636,000 kg Cu, 34,200 g Au, and 466,500 g Ag.

Metamorphosed sulfide deposits in carbonate and metavolcanic host rocks are present at Cornwallis, Copper City, and Moonshine in central southeastern Alaska (Table 1, Plate 1). The Cornwallis Zn-Pb deposit consists of finely disseminated sphalerite, galena, and chalcopyrite in Carboniferous limestone breccia and is associated with pods, veins, and layers of barite as much as 2 m wide and 60 m long in Late Triassic felsic metavolcanic rocks. The Copper City Cu-Zn-Ag-Au deposit consists of massive chalcopyrite, pyrite, and sphalerite in layers and lenses about 1 m thick in metamorphosed early Paleozoic keratophyre and spilite. The Moonshine Ag-Pb deposit consists of galena, sphalerite, minor chalcopyrite and pyrite in fissure veins or pods as much as a few m wide in dolomite veins cutting early Paleozoic marble. The Copper City deposit produced about 1,450 tonnes of ore, and the Moonshine deposit produced about 46,500 g Ag (Table 1); no model is available to classify these two deposits.

Bedded barite deposits are present at Castle Island and Lime Point in central southeastern Alaska (Table 1, Plate 1). The Castle Island deposit consists of lenses of massive barite interlayered with metamorphosed Devonian or Triassic limestone and calcareous and tuffaceous clastic rocks. The deposit produced 680,300 tonnes of ore grading 90% $BaSO_4$. The Lime Point deposit consists of interlayered lenses of barite and dolomite as much as 2 m thick in lower Paleozoic marble. The deposit contains an estimated 4,500 tonnes grading 91% barite.

Greens Creek Zn-Pb-Cu-Ag-Au Deposit
By J. Dunbier and D.A. Sherkenbach

The Greens Creek Zn-Pb-Cu-Ag-Au deposit consists of sulfide bands, laminations, and disseminations hosted in a sequence of chlorite-rich and sericite-rich metasedimentary rocks and of pyrite-chert-carbonate rocks that structurally overlie locally serpentinized mafic volcanic flows and tuffs (Dunbier and others, 1979; Drechsler and Dunbier, 1981). The mafic volcanic rocks crop out in the core of a large southeast-plunging antiform that is overturned to the northeast (Fig. 10); the metasedimentary rocks, exhalite, and associated sulfide bodies occur in the pinched nose and along the northeast limb of the structure several km from the rocks in the core. The sulfide content generally increases structurally upsection and culminates at the contact with overlying black carbonaceous argillite and graywacke. Deformation and lower-greenschist facies metamorphism characterize the host rocks.

The sulfide horizon has a structural hanging wall of finely bedded metasedimentary rocks and pyrite-carbonate-chert exhalite and a footwall of black graphitic argillite that overlies the metamorphosed tuff (Fig. 10). In the transitional contact zone, the sulfides occur in a series of south-plunging, elongate, massive pods as much as 25 m thick, with flanking units of black and white ore. The massive pods consist of layers, laminations, and disseminations of sphalerite, galena, chalcopyrite, and tetrahedrite in a pyrite-rich matrix. Black ore forms an extensive blanket in the deposit and consists of laminated, fine-grained pyrite, sphalerite, galena, and Ag-rich sulfosalt hosted in black carbonaceous exhalite and argillite. White ore is present along the edges of the massive pods and consists of minor amounts of tetrahedrite, pyrite, galena, and sphalerite in laminations, stringers, or disseminations that are hosted in massive chert, carbonate rocks, or sulfate-rich exhalite. Geopetal structures indicate that the ore horizon is overturned. Several vein assemblages are also present; the most interesting contain bornite, chalcopyrite, and gold. These veins are in chlorite-talc-carbonate alteration zones that are stratigraphically below the massive sulfide pods and may have been brine conduits. Extensive drilling has delineated a major mineral deposit, still open at depth, containing an estimated 3.6 million tonnes grading 0.4% Cu, 2.7% Pb, 7.9% Zn, 360 g/t Ag, and 3.4 g/t Au.

Although not dated, the Greens Creek deposit is inferred to have formed in a late Paleozoic backarc or wrench-fault basin in the middle history of the Alexander belt. Early deposition was dominated by arc- or continent-derived clastic and volcaniclastic sediments that intermixed with mafic flows and tuff. Late deposition was dominated by distal turbidites in a starved, euxinic basin. The basin remained tectonically active, with internal sub-basins characterized by locally derived slump and debris breccias. Brines responsible for the deposit probably consisted of convective seawater that circulated in the lower basinal sequence. Brine flow was localized by structural rather than volcanic conduits, and the brines discharged into a dominantly sedimentary environment with local relief caused by active faulting. Ore deposition probably resulted from interaction between buoyant brine phases and seawater, in addition to precipitation in density-stratified pools. Unusually carbon-rich sedimentary rocks in the hanging wall may reflect blooming marine life associated with the brines. The Greens Creek deposit is an intriguing example of a massive sulfide deposit that shows some characteristics of Kuroko massive sulfide, sedimentary exhalative, and Cyprus massive sulfide deposits.

Khayyam Cu-Au-Ag Deposit

The Khayyam deposit, classified as a Kuroko massive sulfide deposit, consists of irregular, elongate, nearly vertical lenses of massive pyrite, chalcopyrite, sphalerite, pyrrhotite, hematite, gahnite, and magnetite in a gangue of quartz, calcite, epidote, garnet, and chlorite (Fosse, 1946, Barrie, 1984 a, b). The sulfides and associated minerals occur in about seven sulfide lenses as much as 70 m long and 6 m thick. The lenses are conformably enclosed in pre-Middle Ordovician felsic to mafic metavolcanic rocks of the Wales Group in the Alexander belt. The metavolcanic rocks show coarse fragmental textures, and intense chlorite alteration is present in the footwall below the sulfide lenses. Several hundred m of underground workings exist. The deposit produced about 6.4 million kg Cu, 40,120 g Au, and 53,210 g Ag from about 205,000 tonnes of ore.

Polymetallic and Au Quartz Vein Deposits, Central Southeastern Alaska

Polymetallic vein deposits occur at Nunatak (described below), Coronation Island, and Bay View in central southeastern Alaska (Table 1, Plate 1). The Cornation Island Pb-Zn deposit consists of lenses of galena, sphalerite, and tetrahedrite in a clay-carbonate gangue in fault zones in Silurian(?) marble intruded by Tertiary(?) diorite. The deposit has produced more than 91 tonnes of ore. The Bay View Ag-Au deposit consists of quartz- and calcite-cemented fault breccia with disseminations and small masses of pyrite, chalcopyrite, and minor sphalerite and bornite in a basalt dike in fault-bounded Silurian trondhjemite. Selected samples contain as much as 10 g/t Ag and 0.1 g/t Au.

Au quartz-vein deposits occur at Reid Inlet, Dawson, and Golden Fleece in central southeastern Alaska (Table 1, Plate 1). The Reid Inlet deposit consists of narrow, discontinuous, steeply dipping quartz veins as much as a few hundred m long and 1.1 m thick in altered Cretaceous granodiorite, Permian(?) metamorphosed pelitic and volcanic rocks, and marble. The deposit has produced 220,000 to 250,000 g Au. The Dawson Au-Ag deposit consists of quartz stringers and veins as much as 1.8 m wide in Paleozoic black graphitic slate. The stringers and veins contain scattered pyrite and base metal sulfides. The deposit has probably produced at least several times ten thousand g each of Au and Ag and minor amounts of Pb, and it contains an estimated 40,000 tonnes grading 34.3 g/t Au. The Golden Fleece Ag-Au deposit consists of irregular quartz fissure veins as much as 3 m thick with pyrite, tetrahedrite, and gold in silicified and dolomitized marble cut by diabase dikes. The deposit has had considerable unrecorded production and contains several hundred m of workings.

Nunatak Cu Deposit

The Nunatak polymetallic vein deposit consists of abundant, closely spaced molybdenite-bearing quartz veins and minor disseminated molybdenite in hornfels, skarn, and a fault zone (Brew and others, 1984). The molybdenite-bearing veins, skarn, and fault zone are adjacent to a Tertiary(?) granite porphyry stock. Sulfides are locally disseminated in the porphyry. Besides molybdenite, sulfides include pyrite, pyrrhotite, chalcopyrite, and sparse tetrahedrite and bornite. The closely spaced vein stockwork contains an estimated 2.0 million tonnes grading 0.067% Mo and 0.16% Cu. The remaining stockwork has inferred resources of 118 thousand tonnes grading 0.026% Mo and 0.18% Cu. The granite porphyry intrudes tightly folded Paleozoic metasedimentary rocks. The deposit is classified as either a polymetallic vein and or a porphyry Cu-Mo deposit; the polymetallic vein classification is more probable.

Skarn and Porphyry Deposits, Central Southeastern Alaska

A major Cu-Fe skarn deposit is present at Kasaan Peninsula (described below), and Cu-Zn-Au skarn deposits occur at Kupreanof Mountain and in the Jumbo district (described below) in central southeastern Alaska (Table 1, Plate 1). A combined porphyry Cu and lesser polymetallic vein deposit occurs at Margerie Glacier. The Kupreanof Mountain deposit consists of local massive pods, lenses, and disseminations of pyrrhotite, magnetite, and chalcopyrite, and minor sphalerite and pyrite in pyroxene-garnet skarn in Devonian(?) marble and in part in highly altered mafic igneous rocks. The deposit contains several hundred m of underground workings.

Kasaan Peninsula Cu-Fe-Au-Ag Deposits

The Kasaan Peninsula deposits consist of contorted tabular masses of magnetite, chalcopyrite, and pyrite in a gangue of calcite and calc-silicate minerals (Warner and Goddard, 1961). The masses generally are in conformable layers, mainly along contacts between calcareous metasedimentary rocks and mafic metavolcanic rocks adjacent to irregular dikes, sills, and plugs of Ordovician or Silurian diorite and quartz monzodiorite and mafic dikes. About 30 deposits are present on the 20-km-long peninsula. The largest deposit produced about 245,000 tonnes containing more than 5.8 million kg Cu, 216,000 g Au, and 1.74 million g Ag. This deposit contains an estimated 2.7 million tonnes averaging 53 to 59% Fe and 0.26 to 0.90% Cu. The deposit exhibits zoned calc-silicate minerals and sulfides and rather low Ag/Au and Zn/Cu ratios. The Kasaan Peninsula deposits are classified as Fe skarn deposits that probably formed during intrusion of Paleozoic plutonic rocks.

Jumbo District

The Jumbo district contains Cu-Au skarn deposits at Jumbo and smaller deposits at Magnetite Cliff and Copper Mountain and elsewhere in the area (Kennedy, 1953; Herreid and others, 1978). The skarns occur in early Paleozoic marble and pelitic metasedimentary rocks that are intruded by a mid-Cretaceous hornblende-biotite granodiorite with concordant hornblende and biotite K-Ar ages of 103 Ma. The Jumbo Cu-Au deposit consists of chalcopyrite, magnetite, sphalerite, and molybdenite in skarn at the contact between marble and an Early Cretaceous granodiorite stock. The gangue is mainly diopside and garnet. The Jumbo deposit, with more than 3.2 km of underground workings, produced 4.6 million kg Cu, 220,000 g Au, and 2.73 million g Ag from 112,000 tonnes of ore. The Magnetite Cliff deposit consists of a 25-m-thick shell of magnetite that mantles the mid-Cretaceous granodiorite in contact with garnet-diopside skarn. The skarn contains 2 to 3% chalcopyrite and an estimated 336,000 tonnes grading 45% Fe and 0.77% Cu. The Copper Mountain deposit consists of scattered chalcopyrite and copper carbonate minerals in diopside endoskarn, veins and masses of epidote, garnet, magnetite, and scapolite, in granodiorite. The Copper Mountain deposit, with about 410 m of underground workings, produced 101,800 kg Cu, 321,000 g Ag, and 4,500 g Au.

Margerie Glacier Cu Deposit

The Margerie Glacier deposit consists of chalcopyrite, arsenopyrite, sphalerite, molybdenite, and minor scheelite in quartz veins in shear zones, in massive sulfide bodies, and as disseminations (Brew and others, 1978). The veins, massive sulfides, and disseminations occur in a propylitically altered porphyritic Cretaceous(?) granite stock and in adjacent hornfels. The granite intrudes Permian(?) metamorphosed pelitic and volcanic rocks and minor marble. The deposit contains an estimated 145 million tonnes grading 0.02% Cu, 0.27 g/t Au, 4.5 g/t Ag, and 0.01% W, and is classified as a combination of porphyry Cu and and subordinate polymetallic vein deposit (Table 1).

Gabbroic Ni-Cu and Mafic-Ultramafic Deposits, Central Southeastern Alaska

A gabbroic Ni-Cu deposit is present at Funter Bay (described below), and zoned mafic-ultramafic deposits occur at Klukwan, Salt Chuck (described below), and Duke Island in central southeastern Alaska (Table 1, Plate 1). The zoned mafic-ultramafic deposits are part of a discontinuous belt of 100- to 110- Ma old mafic-ultramafic plutons. This belt, which includes the Union Bay mafic-ultramafic body and deposit in the Coast Mountains region, is along the strike length of southeastern Alaska (Plate 1).

The Klukwan Fe-Ti-V deposit (Table 1) consists of titaniferous magnetite and minor chalcopyrite, hematite, and Fe sulfides in disseminations or in tabular zones in Cretaceous pyroxenite surrounded by diorite. The deposit contains an estimated 11.8 billion tonnnes grading 0.2% V_2O_5, 13% magnetite, and 1.5 to 4.4% TiO_2. The Duke Island Cr-PGE deposit (Table 1) consists of disseminated to locally massive titaniferous magnetite and sparse chromite in hornblende and clinopyroxene zones in a Cretaceous(?) zoned ultramafic pluton.

Funter Bay Ni-Cu Deposit

The Funter Bay gabbroic Ni-Cu deposit (Table 1) consists of disseminated pyrrhotite, pentlandite, and chalcopyrite that occur in olivine-hornblende gabbro at the base of a gabbro-norite pipe of late(?) Mesozoic age (Barker, 1963; Noel, 1966). The pipe intrudes late Paleozoic or Triassic quartz-mica schist. The deposit contains an estimated 450 to 540 thousand tonnes grading 0.33 to 1.0% each of Cu and Ni and 0.05 to 0.32% Co.

Salt Chuck Cu-Au-Ag Deposit

The Salt Chuck zoned mafic-ultramafic deposit consists of irregularly and randomly distributed veinlets of bornite, minor chalcopyrite, and secondary chalcocite, covellite, native copper, and magnetite (Howard, 1935; Gault, 1945; Donald Grybeck and D.A. Brew, written commun., 1985). The sulfides and oxides occur along cracks and fractures in a pipelike gabbro-pyroxenite stock of late Paleozoic or Mesozoic age intruding Silurian metagraywacke. The deposit has produced about 296,000 tonnes grading 0.95% Cu, 1.2 g/t Au, 5.8 g/t Ag, and 2.2 g/t PGE.

U Deposits, Central Southeastern Alaska

Felsic plutonic U deposits occur at William Henry Bay, Salmon Bay, and Bokan Mountain (described below), and a sandstone U deposit occurs at Port Camden in central southeastern Alaska (Table 1, Plate 1). The William Henry Bay deposit consists of veinlets with pyrite, chalcopyrite, galena, thorianite, and euxenite in a small Tertiary(?) granite pluton intruding Silurian(?) metavolcanic and metasedimentary rocks. The Salmon Bay deposit consists of carbonate fissure veins in Silurian metagraywacke near Tertiary felsic dikes. The veins contain a wide variety of minerals, including fluorite, hematite, magnetite, pyrite, chalcopyrite, thorite, monazite, zircon, parisite, and bastnaesite. The Port Camden sandstone U deposit consists of traces of U minerals in poorly sorted dolomitic sandstone of the Tertiary Kootznahoo Formation, which contains detritus derived from Tertiary or older granitic rocks.

Bokan Mountain U-Th-REE Deposit

The Bokan Mountain felsic plutonic U deposit consists of disseminated accessory U-Th, REE, and niobate minerals, including uranothorite, uranoan thorianite, uraninite, xenotime, allanite, monazite, and accessory pyrite, galena, zircon, and fluorite (MacKevett, 1963; Lancelot and de Saint-Andre, 1982; Thompson and others, 1982; Armstrong, 1985). The U-Th, REE, and niobate minerals are hosted in an irregular, steeply dipping pipe of Jurassic peralkaline granite that grades outward into mostly barren granite. U-Th vein and pegmatite deposits occur in the outer parts of the granite and adjacent country rock. The deposit has produced about 109,000 tonnes grading about 1% U_3O_8. Equivalent grade Th was not recovered.

Coastal Southeastern Alaska

Major gabbroic Ni-Cu, Au quartz vein, and basaltic Cu deposits are present in coastal southeastern Alaska (Table 1, Plate 1). Gabbroic Ni-Cu deposits occur at Brady Glacier (described below), Bohemia Basin (described below), and Mirror Harbor (Table 1). These deposits are in Tertiary mafic and ultramafic stocks that intrude metagraywacke and phyllite of the Cretaceous Sitka Graywacke and metagraywacke, phyllite, and greenschist of the Cretaceous and Cretaceous(?) Kelp Bay Group, part of the Chugach terrane (Plate 1). The mafic and ultramafic plutons are probably postdeformational and postmetamorphic igneous bodies.

Au quartz vein deposits occur at Apex, El Nido, Cobol, Chichagoff and Hirst-Chichagof (described below) in coastal southeastern Alaska (Table 1, Plate 1). These deposits generally consist of quartz fissure veins, as much as 4 m thick, and locally wider stockworks containing pyrite, arsenopyrite, chalcopyrite, galena, sphalerite, tetrahedrite, and gold. Local minor sulfides occur in adjacent metasedimentary, metavolcanic, and granitic wallrocks. The Au quartz vein deposits at Apex, El Nido, and Cobol are in late Paleozoic low-grade pelitic and metavolcanic rocks, including greenstone, quartzite, and siliceous limestone, part of the Wrangellia terrane (Plate 1). The deposits at Chichagoff and Hirst-Chichagof are in the Cretaceous Sitka Graywacke, part of the Chugach terrane (Plate 1). These deposits are interpreted as having formed during Tertiary regional metamorphism and deformation followed by intrusion of granitic plutons.

A possible basaltic Cu deposit occurs at Baker Creek (Table 1, Plate 1). This deposit consists of small masses and disseminations of chalcopyrite and pyrite in zones as much as 4 m thick and 120 m long in metamorphosed subaerial basalt flows of the Triassic(?) Goon Dip Greenstone, part of the Wrangellia terrane (Plate 1).

Brady Glacier Ni-Cu Deposit

The Brady Glacier deposit (Table 1, Plate 1) consists of disseminations and small masses of pentlandite, chalcopyrite, and rare pyrite near the eastern edge and probable base of a layered Tertiary mafic-ultramafic pluton composed of gabbro with minor peridotite, part of the La Perouse gabbro pluton (Brew and others, 1978; Czamanske and Calk, 1981; Himmelberg and Loney, 1981).

The deposit locally locally as much as 10% disseminated sulfides and has an estimated 82 to 91 million tonnes averaging 0.53% Ni, 0.33% Cu, 0.03% Co, and minor amounts of PGE. Selected samples with disseminated to massive sulfides contain 0.2 to 1.3 g/t PGE. The deposit occurs mainly beneath the Brady Glacier but is exposed in three small nunataks. K-Ar ages of 25 to 30 Ma have been obtained for the La Perouse. The pluton intrudes metagraywacke and phyllite of the Cretaceous Sitka Graywacke, part of the Gravina-Nutzotin belt (Plate 1).

Bohemia Basin Ni-Cu Deposit

The Bohemia Basin deposit (Table 1, Plate 1) consists of magmatic segregations of chiefly pyrrhotite, pentlandite, and chalcopyrite (Kennedy and Walton, 1946; Johnson and others, 1982). The segregations occur in a troughlike body, about 45 m thick, near the base of a basin-shaped, composite norite stock of Tertiary age. The norite locally grades into gabbro and diorite. The stock intrudes metagraywacke, phyllite, and greenschist of the Cretaceous and Cretaceous(?) Kelp Bay Group. The deposit contains an estimated 19 million tonnes averaging 0.33% Ni, 0.21% Cu, and 0.04% Co.

Chichagoff and Hirst-Chichagof Au-Ag Deposits

The Chichagoff and Hirst-Chichagof deposits (Table 1, Plate 1) consist of tabular to lenticular bodies of quartz with small masses of pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, and local scheelite and tetrahedrite (Reed and Coats, 1941; Still and Weir, 1981; Johnson and others, 1982; Alaska Mines and Geology, 1985). The quartz bodies are mainly ribbon quartz, as much as a few m thick and a few thousand m long. The main ore shoots are localized along intersections of various splays of the Hirst and Chichagoff faults and probably along warps in the faults. The deposit is in metagraywacke and argillite of the Cretaceous Sitka Graywacke. The deposits have produced about 25 million g Au, 1.24 million g Ag, and minor amounts of Pb and Cu.

PLACER DISTRICTS

More than 960 million g of gold have been produced from Alaskan mines since gold was discovered there in the late 1880's. Of this amount more than 620 million g, or roughly two-thirds, has been obtained from placer deposits. Alaska is probably the only state where placer gold production has recently increased. Placers in Alaska have also yielded approximately 93 million g of silver, about 17 million g of PGE, 1.8 million kg of tin, and unspecified amounts of mercury and tungsten (Eakins and others, 1985). Placer mining in Alaska, principally for gold, is one of the major nonfuel mining industries on the basis of the value of mineral produced. It was second only to sand and gravel in 1982, when approximately $70,000,000 worth of gold was mined (Eakins and others, 1985). Silver in Alaska is produced primarily as a byproduct of placer gold. In 1982 Alaskan gold placer mines produced approximately 684,000 g of silver, as well as 6,160 kg of tin. Approximately 28,000 g of placer platinum was produced in 1981, the most recent year for which figures are available (Eakins and others, 1985). The fluctuating price of gold is a major factor in placer mining in Alaska, where operating costs are high. A number of mines are not economic when the price drops below about $10/g ($300/oz). Consequently, yearly production can vary greatly when the price fluctuates around this figure.

History of Placer Discovery and Mining in Alaska

The native Americans in Alaska used native gold in ornamental jewelry and occasionally as decoration on pottery, utensils, and weapons. Gold was reported from Alaska as early as 1834 by a party of Russian-Americans exploring on the Russian River drainage of the Kenai Peninsula; however, gold was not actually mined until the late 1860's and early 1870's, initially near Sitka and near Juneau in the Silver Bow Basin area. The discovery of placer gold on tributaries of the Forty Mile River in 1886 was instrumental in opening up the interior of Alaska to gold discovery and mining. Gold was found on Birch Creek, south of the Yukon River, leading to the development of the Circle Mining District in the 1890's, a district that continues to produce gold. The discovery of gold in the Klondike area of the Yukon Territory led to more discoveries in Alaska. Many of the Klondike prospectors who were not successful on the Dawson creeks drifted down the Yukon River into Alaska and eventually reached the beaches at Nome. A promising discovery was made there on Anvil Creek in 1898. The realization that the beaches around Nome could be worked sparked a major stampede to this new district.

The many prospectors in Alaska soon made other discoveries. A major discovery on tributaries of the Tanana River led to the founding of Fairbanks, in what would eventually become the richest gold mining region of the state. Gold in the upper Koyukuk River was discovered in 1898, and later discoveries in 1905 and 1908 resulted in the gold mining towns of Coldfoot and Wiseman. The lower Yukon and Kuskokwim River basins witnessed minor rushes during 1909 to 1912; deposits were discovered in the Iditarod, Ruby, Flat, and Ophir districts. The remote Chandalar River district above the Arctic Circle was investigated in 1902, and a small rush ensued in 1906 with the discovery of deposits on Little Squaw Creek. During the same period, placer deposits in the Chistochina area in the eastern Alaska Range were discovered. A general decline in new discoveries and production occurred about 1918. This trend continued until about 1928, when mechanization of mining resulted in increased production. In 1934 the price of gold was raised from $20 to $35 per ounce, and this resulted in a peak production of about 23 million g of gold in 1940.

War Production Board Order L-208 almost stopped gold mining by October 1942. Operating placer mines decreased from 554 to 142 by 1943. The recovery from 1944 to 1950 was slow because replacing equipment was costly. Lode mining suffered even more greatly; as a result, 95 percent of the gold mined during this period came from placers. After World War II the price of gold remained at the 1934 standard of $35 per ounce, which caused a general decline in the industry. Almost all the great gold dredges had shut down by the early 1960's. Some small-scale placer mines survived by selectively mining the richer parts of deposits, but all-time low production figures were recorded in 1971 and 1972. The depressed price of gold, together with the high cost of labor and equipment, limited production to less than $500,000 from about a dozen gold-mining operations. The dramatic increase in the gold price in the late 1970's and early 1980's resulted in a striking increase in Alaskan gold production. By 1981 there were approximately 400 placer mines in the state employing about 3,000 miners, with annual production of about 4.2 million g of gold.

The major placer districts of Alaska are summarized in Table 2 (Plate 2), using the regional division of Alaska of Cobb (1973). The districts are arranged by geographic region with the same order as for lode deposits (Table 1). Data were compiled only for areas with production of more than 31,000 g (1,000 oz) of gold. The third column in Table 2 lists the major metals and other commodities in each placer district. Production figures are from Cobb (1973), and Robinson and Bundtzen (1979). Additional information on Alaskan placer deposits is provided by Cobb (1973), Robinson and Bundtzen (1979), and Cook (1983). Starting in 1980, annual conferences on Alaskan placer mining in Fairbanks have resulted in the yearly publication of a conference proceedings, the most recent being for the Seventh Annual Conference (Alaska Prospectors Publishing, 1985).

Major Placer Districts - Brooks Range

Major placer districts are at Chandalar, Kiana, Noatak, Shungnak, and Wiseman in the Brooks Range (Table 2, Plate 2). The largest gold-producing placer district is the Wiseman district with production of 9 million g of gold since its discovery in 1893. The next largest producer is the Chandalar district with 964,000 g of gold. Native gold and other heavy minerals in the Wiseman and Chandalar districts, including chalcopyrite, galena, magnetite, molybdenite, native bismuth, native copper, pyrite, scheelite, silver, and stibnite, are probably derived mainly from either volcanogenic massive sulfide deposits in the Ambler district or from Au quartz vein, Sb-Au vein, skarn, and porphry deposits associated with Devonian or Mesozoic granitic plutons, or with Mesozoic metamorphism in the area. Gold and other heavy minerals in the Kiana, Shungnak, and Noatak districts may be derived from Au quartz vein deposits.

The Wiseman district (Table 2, Plate 2) contains perhaps the only year-round placer mine in Alaska. The operation has remained active by means of underground mining. From November to April, shafts and drifts are sunk and driven in frozen river gravel. This frozen gold-bearing gravel is brought to the surface and stacked by a self-dumping machine. From June until sometime in the fall, a three-man crew washes the thawed gravel to recover the contained gold.

Major Placer Districts - Seward Peninsula and Western Yukon-Koyukuk Basin

Major placer districts are at Council, Kougarok, Nome, and Port Clarence on the Seward Peninsula (Table 2, Plate 2). The Nome district placers are some of the larger producers of gold in Alaska and have produced as much as 140 million g of gold. Gold, cassiterite, cinnabar, columbite, scheelite-powellite, tantalite, wolframite, and other heavy minerals in these four major Seward Peninsula districts are derived mainly from Au quartz vein deposits occurring in regional metamorphic rocks and from Sn vein, Sn skarn, and Sn granite and polymetallic vein deposits associated with Cretaceous silicic granitic plutons in the region.

The principal gold deposits in the Nome district of the Seward Peninsula are contained within the sand and gravel of five distinct emerged Pleistocene beaches. Several submerged beachlines are also known. The Alaska Gold Company currently operates two dredges at Nome which can process about 12,000 m^3 of gravel per day at maximum production. In addition, numerous small operators are working beaches and creeks with pans, rockers, sluice boxes, and suction dredges. In 1982, cold-water thawing continued ahead of the dredge on a 1,200 acre block of frozen ground that is estimated to contain as much as 31 million g of gold (Eakins and others, 1983). Exploration of offshore gold placers near Nome has been done by several companies.

Major placer districts in the western Yukon-Koyukuk basin are in the Fairhaven and Koyuk areas (Cobb, 1973) (Table 2, Plate 2), in areas underlain by Late Cretaceous sedimentary, volcanic, and plutonic rocks. The largest placer gold producer is the Fairhaven district with production of 14 million g of gold. Gold, scheelite, magnetite, stibnite, uranothorianite, wolframite, and other heavy minerals in the districts are mainly derived from lode deposits associated with the Cretaceous plutonic and volcanic centers in the region.

Major Placer Districts - West-Central Alaska

Major placer districts are at Aniak, Goodnews Bay, Hot Springs, Iditarod, Innoko, McGrath, Marshall, Melozitna, Rampart, Ruby, and Tolovana in west-central Alaska (Table 2, Plate 2). The largest producer in the region is the Iditarod district with production of 41 million g of gold, followed by the Innoko district with 16.8 million g of gold, the Hot Springs district with 14 million g of gold, and the Ruby district with 12 million g of gold (Table 2). The Goodnews Bay district has produced more than 16.8 million g of PGE and 0.9 million g of gold (Table 2).

Gold, cassiterite, cinnabar, magnetite, native bismuth, pyrite, scheelite, stibnite, tourmaline, and other heavy minerals in the Aniak, Iditarod, Innoko, McGrath, Marshall, and Ruby districts are probably derived from polymetallic vein and porphyry deposits associated chiefly with Cretaceous and early Tertiary plutonic and volcanic centers and from Cretaceous sedimentary rocks. Chromite and platinum in the Innoko, McGrath, and Ruby districts are probably derived from Cr deposits in ultramafic rocks within thrust slices in the Tozitna and Innoko areas. Gold, cassiterite, cinnabar, magnetite, pyrite, REE-minerals, scheelite, stibnite, tourmaline, and other heavy minerals in the Hot Springs, Melozitna, Rampart, and Tolovana districts are probably derived from vein deposits associated with Cretaceous or Tertiary granitic plutons and sedimentary rocks. PGE and gold in the Goodnews Bay district are interpreted as being derived from the informally named Middle Jurassic Goodnews Bay mafic-ultramafic complex of Southworth and Foley (1986).

Goodnews Bay District

The Goodnews Bay Pt deposit (Table 2, Plate 2) has been the largest producer of PGE in the United States (Mertie, 1976; Eakins and others, 1983; Southworth and Foley, 1986). From 1937 to 1975, approximately 16.8 million g of PGE was recovered. Large platinum nuggets are rare at Goodnews Bay; the largest recovered weighed about 124 g. Heavy-mineral concentrates, in addition to PGE minerals, include magnetite, ilmenite, chromite, and gold. Gold is a significant byproduct and makes up as much as 10 percent of the precious metal concentrate by volume. About 0.9 million g of gold has been produced. The pay streak on Salmon River is 105 to 140 m wide and reaches a maximum width of 180 m reached on Platinum Creek. The principal reserves remaining in this district are clay-rich parts of tailings and deep ground in the lower Salmon River drainage.

Innoko District

Placer gold has been intermittently mined in the Innoko district from modern stream and bench gravel since 1906 (Mertie, 1936; Bundtzen and Laird, 1980) (Table 2, Plate 2). Production has been about 17 million g of gold from approximately 25 placer mines over the last 75 years. The gravel is generally 2 to 6 m thick and is overlain by a frozen muck layer 1 to 5 m in thickness. This muck layer must be thawed and stripped before mining of the underlying gold-bearing gravel. The gold is concentrated in the lowest 1 m of gravel and in cracks in the uppermost 1 m of bedrock. Aplitic and porphyry dikes intrude Cretaceous flysch bedrock; the dikes are more resistant to weathering and so form ridges that act as barrier traps for the gold moving along streambeds. Gold also is found at the intersections of tributary streams with main streams where a gradient change occurs. The gold is generally finegrained and flattened, is occasionally iron stained, and includes adhering grains of quartz and magnetite. Yields of $5.20 to $10.50 per m^3 are common for the modern gravel and as much as $12.50 per m^3 for the bench gravels. Mineralized dikes, faults, and igneous rocks occur within or adjacent to creeks that are being mined in the area, some of which contain gold.

Most of the production in the district has been from the Ophir and Candle Hills deposits. The placer deposits in the Ophir area are downslope and downstream from basaltic to rhyolitic dike swarms and are concentrated along faults and dikes trending across stream channels (Bundtzen, 1980; Bundtzen and others, 1986). The dike swarms contain anomalous amounts of Au, Ni, Cr, and Zr. In the Candle Hills, fractures in plutons and hornfels locally contain anomalous amounts of base and precious metals and may be the lode source for the placer deposits.

Hot Springs District

About 14 million g of gold and 213,000 kg of tin have been produced from the Tofty area in the Hot Springs district; approximately 1.8 million kg of tin are estimated to remain (Table 2, Plate 2) (Wayland, 1961; Bundtzen, 1980; Robinson and others, 1982; Warner and Southworth, 1985). The heavy mineral concentrates include brown tourmaline, cassiterite (wood tin), chromite, aeschyite, tantalite, and monazite. Bedrock in the area consists of low-grade metamorphic rocks, serpentine, gabbro, quartz monzonite, and granite. The placers are in modern stream deposits and in bench deposits extending for a distance of 19 km. The lode source of Sn is probably related to granitic plutons in the area. Clasts of phyllite and quartz breccia are found with masses of cassiterite in the placers and indicate that some of the tin has been derived from Sn veins in metamorphic rocks.

Tolovana District

The Tolovana district deposits are in stream and bench gravel on a mature erosion surface largely buried by younger sediment (Table 2, Plate 2). Gold also is present in buried bedrock benches that are not completely exhumed. Approximately 11.7 million g of gold has been produced. The Livengood gold placer deposit on Livengood Creek, the largest placer mine in the district, has been worked intermittantly for 70 years. This deposit, which lies beneath a layer of frozen silt and barren gravel as much as 160 m thick, is estimated to contain 30 million m^3 of gravel averaging 1.4 g/m^3 Au. Gold in the district may be derived from polymetallic vein deposits associated with Cretaceous granitic plutons in the area.

Major Placer Districts - East-Central Alaska

Major placer districts are at Bonnfield, Circle, Eagle, Fairbanks, and Fortymile in the Yukon-Tanana Upland and at Kantishna in east-central Alaska (Table 2, Plate 2). The largest producer of placer gold in Alaska is the Fairbanks district, which has produced about 238 million g of gold. Other major producers are the Fortymile district with 13 million g and the Circle district with 23 million g. Gold, base-metal sulfides, cinnabar, native silver, scheelite, and other heavy minerals in the placer deposits in these districts are probably derived from Au quartz vein, polymetallic vein, W skarn, and possible massive sulfide deposits in the region. Sparse chromite and PGE are probably derived from Cr deposits in mafic and ultramafic bodies in thrust slices.

Fairbanks District

The Fairbanks district, with production of 238 million g of gold, has produced more placer gold than any other district of Alaska (Table 2, Plate 2) (Cobb, 1973). The area also contains rich lode gold deposits. This region of Alaska has not been recently glaciated, which may account for the presence of well-developed and well-preserved deposits. The subdued topography reflects the long erosional cycles that have operated in the area, allowing ample time for the erosion of gold lode deposits and the development of placer deposits. Several cycles of alluviation during the Pleistocene have periodically concentrated and reconcentrated the gold and associated heavy minerals. Late Tertiary and Quaternary alluviation, caused in part by tectonic action and (or) the rise of local base level, has resulted in the deposition of as much as 320 m of coarse gravel deposits. A later period of erosion has resulted in removal of much of the gravel, but basal paystreaks remain largely intact. The auriferous gravel, mainly of late Tertiary and Quaternary age, are now buried by frozen silt and other sediment, including windblown loess, which must be thawed before mining the underlying gravels.

Circle District

Placer gold has been mined in the Circle district since 1892, and approximately 23 million g of gold has been produced over the last 90 years (Table 2, Plate 2) (Yeend, 1982). Gold is concentrated in alluvial and colluvial deposits in the stream valleys draining into Birch and Crooked Creeks in the east-central part of the Circle quadrangle. In the North Fork of Harrison Creek, gold values range from \$0.52 to \$17.80 per m^3 but are most commonly \$3.10 to \$8.40 per m^3.

Substantial amounts of gold remain in the Circle district, and many placer deposits are currently being mined. Approximately 500 miners were working in the Circle district during the summer of 1980. Many gold-bearing stream channels previously unmined have become attractive as a result of recent increases in the gold price. A moderately large, low-grade, but as yet largely unevaluated gold resource may be contained in the extensive valley-fill deposits in the lower reaches of Crooked and Birch Creeks, as well as in the broad topographic trough on the south side of the Crazy Mountains.

Fortymile District

The Fortymile district (Table 2, Plate 2) is one of the oldest districts in Alaska, gold having been discovered near the mouth of the Fortymile River in 1886 (Cobb, 1973; Eakins and others, 1983). From the time of discovery through 1961, placers in the Fortymile district were worked every year, yielding a total of about 13 million g of gold. The source of the gold in the placers is probably small polymetallic vein and Au quartz vein deposits in metamorphic rocks near contacts with Cretaceous and early Tertiary granitic plutons. Heavy minerals in the placer deposits consist of magnetite, ilmenite, hematite, barite, garnet, and pyrite and other sulfides. Small amounts of scheelite were reported from Chicken Creek and its tributaries. Both stream and bench placers have been mined in the Fortymile district. Gold nuggets as heavy as 780 g have been recovered from Jack Wade Creek, and commonly as much as 25 percent of the gold recovered is of jewelry size or larger. As recently as 1982 there were 26 active placer mines in the district.

Kantishna District

Gold placer deposits in the Kantishna district are present in modern streams and benches (Gilbert and Bundtzen, 1979; Bundtzen, 1981). Scheelite and native silver nuggets occur in the deposits. The gold and silver are probably derived mainly from polymetallic vein deposits that formed during Cretaceous regional metamorphism and plutonism in the region. The Kantishna district contains a rich lode source for placer deposits, but placer production is currently modest; the district has produced about 1.4 million g Au.

Major Placer Districts – Southern Alaska Range and Wrangell Mountains, Southern Alaska

Major placer deposits occur in the Chisana, Chistochina, Delta River, Nizina, Valdez Creek, and Yentna districts in southern Alaska (Table 2, Plate 2). The largest producer of placer gold in the area is the Chistochina district with 4.4 million g of gold since discovery in 1898. Cassiterite, galena, magnetite, molybdenite, native copper, pyrite, silver, PGE, and other heavy minerals are probably derived from a variety of lode deposits, including Cu-Ag vein, polymetallic vein, skarn, and porphyry deposits, and from Late Jurassic and older flysch, Late Jurassic and Early Cretaceous flysch of the Gravina-Nutzotin belt, and Tertiary sandstone. PGE and chromite are probably mainly derived from Triassic ultramafic rocks associated with the Nikolai Greenstone. Native Cu is probably derived from the Nikolai Greenstone and associated basaltic Cu deposits.

Yenta District

Placer deposits in the Yentna district (Table 2, Plate 2) are in stream and bench deposits, Pleistocene glaciofluvial deposits, and Tertiary conglomerate and sandstone (Cobb, 1973). Placer mining in the Yenta district occurs mainly in the Petersville-Cache Creek area, which has had at least 12 separate mining operations. The largest mining operation uses two floating dredges supported by three large backhoes and has a capacity of about 3,800 m^3 per day. The district has produced approximately 3.58 million g of gold (Table 2).

Valdez Creek District

Placer deposits in the Valdez Creek district (Table 2, Plate 2) are mainly in a buried gold-bearing gravel-filled channel, the Tammany channel, in the Valdez Creek drainage. This channel has been mined on a moderately large scale. The mine is an openpit operation and employs as many as 70 persons (Bressler and others, 1985). Gold was originally discovered on Valdez Creek in 1902, and soon thereafter the buried channel was found to contain rich concentrations of placer gold. Approximately 1.2 million g of gold has been produced from the channel, and an additional 2.1 million g of gold is estimated. The high-grade gravel averages more than 8 g gold per m^3 (Bressler and others, 1985). Exploration has identified multiple, superposed, gold-bearing paleochannels, indicating a history of successive downcutting and fluvial deposition. The placer gold mines in this district are some of the largest in Alaska.

Chistochina District

Placer gold deposits have been worked intermittently in the Chistochina district (Table 2, Plate 2) in the eastern Alaska Range since the early 1900's, with production of approximately 4.4 million g of gold (Yeend, 1981a, b). During the summer of 1985, about six deposits were being mined, three of which were in the Slate Creek area. The gold occurs in poorly sorted gravel that has diverse origins and includes alluvium, colluvium, and glaciofluvial deposits. Well-rounded boulders and cobbles derived from Tertiary(?) conglomerate are common in the deposits. Gold nuggets are rare and seldom exceed 6 mm in diameter. The bulk of the gold occurs as thin plates less than 1 mm in diameter, and large quantities of black sand make complete separation of the gold difficult. The source of the gold is probably the Tertiary(?) conglomerate that is present in small isolated outcrops and commonly as small fault slivers. In the Slate Creek area, Tertiary(?) conglomerate caps the high hills to the north between Slate Creek and the Chistochina Glacier. The ultimate source of the gold and of the clasts in the Tertiary(?) conglomerate is probably on the north side of the nearby Denali fault.

Major Placer Districts -
Kodiak Island, Talkeetna and Chugach Mountains, Southern Alaska

Major placer deposits occur in the Kodiak, Hope, Nelchina, and Willow Creek districts on Kodiak Island and in the Talkeetna and Chugach Mountains (Cobb, 1973) (Table 2, Plate 2). The largest producer is the Hope district with approximately 3.1 million g of gold. Gold, cinnabar, magnetite, native copper and silver, pyrite, and scheelite in the Hope, Kodiak, and Nelchina districts are probably derived mainly from Au quartz vein lode deposits in the Late Cretaceous metagraywacke and phyllite of the Valdez Group and possibly from early Tertiary granitic plutons intruding the Valdez Group. Chromite and PGE in the Kodiak district are probably derived from the informally named Border Ranges ultramafic and mafic complex of Burns (1985). Gold and chalcopyrite in the Willow Creek district are derived from Au quartz vein deposits occurring mainly in the Talkeetna Mountains batholith.

Placer Au and Ti in modern beach deposits also are present in the Yakataga and Yakutat districts and include the Lituya Bay deposit (Thomas and Berryhill, 1962) (Table 2, Plate 1). The largest placer-gold producer is the Yakataga district, which has produced about 498,000 g of gold. Gold, chromite, magnetite, native copper, and other heavy minerals were probably derived from a combination of bedrock sources in eastern southern Alaska. These deposits are near the mouth of the Copper River which drains a major part of eastern southern Alaska, including parts of the Wrangellia, Peninsular, Chugach, and Prince William terranes (Plate 1).

Major Placer Districts - Southeastern Alaska

Major placer deposits occur in the Juneau and Porcupine Creek districts in southeastern Alaska (Wright, 1904; Cobb, 1973) (Table 2, Plate 2). The Juneau and Porcupine Creek districts have produced about 1.9 million g of gold each. The Porcupine Creek placer deposits are in bench and stream gravel. The Juneau district deposits are in hill, residual, gulch, and creek placers. Alluvial gravel contains most of the placer gold, though much of the gold has been eroded and transported by glaciers and some is in submerged glacial deposits. Placer gold and associated heavy minerals in the Juneau district deposits are probably derived mainly from Au quartz vein deposits in the Juneau gold belt.

SUMMARY

The local geology, geologic setting, classification, and metallogenesis of the major metalliferous lode and placer mineral deposits of Alaska are described for each of seven regions making up the state. The deposits are classified into types by comparing the properties of each deposit with newly developed mineral-deposit models. The mineral-deposit types in Alaska generally form specific suites for each geographic region. Within each region, the metalliferous lode mineral deposits are generally restricted to geologic units of narrow age ranges major fold, thrust, and (or) igneous belts. The origin and modification of the lode deposits in these belts is mainly is related to specific sedimentary, magmatic, metamorphic, and (or) deformational events: Deep marine, continental shelf, and epicontinental sedimentation; volcanism and plutonism in island-arc or in submerged continental-margin arc settings; arc and backarc volcanism and plutonism along continental margins; oceanic rifting and continental rifting; regional metamorphism; and regional deformation.

The northwestern Brooks Range contains several sedimentary exhalative Zn-Pb, one bedded barite, several podiform chromite, one Kipushi Cu-Pb-Zn, and various vein deposits. The southern flank of the central Brooks Range contains an extensive suite of major Kuroko massive sulfide deposits and one major carbonate-hosted Kipushi Cu-Pb-Zn deposit. The central Brooks Range contains a suite of of moderate-size polymetallic vein, Au quartz vein, Sb-Au vein, porphyry Cu and Mo, and Cu-Pb-Zn and Sn skarn deposits. The northeastern Brooks Range contains a cluster of Pb-Zn skarn, polymetallic vein, and porphyry Mo deposits. The Brooks Range contains five major districts of placer Au deposits.

The Seward Peninsula contains an extensive suite of Sn vein, Sn skarn, and Sn greisen deposits, a suite of Au quartz vein deposits, several polymetallic vein deposits, and individual porphyry Mo, felsic plutonic U, sandstone U, and metamorphosed sulfide deposits. The Seward Peninsula contains four major districts of placer Au deposits and two districts of combined placer Au and Sn deposits.

The southwestern Kuskokwim Mountains of west-central Alaska contain an Sb-Hg vein deposit, a zoned mafic-ultramafic Fe-Ti deposit, and a hot-spring Hg deposit. The central Kuskokwim Mountains contain a complex and extensive suite of Au quartz vein, Sb-Au vein, polymetallic vein, epithermal vein, hot spring Hg, Cu and Fe skarn, and felsic plutonic U deposits, and a carbonate-hosted sulfide deposit. The northeastern Kuskokwim Mountains contains several podiform chromite deposits in thin discontinuous thrust sheets of ultramafic and related rocks. The west-central Yukon-Koyukuk basin in west-central Alaska contains a suite of polymetallic vein and porphyry Mo and Cu deposits. The northern and eastern Yukon-Koyukuk basin contains suites of felsic plutonic U, polymetallic and epithermal vein, and W skarn deposits and a suite of podiform chromite and serpentinite-hosted asbestos deposits in thin discontinuous thrust sheets of ultramafic and related rocks. West-central Alaska contains seven major districts of placer Au deposits and two major districts of combined placer PGE and Au deposits.

The Manley and Livengood area in east-central Alaska contains polymetallic vein, Sb-Au vein, Mn-Ag vein, Hg vein, felsic plutonic U, Sn greisen, and Sn vein deposits. The northern and central parts of the Yukon-Tanana Upland in east-central Alaska contains suites of Sb-Au vein, Au-quartz vein, polymetallic vein, W skarn, and porphyry Cu-Mo deposits, a Au-As vein deposit, and a Sn greisen deposit. The Manley and Livengood area also contains a serpentinite-hosted asbestos deposit and a minor Pt deposit in thrust sheets of ultramafic and associated rocks. The northern Alaska Range in east-central Alaska contains an extensive district of polymetallic and Sb-Au vein and Kuroko massive sulfide deposits. East-central Alaska contains nine major placer Au districts.

The Aleutian Islands and southwest Alaska Peninsula contain an extensive suite of epithermal and polymetallic vein and porphyry Cu and Mo deposits. The northeast Alaska Peninsula contains suites of Cu-Zn-Au and Fe skarn, polymetallic vein, and porphyry Cu deposits, and one epithermal vein deposit. This region contains no major placer districts.

The southwestern Alaska Range in southern Alaska contains a suite of Cu-Pb-Zn skarn, polymetallic vein, Sn greisen and vein, and porphyry Cu-Au and Mo vein deposits, a Besshi massive sulfide deposit, and a gabbroic Ni-Cu(?) deposit. The central and eastern Alaska Range and the Wrangell Mountains in southern Alaska contain a suite of Cu-Ag and Fe skarn, polymetallic vein, and porphyry Cu and Cu-Mo deposits, and a suite of Cu-Ag quartz vein, basaltic Cu, and Besshi massive sulfide deposits. In southern Alaska, the Talkeetna Mountains contain a suite of Au quartz vein deposits, and a suite of podiform chromite deposits is present on Kodiak Island, the Kenai Peninsula, and the northern Chugach Mountains. The southern Chugach Mountains, southeast Kenai Peininsula, and Kodiak Island contain an extensive suite of Au quartz vein deposits, and the Prince William Sound district contains an extensive suite of Besshi and Cyprus massive sulfide deposits. Southern Alaska contains eleven placer Au districts and one combined placer Au and Ti district.

The Coast Mountains region in southeastern Alaska contains extensive suites of Au quartz vein, metamorphosed sulfide, and zoned mafic-ultramafic deposits, a suite of Fe skarn and porphyry Mo deposits, and a Besshi massive sulfide deposit. Central southeastern Alaska contains extensive suites of Kuroko massive sulfide and bedded barite deposits, metamorphosed sulfide deposits, Cu-Zn-Au-Ag and Fe skarn and porphyry Cu deposits, Au quartz vein deposits, zoned mafic-ultramafic deposits, a gabbroic Ni-Cu deposit, and a felsic plutonic U and a sandstone U deposit. Coastal southeastern Alaska contains suites of Au quartz vein and gabbroic Ni-Cu deposits and a basaltic Cu deposit. Southeastern Alaska contains two major placer Au districts.

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APPENDIX 1 - MAJOR TYPES OF ALASKAN METALLIFEROUS LODE AND PLACER MINERAL DEPOSITS

CLASSIFICATION OF MINERAL DEPOSITS

Metalliferous lode deposits in this report are classified into 29 types, and placer deposits are classified into four types, described below. This classification of mineral deposits is mainly derived from the mineral-deposit models developed by various specialists and compiled in Cox and Singer (1986) and to a lesser degree from those in the prior compilations of Erickson (1982) and Cox (1983a, b). In additon, four mineral deposit models for metalliferous lode deposits common in Alaska were newly formulated for this study. These additional models are for metamorphosed sulfide, Cu-Ag quartz vein, felsic-plutonic U lode, and placer Sn deposits. The lode-deposit types are listed in order from those at or near the surface, such as various stratiform deposits, to those formed at deeper levels, such as zoned mafic-ultramafic and podiform chromite deposits. Types of placer deposits are listed last. Some types of lode mineral deposits, such as various types of contact metasomatic or porphyry deposits, share a common origin and are grouped together. For a few lode deposits, lack of data precludes classification into a specific mineral deposit type. For these deposits, a brief description of the deposit is enclosed in parentheses under the Type heading in Table 1.

The mineral-deposit models used in this report and as described by various mineral-deposits geologists in Cox and Singer (1986) consist of both descriptive and genetic information that is systematically arranged to describe the essential properties of a class of mineral deposits. Some models are descriptive (empirical), in which case the various attributes are recognized as essential, even though their relationshiops are unknown. An example of a descriptive mineral deposit model is the basaltic Cu model, as adapted for this study, in which the empirical geologic association of Cu sulfides with relatively Cu-rich metabasalt or greenstone is the essential attribute. Other models are genetic (theoretical), in which case the attributes are interrelated through some fundamental concept. An example of a genetic mineral-deposit model is the W or Fe skarn (contact metasomatic) deposit model, in which the genetic process of contact metasomatism is the essential attribute. For additional information on the methodology of mineral deposit models, the reader is referred to the discussion by Cox and Singer (1986).

LODE DEPOSIT TYPES

Kuroko Massive Sulfide Deposit
(Donald A. Singer _in_ Cox and Singer, 1986)

This deposit type consists of volcanogenic, massive to disseminated sulfides in felsic to intermediate marine volcanic and pyroclastic rocks and interbedded sedimentary rocks. The volcanic rocks are mainly rhyolite and dacite with subordinate basalt and andesite. The depositional environment is mainly hot springs related to marine volcanism in island-arc or extensional regimes. The deposit minerals include pyrite, chalcopyrite, sphalerite, and lesser galena, tetrahedrite, tennantite, and magnetite. Alteration products including zeolite, montmorillonite, silica, chlorite, and sericite may be present. Notable examples of Kuroko massive sulfide deposits in Alaska are the Arctic, Smucker, and Sun deposits in the Brooks Range, the WTF, Red Mountain deposits, and Delta district deposits in east-central Alaska, and the Greens

Creek, Glacier Creek, Khayyam, and Orange Point deposits in southeastern Alaska.

Besshi Massive Sulfide Deposit
(Dennis P. Cox _in_ Cox and Singer, 1986)

This deposit type consists of thin, sheetlike bodies of massive to well-laminated pyrite, pyrrhotite, and chalcopyrite, and less abundant sulfide minerals, within thinly laminated clastic sedimentary rocks and mafic tuff. The rock types are mainly marine clastic sedimentary rocks, basaltic and lesser andesite tuff and breccia, and local black shale and red chert. The depositional environment is uncertain, but may possibly be submarine hot springs related to submarine basaltic volcanism. Associated minerals include sphalerite and lesser magnetite, galena, bornite, and tetrahedrite, with gangue quartz, carbonate, albite, white mica, and chlorite. Alteration is sometimes difficult to recognize because of metamorphism. Notable examples of Besshi massive sulfide deposits in Alaska are the Midas, Latouche, Beatson, Ellamar, and Fidalgo-Alaska mines in the Prince William Sound region of southern Alaska.

Cyprus Massive Sulfide Deposit
(Donald A. Singer _in_ Cox and Singer, 1986)

This deposit type consists of massive sulfides in pillow basalt. The depositional environment consists of submarine hot springs along an axial graben in oceanic or backarc spreading ridges or hot springs related to submarine volcanoes in seamounts. The deposit minerals consist mainly of pyrite, chalcopyrite, sphalerite, and lesser marcasite and pyrrhotite. The sulfides occur in pillow basalts that are associated with tectonized dunite, harzburgite, gabbro, sheeted diabase dikes, and fine-grained sedimentary rocks, all part of an ophiolite assemblage. Beneath the massive sulfides in places is stringer or stockwork pyrite, pyrrhotite, minor chalcopyrite, and spalerite. The sulfide minerals are locally brecciated and recemented. Alteration in the stringer zone consists of abundant quartz, chalcedony, chlorite, and some illite and calcite. Some deposits are overlain by Fe-rich and Mn-poor ochre. Notable examples of Cyprus massive sulfide deposits in Alaska are the Knight Island and Threeman mines and the Copper Bullion deposit, all in coastal southern Alaska.

Sedimentary Exhalative Zn-Pb Deposit
(Joseph A. Briskey _in_ Cox and Singer, 1986)

This deposit type consists of stratiform, massive to disseminated sulfides in sheetlike or lenslike tabular bodies that are interbedded with euxinic marine sedimentary rocks including dark shale, siltstone, limestone, chert, and sandstone. The depositional environment consists mainly of marine epicratonic embayments and intracratonic basins, with smaller local restricted basins. The deposit minerals include pyrite, pyrrhotite, sphalerite, galena, barite, and chalcopyrite. Extensive alteration may be present, including stockwork and disseminated sulfides, silica, albite, and chlorite. Notable examples of sedimentary exhalative Zn-Pb deposits in Alaska are the Lik and Red Dog Creek deposits in the northwestern Brooks Range.

Kipushi Cu-Pb-Zn (carbonate-hosted Cu) Deposit
(Dennis P. Cox *in* Cox and Singer, 1986)

This deposit type consists of stratabound, massive sulfides hosted mainly in dolomitic breccia. The depositional environment consists mainly of stong fluid flow along faults or karst(?)-breccia zones. Generally no rocks of unequivocal igneous origin are related to the deposit. The deposit minerals include pyrite, bornite, chalcocite, chalcopyrite, carrollite, sphalerite, and tennantite with minor renierite and germanite. Local dolomite, siderite, and silica alteration may occur. Notable examples of carbonate-hosted Cu deposits in Alaska are the Ruby Creek and Omar deposits in the Brooks Range.

Metamorphosed Sulfide Deposit
(this study)

This deposit type consists of stratabound, massive to disseminated sulfides hosted in moderately to highly metamorphosed and deformed metavolcanic or metasedimentary rocks. Metamorphism and deformation have obscured protoliths of host rocks and deposits so as to preclude classification into more specific deposit types. The interpreted host rocks for these deposits are mainly felsic to mafic metavolcanic rocks and metasedimentary or metavolcanic schist and gneiss. The deposit minerals include chalcopyrite, sphalerite, galena, and bornite, sometimes with pyrite, magnetite, and hematite. Alteration is usually difficult to recognize because of metamorphism. These deposits occur mainly in the regional metamorphic rocks in southeastern Alaska in either the informally named Coast plutonic-metamorphic complex of Brew and Ford (1984a, b) or the Alexander belt. Notable examples of metamorphosed sulfide deposits are the Sweetheart Ridge, Sumdum, Groundhog Basin, and Moth Bay deposits, all in southeastern Alaska.

Bedded Barite Deposit
(Greta J. Orris *in* Cox and Singer, 1986)

This deposit type consists of stratiform, massive barite interbedded with marine cherty and calcareous sedimentary rocks, mainly dark chert, shale, mudstone, and dolomite. The depositional environment consists of epicratonic marine basins or embayments, often with smaller local basins. Bedded barite deposits are often associated with sedimentary exhalative Zn-Pb or Kuroko massive sulfide deposits, described above. Alteration consists of secondary barite veining and local, weak to moderate sericite replacement. Associated minerals include minor witherite, pyrite, galena, and sphalerite. Notable examples of bedded barite deposits in Alaska are the Nimiuktuk deposit in the northwestern Brooks Range and the Castle Island mine in southeastern Alaska.

Sandstone U Deposit
(Christine Turner Peterson and Carroll A. Hodges
in Cox and Singer, 1986)

This deposit type consists of concentrations of U oxides and related U minerals in localized, reduced environments in medium- to coarse-grained feldspathic or tuffaceous sandstone, arkose, mudstone, and conglomerate. The depositional environment is continental basin margins, fluvial channels, fluvial fans, or stable coastal plain, sometimes with nearby felsic plutons or felsic volcanic rocks. The deposit minerals include pitchblende, coffinite, carnotite, and pyrite. The notable example of a sandstone U deposit in Alaska is the Death Valley deposit in west-central Alaska.

Basaltic Cu Deposit
(adapted from Dennis P. Cox <u>in</u> Cox and Singer, 1986)

This deposit type consists of copper sulfides in large pipes and lenses in carbonate rocks within a few tens of meters of disconformably underlying subaerial basalt. The depositional environment consists of subaerial basalts overlain by mixed shallow marine and nearshore carbonate sedimentary rocks, including sabhka facies carbonate rocks; subsequent subaerial eroson, groundwater leaching and (or) low-grade regional metamorphism may concentrate copper sulfides into pipes and lenses. The deposit minerals consist mainly of chalcocite and lesser bornite, chalcopyrite, and other Cu sulfides, pyrite, and oxidized Cu minerals. Alteration minerals are sometimes obscured by, or may include, malachite, azurite, metamorphic chlorite, actinolite, epidote, albite, quartz, and zeolites, and secondary dolomite. Notable examples of basaltic Cu deposits in Alaska are the Kennecott, Westover, Nelson, and Erickson mines, all in southern Alaska. This deposit type may be transitional to Besshi massive sulfide deposits, particularly those that occur in pelitic sedimentary rocks interlayered with basalt and greenstone derived from basalt, such as at the Denali deposit.

Hot-Spring Hg Deposit
(James J. Rytuba <u>in</u> Cox and Singer, 1986)

This deposit type consists of cinnabar, antimony, pyrite, and minor marcasite and native Hg in veins and in disseminations in graywacke, shale, andesite and basalt flows, andesite tuff and tuff breccia, and diabase dikes. The depositional environment is near the groundwater table in areas of former hot springs. Various alteration minerals such as kaolinite, alunite, Fe oxides, and native sulfur occur above the former groundwater table; pyrite, zeolites, potassium feldspar, chlorite, and quartz occur below the former groundwater table. Notable examples of hot-spring Hg deposits in Alaska are the Red Devil, DeCoursey Mountain, and Cinnabar Creek mines in west-central Alaska.

Epithermal Vein Deposit
(Dan L. Mosier, Takeo Sato, Norman J Page, Donald A. Singer, and Byron R. Berger <u>in</u> Cox and Singer, 1986)

This deposit type consists of quartz-carbonate-pyrite veins with a wide variety of minerals, including gold, silver sulfosalts, chalcopyrite, argentite, galena, sphalerite, and arsenopyrite. The veins occur in felsic to intermediate volcanic rocks, sometimes overlying older volcanic sequences or igneous intrusions. One class of epithermal vein deposits such as those at Creede, Colorado, has high Pb, Zn, and Ag, sometimes high Cu, and low Au concentrations; another class, such as those at Sado, Japan, has high Au, moderate to low Ag, sometimes high Cu, and generally low Pb and Zn concentrations. For both groups, the host volcanic rock composition ranges from andesite to rhyolite. The depositional environment is intermediate to felsic volcanic arcs and centers. Associated minerals include electrum, chalcopyrite, copper and silver sulfosalts, with lesser tellurides and bornite. Alteration minerals include quartz, kaolinite, montmorillonite, illite, and zeolites. Notable examples of epithermal deposits in Alaska are the Aquila and Shumagin deposits, and the Apollo-Sitka mine on the Alaska Peninsula.

Low-Sulfide Au Quartz Vein Deposit
(Byron R. Berger _in_ Cox and Singer, 1986)

This deposit type, abbreviated to Au quartz vein in this report, consists of gold in massive, persistent quartz veins in regionally metamorphosed volcanic rocks, metamorphosed graywacke, chert, and shale. The depositional environment is low-grade metamorphic belts. The veins are generally late synmetamorphic to postmetamorphic and locally cut granitic rocks. Associated minerals are minor pyrite, galena, sphalerite, chalcopyrite, arsenopyrite, and pyrrhotite. Alteration minerals include quartz, siderite, albite, and carbonate. Notable examples of low-sulfide Au quartz veins in Alaska are the Big Hurrah mine on the Seward Penisula, the Chandalar district mines in the southern Brooks Range, the Willow Creek district mines, the Nuka Bay, Monarch, Jewel, Granite, and Cliff mines in southern Alaska, and the Alaska-Juneau, Jualin, Kensington, Sumdum Chief, Treadwell, Nido, and Chichagoff mines in southeastern Alaska.

Cu-Ag Quartz Vein Deposit
(this study)

This deposit type consists of Cu sulfides and accessory Ag in quartz veins and disseminations in regionally metamorphosed mafic igneous rocks, mainly basalt, gabbro, and lesser andesite and dacite. The depositional environment is low-grade metamorphic belts. The veins are generally late-stage metamorphic. The deposit minerals include chalcopyrite, bornite, lesser chalcocite and pyrite, and rare native copper. Alteration minerals include epidote, chlorite, actinolite, albite, quartz, and zeolites. Notable examples of Cu-Ag quartz veins in Alaska are the Kathleen-Margaret and Nikolai mines in southern Alaska.

Polymetallic Vein Deposit
(Dennis P. Cox _in_ Cox and Singer, 1986)

This deposit type consists of quartz-carbonate veins with Ag, Au, and associated base-metal sulfides. The veins are related to hypabyssal intrusions in sedimentary and metamorphic terranes or to metamorphic fluids forming during waning regional metamorphism. The associated igneous rocks range in composition from calcalkaline to alkaline and occur in dike swarms, hypabyssal intrusions, and small to moderate-size, intermediate to felsic plutons, locally associated with andesite to rhyolite flows. The depositional environment is near-surface fractures and breccias within thermal aureoles of small to moderate-size intrusions and also within the intrusions. The deposit minerals include native gold, electrum, pyrite, and sphalerite, sometimes with chalcopyrite, galena, arsenopyrite, tetrahedrite, Ag sulfosalts, and argentite. Alteration consists of wide propylitic zones and narrow sericitic and argillic zones. Notable examples of polymetallic veins in Alaska are the Independence and Golden Horn mines and the Broken Shovel and Beaver Creek deposits in west-central Alaska, the Quigley Ridge, Banjo, Spruce Creek, and Stampede deposits in the Kantishna district of east-central Alaska, the Cleary Summit and Ester Dome mines in the Fairbanks district of east-central Alaska, the Sedanka and Bonanza Hills deposits of the Alaska Peninsula, and the Golden Zone deposit of southern Alaska.

Sb-Au Vein Deposit
(Adapted from simple Sb deposit of James D. Bliss and Greta J. Orris *in* Cox and Singer, 1986)

This deposit type consists of massive to disseminated stibnite and lesser gold in quartz-carbonate veins, pods, and stockworks in or adjacent to brecciated or sheared fault zones, in sedimentary, volcanic, and metamorphic rocks adjacent to granitic plutons, in contact aureoles around granitic plutons, and in peripheries of granodiorite, granite, and monzonite. The depositional environment is faults and shear zones, epizonal fractures adjacent to, or within the margins of epizonal granitic plutons. Associated minerals include arsenopyrite, chalcopyrite, and tetrahedrite, sometimes with cinnabar and galena. This deposit type is locally associated with polymetallic vein deposits. Alteration consists mainly of silica, sericite, and argillite. Notable examples of Sb-Au veins in Alaska are the Slate Creek, Eagles Den, and Caribou Creek deposits in the Kantishna district of east-central Alaska and the Scrafford mine in east-central Alaska.

Sn Greisen, Sn Vein, and Sn Skarn Deposits
(Bruce L. Reed and Dennis P. Cox *in* Cox and Singer, 1986)

These three deposit types commonly occur in the same area and sometimes grade into one another. Sn greisen deposit type consists of disseminated cassiterite, cassiterite-bearing veinlets, and Sn sulfosalts in stockworks, lenses, pipes, and breccia in greisenized granite, mainly biotite and (or) muscovite leucogranite emplaced in a mesozonal to deep volcanic environment. Sn greisens are generally postmagmatic and are associated with late-stage, fractionated granitic magma. Associated minerals include molybdenite, arsenopyrite, beryl, and wolframite. Alteration consists of incipient to massive greisen with quartz, muscovite, tourmaline, and fluorite replacement. Notable examples of Sn greisen deposits in Alaska are the Kougarok deposit on the Seward Peninsula and the Coal Creek deposit in southern Alaska.

Sn vein deposit type consists of simple to complex fissure fillings or replacement lodes in or near felsic plutonic rocks, mainly mesozonal to hypabyssal plutons, often with dike swarms. The deposits tend to occur within or above the apices of granitic cusps and ridges. The deposit minerals are extremely varied and include cassiterite, wolframite, arseonpyrite, molybdenite, scheelite, and beryl. Alteration minerals consist of sericite, tourmaline, quartz, chlorite, and hematite. The notable example of a Sn vein deposit in Alaska is the Lime Peak deposit in east-central Alaska.

Sn skarn deposit type consists of Sn, W, and Be minerals in skarns, veins, stockworks, and greisen near intrusive contacts between epizonal(?) granitic plutons and limestone. The deposit minerals include cassiterite, sometimes with scheelite, sphalerite, chalcopyrite, pyrrhotite, magnetite, and fluorite. Alteration consists of greisen near granite margins and metasomatic development of andradite, idocrase, amphibole, chlorite, and mica in skarn. The notable example of a Sn skarn deposit in Alaska is the Lost River mine on the Seward Peninsula.

Cu-Zn-Pb (± Au, Ag), W, and Fe (± Au) Skarn Deposits
(Dennis P. Cox and Theodore G. Theodore
in Cox and Singer, 1986)

Cu-Zn-Pb skarn deposit type consists of chalcopyrite, sphalerite, and galena in calc-silicate skarns that replace carbonate rocks along intrusive contacts with quartz diorite to granite and diorite to syenite plutons. Zn-Pb-rich skarns tend to occur farther from the intrusion; Cu-rich and Au-rich skarns tend to occur closer to the intrusion. The depositional environment is mainly calcareous sedimentary sequences intruded by felsic to intermediate granitic plutons. Associated minerals include pyrite, hematite, magnetite, bornite, arsenopyrite, and pyrrhotite. Metasomatic replacements consist of a wide variety of calc-silicate and related minerals. Notable examples of Cu-Zn-Pb skarn deposits in Alaska are the Bowser Creek, Rat Fork, Sheep Creek, and Tin Creek deposits. Notable examples of Cu-Au and Au skarn deposits in Alaska are the Nixon Fork-Medfra mine in west-central Alaska and the Jumbo mine in southeastern Alaska.

W skarn deposit type consists of scheelite in calc-silicate skarns that replace carbonate rocks along or near intrusive contacts with quartz diorite to granite plutons. The depositional environment is along contacts and in roof pendants of batholiths and in thermal aureoles of stocks that intrude carbonate rocks. Associated minerals are molybdenite, pyrrhotite, sphalerite, chalcopyrite, bornite, pyrite, and magnetite. Metasomatic replacements consist of a wide variety of calc-silicate and related minerals. Notable examples of W skarns in Alaska are the deposits and mines in the Gilmore Dome area of the Fairbanks district in east-central Alaska.

Fe skarn deposit type consists of magnetite and (or) Fe sulfides in calc-silicate skarns that replace carbonate rocks or calcareous clastic rocks along intrusive contacts with diorite, granodiorite, granite, and coeval volcanic rocks. The depositional environment is along intrusive contacts. The chief associated mineral is chalcopyrite. Metasomatic replacements consist of a wide variety of calc-silicate and related minerals. Notable examples of Fe skarns in Alaska are the Medfra deposit in west-central Alaska, and the Nabesna and Rambler mines in southern Alaska.

Porphyry Cu-Mo, Porphyry Cu, and Porphyry Mo Deposit
(Dennis P. Cox and Theodore G. Theodore in Cox and Singer, 1986)

The porphyry Cu-Mo deposit type consists of stockwork veinlets of quartz, chalcopyrite, and molybdenite in or near porphyritic intermediate to felsic intrusions. The intrusions are mainly stocks and breccia pipes that intrude batholithic, volcanic, or sedimentary rocks. The depositional environment is high-level intrusive porphyries that are contemporaneous with abundant dikes, faults, and breccia pipes. Associated minerals include pyrite and peripheral sphalerite, galena, and gold. Alteration minerals consist of quartz, K-feldspar, and biotite or chlorite. Notable examples of porphyry Cu-Mo deposits in Alaska are the Taurus deposit in east-central Alaska, the Orange Hill, Bond Creek, Baultoff, Horsfeld, and Carl Creek deposits in southern Alaska, and the Pyramid deposit in the Alaska Peninsula.

Porphyry Cu deposit type consists of chalcopyrite in stockwork veinlets in hydrothermally altered porphyry and adjacent country rock. The porphyries range in composition from tonalite to monzogranite to syenitic porphyry. The depositional environment is epizonal intrusive rocks with abundant dikes, breccia pipes, cupolas of batholiths, and faults. Associated minerals include pyrite, molybdenite, magnetite, and bornite. Alteration consists of sodic, potassic, phyllic, argillic, and propylitic types. An example of a porphyry Cu deposit in Alaska is the Margerie deposit in southeastern Alaska.

Porphyry Mo deposit type consists of quartz-molybdenite stockwork veinlets in granitic porphyry and adjacent country rock. The porphyries range in composition from tonalite to granodiorite to monzogranite. The depositional environment is epizonal. Associated minerals are pyrite, scheelite, chalcopyrite, and tetrahedrite. Alteration is potassic grading outward to propylitic, sometimes with phyllic and argillic overprint. A notable example of a porphyry Mo deposit in Alaska is the Quartz Hill deposit in southeastern Alaska.

Felsic Plutonic U Deposit
(this study)

This deposit type consists of disseminated U, Th, and REE minerals in fissure veins and alkalic granite dikes in, or along the margins of alkalic and peralkalic granitic plutons or in granitic plutons including granite, alkalic granite, granodiorite, syenite, and monzonite. The depositional environment is mainly the margins of epizonal to mesozonal granitic plutons. The deposit minerals include allanite, thorite, uraninite, bastnaesite, monazite, uranothorianite, and xenotime, sometimes with galena and fluorite. Notable examples of felsic plutonic U deposits in Alaska are the Mount Prindle deposit in east-central Alaska and the Bokan Mountain deposits in southeastern Alaska.

Gabbroic Ni-Cu Deposit
(Adapted from synorogenic-synvolcanic Ni-Cu deposit of Norman J Page *in* Cox and Singer, 1986)

This deposit type consists of massive lenses and disseminated sulfides in small to medium-size gabbroic intrusions in metamorphic belts of metasedimentary and metavolcanic rocks. In most areas of Alaska, the depositional environment consists of post-metamorphic and post deformational, intermediate-level intrusion of norite, gabbro-norite, and ultramafic rocks. The deposit minerals include pyrrhotite, pentlandite, and chalcopyrite, sometimes with pyrite, Ti or Cr magnetite, and PGE minerals and alloys. Accessory Co also occurs in some deposits. Notable examples of gabbroic Ni-Cu deposits in Alaska are the Funter Bay, Brady Glacier, Bohemia Basin, and Mirror Harbor deposits, all in southeastern Alaska.

Zoned Mafic-Ultramafic Cr-Pt (± Cu, Ni, Co, Ti or Fe) Deposit
(Adapted from Alaskan PGE deposit type of Norman J Page and Floyd Gray *in* Cox and Singer, 1986)

This deposit type consists of crosscutting ultramafic to mafic plutons with approximately concentric zoning that contain chromite, PGE (Pt-group elements), PGE minerals and alloys, and Ti-V magnetite. In most areas of Alaska, the depositional environment consists of postmetamorphic and postdeformational, intermediate-level intrusion of mafic and (or) ultramafic plutons. The deposit minerals include combinations of chromite, PGE, pentlandite, pyrrhotite, Ti-V magnetite, bornite, and chalcopyrite. Notable examples of zoned mafic-ultramafic deposits in Alaska are the Kemuk Mountain deposit in west-central Alaska, and the Union Bay, Duke Island, and Klukwan deposits and the Salt Chuck mine, all in southeastern Alaska.

Podiform Chromite Deposit
(John P. Albers in Cox and Singer, 1986)

This deposit type consists of podlike masses of chromite in the ultramafic parts of ophiolite complexes, locally intensely faulted and dismembered. The host rock types are mainly dunite and harzburgite, commonly serpentinized. The depositional environment consists of magmatic cumulates in elongate magma pockets. The deposit minerals include chromite, magnetite, and PGE minerals and alloys. Notable examples of podiform chromite deposits in Alaska are the the Iyikrok Mountain and Avan deposits in the northwestern Brooks Range, the Kaiyuh River deposit in west-central Alaska, and the Halibut Bay and Claim Point deposits and the Red Mountain mine in southern Alaska.

Serpentinite-Hosted Asbestos Deposit
(Norman J Page in Cox and Singer, 1986)

This deposit type consists of chrysotile asbestos developed in stockworks in serpentinized ultramafic rocks. The depositional environment is usually an ophiolite sequence, sometimes with later deformation or igneous intrusion. Associated minerals are magnetite, brucite, talc, and tremolite. The notable example of a serpentinite-hosted asbestos deposit in Alaska is the Fortymile deposit in east-central Alaska.

PLACER DEPOSIT TYPES

Placer Au Deposit
(Warren Yeend in Cox and Singer, 1986)

This deposit type consists of elemental gold as grains and rarely as nuggets in gravel, sand, silt, and clay and their consolidated equivalents in alluvial, beach, aeolian, and rarely in glacial deposits. The depositional environment is high-energy alluvial where gradients flatten and river velocities lessen, as at the inside of meanders, below rapids and falls, and beneath boulders, and in shoreline and beaches where the winnowing action of surf causes Au concentrations. The major deposit minerals are gold, sometimes with attached quartz, magnetite, and (or) ilmenite. Notable examples of placer Au deposits in Alaska are in the Wiseman district in the southern Brooks Range, the Nome, Council, and Fairhaven districts on the Seward Peninsula, the Marshall, Aniak, Iditarod, Innoko, McGrath, Ruby, Hughes, Hot Springs, and Tolovana districts in west-central Alaska, the Fairbanks, Circle, Fortymile, and Kantishna placer districts in east-central Alaska, the Valdez, Chistochina, Nizina, Hope, and Willow Creek districts in southern Alaska, and the Porcupine Creek and Juneau districts in southeastern Alaska.

Placer Sn Deposit
(this study)

This deposit type consists mainly of cassiterite and elemental gold in grains in gravel, sand, silt, and clay and their consolidated equivalents mainly in alluvial deposits. The depositional environment is similar to that of placer Au deposits. Notable examples of placer Sn deposits in Alaska are those derived from Sn granites, such as in the Kougarok district on the Seward Peninsula and the Hot Springs district in west-central Alaska.

Placer PGE-Au Deposit
(Warren Yeend and Norman J Page *in* Cox and Singer, 1986)

This deposit type consists of PGE minerals and alloys in grains in gravel, sand, silt, and clay and their consolidated equivalents in alluvial, beach, aeolian, and rarely in glacial deposits. In some areas, placer Au and placer PGE deposits occur together. The depositional environment is high-energy alluvial where gradients flatten and river velocities lessen, as at the inside of meanders, below rapids and falls, and beneath boulders, and in shoreline areas where the winnowing action of surf causes PGE and Au concentrations in beaches. The major deposit minerals are Pt-group alloys, Os-Ir alloys, magnetite, chromite, and (or) ilmenite. The notable example of a placer PGE deposit in Alaska is the Goodnews Bay placer district.

Shoreline Placer Ti Deposit
(Eric R. Force *in* Cox and Singer, 1986)

This deposit type consists of ilmenite and other heavy minerals concentrated by beach processes and enriched by weathering. The hosting sediment types are medium- to fine-grained sand in dune, beach, and inlet deposits. The depositional environment is stable coastal region receiving sediment from bedrock regions. The major deposit minerals are low-Fe ilmenite, sometimes with rutile, zircon, and gold. Notable examples of shoreline placer Ti deposits in Alaska are the Yakutat (Lituya Bay) placer districts.

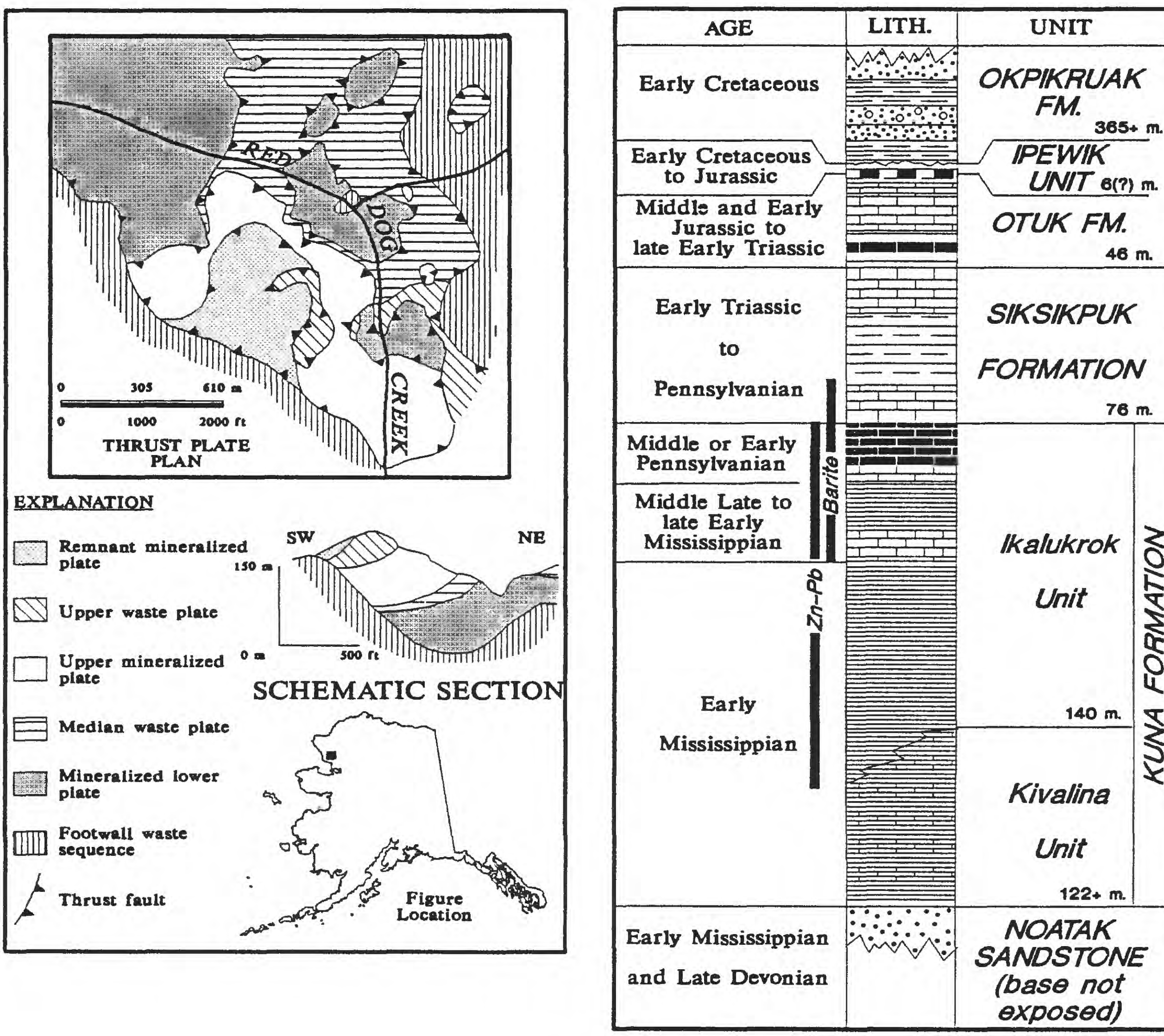


Figure 1. Thrust plate map and simplified cross section of the Red Dog Creek Zn-Pb-Ag deposit, Delong Mountains, northwestern Brooks Range. Base-metal sulfides and barite deposits occur in the Kuna Formation.

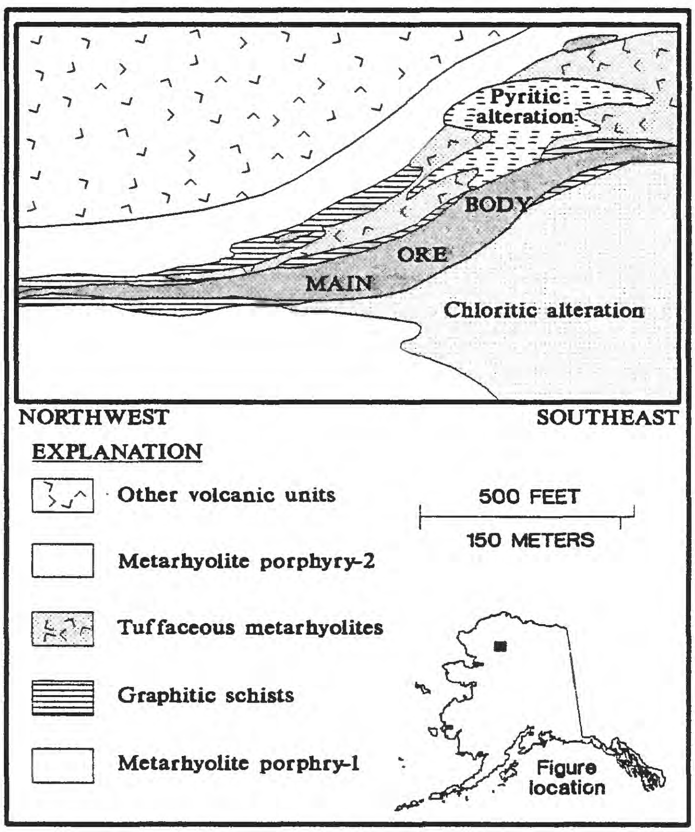


Figure 2. Schematic cross section of the Arctic Zn-Cu-Ag deposit, Ambler district, southern Brooks Range. The Main ore body is overlain by a pyritic alteration zone and underlain by a zone of intense chloritic alteration.

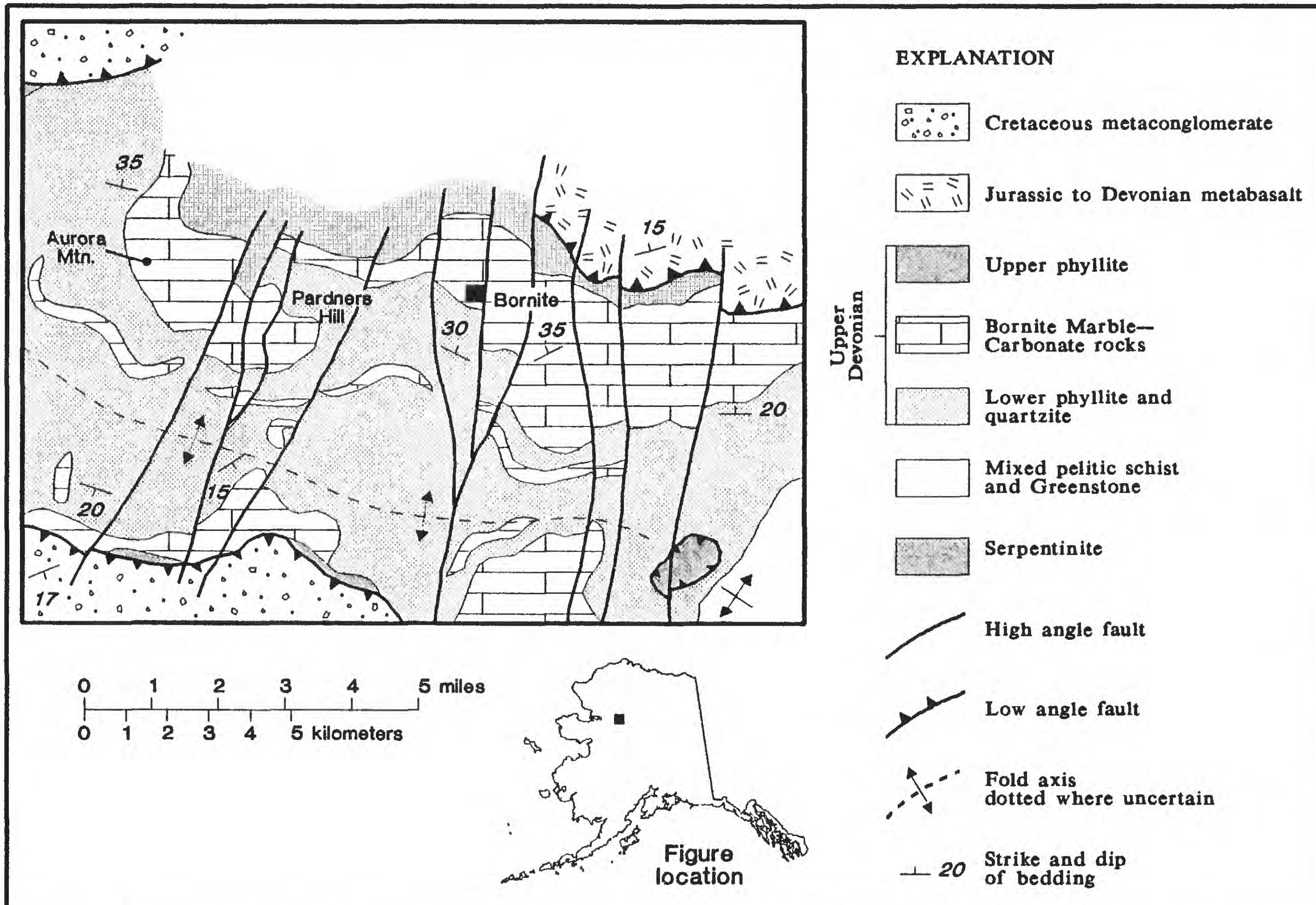


Figure 3. Generalized geologic map of the Cosmos Hills showing the Bornite (Ruby Creek) area, Ambler district, southern Brooks Range.

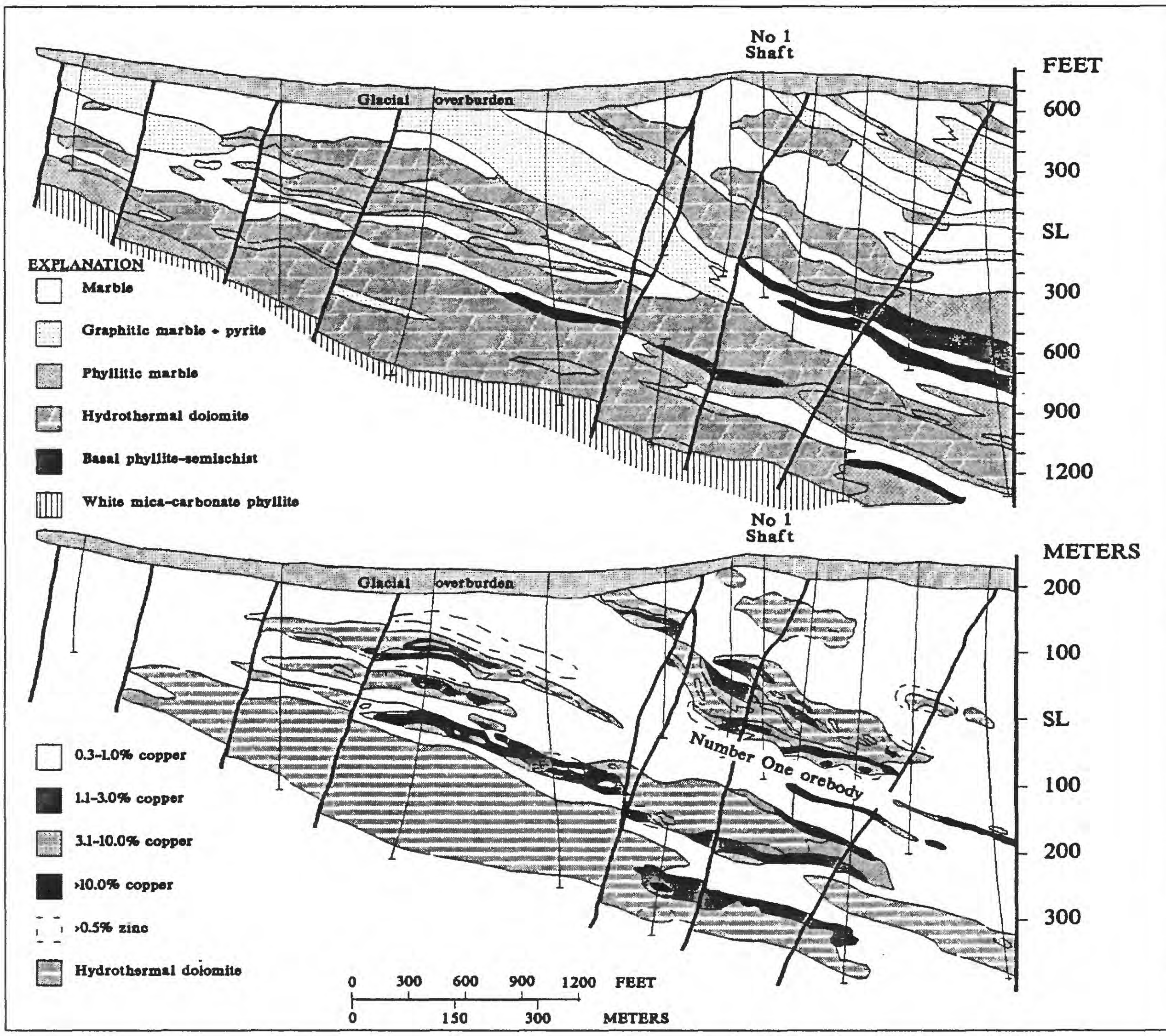
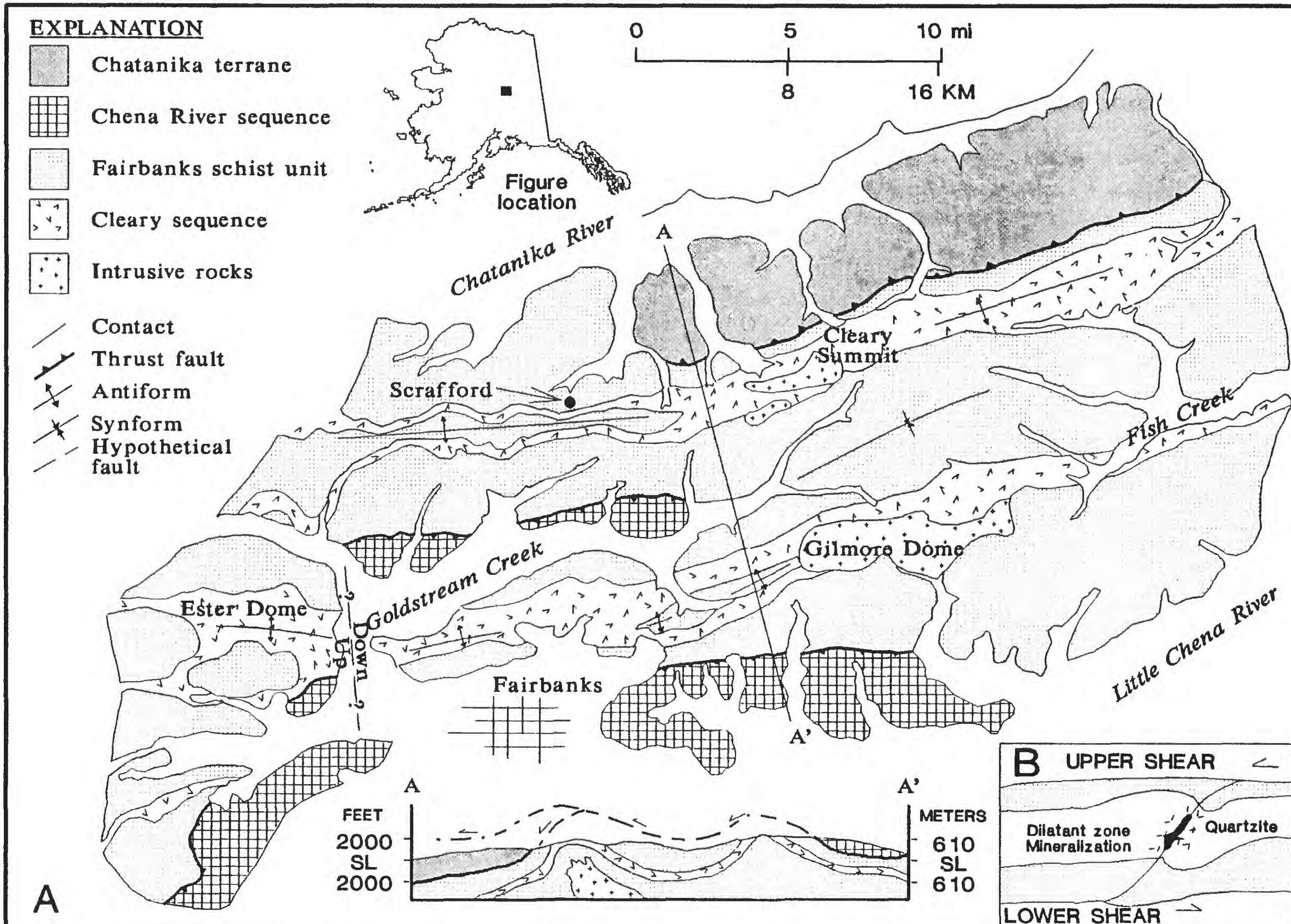


Figure 4. Interpretive cross section and Cu and Zn distributions for the Ruby Creek Cu deposit, Ambler district, southern Brooks Range. Note the relationship between the sulfide deposits and the occurrence of hydrothermal dolomite.

Figure 5. Fairbanks district, northern Yukon-Tanana Upland, east-central Alaska. A. Generalized bedrock geologic map and cross section showing distribution of the Cleary sequence along anticlinal ridge crests and locations of four principal areas of mineral deposits. B. Model of typical sulfide-bearing shear with crushed zone where shear intersects a competent quartzite horizon. The crush zones typically host gold-bearing quartz veins.



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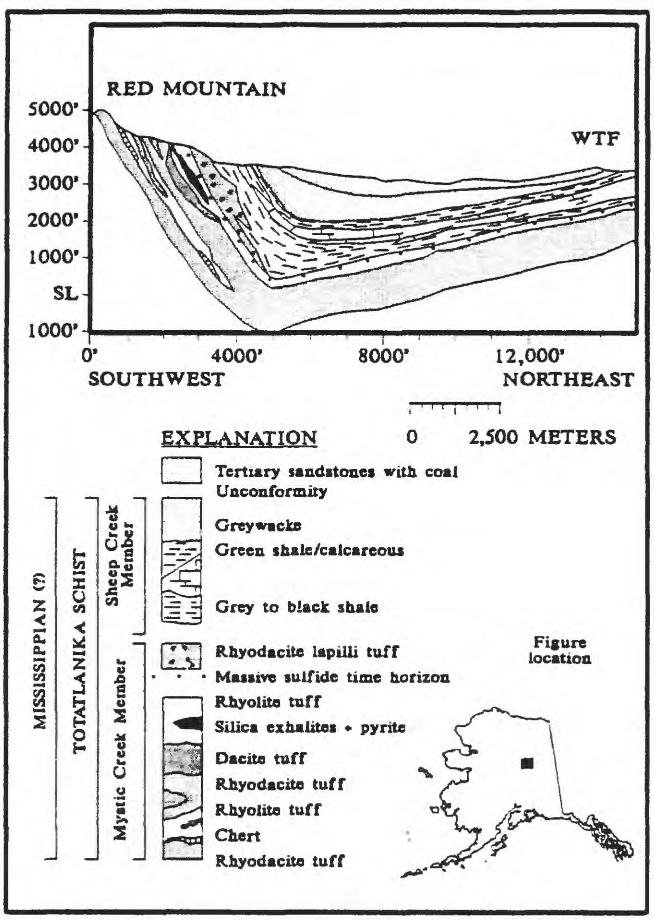

Figure 6. Generalized cross section through WTF and Red Mountain Zn-Pb-Cu-Ag deposits, northern Alaska Range, east-central Alaska. No vertical exxageration. The deposits are localized near the top of the Mystic Creek Member of the Totatlanika Schist. The WTF and Red Mountain deposits appear to represent coeval proximal and distal volcanogenic sulfide deposits, respectively.

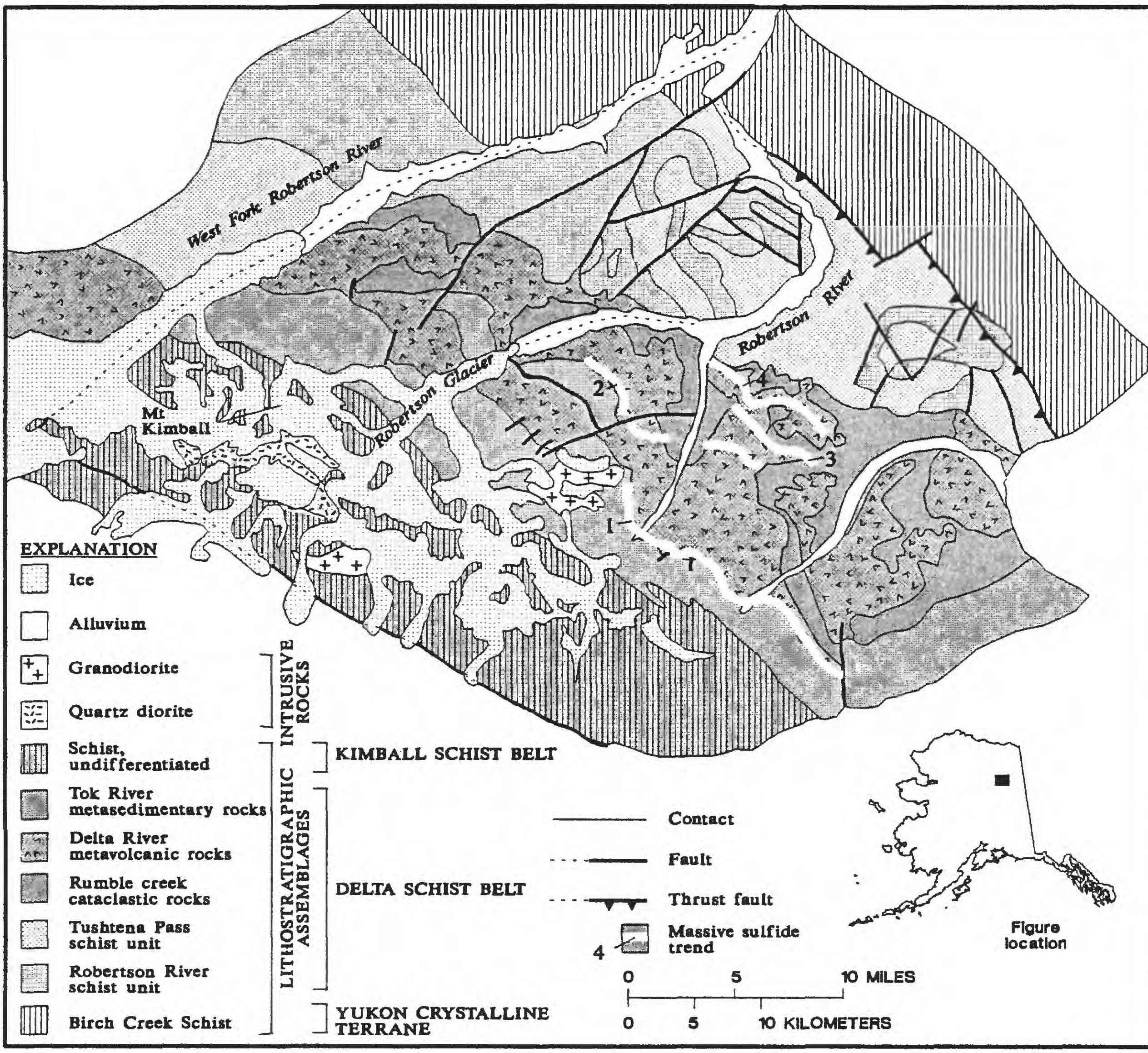

Figure 7. Generalized geologic map of the Pb-Zn-Cu-Ag deposits in the Delta district, northern Alaska Range, east-central Alaska.

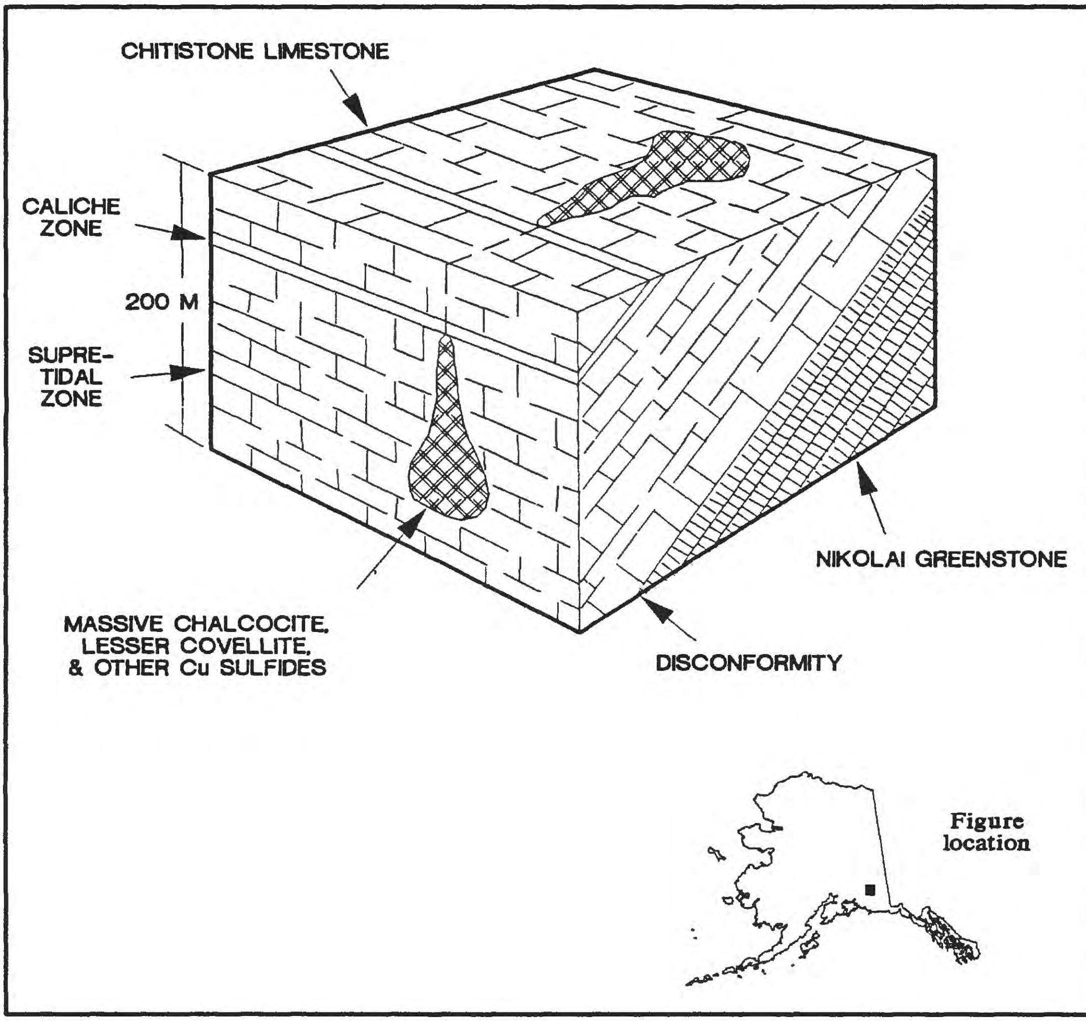

Figure 8. Generalized oblique view block diagram of the Bonanza Cu-Ag deposit in the Kennecott district, Wrangell Mountains, southern Alaska. Adapted from Bateman and McLaughlin (1920), and Armstrong and Mackevett (1982).

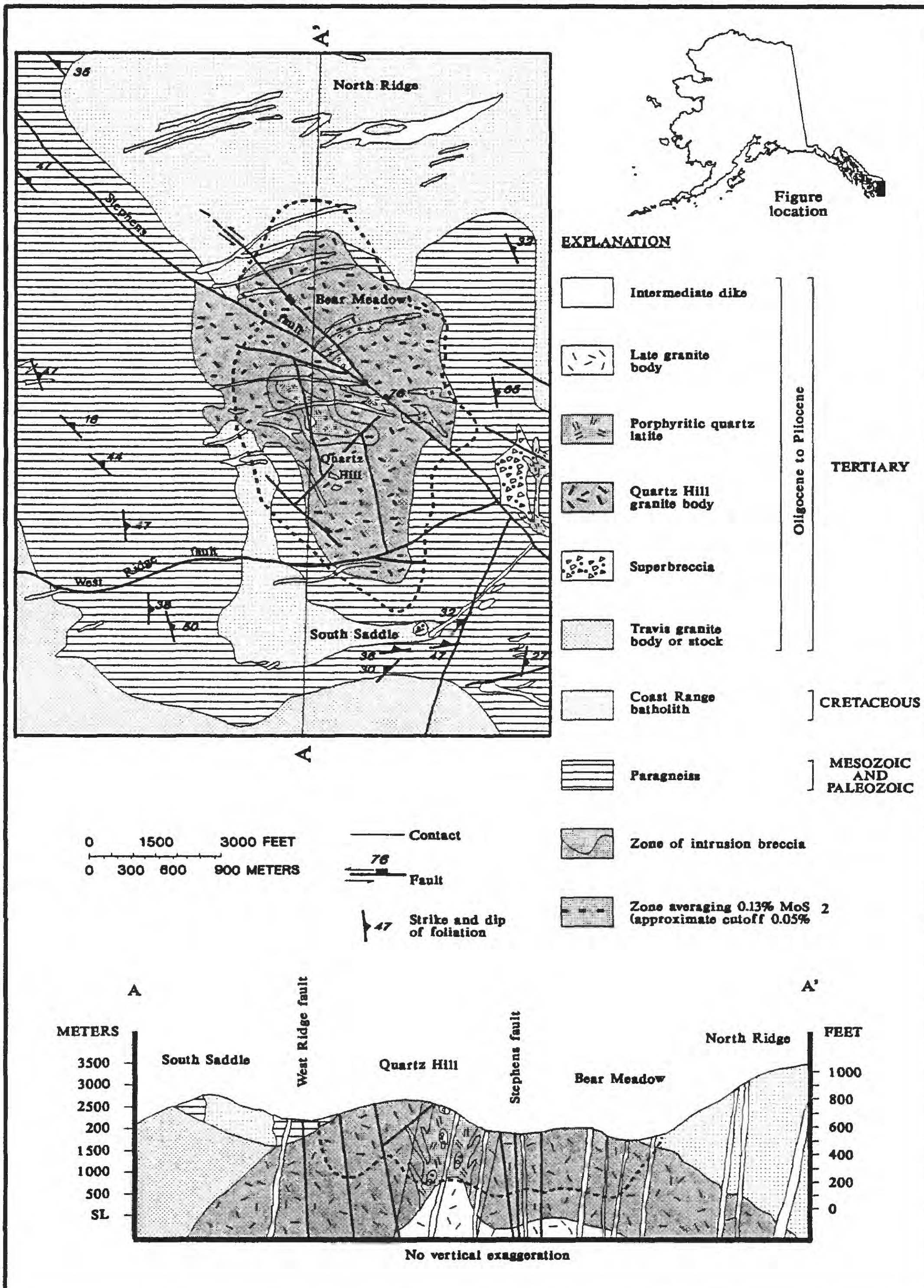

Figure 9. Generalized geologic map and cross section of the Quartz Hill porphyry Mo deposit, Coast Mountains Region, southeastern Alaska. The Mo deposit is hosted in a hypabyssal Tertiary intrusive complex informally named the Quartz Hill stock.

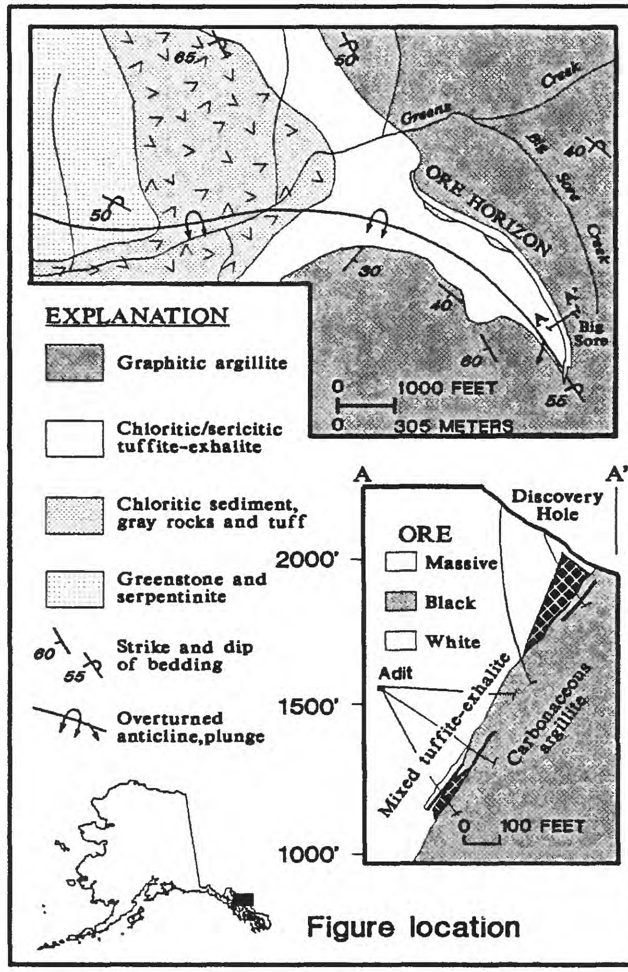

Figure 10. Generalized geologic map and cross section of the Greens Creek Zn-Pb-Ag-Au deposit, Admiralty island, central southeastern Alaska. The location of sulfides is near the nose of an asymmetrical overturned anticline, between a stratigraphic footwall of mixed tuff and exhalite and a hanging wall of carbonaceous argillite.