Metallogenesis and Tectonics of the Russian Far East, Alaska, and the Canadian Cordillera

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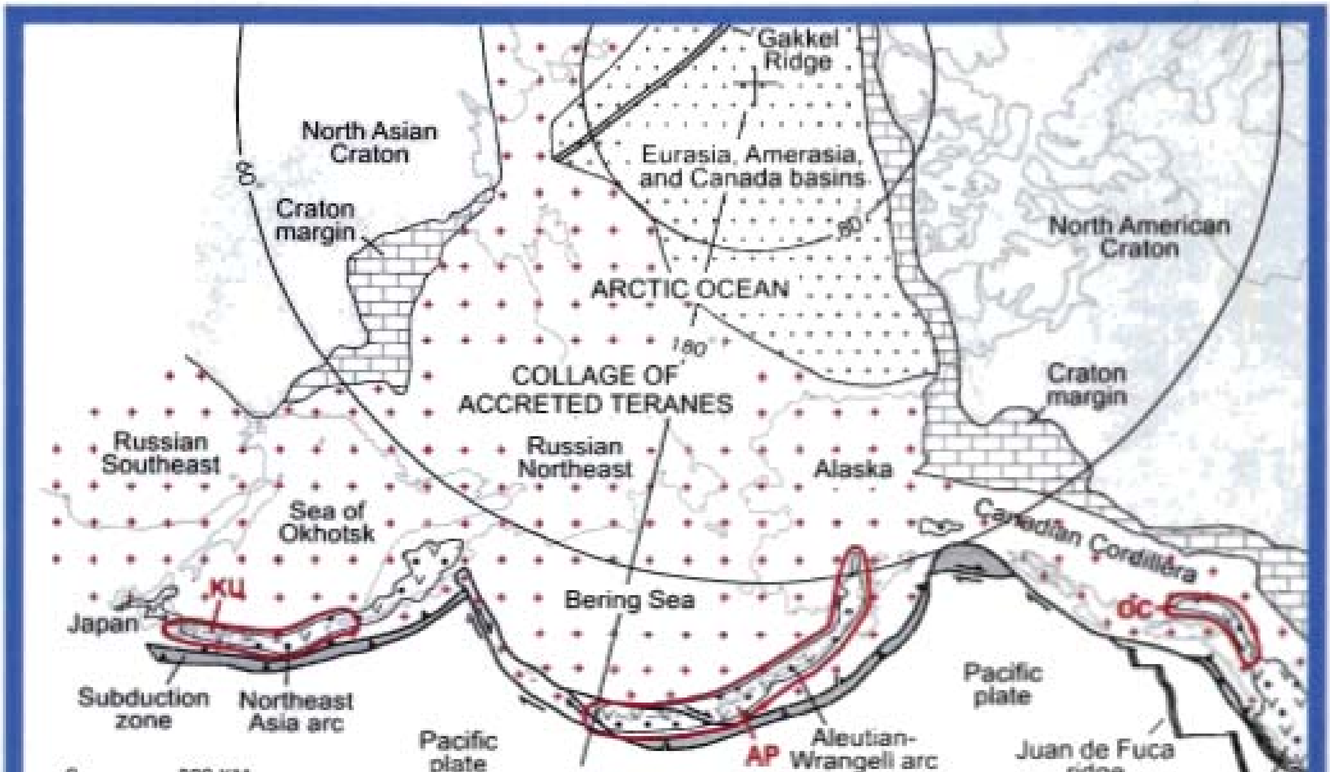

MAJOR PRESENT-DAY METALLOGENIC BELTS AND TECTONIC ELEMENTS FOR CIRCUM-NORTH PACIFIC

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U.S. Department of the Interior
U.S. Geological Survey

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

METALLOGENESIS AND TECTONICS OF THE RUSSIAN FAR EAST, ALASKA, AND THE CANADIAN CORDILLERA

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Cover Figure. Major present-day metallogenic and tectonic elements for the Circum-North Pacific and geographic names for major regions. The major features, continued from the Neogene are: (1) a series of continental-margin arcs and companion subduction-zone assemblages around the Circum-North Pacific; (2) continuation of opening of major sedimentary basins behind major arcs; (3) in the eastern part of the Circum-North Pacific, dextral transpression between the Pacific Ocean plate and the present-day Canadian Cordillera margin; and (4) sea-floor spreading in the Arctic and eastern Pacific Oceans. Refer to text for detailed explanation of tectonic events (section on Pliocene to Present) and to figure 18 for explanation of abbreviations, symbols, and patterns. The major metallogenic belts are: (1) the Kuril (KU) metallogenic belt which is hosted in the Kuril volcanic-plutonic belt; (2) the Alaska Peninsula and Aleutian Islands (AP) metallogenic belt which contains granitic-magmatism-related deposits and is hosted in the Aleutian volcanic belt; and (3) the Owl Creek (OC) metallogenic belt which is hosted in the Cascade volcanic-plutonic belt.

Metallogenesis and Tectonics of the Russian Far East, Alaska, and the Canadian Cordillera

Abstract

The Proterozoic and Phanerozoic metallogenic and tectonic evolution of the Russian Far East, Alaska, and the Canadian Cordillera is recorded in the cratons, craton margins, and orogenic collages of the Circum-North Pacific mountain belts which separate the North Pacific from the eastern North Asian and western North American Cratons. The collages consist of tectonostratigraphic terranes and contained metallogenic belts which are composed of fragments of igneous arcs, accretionary-wedge and subduction-zone complexes, passive continental margins, and cratons. The terranes are overlapped by continental-margin-arc and sedimentary-basin assemblages and contained metallogenic belts. The metallogenic and geologic history of terranes, overlap assemblages, cratons, and craton margins has been complicated by post-accretion dismemberment and translation during strike-slip faulting which occurred subparallel to continental margins.

Seven processes overlapping in time were responsible for most of metallogenic and geologic complexities of the region. (1) In the Early and Middle Proterozoic, marine sedimentary basins developed on major cratons and were the loci for ironstone (Superior Fe) deposits and sediment-hosted Cu deposits which occur along both the North Asia Craton and North American Craton Margin. (2) In the Late Proterozoic, Late Devonian, and Early Carboniferous, major periods of rifting occurred along the ancestral margins of present-day Northeast Asia and northwestern North American. The rifting resulted in fragmentation of each continent, and formation of cratonal and passive continental-margin terranes which eventually migrated and accreted to other sites along the evolving margins of the original or adjacent continents. The rifting also resulted in formation of various massive-sulfide metallogenic belts. (3) From about the late Paleozoic through the mid-Cretaceous, a succession of island arcs and contained igneous-arc-related metallogenic belts, and tectonically paired subduction zones formed near continental margins. (4) From about mainly the mid-Cretaceous through the present, a succession of continental-margin igneous arcs (some extending offshore into island arcs) and contained metallogenic belts, and tectonically paired subduction zones formed along the continental margins. (5) From about the Jurassic to the present, oblique convergence and rotations caused orogen-parallel sinistral, and then dextral displacements within the plate margins of the Northeast Asian and North American cratons. The oblique convergences and rotations resulted in the fragmentation, displacement, and duplication of formerly more continuous arcs, subduction zones, passive continental margins, and contained metallogenic belts. These fragments were subsequently accreted along the margins of the expanding continental margins. (6) From the Early Jurassic through Tertiary, movement of the upper continental plates toward subduction zones resulted in strong plate coupling and

accretion of the former island arcs, subduction zones, and contained metallogenic belts to continental margins. In this region, the multiple arc accretions were accompanied and followed by crustal thickening, anatexis, metamorphism, formation of collision-related metallogenic belts, and uplift; this resulted in the substantial growth of the North Asian and North American continents. And (7) in the middle and late Cenozoic, oblique to orthogonal convergence of the Pacific Plate with present-day Alaska and Northeast Asia resulted in formation of the present ring of volcanoes and contained metallogenic belts around the Circum-North Pacific. Oblique convergence between the Pacific Plate and Alaska also resulted in major dextral-slip faulting in interior and Southern Alaska and along the western part of the Aleutian-Wrangell arc. Associated with dextral-slip faulting was crustal extrusion of terranes from Western Alaska into the Bering Sea.

Introduction

This report provides an analysis of the metallogenesis and tectonics of significant metalliferous lode deposits, selected major nonmetalliferous lode deposits, and host rocks in the Russian Far East, Alaska, and the Canadian Cordillera. The report is based on a series of published terrane and overlap assemblage maps, mineral deposit and metallogenic belt maps, and mineral deposit databases, and interpretive articles for the region (Nokleberg and others, 1987, 1993, 1994a, b, c, d, 1995a, 1996, 1997a, b, c, 1988a, b, 1989a, b, 2000). For the analysis, this report synthesizes and combines coeval and genetically-related groups of significant lode mineral deposits into metallogenic belts. Each section on a specific metallogenic belt contains: (1) a description of the significant mineral deposits; (2) a description of the host rocks for the significant lode deposits; and (3) an interpretation of the origin of, and tectonic controls for the host rocks and contained deposits and metallogenic belt(s). The report also provides: (1) metallogenic and tectonic definitions; (2) explanation of methodology; (3) list of mineral deposits models; (4) an integrated metallogenic and tectonic model for the Phanerozoic geologic history of the region; and (5) an extensive list of cited references for the geology, mineral deposits, metallogenesis, and tectonics of the region. The descriptions of significant mineral deposits in this report are adapted from Nokleberg and others (1997a), with additional data and revision from the authors. For British Columbia (southwest Canadian Cordillera), descriptions of significant mineral deposits are also revised with new data from MINFILE (2002).

The Russian Far East, Alaska, and the Canadian Cordillera are commonly regarded as frontier areas in the world for the discovery of metalliferous lode and placer deposits. During the late 1800's and early 1900's, the region was subject to recurring *rushes* or *stampedes* to sites of newly discovered deposits. During the last few decades, the region has been substantially explored

for lode and placer deposits, and geologically mapped and assessed for mineral resource potential at various scales. These activities have resulted in abundant new information on lode and placer deposits, geology, and patterns of mineral resources. In addition over the last three decades, various tectonic analyses have interpreted the region as being composed of numerous fault-bounded assemblages of rocks defined as tectono-stratigraphic terranes (Jones and others, 1987; Monger and Berg, 1984, 1987; Zonenshain and others, 1990; Silberling and others, 1992; Nokleberg and others, 1994c, 1997c; 2000; Parfenov, 1995a; Monger and Nokleberg, 1996).

This report defines, describes, synthesizes, and interprets the major metallogenic belts and contained significant lode mineral deposits according to tectonic origins. This paper contains five types of information and interpretation: (1) an introduction and discussion of terms, methods, and concepts applied to the metallogenesis and tectonics of the region; (2) descriptions and interpretations of metallogenic belts and their notable or significant lode deposits; (3) description of the host rocks for the major metallogenic belts; (4) interpretation of the tectonic origin of metallogenic belts and host rocks; and (5) a model for the Phanerozoic metallogenic and tectonic evolution of the region. The method of metallogenic analysis utilized in this study is modeled after that employed for a metallogenic and tectonic analysis of porphyry copper and molybdenum (gold, silver), and granitoid-hosted gold deposits of Alaska (Nokleberg and others, 1995). Related recently-published articles are: (1) a dynamic computer model, which illustrates the metallogenesis and tectonics of the Circum-North Pacific (Scotese and others, 2001); and an article interpreting the Phanerozoic tectonic evolution of the Circum-North Pacific by Nokleberg and others (2000).

Associated Project

This study is the concluding part of a project on the significant mineral deposits, metallogenesis, and tectonics of the Russian Far East, Alaska, and the Canadian Cordillera. The project provides critical information on bedrock geology and geophysics, tectonics, major metalliferous mineral resources, metallogenic patterns, and crustal origin and evolution of mineralizing systems of the region. The major scientific goals and benefits of the project are to: (1) provide a comprehensive international data base for the mineral resources of the region in English; (2) provide major new interpretations of the origin and crustal evolution of mineralizing systems and their host rocks, thereby enabling enhanced, broad-scale tectonic reconstructions and interpretations; and (3) promote trade, scientific, and technical exchanges between North America and the Russian Far East. The project provides sound scientific data and interpretations for commercial firms, governmental agencies, universities, and individuals which are developing new ventures and studies in the project area, and also for land-use planning studies which deal with mineral-resource potential issues. Vast potential for known and undiscovered mineral deposits exists in the western part of the study area; however, prior to this study, little information existed in English in the West.

Major companion studies already published are: (1) a compilation and analysis of the regional metallogenesis of the Circum-North Pacific (Nokleberg and others, 1993); (2) a tectono-stratigraphic terrane map of the Circum-North Pacific at a scale of 1:5,000,000, including a detailed explanation of map units and stratigraphic columns (Nokleberg and others, 1994c; digital version in Grenninger and others, 1999); (3) a summary terrane map of the Circum-North Pacific at a scale 1:10,000,000 (Nokleberg and others, 1997c); (4) detailed tables of mineral deposits and placer districts for the Russian Far East, Alaska, and the Canadian Cordillera in paper format (Nokleberg and others, 1996) and in CD-ROM format (Nokleberg and others, 1997a); (5) a GIS compilation of the summary terrane map, mineral deposit maps, and metallogenic belt maps of the Russian Far East, Alaska, and the Canadian Cordillera (Nokleberg and others, 1998); (6) a study of the Phanerozoic tectonic evolution of the Circum-North Pacific (Nokleberg and others, 2000); and (7) a dynamic computer model for the metallogenesis and tectonics of the Circum-North Pacific (Scotese and others, 2001). These articles, tables, and maps contain the full suite of mineral deposit data, mineral deposit location maps, metallogenic belt maps, and tectonic interpretations which are utilized in this study.

A complete listing of the project goals, and methods are available on the Internet/Web at http://minerals.er.usgs.gov/wr/projects/majdeps.html. Major recent articles for the project (Nokleberg and others, 1993, 1994a, 1996, 1997a, b, c, 1998, 2000) are available on the Internet/Web at http://wrgis.wr.usgs.gov/. This project was started at the invitation of the Soviet Academy of Sciences to the U.S. Geological Survey in 1988. Subsequently, several organizations and many individuals volunteered to work on various aspects of the project which has produced a large variety of articles and maps. Other organizations participating in the project include the Russian Academy of Sciences, Russian Ministry of Natural Resources (former Ministry of Geology and ROSKOMNEDRA), Alaska Division of Geological and Geophysical Surveys, Geological Survey of Canada, Geological Survey of Japan, Exxon Exploration Company, University of Alaska, and Michigan State University.

This project represents a major joint attempt of a large group of geologists from Russia, Alaska, and the Canadian Cordillera to compile, synthesize, interpret, and publish major studies on the mineral resources, metallogenesis, and tectonics of this vast and geologically complicated region of the earth. The project includes a number of geologists who have each gathered field data and observations in their respective parts of the Russian Far East, Alaska, and Canadian Cordillera over many years and who have come together as a large international team to compile and synthesis a vast amount of data for a large region of the earth. Other recent metallogenic synthesis of parts of the Russian Far East, Alaska, and the Canadian Cordillera include those by Dawson and others (1991), Sidorov and Eremin (1994), Goncharov (1995a, b), Goryachev (1995, 2003), Nekrasov (1995), Parfenov (1995d), Popeko (1995), Ratkin (1995), Ratkin and Khanchuk (1995), Nokleberg and others (1984, 1987, 1988, 1993, 1994a, b, 1995a, 1996, 1997a, b), Sidorov and Eremin (1995), Goldfarb (1997), Goldfarb and others (1997, 1998, 2000), and Young and others (1997). A volume containing papers on the geology and mineral deposits of the Russian Far East was edited by Bundtzen and others (1995). A volume containing papers on the stratiform ore deposits in northeastern Asia was edited Goryachev and Byalobzhesky (1996). A volume containing papers on the mineral deposits of Alaska was edited by Goldfarb and Miller (1997). A volume on the geology of Mesozoic gold quartz veins in Northeastern Asia was published by Goryachev (1998). A volume on the pre-Cretaceous metallogeny of Northeastern Asia was published by Shpikerman (1998). A volume containing papers on the Tintina Gold Belt in Alaska and the Yukon-Territory, Canada was edited by Tucker and Smith (2000).

Metallogenic Belts

In this study, the regional metallogenesis of the Russian Far East, Alaska, and the Canadian Cordillera is synthesized, compiled, and interpreted in terms of metallogenic belts. This synthesis and compilation is based on data for about 1,079 significant lode deposits and 144 major metallogenic belts for the region (Nokleberg and others 1997a, b, 1998). A key element for this type of analysis is definition of metallogenic belt which is defined on the basis of a geologic unit (area) which either contains or is favorable for a group of coeval and genetically related, significant lode mineral deposit types (defined in the below section on definitions). A metallogenic belt may be of irregular shape and variable size; the size is partly a function of the scale of the analysis; in this study, metallogenic belts were synthesized and compiled at a scale of 1:10,000,000 scale (Nokleberg and others 1997a, b, 1998). In this report for each time span, metallogenic belts are described in a clockwise geographic succession, according to similar tectonic environments, around the Circum-North Pacific, from the Russian Far East to Alaska to the Canadian Cordillera.

For definition and outline of metallogenic belts, the following criteria were used. (Nokleberg and others, 1995a). (1) *Mineral Deposit Association.* Each metallogenic belt includes a single mineral deposit type or a group of coeval, closely-located and genetically-related mineral deposits types for the region, as listed in Table 1. (2) *Tectonic Event for Formation of Mineral Deposits.* Each belt includes a group mineral deposits which formed in a specific tectonic event (e.g., collision, accretion, rifting, etc.). And (3) *favorable Geological Environment.* Because a metallogenic belt is underlain by a geological host rock and (or) structure which is favorable for a particular suite of mineral deposit types, a belt is predictive for undiscovered deposits. Consequently, the synthesis and compilation of metallogenic belts can be useful for mineral exploration, land-use planning, and environmental studies.

In this study, a metallogenic belt is essentially synonymous with the term *mineral-resource tract* as originally defined by Pratt (1981) and used for assessment of mineral resource potential in the USA, as exemplified in Ludington and Cox (1996). The metallogenic belt maps and underlying regional geologic (terrane and overlap assemblage) maps constitute a basic part of the three-part methodology of quantitative mineral resource assessment as described by Cox (1993) and Singer (1993, 1994).

Methodology

The methodology for the analysis of the complex metallogenic and tectonic history of the Russian Far East, Alaska, and the Canadian Cordillera consists of the following steps. (1) The significant lode deposits are described and classified according to defined mineral deposit models (table 1). Description of the mineral deposit models for the region, and descriptions of the 1,079 significant lode deposits and 161 placer districts for the region are contained in Nokleberg and others (1996, 1997a); (2) Metallogenic belts are delineated (Nokleberg and others, 1997b). (3) Tectonic environments (Tables 2, 3) for the cratons, craton margins, orogenic collages of terranes, overlap assemblages, and contained metallogenic belts are assigned from regional compilation and synthesis of stratigraphic, structural, metamorphic, isotopic, faunal, paleomagnetic, and provenance data. The tectonic environments include cratonal, passive continental margin, metamorphosed continental margin, continental-margin arc, island arc, transform continental-margin arc, oceanic crust, seamount, ophiolite, accretionary wedge, subduction zone, turbidite basin, and metamorphic (Nokleberg and others, 1994c, 1997c; Greninger and others, 1999). (4) Correlations are made between terranes, fragments of overlap assemblages, and fragments of contained metallogenic belts. (5) Coeval terranes and their contained metallogenic belts are grouped into those that formed in a single metallogenic and tectonic origin, for instance, into a single island arc or subduction zone. (6) Igneous-arc and subduction-zone terranes, which are interpreted as being tectonically linked, and their contained metallogenic belts, are grouped into coeval, curvilinear arc-subduction-zone-complexes. (7) Geologic, faunal, and paleomagnetic data are employed to interpret the original geographic positions of terranes and their metallogenic belts. (8) The paths of tectonic migration of terranes and contained metallogenic belts are constructed. (9) The timing and nature of accretion of various terranes and contained metallogenic belts are determined from geologic, age, and structural data. (10) The nature of collision-related geologic units and their contained metallogenic belts are determined from geologic data. (11) The age and nature of post-accretionary overlap assemblages and contained metallogenic belts are determined from geologic and age data. The part of this methodology, that enables the correlation of belts of related lode deposits to the tectonic origin of host rock units, was first employed for Northern and Central America by Albers and others (1988).

For additional information on the tectonic analysis of the region, including correlations of terranes and tectonic linkages between terranes and overlap assemblages, the reader is referred to Table 2 (derived from Nokleberg and others, 2000). For a summary of the tectonic setting (environment) of the major Proterozoic and Phanerozoic metallogenic belts in the region, the mineral deposit models, and the significant mineral deposits in each belt, the reader is referred to Table 3. For a listing of the significant mineral deposits in each major metallogenic belt, locations of deposits, major metals in each deposit, refer to Table 4. Most significant mineral deposits for British Columbia (southwest Canadian Cordillera) have deposit numbers from MINFILE (2002). These deposit descriptions can be accessed from the MINFILE Web site at www.em.gov.bc.ca/mining/geolsurv/minfile/

A theoretical example of the first steps of the methodology for the metallogenic and tectonic analysis is provided in figure 1. Figure 1A illustrates a theoretical suite of metallogenic belts which are hosted in several geologic units cratons, terranes, and overlap assemblages, or along major faults between terranes. Figure 1B illustrates the stratigraphic and metallogenic history of the map area. The steps in this theoretical example are as follows. (1) Key terms are defined or cited from previous studies (e.g., Nokleberg and others, 1997a). (2) A regional geologic base map is constructed which illustrates two major cratons (A, B), several fault-bounded terranes (1, 2, 3, 4), one accretionary assemblage (a), and four post-accretion overlap assemblages (b, c, d, e). (3) A series of mineral deposit models are defined and described, and a high-quality mineral deposit data base is compiled. For this theoretical example, the major mineral deposit types are low-sulfide Au quartz vein, ironstone, epithermal Au vein, porphyry Cu, bedded barite, and kuroko massive sulfide. (4) Metallogenic belts are delineated. For simplicity in this example, each metallogenic belt contains only a single mineral deposit type. The two cratons (A, B) each contain distinctive, pre-accretionary metallogenic belts (ironstone and bedded barite deposits) which formed early in their geologic history, and an island arc assemblage (terrane 4) contains a pre-accretionary metallogenic belt of kuroko massive sulfide deposits. A collisional granitic pluton with a porphyry Cu metallogenic belt formed during accretion of terrane 3 against terrane 4. A metallogenic belt containing Au quartz vein deposits formed during accretion of terrane 1 against terrane 2. Overlying all terranes and both cratons is a post-accretion overlap assemblage which contains a metallogenic belt of epithermal Au vein deposits. (5) The genesis of formation of bedrock geologic units and (or) structures and contained mineral resource tract or metallogenic belt is interpreted using modern tectonic concepts (fig. 1B). Examples include: kuroko massive sulfide deposits forming in an island arc environment; porphyry Cu and low-sulfide Au quartz vein deposits forming in an accretionary environment, and epithermal Au vein deposits forming in a continental-margin igneous-arc environment. And (6) by carefully defining each metallogenic belt to be the geologically-favorable area for a group of coeval and genetically-related mineral deposits, a predictive character is established within the belt for undiscovered deposits. Hence, regional metallogenic analysis should be valuable for mineral exploration, land-use planning, and environmental studies.

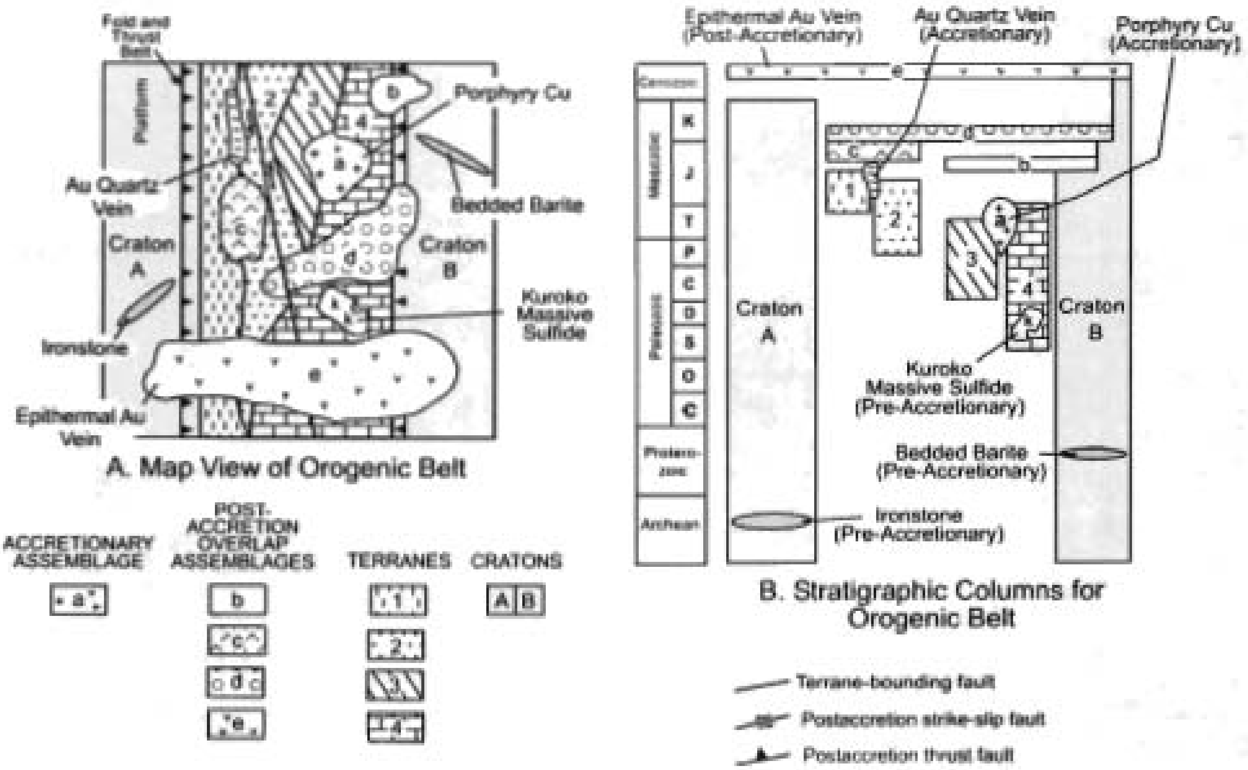

Figure 1. Generalized theoretical example illustrating the methodology for metallogenic analysis of cratons, terranes, accretionary assemblages, overlap assemblages, and contained metallogenic belts. A. Map view example of orogenic belt. B. Stratigraphic columns for example orogenic belt. Refer to text for discussion.

Tectonic Controls for Metallogenesis

Interpretation of the comprehensive data base of mineral deposits (Nokleberg and others, 1997a), mineral-resource tract maps (Nokleberg and others, 1997b, 1998), terrane and overlap assemblage maps (Nokleberg and others, 1997c, 1998), and the companion metallogenic and tectonic model for the Russian Far East, Alaska, and the Canadian Cordillera, reveals seven major tectonic environments for the Phanerozoic metallogenesis of the region: (1) subduction-related arc; (2) collisional (anatectic)-related arc; (3) post-collisional extension; (4) oceanic rift; (5) continental rift; (6) back-arc rift; and (7) transform continental-margin arc. Each tectonic environment provides a unique interpretation for the origin of the 144 major metallogenic belts and

1,079 significant mineral deposits in the region. Examples of metallogenic belts associated with each of the seven tectonic environment are as follows: (1) An example of a subduction-related arc tectonic environment is the mid- and Late Cretaceous Eastern Asia metallogenic belt of mainly epithermal and polymetallic vein deposits which is hosted by the Okhotsk-Chukotka volcanic-plutonic belt. (2) An example of a collisional (anatectic)-related arc tectonic environment is the Late Jurassic-Early Cretaceous Yana-Kolyma metallogenic belt of mainly Au quartz vein deposits which is hosted along the suture bordering Kolyma-Omolon superterrane. (3) An example of a post-collisional extension tectonic environment is the Late Cretaceous and early Tertiary Chugach Mountains metallogenic belt of Au quartz vein deposits which is associated with underthrusting of Kula-Farallon oceanic ridge and post-underthrusting extension. (4) An example of an oceanic rifting tectonic environment is the Early Tertiary Prince William metallogenic belt of Besshi and Cyprus massive sulfide deposits which is associated with the Kula-Farallon oceanic ridge. (5) An example of a continental rifting tectonic environment is the Late Devonian Selennyakh metallogenic belt of Southeast Missouri Pb-Zn deposits which is associated with rifting of North Asian craton margin. (6) An example of a back-arc rifting tectonic environment is the Late Triassic Alexander metallogenic belt of Cyprus massive sulfide deposits associated with the back arc of Talkeetna-Bonanza arc. And (7) an example of a transform continental-margin arc tectonic environment is the Early Tertiary Central Koryak metallogenic belt of polymetallic and epithermal vein deposits associated with the Kamchatka-Koryak igneous belt. The tectonic controls for each of the metallogenic belts of the region are listed in Table 3 and described in more detail in the below sections on descriptions and interpretations of origins of metallogenic belts.

The tectonic classification of lode mineral deposits has been a topic of considerable debate (Sawkins, 1990); however classification of lode mineral deposits by mineral deposit types and tectonic environment can be extremely useful. These classifications are useful for regional mineral exploration and assessment, for research on the critical or distinguishing characteristics of metallogenic belts, and for synthesizing of metallogenic and tectonic models. For this report in describing the metallogenic belts of the region, the significant lode deposits are classified both according to mineral deposit type and tectonic environment.

Metallogenic and Tectonic Definitions

Definitions for mineral deposit, metallogenic, and tectonic terms used in this report were adapted from Coney and others (1980), Jones and others (1983), Howell and others (1985), Monger and Berg (1987), Nokleberg and others (1987, 1994a, c, 2000), and Wheeler and others (1988). In alphabetical order, these terms and their definitions are as follows.

Accretion. Tectonic juxtaposition of two or more terranes, or tectonic juxtaposition of terranes to a craton margin.

Accretionary wedge and subduction-zone terrane. Fragment of a mildly to intensely deformed complex consisting of varying amounts of turbidite, hemipelagic, and pelagic deposits, and oceanic crust and upper mantle. This type of terrane is divided into units composed predominantly of turbidite deposits or predominantly of oceanic rocks. Units are interpreted to have formed during tectonic juxtaposition in a zone of major thrusting of one lithospheric plate over another, generally along the margin of a continent or an island arc. The terrane may include large fault-bounded units which contain a coherent internal stratigraphy. Many subduction-zone terranes contain fragments of oceanic crust and associated rocks which exhibit a complex structural history, occur in a major thrust zone, and possess blueschist-facies metamorphism.

Collage of terranes. A composite group of tectonostratigraphic terranes.

Craton. Regionally metamorphosed and deformed shield assemblages of Archean and Early Proterozoic sedimentary, volcanic, and plutonic rocks, and overlying platform successions of Late Proterozoic, Paleozoic, and local Mesozoic and Cenozoic sedimentary and lesser volcanic rocks.

Craton margin. Chiefly Late Proterozoic through Jurassic miogeoclinal units deposited on a continental shelf or slope. Locally has, or may have had an Archean and Early Proterozoic cratonal basement.

Cratonal terrane. Fragment of a craton.

Continental-margin arc terrane. Fragment of an igneous belt of coeval plutonic and volcanic rocks, and associated sedimentary rocks which formed on or close to a continent, above a subduction zone dipping beneath a continent. Inferred to possess a sialic basement.

Deposit. A general term for any lode or placer mineral occurrence, mineral deposit, prospect, and (or) mine.

Island-arc terrane. Fragment of a belt of plutonic rocks, coeval volcanic rocks, and associated sedimentary rocks which formed above an intraoceanic subduction zone.

Metallogenic belt. A geologic unit (area) which either contains or is favorable for a group of coeval and genetically-related, significant lode and placer deposit models. Using this definition, a metallogenic belt is a predictive tool for undiscovered deposits.

Metamorphic terrane. Fragment of a highly metamorphosed or deformed assemblage of sedimentary, volcanic, and (or) plutonic rocks which cannot be assigned to a single tectonic environment because the original stratigraphy and structure are obscured. Includes intensely-deformed structural melanges which contain fragments of two or more terranes.

Metamorphosed continental margin terrane. Fragment of a passive continental margin, in places moderately to highly metamorphosed and deformed, which cannot be linked with certainty to the nearby craton margin. May be derived either from a nearby craton margin or from a distant site.

Mine. A site where valuable minerals have been extracted.

Mineral deposit. A site where concentrations of potentially valuable minerals for which grade and tonnage estimates have been made.

Mineral occurrence or prospect. A site of potentially valuable minerals on which no known exploration has occurred, or for which no grade and tonnage estimates have been made.

Oceanic crust, seamount, and ophiolite terrane. Fragment of part or all of a suite of *eugeoclinal* deep-marine sedimentary rocks, pillow basalt, gabbro, and ultramafic rocks which are interpreted as a fragment of oceanic sedimentary and volcanic rocks and the upper mantle. Includes both inferred offshore oceanic and marginal ocean basin rocks, minor volcaniclastic rocks of magmatic arc derivation, and major marine volcanic accumulations formed at a hotspot, fracture zone, or spreading axis.

Overlap assemblage. A postaccretion unit of sedimentary or igneous rocks deposited on, or intruded into two or more adjacent terranes. The sedimentary and volcanic parts either depositionally overlie, or are interpreted to have originally depositionally overlain two or more adjacent terranes, or terranes and the craton margin. Plutonic rocks, which may be coeval and genetically related to overlap volcanic rocks, may stitch together adjacent terranes, or a terrane and a craton margin.

Passive continental margin terrane. Fragment of a craton margin.

Post-accretion rock unit. Suite of sedimentary, volcanic, or plutonic rocks which formed late in the history of a terrane, after accretion. May occur also on adjacent terranes or on the craton margin either as an overlap assemblage or as a basinal deposit. A relative-time term denoting rocks formed after tectonic juxtaposition of one terrane to an adjacent terrane.

Pre-accretion rock unit. Suite of sedimentary, volcanic, or plutonic rocks which formed early in the history of a terrane, before accretion. Constitutes the unique stratigraphy and igneous geology of a terrane. A relative-time term denoting rocks formed before tectonic juxtaposition of one terrane to an adjacent terrane.

Prospect. A site of potentially valuable minerals at which exploration has occurred.

Significant mineral deposit. A mine, mineral deposit, prospect, or occurrence which is judged as important for the metallogenesis of a geographic region.

Subterrane. A fault-bounded unit within a terrane which exhibits similar, but not identical geologic history relative to another fault-bounded unit in the same terrane.

Superterrane. An aggregate of terranes which is interpreted to share either a similar stratigraphic kindred or affinity, or a common geologic history prior to accretion (Moore, 1992). An approximate synonym is *composite terrane* (Plafker and Berg, 1994).

Tectonic linkage. The interpreted association of a suite of coeval tectonic units which formed in the same region and as the result of the same tectonic processes. An example is the linking of a coeval continental-margin arc, forearc deposits, a back-arc rift assemblage, and a subduction-zone complex, all related to the underthrusting of a continental margin by oceanic crust.

Tectonostratigraphic terrane. A fault-bounded geologic entity or fragment which is characterized by a distinctive geologic history which differs markedly from which of adjacent terranes (Jones and others, 1983; Howell and others, 1985).

Transform continental-margin arc. An igneous belt of coeval plutonic and volcanic rocks, and associated sedimentary rocks which formed along a transform fault which cuts the margin of a craton, passive continental margin, and (or) collage of terranes accreted to a continental margin.

Turbidite basin terrane. Fragment of a sedimentary basin filled with deep-marine clastic deposits in either an orogenic forearc or backarc setting. May include continental-slope and continental-rise turbidite, and submarine-fan turbidite deposited on oceanic crust. May include minor epiclastic and volcaniclastic deposits.

Mineral Deposit Models

For the metallogenic analysis of the Russian Far East, Alaska, and the Canadian Cordillera, metalliferous and selected non-metalliferous lode deposits are classified into various models or types as described in Nokleberg and others (1996, 1997a) and as listed in Table 1. This classification of mineral deposits was chiefly derived mainly from the mineral deposit types of Eckstrand (1984), Cox and Singer (1986), Bliss and others (1992), and Eckstrand and others (1995), but includes some modifications. The mineral deposit types are systematically arranged to describe the essential properties of a class of mineral deposits. Some mineral deposit models are descriptive (empirical), in which instance the various attributes are recognized as essential, even though their relationships may not be known. An example of a descriptive mineral deposit type is the basaltic Cu type in that the essential attribute is empirical datum of a geologic association of Cu sulfides with relatively Cu-rich metabasalt or greenstone. Other deposit types are genetic (theoretical), in which case the attributes are related through some fundamental concept. An example is the W skarn deposit type in which the essential attribute is the genetic process of contact metasomatism is the essential attribute. For additional information on the methodology of mineral deposit types, the reader is referred to the discussions by Eckstrand (1984), Cox and Singer (1986), and Bliss (1992). The lode deposit models which are utilized in this report and previous, related publications (Nokleberg and others, 1996, 1997a) are listed in Table 1, and are grouped according to host rock lithologies and (or) origin. Lode deposit models which share a common origin, such as contact metasomatic deposits, or porphyry deposits, are grouped together under a single heading.

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Introduction to Phanerozoic Metallogenic and Tectonic Model for the Russian Far East, Alaska, and the Canadian Cordillera

In the below Phanerozoic (Devonian through Recent) time-span sections on metallogenesis of the region, an interpretative model is presented for the Phanerozoic metallogenic-tectonic evolution of the Russian Far East, Alaska, and the Canadian Cordillera. The model is derived from the below descriptions of metallogenic belts and host rocks, and from a detailed analysis of the Phanerozoic tectonic evolution of the region (Nokleberg and others, 2000). The metallogenic-tectonic model attempts to: (1) integrate stratigraphic, age, structural, and paleomagnetic data and field relations for the region; (2) integrate data on metallogenic belts and contained lode deposits with host-rock geology and structures; and (3) portray the regional metallogenic-tectonic interactions between the North Asian and North American continents. The model concentrates on the Devonian through the Present. For more descriptions of the regional geology and tectonics of the region, a detailed analysis was published by Nokleberg and others (2000).

The metallogenic-tectonic model illustrates: (1) major metallogenic belts superposed, at approximate scale, over major units, including cratons, craton margins, terranes, and overlap assemblages; (2) geologic units which are proportional to those on detailed terrane and overlaps assemblage maps (Nokleberg and others, 1994a, 1997b,c; Monger and Nokleberg, 1996); and (3) known or interpreted displacements along major strike-slip and thrust faults. In most cases, however, the tectonic model does not incorporate internal deformation of terranes or tectonic erosion of terrane margins. In the following descriptions of the metallogenic-tectonic model, the tectonic features of the model are condensed. For complete description of tectonic features, refer to the separate publication on Phanerozoic tectonic evolution of the Circum-North Pacific (Nokleberg and others, 2000). A dynamic (computer) version of the metallogenic-tectonic model is published by Scotese and others (2001).

The metallogenic-tectonic model provides a guide for future research by: (1) integrating geologic, mineral deposit, metallogenic belt, paleontologic, isotopic, and paleomagnetic data from the Russian Far East, Alaska, the Canadian Cordillera, the Pacific Ocean, and the Arctic Ocean; (2) proposing a new, unified interpretation which spans the area from northeastern part of the North Asian Craton to the northwestern part of the North American Craton; and (3) identifying problems with data and interpretations. Because of a lack of abundant Proterozoic and older rock units exterior to the craton margins, the model starts with the Devonian. For various published tectonic reconstructions for the Proterozoic, which illustrate highly different global interpretations, the studies of Hoffman (1989, 1991), Moores (1991), Ross and others (1992), Scotese (1997), Unrug (1997), and Karlstrom and others (1999) are recommended.

An important complication of terrane recognition and analysis is that the margins of terranes and parts of their pre-accretionary metallogenic belts, have been tectonically removed, either by dislocation of terranes from distant locations, or by tectonic erosion of the margins of terranes. In the case of dislocation, detailed analysis of each terrane with respect to in-place overlap assemblages, passive continental-margin assemblages, and cratonal assemblages should provide the original site of origin. In the case of tectonic erosion, as in the case of subduction-zone terranes, large parts of the original unit (such as an oceanic plate) may have been thrust to great depths and thereby may essentially have disappeared.

An important interpretation in the metallogenic-tectonic model is that a succession of coeval single arcs and companion subduction zones, and their contained, pre-accretionary metallogenic belts formed on or near the margins of the North Asian and North American Plates. One consequence of this interpretation is that many of the complexities of the collage of accreted terranes and contained metallogenic belts in the region are the results of oblique subduction and resultant strike-slip displacements within active continental margins, rather than the migration of island-arc systems across ocean basins to accrete eventually to the margins of plates. Substantiation of this interpretation will require: (1) determination of the facing directions of the arcs with respect to cratons; (2) correlation of coeval arc and tectonically linked (companion) subduction zones to establish them as different parts of a former, single, curvilinear arc/subduction-zone system; and (3) determination of the linkage of arcs to cratons. This interpretation is reasonably well established for most of the Mesozoic and Cenozoic, but less so for the Paleozoic. For each time interval (stage) in the metallogenic-tectonic model, specific (numbered) tectonic events are described in a clockwise order, according to similar tectonic environments, starting with the area of the Russian Southeast and ending with the area of the southern Canadian Cordillera. The time scale used for the tectonic model is from Palmer (1983).

Paleomagnetic Dilemma: Loci of Accretion of Wrangellia Superterrane

A major paleomagnetic dilemma exists for the loci of accretion of superterranes to the margin of the North American Craton in the mid-Cretaceous to early Tertiary. The dilemma consists of two conflicting hypotheses for the loci of accretion of the Wrangellia superterrane, which constitutes most of the Insular superterrane, and the Intermontane superterrane which consists of the Stikinia, Quesnellia, and Cache Creek terranes (Cowan, 1994; Cowan and others, 1997). One hypothesis, based on geologic evidence, including magmatic, stratigraphic, and faunal ties, interprets the Wrangellia superterrane as accreting at a northerly paleolatitude, approximately at its present latitude. The other hypothesis, based on paleomagnetic data for both continental volcanic rocks and coeval plutonic rocks, interprets the Wrangellia superterrane and the western part of the Intermontane terrane as accreting at a paleolatitude approximately 3,000 km farther south. This hypothesis is informally named the Baja British Columbia controversy, in reference to accretion of the Wrangellia superterrane at the approximate latitude of Baja California (Umhoefer, 1987; Cowan and others, 1997; Dickinson and Butler, 1998). For the synthesis of the tectonic evolution of the Circum-North Pacific, these two hypothesis are called the northern-accretion interpretation and southern-accretion interpretation. For the metallogenic analysis of the Wrangellia superterrane in the Mesozoic and early Cenozoic, only the northern-accretion interpretation is considered. For additional information and references for both interpretations, please refer to the discussion and references in Nokleberg and others (2000).

Proterozoic Metallogenic Belts (2500 to 570 Ma; Figures 2, 3)

Overview

The major Proterozoic metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 2 and 3. The major belts (and their major mineral deposit types) are as follows. (1) In the central and southeastern part of the Russian Northeast, are the Bilyakchan (BI) (basaltic Cu), Oroek (OK) (ironstone and sediment-hosted Cu), Omolon (OM) (Ironstone (Superior Fe)), and Ulkan (UL) (Felsic Plutonic REE and related deposits) metallogenic belts. These belts are interpreted as forming during incipient rifting of the passive continental margin of the North Asian Craton or Craton Margin. (2) In the same region are the Lantarsky-Dzhugdzhur (LD) metallogenic belts of anorthosite-hosted apatite Ti-Fe and gabbroic Cu-Ni-Co-PGE that is interpreted as forming during Mesoproterozoic rifting of passive continental margin of North Asian Craton. (3) On the Seward Peninsula in Western Alaska, the Sinuk River (SR) metallogenic belt, which contains massive sulfide-barite and stratabound Fe-Mn deposits, is hosted in Proterozoic or older metavolcanic and sedimentary rock. The belt is interpreted as forming during marine volcanogenic rifting(?) of the North American Continental Margin. (4) In Southwestern Alaska, the Kilbuck (KI) metallogenic belt, which contains mainly ironstone (Superior Fe) deposits, is hosted in the Kilbuck-Idono cratonal terrane and is interpreted as forming during rifting of the North Asian Craton. (5) In the northern part of the Canadian Cordillera is the Wernecke (WR) metallogenic belt of U-Cu-Fe (Au-Co) vein and breccia deposits. This belt is hosted in the North American Craton Margin and is interpreted as forming during hydrothermal activity along a Paleoproterozoic passive continental margin.

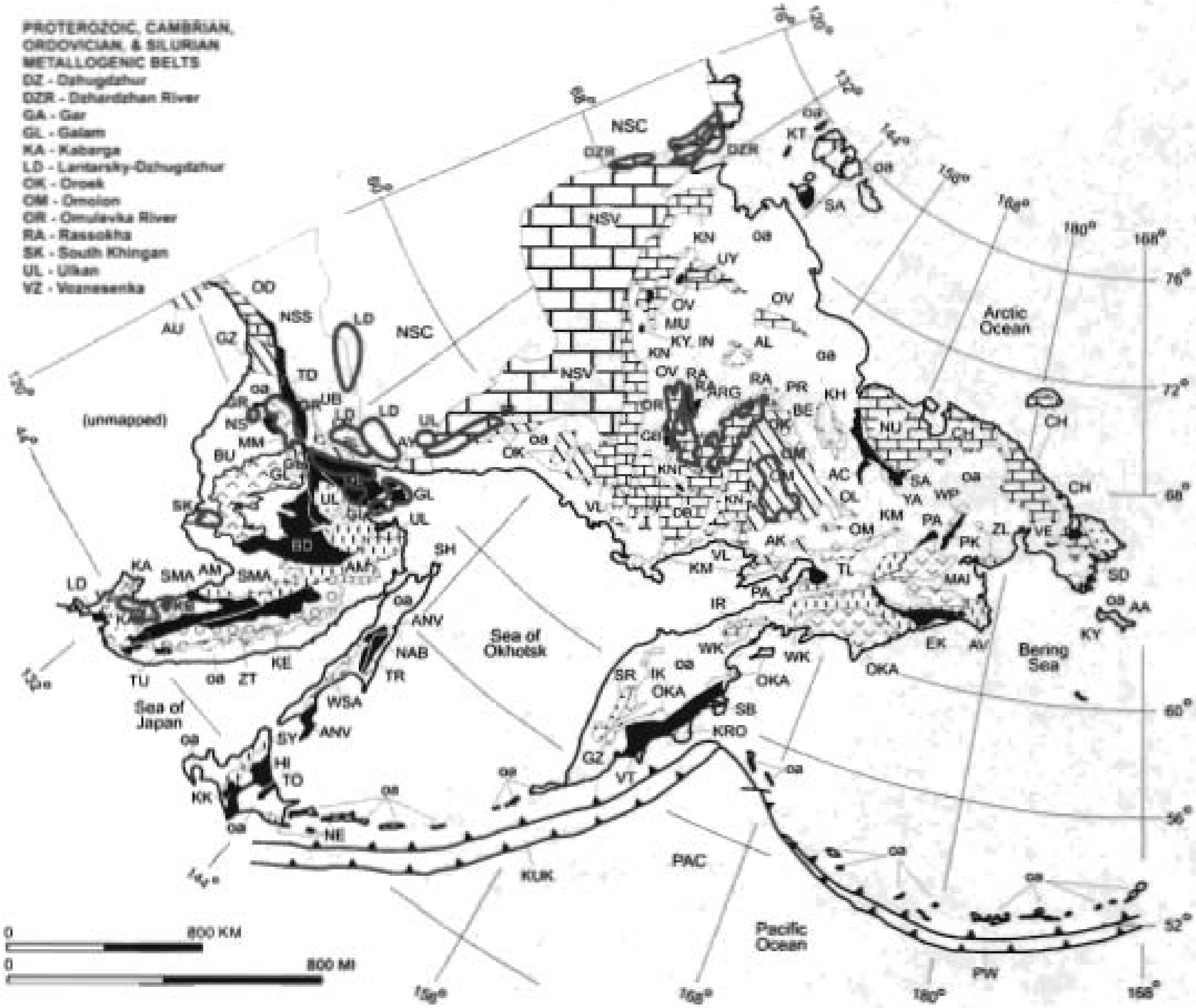
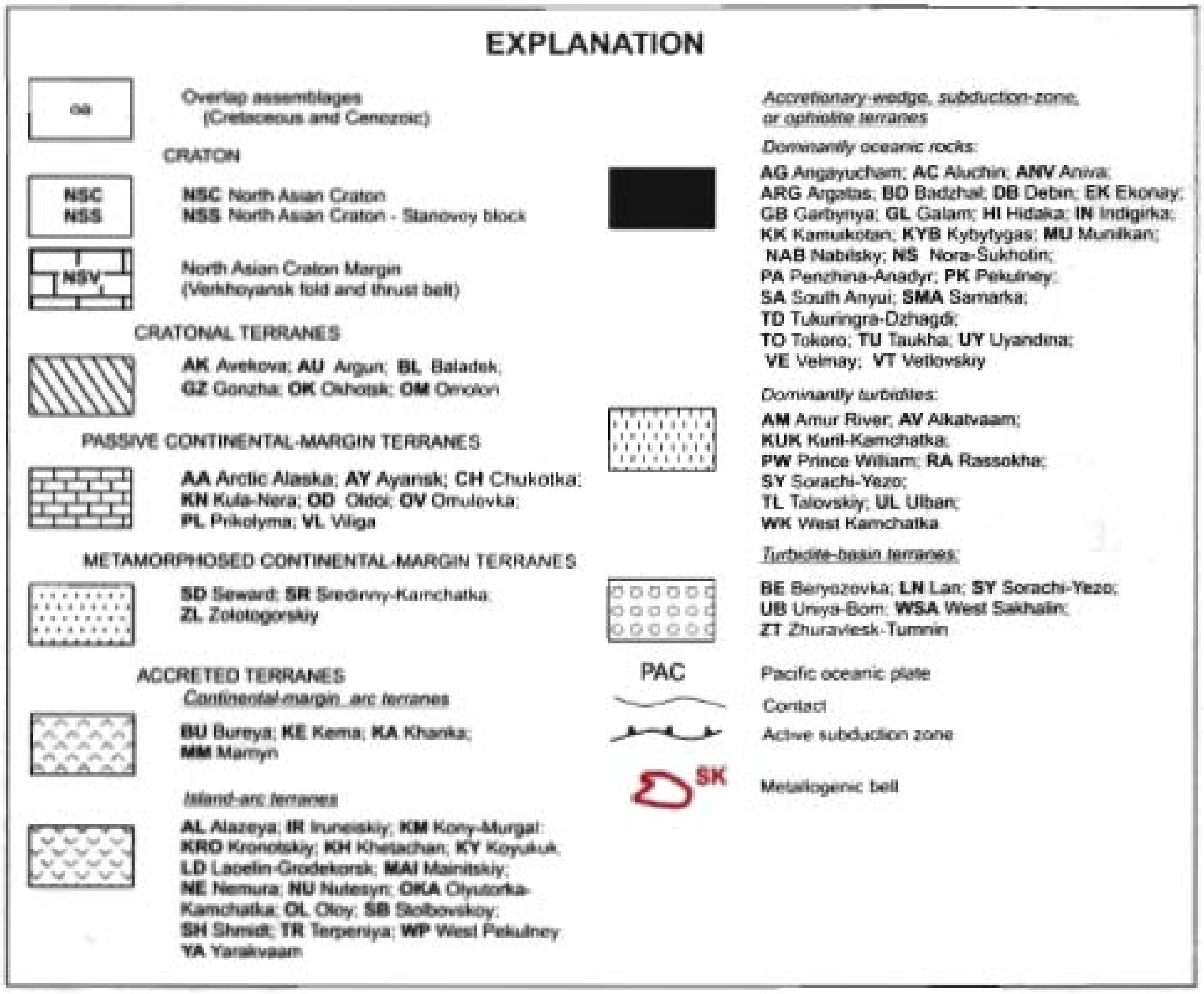


Figure 2. Generalized map of major Proterozoic and Cambrian through Silurian metallogenic belts and terranes for Russian Far East, northern Japan, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998)

(6) In the same region is the Gillespie (GE) metallogenic belt of SEDEX Pb-Zn deposits that is hosted in the North American Craton Margin and is interpreted as forming during Intrusion of gabbro and diorite sills during Paleoproterozoic rifting. (7) In the same region is the Rapitan (RA) metallogenic belt of iron formation deposits that is hosted in the North American Craton Margin. This belt is interpreted as forming during marine exhalation along Mesoproterozoic North American Craton Margin. (8) In the same region is the Redstone (RD) metallogenic belt of sediment-hosted Cu-Ag deposits that is hosted in the North American Craton Margin. This belt is interpreted as forming during incipient Neoproterozoic rifting of the North American Craton Margin. (9) In the southern Canadian Cordillera is the Monashee (RD) metallogenic belt of SEDEX Zn-Pb-Ag deposits. This belt, that is hosted in the Monashee terrane, is interpreted as a fragment of North American Craton and formed during Late Proterozoic rifting of North American Craton. (10) In the same region, the Purcell (PR) belt of massive sulfide deposits is hosted in the North American Craton Margin, and is interpreted as forming during incipient rifting of the craton. And (11) in the same region, the Clark Range (CR) belt of sediment-hosted Cu-Ag deposits is hosted in the North American Craton Margin, and is interpreted as forming during incipient rifting of the craton margin. In the below descriptions of metallogenic belts, only notable examples of significant lode deposits are described for each belt. Table 4, which is adapted and revised from Nokleberg and others (1997a), lists the significant lode deposits in each metallogenic belt.



Metallogenic Belts Formed During Proterozoic Rifting of North Asian Craton or Craton Margin

Oroek Metallogenic Belt of Ironstone and Sediment-Hosted Cu Deposits (Belt OK) West-Central Part of Russian Northeast

The Oroek metallogenic belt of ironstone and sediment-hosted Cu deposits (fig. 2; tables 3, 4)occurs mainly in the Shamanikha River basin in the central part of the Russian Northeast (Shpikerman, 1998). The belt is hosted in the Shamanikha subterrane of the Prikolyma passive continental margin terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c). The belt trends north-south for 400 km along the axis of the Prikolyma terrane and has a maximum width of 100 km. The ironstone deposits occur in the Late Proterozoic Spiridon and Gorbunov Formations. The significant deposits are at Pobeda and Oroek (Nokleberg and others 1997a, b, 1998). The Oroek metallogenic belt is herein interpreted as a faulted fragment of the Bilyakchan metallogenic belt, described below, which is hosted in the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV).

Pobeda Ironstone Deposit

One part of the Pobeda ironstone deposit (fig. 4) occurs in the Spiridon Formation consists of stratiform hematite (Z.G. Potapova, written commun., 1954; A.G. Kats, written commun., 1979) and is interpreted as a fossil littoral zircon-titanium-magnetite placer deposit. The other part of the deposit occurs in Late Proterozoic dolomitic marble of the Gorbunov Formation in a zone of imbricated thrust faults. This part of the deposit consists of gabbro and gabbro-amphibolite bodies and with hematite masses which occur along thrust fault planes. The deposit contains massive, brecciated, and stockwork ores. Massive ores contain

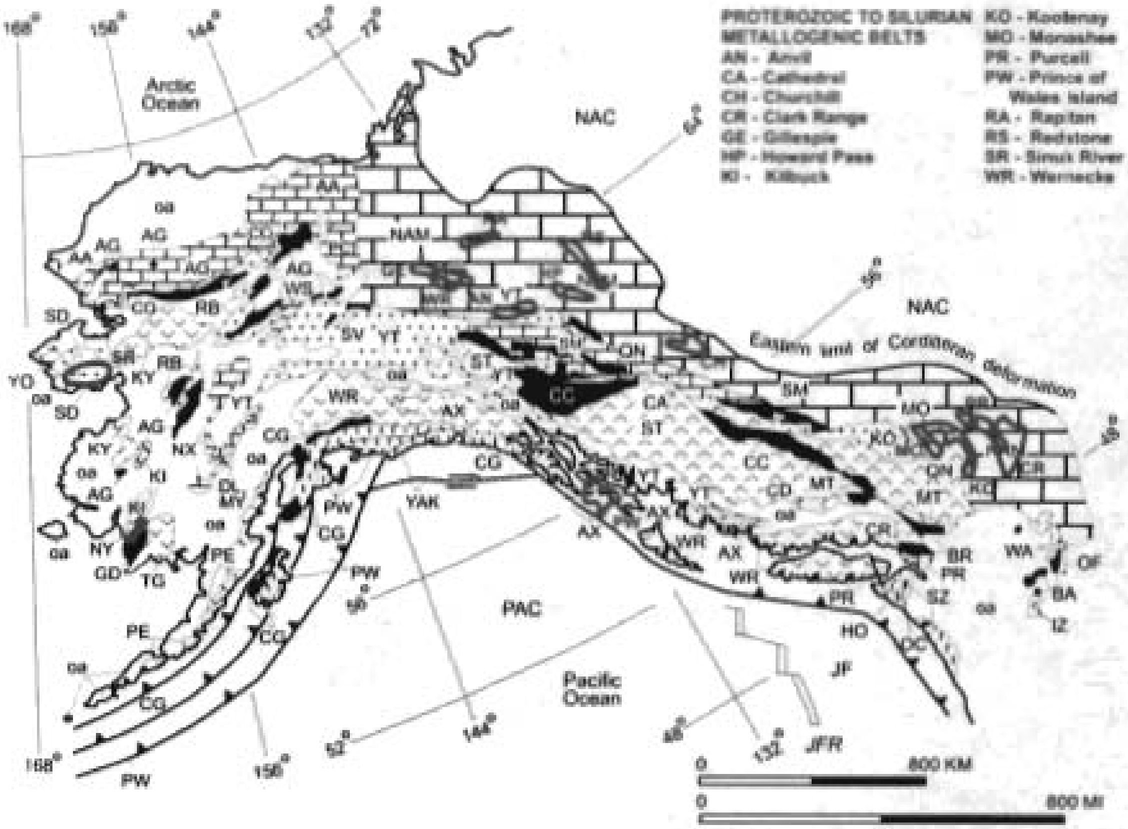


Figure 3. Generalized map of major Proterozoic and Cambrian through Silurian metallogenic belts and terranes for Alaska, Canadian Cordillera, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998).

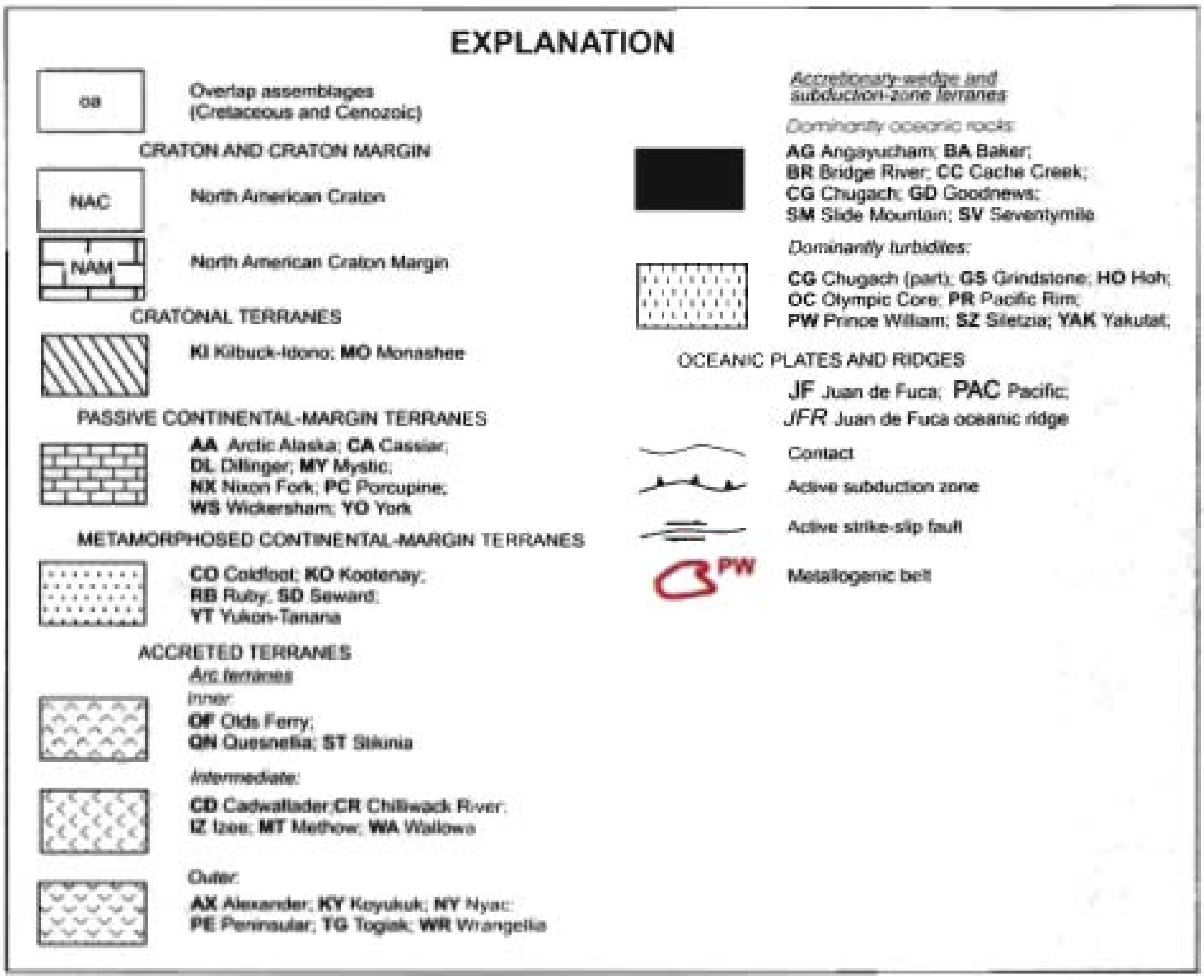
up to 70% Fe. The brecciated ores are composed of clasts of dolomite and gabbro-amphibolite cemented by hematite. The stockwork is defined by separate, halo-shaped bodies which are located around the massive and brecciated ores. Ore minerals also include calcite, quartz, barite, chlorite, pyrite, chalcopyrite, galena, and malachite. The ore-bearing horizon extends for 18 km, but the best defined stratiform hematite deposit is 150 to 600 m long and 2 to 20 m thick. A related dolomite-hosted Fe deposit in theGorbunov Formation is interpreted as forming during chemical deposition of Fe from seawater.

Oroek Sediment-Hosted Cu Deposit

The sediment-hosted Cu Oroek deposit (fig. 5) (I.G. Volkodav and Korobitsyn, A.V. written commun., 1979, Shpikerman and Shpikerman, 1996) occurs in the Oroek Formation which consists of an Late Proterozoic volcaniclastic rock sequence which varies between 150-180 m thick. The sequence consists mainly of quartzite, quartz-chlorite and graphite-chlorite schist, and phyllite and thin conformable beds of basalt and tuffaceous rocks. The major ore minerals are chalcocite, bornite, and chalcopyrite which occur in metamorphosed sandstone, siltstone, and shale. Local abundant quartz bodies also contain chalcopyrite, bornite, and hematite. Later cross-cutting quartz veins also contain minor malachite, chalcocite, azurite, chrysocolla, bornite, and native copper. Mineralized rocks are deformed and form an overturned, isoclinal fold whose limbs dip southeast at 40° to 90°.

Origin of and Tectonic Controls for Oroek Metallogenic Belt

The sediment-hosted Cu deposits of the Oroek metallogenic belt are hosted mainly in the Middle Riphean Oroek Formation which consists of metamorphosed sedimentary rocks with a thickness of 1300 to 1500 m (Shpikerman, 1998). The Cu deposits occur only in two lithologies: quartz-chloritoid and quartz-chlorite schist. The quartz-chloritoid schist locally contains polimictic siltstone and sandstone with parallel and oblique laminations. The chlorite schists contain dark green chloritoid porphyryblasts, dark green chlorite, quartz, epidote, mica, and rutile, and have a dark color, fine-grain composition, and a laminated shaley and lenticular texture. The ore-bearing rocks of the Oroek Formation are derived from subaqueous, polimictic sandstone, siltstone and shale (pelite) which contain considerable volcanic rock fragments (L.A. Shpikerman, written commun.,



1999). Metamorphism occurred at quartz-albite- epidote-biotite subfacies, and the age of metamorphism is probably Pre-Vendian (Shpikerman, 1998). The sediment-hosted Cu deposits and host rocks are interpreted as forming in rift-related troughs in a sublittoral and shelf area during the early history of the Prikolyma passive continental margin terrane, during Middle or Late Proterozoic incipient rifting of the North Asian Craton Margin (Shpikerman, 1998). The ironstone deposits of the Oroek metallogenic belt (Pobeda deposit and others) occur in the Vendian Syapyakane suite which ranges from 300 to 800 m thick and is composed of mainly feldspathic-quartz sandstones with thin interbeds and lenses consisting of hematite (martite), magnetite, titanic magnetite, ilmenite, rutile, and zircon (Shpikerman, 1998). The sandstones are typical occurrences of Vendian beach placers and are similar to sandstones in the Middle Riphean Spiridonova Formation which occurs to the west, also in the Prikolyma terrane. However, these formations are underlain by the Gorbunova Formation which contains beds of dolomite and stratiform hematite-carbonate iron deposits. The Prikolyma terrane is interpreted as a rifted fragment of the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV; Nokleberg and others, 1994c, 1997c; Shpikerman, 1998).

Lantarsky-Dzhugdzhur Metallogenic Belt of Anorthosite Apatite-Ti-Fe and Gabbroic Ni-Cu (PGE) Deposits (Belt LD) Central Part of Russian Far East)

The Lantarsky-Dzhugdzhur metallogenic belt of anorthosite apatite-Ti-Fe and gabbroic Cu-Ni-Co-PGE deposits is hosted in the co-named igneous belt of layered gabbro and anorthosite complexes in one of a linear series of mafic plutons which crop out along in the Stanovoy block along the southern flank of the North Asian Craton (fig. 2; tables 3, 4) (Nokleberg and others, 1997b, 1998).. The belt occurs in the northern Khabarovsk Province in the central part of the Russian Far East and in southern Yakutia. U-Pb and Sm-Nd isotopic ages for the host anorthosite intrusions range from 1.7 to 1.9 Ga (Sukhanov and others, 1989; Neimark and others, 1992).

The Lantarsky-Dzhugdzhur igneous belt consists of five gabbroic Cu-Ni-Co-PGE deposits that are hosted in anorthosite and gabbro bodies that occur along the 1,000 km-long Stanvoy suture (collisional) zone between the Archean Aldan shield of the North Asian Craton to the North and the Proterozoic Stanovoy block to the south. The Archean rocks to the north consist of gneiss and schist intruded by Paleozoic to Mesozoic granitic rock (Lennikov, 1979). The rocks south of the suture zone consist of

Archean granulite facies metamorphic rock, and Paleozoic greenschist to amphibolite facies metamorphic rock. The Lantrasky-Dzhugdzhur anorthosite complex is elongated along the Stanvoy suture zone, is 170 km long, varies from 5 to 34 km wide, and covers and areas of approximately 2,700 km^2. The complex is composed of approximately 70 percent anorthosite, and 30 percent gabbro, norite, and ultramafic rock. The complex contains a classic layered series of anorthosite plutons, including those in Finland, Canada, and South America (Papunen, 1986; Ryan and others, 1995). The five gabbroic Cu-Ni-Co-PGE prospects, that have been identified since 1990, are at Avlandzhinsky, Kontaktovy, Nyandomi, Ozerny, and Odorin. These prospects occur near the contact between anorthosite and gabbro layers, and REE-bearing alkali granitic rock. The two largest prospects at the Kontaktovy and Nyandomi are 300 to 600 m wide and range up to several km long. Surface samples of massive sulfides contain up to 3.4% Cu, 0.74% Ni, 0.17% Co, 5.43 g/t Pt, 2.8 g/t Pd, and 0.85 g/t Rh (Pollack, 1997; Panskikh, 1978). These prospects are geological and geochemical analogs to the Cu-Ni-Co-PGE deposits in the layered Svecokarelian complexes of Finland and Western Russia, and Cu-Ni-PGE deposits in the Nain plutonic suite at Voisey Bay, Canada (Papunen, 1986; Pollack, 1997). The deposits in the Lantasky-Dzhugdzhur belt have been explored by Vostok Gold Corporation.

Another similar group of anorthosite Apatite-Ti-Fe deposits are the Bogidenskoe, Gayumskoe, Maimakanskoe, and Dzhaninskoe deposits. These deposits occur to the south of the above-described deposits generally consist of apatite, ilmenite, and titanium magnetite which are hosted in melanocratic olivine gabbro, gabbrosyenite, gabbro-pyroxenite, and pyroxenite. These mafic and ultramafic rock often forms stock-like bodies in the Geransky anorthosite massif (Lennikov and others, 1987) that has a Pb-Pb isotopic age of 2.2 to 1.8 Ga. The deposits occur on the southern, southwestern, and western margins of the Geransky anorthosite massif. The four largest deposits are spaced about 15 to 30 km between each other, and together contain an estimated 350 million tonnes P_2O_5 (Panskikh and Gavrilov, 1984). Together, the deposits in the belt contain approximately one billion tonnes of P_2O_5, an amount which is comparable with deposits in the Kola province in northwestern Russia near Sweden.

Origin of and Tectonic Controls for Lantarsky-Dzhugdzhur Metallogenic Belt

The Lantasky-Dzhugdzhur metallogenic belt is interpreted as forming during Mesoproterozoic rifting along the edge of the North Asian Craton. During rifting, coeval, large anorthosite plutons intruded the Stanovoy suture and adjacent area for a distance of more than 1,000 km, and adjacent region to the south.

Ulkan Metallogenic Belt of Felsic Plutonic REE Deposits (Belt UL) Northwestern Part of Russian Southeast

The Ulkan metallogenic belt of felsic plutonic REE deposits occurs in the northwestern part of the Russian Southeast (fig. 2; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt occurs mainly in the Paleoproterozoic Ulkan volcano-tectonic basin that has isotopic ages of 1.9 to 1.5 Ga, and which overlies folded Archean basement rocks of the North Asian Craton (unit NSC). The REE, Be, U-Mo, Nb-Ta and related deposits are interpreted as forming in two periods.

Omolon Metallogenic Belt of Ironstone (Superior Fe) Deposits (Belt OM) Central Part of Russian Northeast

The Omolon metallogenic belt of ironstone (Superior Fe) deposits (fig. 2; tables 3, 4) occurs in the central part of the Russian Northeast. The belt is hosted in Archean metamorphic rocks of the Omolon cratonal terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c; Shpikerman, 1998). More than ten local ironstone deposits are known in the belt (table 4) (Nokleberg and others, 1997a, b, 1998). The significant deposit is at Verkhny-Omolon.

Verkhny-Omolon Ironstone Deposit

The significant Verkhny-Omolon ironstone deposit (fig. 6) consists of sheet-like and podiform bodies of banded iron formation which occur in Archean migmatite, amphibole and biotite-amphibole plagiogneiss, amphibolite, and mafic schist (Gelman, Titov, and Fadeev, 1974; Fadeev, 1975; Zhulanova, 1990; Milov, 1991). The banded iron ore consists of medium- to coarse-grained masses or layers of magnetite and quartz which is intergrown with apatite and actinolite. The deposit extends for 3.5

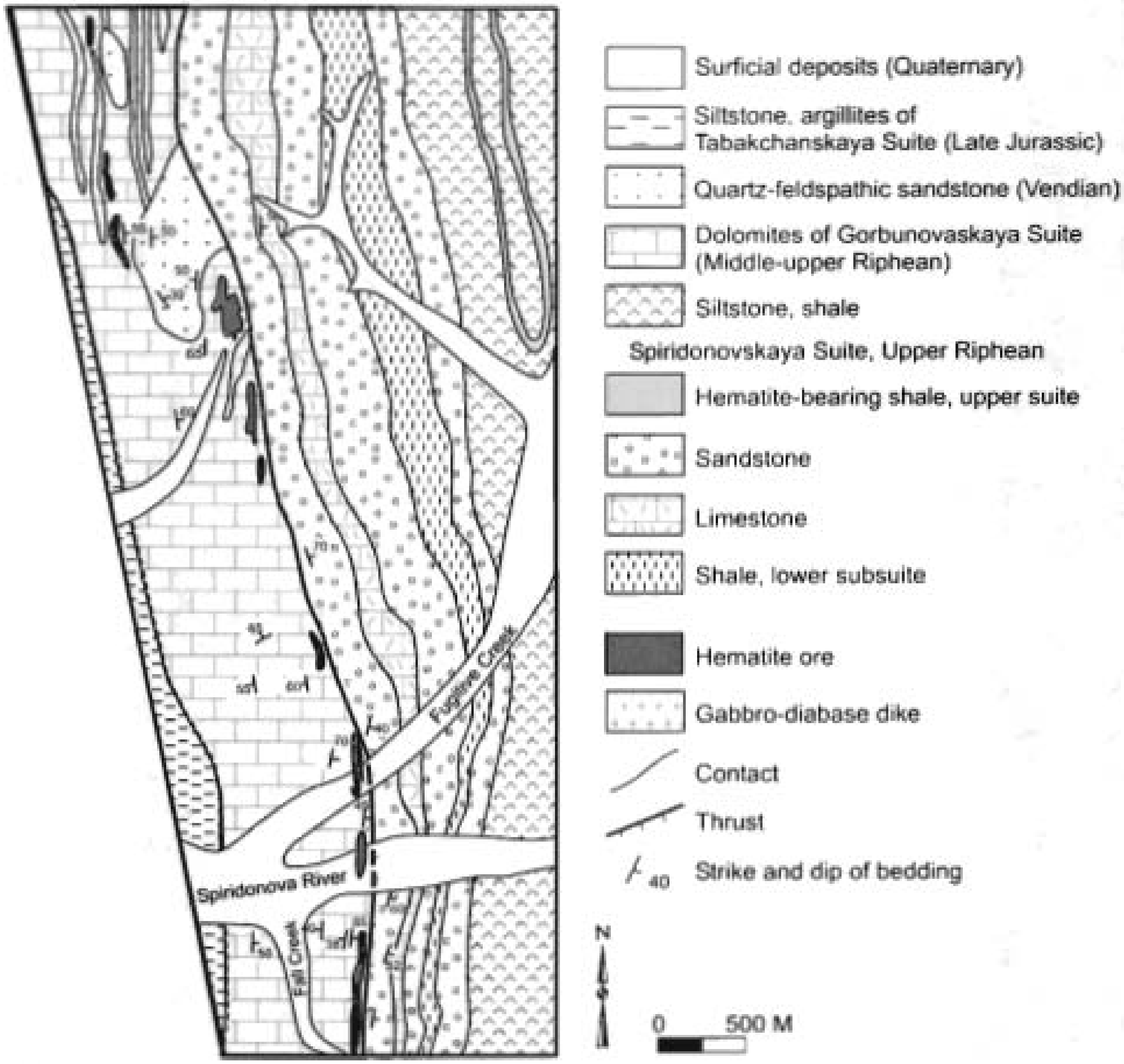


Figure 4. Pobeda ironstone deposit, Oroek metallogenic belt, Russian Northeast. Adapted from Shpikerman (1998).

km, averages 250 m thick in the central portion, and locally consists of alternating, nearly conformable ore bodies and horizons in the country rock. The original quartzite and possibly the ironstone deposits may be derived from marine sedimentary rocks which originally contained ironstone (Superior Fe) deposits. The host rocks are extensively granitized. Rb-Sr isotopic data reveal polymetamorphisms of the Archean basement. Granulite facies metamorphism occurred at 3.4 to 3.8 Ga; regional granitization occurred approximately at 2.0 Ga; and low grade metamorphism and deformation occurred approximately at 1.0 Ga (Zhulanova, 1990; Milov, 1991).

Origin of and Tectonic Controls for Omolon Metallogenic Belt

The Omolon metallogenic belt is hosted in various outcrops of the Archean crystalline basement of the Omolon metamorphic assemblage in the Omolon cratonal terrane (Zhulanova, 1990; Shpikerman, 1998). These crystalline rocks consist of Archean to Early Proterozoic sedimentary, volcanic, and magmatic rocks which are metamorphosed at granulite and amphibolite facies into gneiss, granitic gneiss, and amphibolite. Isotopic ages range from 2.3 to 1.7 Ma. The assemblage exhibits granulite facies of metamorphism, including amphibole, clinopyroxene-amphibole, and hypersthene-bearing schist, and biotite-hypersthene plagiogneiss and garnet-clinopyroxene gneiss. Leucocratic migmatites prevail in the assemblage and formed from multiple

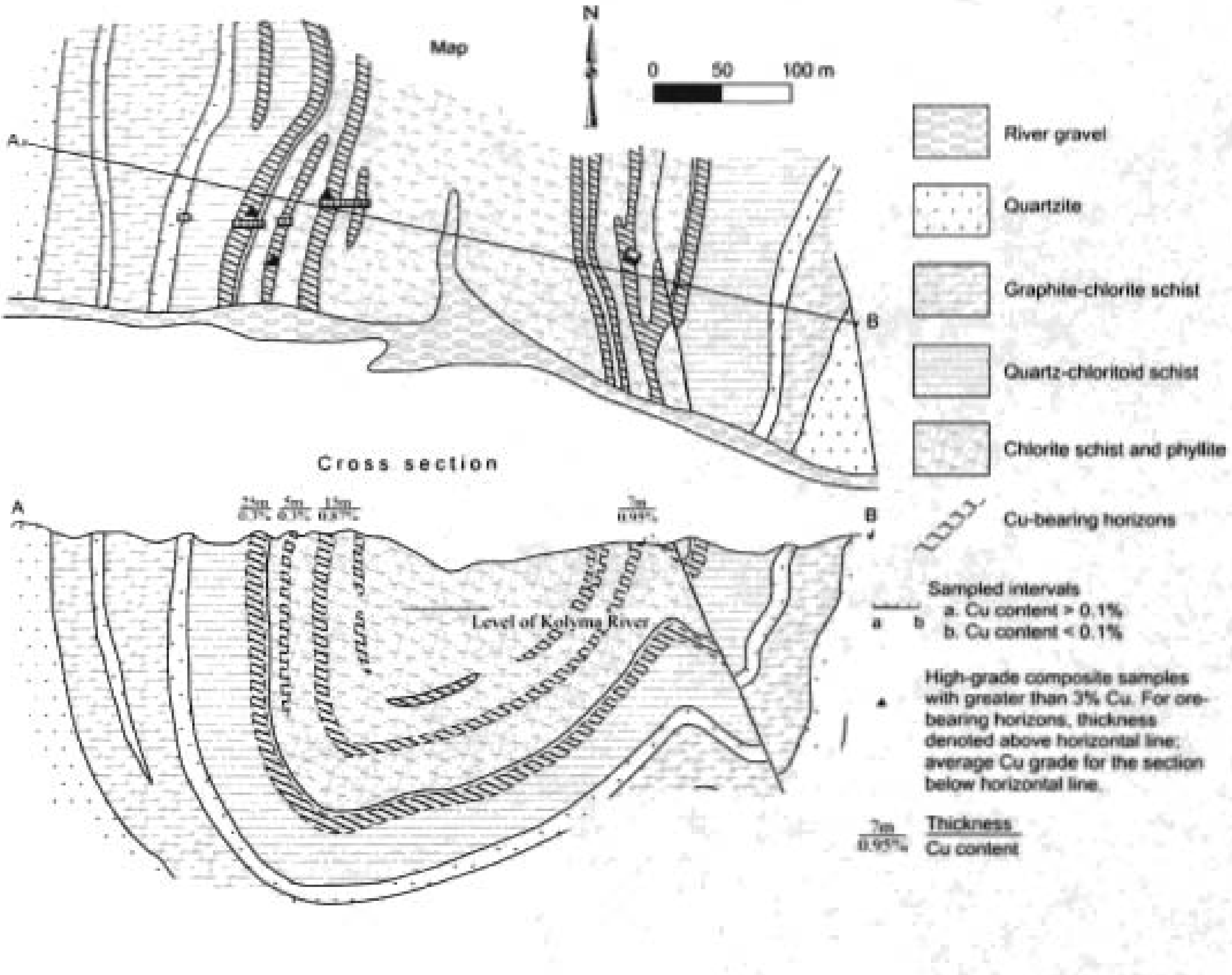


Figure 5. Oroek sediment-hosted Cu deposit, Oroek metallogenic belt, Russian Northeast. Schematic geologic map and cross section for southern part of deposit. Adapted from Shpikerman (1996).

granitization. The crystalline basement is unconformably overlain by a gently-dipping sedimentary and volcanic rock sequence of Riphean and younger age. The Omolon terrane is interpreted as a rifted fragment of the North Asian Craton (unit NSC; Nokleberg and others, 1994c, 1997c). Rifting is interpreted as occurring in the Late Devonian and Early Carboniferous (Nokleberg and others, 2000). The Omolon terrane and contained ironstone metallogenic belt are herein interpreted as possibly correlative with the Kilbuck-Idono terrane and contained Kilbuck ironstone metallogenic belt in southwestern Alaska (fig. 3) (Nokleberg and others, 1998, 2000).

An older group of Be, Ce, La, Y, Nb, and Ta deposits is related to Rapakivi-type granites with isotopic ages of 1.65 to 1.7 Ga. The granites intrude subalkalic siliceous volcanic rocks. The Be deposits, as at Burgundiy and Nygvagan, occur in albite-genthevite-bearing zones within granite intrusions. The Ce, La, Y, Nb, and Ta deposits, as at Albititovoe and Gurjanouskoe, occur within zones of quartz, microcline, albite, riebeckite, aegirine along a linear zone of altered volcanic rocks. For both types of deposits, the main ore minerals are zircon, monazite, gagarinite, cassiterite, bastnasite, columbite, xenotime, and pyrochlore.

A younger group of Y, Ce, U, Mo, Nb, and Ta deposits exhibit isotopic ages of 1.1 to 1.3 Ga, but show no clear connection with igneous rocks. Coeval dikes of alkalic basalt, with up to 12% K_2O, occur in the area. The large Y-Ce deposit at Uzhnoe consists of metasomatic albite and apatite which occur in a fault zone. The apatite contains Ce and up to 1% Y. Other ore minerals are zircon, synchysite, monozite, xenotime, thorite, and brannerite. The U-Mo deposits, as at Mezhdurechnoe and Zapadnoe, are associated with altered beresite formed of muscovite, sericite, hydromica, pyrite, and Ca-Fe-Mg carbonate minerals. The chief ore minerals are mainly molybdenite, native gold and Cu-, Zn-, and Pb-sulfides. The Nb-Ta deposits, as at Krasnogorskoe, occur in zones of argillaceous-altered volcanic rocks now mainly quartz, hydromica, and clay. The chief ore minerals are Nb-bearing gematite (up to 1% Nb), euxenite, and molybdenite. The deposits of the Ulkan metallogenic belt are similar to those in the Pikes Peak, Colorado region in the U.S.A. The metallogenic belt is isolated, distant from roads, and has only recently been studied (Kirillov, 1991,1993). Insufficient data preclude determining the origin of the Ulkan metallogenic belt. The Ulkan belt is coeval anorthosite to the south which is interpreted as forming in a Mesoproterozoic rift-related volcanic-plutonic center.

Bilyakchan Metallogenic Belt of Sediment-Hosted Cu and Basaltic Cu Deposits (Belt BI) Southwestern Part of Russian Northeast

The Bilyakchan metallogenic belt of sediment-hosted Cu and basalt Cu deposits (fig. 2; tables 3, 4) occurs in the southwestern part of the Russian Northeast in Proterozoic rocks of the Verkhoyansk fold belt (unit NSV) that constitutes the North Asian Craton Margin (Nokleberg and others, 1994c, 1997b, c, 1998; Shpikerman, 1998). The belt strikes north-northeast for 350 km along the western folded margin of the Okhotsk cratonal terrane and is about 50 km wide. The deposits occur in metamorphosed sandstone and basalt of the Riphean and Vendian Bilyakchan sequence with a thickness of 3,100 m (Kutyrev and others, 1986). The Bilyakchan metallogenic belt is correlated with the tectonically-displaced Oroek metallogenic belt of ironstone and sediment-hosted Cu deposits which is described above.

Dzhagdag Basaltic Cu and Severny Uy Occurrences

Basaltic Cu occurrences, as at Dzhagdag, occur in the lower part of the sequence. The Dzhagdag deposit consists of two layers of late Riphean (Vendian) amygdaloidal basalt, intercalated with tuff and sandstone, which contain Cu-bearing horizons which are 0.4-5 m thick and contain finely disseminated to small masses of chalcocite, bornite, native copper, cuprite, covellite, and malachite (Kutyrev and others, 1988). The basaltic Cu deposits and the hosting basalts are interpreted as forming during rifting on a shallow-submerged scarp of the western Okhotsk cratonal terrane. The sediment-hosted (sandstone) Cu occurrences, as at Severny Uy and Borong, occur at higher stratigraphic levels. The Severny Uy deposit consists of Cu-bearing horizons from 1 to 3 m thick and occur in Late Riphean (Vendian) quartz- and polymictic sandstone and siltstone (Kutyrev and others, 1986). The deposit contains fine disseminations and pockets of massive pyrite, chalcopyrite, bornite, chalcocite, and hematite. The sediment-hosted Cu deposits and the host sandstones are interpreted as forming during erosion of volcanic rocks with basaltic Cu deposits.

Origin of and Tectonic Controls for Bilyakchan Metallogenic Belt

The southwestern part of the North Asia Craton Margin (Verkhoyansk fold belt, unit NSV), which hosts the Bilyakchan metallogenic belt, consists of the following major units: (1) Middle to Late Riphean shelf limestone, sandstone, and shale with a combined thickness of more than 3 km; and (2) Late Riphean to Late Vendian clastic and volcanic rocks, including variegated conglomerate, sandstone, siltstone, basalt, and rare rhyolite. The late Riphean (Vendian) sedimentary and volcanic rock which host the Cu deposits are interpreted as forming in a rift-related depression which formed in the transition between a continental shelf and adjacent onshore area, within the Siberian paleocontinental passive margin. The rift-related sedimentary rocks and Cu deposits were subsequently deformed into gentle folds and metamorphosed at greenschist facies. Sedimentary rocks of the fold belt are apparently tectonically detached from crystalline basement of craton. In this region, the Verkhoyansk fold belt is separated from the North Asian Craton by a west-verging thrust fault.

Kilbuck Metallogenic Belt of Ironstone (Superior Fe) Deposits (Belt KI) Southwestern Alaska

The Kilbuck metallogenic belt of ironstone (probable Superior Fe type) deposits (fig. 3; tables 3, 4) occurs in southwestern Alaska. The metallogenic belt is hosted in the Kilbuck-Idono cratonal terrane which occurs in two discontinuous fragments separated along the dextral-slip Nixon Fork fault (fig. 3). The one known occurrence is at Canyon Creek (table 4) (Nokleberg and others 1997a, b, 1998).

The Canyon Creek ironstone (Superior Fe) occurrence consists of rhythmically-layered hematite, magnetite, and siderite in layers up to 4 cm thick which occur in bleached Early Proterozoic quartzite (Bruce Hickok, T.K. Bundtzen, and M.L. Miller, written commun., 1992). The host rocks are mainly quartzite, garnet-biotite schist, meta felsic volcanic rocks, and amphibolite which are metamorphosed at amphibolite facies. The occurrence is about 150 m long, but is poorly exposed.

The Kilbuck-Idono terrane which hosts the Canyon Creek ironstone (banded Fe formation) occurrence consists chiefly of metamorphosed diorite, tonalite, trondhjemite, and granite orthogneiss, subordinate amphibolite, and minor metasedimentary rocks (Box and others, 1993; Miller and others, 1991). The metasedimentary rocks of the terrane are mainly quartz-mica schist, marble, garnet amphibolite, and minor banded iron formation. The metaplutonic rocks of the terrane yield Early Proterozoic (2.06 to 2.07 Ga) U-Pb zircon ages of emplacement (Box and others, 1990; Miller and others, 1991). The Kilbuck-Idono terrane may be a displaced cratonal fragment of either the North America Craton or the North Asian Craton. The Kilbuck-Idono terrane is possibly

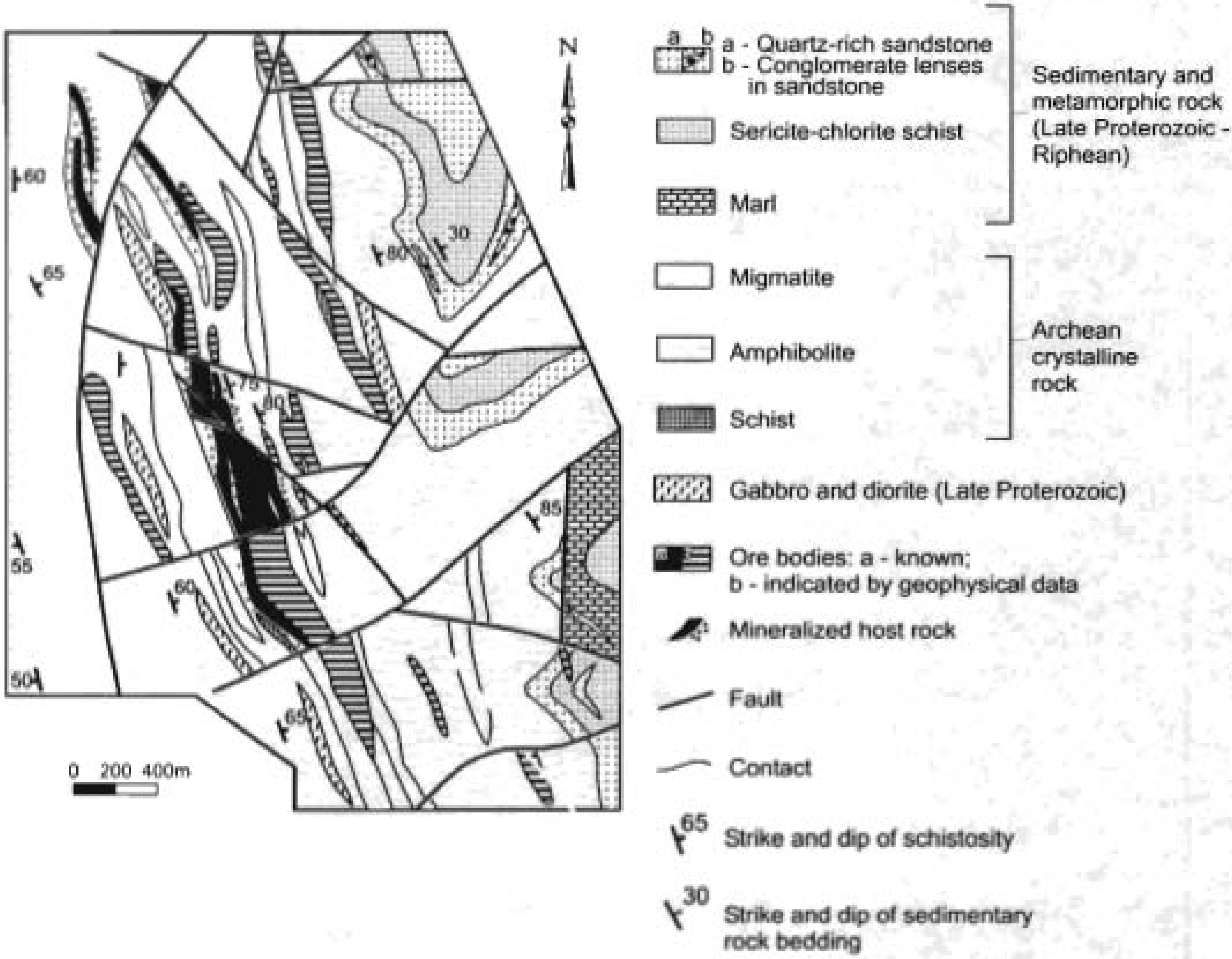


Figure 6. Verkhny-Omolon ironstone deposit, Omolon metallogenic belt, Russian Northeast. Schematic geologic map. Adapted from Gelman and Fadeev (1983).

correlative with the Omolon terrane of the Kolyma-Omolon superterrane, or the Okhotsk terrane, both in the Russian Northeast and interpreted as rifted fragments of the North Asian Craton (fig. 2) (Nokleberg and others, 1994c, 1997c, 2000). The Omolon terrane has a somewhat similar stratigraphy and also contains ironstone deposits in the Omolon metallogenic belt.

Metallogenic Belts Formed During Proterozoic Sedimentation, Rifting, and Hydrothermal Activity Along Cratons or Craton Margins

Sinuk River Metallogenic Belt of Massive Sulfide-Barite and Stratabound Fe and Mn Deposits (Belt SR) Northwestern Alaska

The Sinuk River metallogenic belt of stratiform massive sulfide-barite and stratabound Fe deposits occurs in the Sinuk River area in the southwestern part of the Seward Peninsula in northwestern Alaska (fig. 3; tables 3, 4) (Nokleberg and others, 1997b, 1998). The metallogenic belt occurs in a 250 km^2 region of metamorphosed, upper Paleozoic, carbonate-dominated rocks of the Seward metamorphosed continental margin terrane (Nokleberg and others, 1994c, 1997c), about 30 km west of Nome (Herreid, 1968; Hudson and others, 1977; Bundtzen and others, 1994, 1995; Newberry and others, 1997). At least 15 separate occurrences of massive to disseminated galena, sphalerite, fluorite, and barite, and massive hematite occur in the area. The deposits vary widely in morphology and size and consist of: (1) disseminated to massive barite sulfide lenses (Aurora Creek, Nelson, Rocky Mountain Creek, Quarry) which are hosted in felsic metavolcanic schist, carbonate rock, and metamorphosed mafic flows(?), and which are interpreted as kuroko massive sulfide and replacement deposits; and (2) massive, stratabound segregations of hematite, magnetite, and pyrolusite, interpreted as volcanogenic(?) Fe and Mn deposits (American, Bear, Cub, Monarch) which are hosted in calc-schist and marble.

Aurora Creek Massive Sulfide-Barite Deposit

The Aurora Creek massive sulfide-barite deposit (Herreid, 1968, 1970; Bundtzen and others, 1994, 1995; Schmidt, 1997b) consists of disseminated to massive sphalerite, galena, barite, pyrite, magnetite, and minor chalcopyrite in muscovite-feldspar metavolcanic schist of Aurora Creek sequence, which is part of the Late Proterozoic and early Paleozoic Nome Group. Sulfide minerals occur for 2,400 m along strike. Significant dolomite formation is interpreted to have accompanied sulfide deposition. The deposit has been explored by with limited drill cores and trenches. Intense alteration to tourmaline occurs in feldspar-rich metavolcanic schists near massive sulfides and barite occurrences. Limited sulfur isotopic analyses indicate which heavy sulfur probably formed in a seawater-contaminated, marine volcanogenic setting. Lead isotope analyses from the Aurora Creek, Quarry, and Rocky Mountain Creek suggest either a kuroko massive sulfide and SEDEX deposit type (Bundtzen and others, 1995). One zone in one drill core contains an average of 15.9% Zn, 1.38% Pb, 0.07 % Cu, 35% Ba, 2.6 g/t Au, 45 g/t Ag. Similar, but smaller occurrences are located at the Nelson, Rocky Mountain Creek, and Quarry prospects. The Aurora Creek and nearby deposits are interpreted as similar to the Ansil mine and related deposits in the Noranda area of Quebec.

Origin of and Tectonic Controls for Sinuk River Metallogenic Belt

The Sinuk River metallogenic belt, which contains the Aurora Creek, Quarry, Nelson, and Rocky Mountain Creek Zn-Pb-barite-Ag deposits, is hosted in the Aurora Creek sequence of the Nome Group (Bundtzen and others, 1994; Schmidt, 1997b). The Monarch, Quarry, American, and Cub Bear Fe-Mn deposits are hosted in the overlying Mount Distan sequence. New U-Pb zircon isotopic ages of 675 and 681 Ma were obtained from orthogneiss which intrudes the Mount Distan sequence (T.K. Bundtzen, this study). This relation suggests which both the stratiform massive sulfide-barite and stratabound Fe and Mn deposits of the Sinik River metallogenic belt are probably of Late Proterozoic or older age (Bundtzen and others, 1994, 1995; Patrick and McClelland, 1995). Sulfur isotopic analyses of sulfides from the massive sulfide-barite deposits suggest formation in a seawater-contaminated, marine volcanogenic rift(?) environment. The Aurora Creek sequence and the hosting Nome Group are part of the Seward metamorphosed continental margin terrane that is interpreted as part of the North American Continental Margin (Nokleberg and others, 2000). The Sinuk River metallogenic belt is interpreted as forming during marine volcanogenic rifting(?) of the North American Continental Margin.

Gillespie Metallogenic Belt of SEDEX Zn-Cu-Pb-Au-Ag Deposits (Belt GM) Northern Yukon Territory

The Gillespie metallogenic belt of SEDEX Zn-Cu-Pb-Au-Ag deposits occurs in the northern Yukon Territory (fig. 3; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt is hosted in the Gillespie Lake Group which is the uppermost unit of the Early Proterozoic Wernecke Supergroup of the North American Craton margin. The group is about 1 km thick and consists mainly of dolostones and dolomitic clastic rocks (Mustard and others, 1990). The major SEDEX occurrences are Blende in the eastern Ogilvie Mountains, and Hart River.

Blende SEDEX Zn-Cu-Pb-Au-Ag Deposit

The East and West Zones of the Blende deposit consist primarily of galena, sphalerite and pyrite, with lesser chalcopyrite and tetrahedrite, in vein and breccia zones with siderite-dolomite-quartz gangue (NDU Resources, press release, 1993; Robinson and Godwin, 1995). The deposit contains an estimated resource of 19.6 million tonnes grading 3.04% Zn, 2.81% Pb, 1.6% Cu, 56 g/t Ag, and 2.75 g/t Au. Ore horizons extend over 700 m vertically and 6 km along strike along a structural zone of shears and breccia. The mineralization is multistage. The deposits are hosted in stromatolite-bearing dolostone of the Middle Proterozoic Gillespie Lake Group in the Wernecke Supergroup. Stocks, plugs, and dikes of hornblende gabbro intrude the dolostone and appear to be associated with mineralization (Robinson and Godwin, 1995).

Hart River SEDEX Zn-Cu-Ag Deposit

The Hart River SEDEX Zn-Cu-Ag deposit consists of pyrite and pyrrhotite and minor sphalerite, galena and tetrahedrite which occur as a tabular mass along a facies change from dolomite to calcareous black argillite of the Early Proterozoic Gillespie Lake Group (EMR Canada, 1989; MacIntyre, 1991). The host rocks are cut by numerous diabase sills and dikes which metamorphose the dolomite to serpentinite-talc and the argillite to hornfels. The footwall is silicified and contains a stockwork of sulfide veinlets, whereas the hanging wall contains thinly layered sulfides. The deposit has estimated reserves of 1.1 million tonnes grading 3.6% Zn, 1.45% Cu, 0.9% Pb, 49.7 g/t Ag, and 1.4 g/t Au (MacIntyre, 1991; Abbott and others, 1994).

Origin of and Tectonic Setting for Gillespie Metallogenic Belt

The Gillespie metallogenic belt SEDEX deposits is hosted in the Wernecke Supergroup which is part of a shelf assemblage, at least 14 km thick and is part of the North American Craton Margin. The assemblage consist of fine-grained, turbidite clastic rocks which grade upward into carbonate rocks, and is broadly correlated with the Purcell Supergroup of the southern Canadian Cordillera (Young and others, 1979). The major SEDEX occurrences in the Gillespie metallogenic belt at Blende (and the Carpenter Ridge prospect) may be related to Proterozoic gabbro-diorite sills (Robinson and Godwin, 1995), or may be possibly related to correlative overlying mafic volcanic flows as at Hart River (Abbott and others, 1994). Other SEDEX Zn-Pb occurrences, as at Cord, which is hosted by the upper Gillespie Lake Group in the Wernecke Mountains, and other stratabound Zn-Pb-Ag vein occurrences, as at Oz, Monster, and Tart, may also be related to this mafic igneous activity. Similar mineralization ages occur at Blende (1.4 Ga; Robinson and Godwin, 1995), Hart River (1.24 to 1.28 Ga; Morin, 1978), and Sullivan (1.43 Ga; LeCouteur, 1979). These ages and host rock setting indicate sedimentary exhalation occurred in a distal sedimentary shelf facies and was possibly related to a widespread Middle Proterozoic event, including faulting, rifting, and associated mafic intrusion (Dawson and others, 1991). This rifting is interpreted as influencing sedimentation in the Wernecke and Purcell Supergroups and the Muskwa Ranges Assemblage.

Wernecke Metallogenic Belt of U-Cu-Fe (Au-Co) Vein and Breccia Deposits (Belt WR) Central Yukon Territory

The Wernecke metallogenic belt of U-Cu-Fe (Au-Co) vein and breccia deposits (fig. 3; tables 3, 4) occurs in the central Yukon Territory and is hosted in the Early Proterozoic Wernecke Supergroup in the North American Craton Margin. In this area, the Early Proterozoic Wernecke Supergroup consists of a thick sequence of dominantly fine-grained clastic rocks (Delaney, 1981). More than forty deposits of Cu, U and Fe are associated with extensive heterolithic breccias, as veins, and disseminations in the matrices and clasts, and in adjacent hydrothermally altered rock (Nokleberg and others 1997a, b, 1998). The significant deposits are at Dolores, Igor, Irene, Pagisteel, Porphyry, and Slab (table 4). Chalcopyrite, brannerite, hematite and magnetite are associated with alteration assemblages of Na and K-feldspar, silica, chlorite and carbonate (Dawson and others, 1991). No definitive tonnage and grade data exist for the deposits and occurrences in the Wernecke metallogenic belt; however, resource estimates exist for two significant occurrences which contain varying proportions of Cu, U, Au, Fe and Co. The Igor occurrence contains an estimated resource of 0.5 million tonnes grading 1.0% Cu, and the Pagisteel occurrence contains an estimated resource of 1 tonne grading 29% Fe (Archer and others, 1986; Hitzman and others, 1992; Abbott and others, 1994). Other significant occurrences are at Slab, Irene, Porphyry, Dolores, Athens, and Olympic (table 4).

Formation of the vein and breccia deposits in spatial relationship to associated mafic dikes and minor diorite intrusions was proposed by Abbott and others (1994). Similarities between these deposits in the Wernecke belt and those in the better known Kiruna-Olympic Dam deposit type were discussed by Gandhi and Bell (1996), but evidence of coeval, large-scale magmatic activity, regarded as an important feature of the later deposit type, is lacking. A deep-seated magmatic hydrothermal source for the formation and mineralization of the breccias was proposed for both the Kiruna-Olympic Dam deposit type and the deposits in the Wernecke belt (Hitzman and others, 1992; Thorkelson and Wallace, 1993). A recent, unpublished U-Pb zircon isotopic age of 1.72 Ga for a post-deposit dike suggests an Early Proterozoic age for both the Wernecke Supergroup and the mineralization (D.J. Thorkelson, personal communication, 1994).

Rapitan Metallogenic Belt of Sedimentary Iron Formation Deposits (Belt RA) Central Yukon Territory

The Rapitan metallogenic belt of iron formation deposits (fig. 3; tables 3, 4) occurs in the central Yukon Territory and is hosted in the Rapitan Sedimentary Assemblage, the lowest and easternmost unit of the Windermere Supergroup which is part of the North American Craton Margin. The Rapitan assemblage is interpreted as forming in a rift environment which exhibits rapid facies and thickness changes, and contains a suite of rift-related igneous intrusions and extrusions with isotopic ages of about 770 Ma (Gabrielse and Campbell, 1991). Diamictite, in part glaciogenic, occurs at several localities and stratigraphic levels, notably at two well defined horizons in eastern Mackenzie Mountains. The largest deposit of hematite-jaspilite iron deposit in North America occurs in one of these horizons at Snake River (Crest; table 4) (Nokleberg and others 1997a, b, 1998).

Crest Iron Formation Deposit

The Crest Iron (Snake River) formation deposit consists of a main zone of banded, laminated or nodular jasper hematite which occurs along a stratigraphic interval about 130-m thick near the base of the 'ice marginal' glacial diamictite complex of the Shezal Formation. The richest part of the deposit occurs in the top 80 m which contains little or no interbedded sedimentary rocks. Estimated resources are 5.6 billion tonnes grading 47.2% Fe. Numerous smaller regional occurrences are also hosted in the 'proglacial' siltstone facies of the underlying Sayunei Formation (Eisbacher, 1985; Yeo, 1986). This type of banded iron formation mineral deposit is named the Rapitan-type by Gross (1996). This type iron of deposit exhibits distinctive lithological features, including association with diamictites (tillite) which contain dropstone, sandstone, conglomerate, and argillite. The Crest Iron deposit and the Jacadigo iron formation in Brazil are interpreted as having been deposited in Late Proterozoic or early Paleozoic rocks grabens and fault-scarp basins along the rifted margins of continents or ancient cratons (Gross, 1996).

Origin of and Tectonic Setting for Rapitan Metallogenic Belt

An origin of marine exhalation along synsedimentary faults was proposed for this type of hematite-jaspilite iron formation by Gross (1965), with modifications by Yeo (1986) to include brine transport by currents generated by the thermal gradients between cold glacial and warm hydrothermal waters. The iron deposits in the Rapitan assemblage are correlated with hematite-jasper iron formation in siltstone and diamictite of the Late Proterozoic Tindir Group near Tatonduk River in eastern Alaska (Payne and Allison, 1981; Young, 1982). Dawson and others (1994) correlate the iron deposits in the Rapitan Assemblage and Tindir Group with Late Proterozoic tillite and hematite iron units of the Prikolyma terrane of the Kolyma region in eastern Siberia (Furduy, 1968). This interpretation tentatively supports juxtaposition of Siberia and Laurentia in the Late Proterozoic.

Metallogenic Belts Formed During Proterozoic Rifting of North American Craton or Craton Margin

Redstone Metallogenic Belt of Sediment-Hosted Cu-Ag Deposits (Belt RS) Central Yukon Territory

The Redstone metallogenic belt of sediment-hosted Cu-Ag deposits (fig 3; tables 3, 4), which occurs in the western Mackenzie district in the central Yukon Territory, is hosted in the dominantly clastic rocks of the Late Proterozoic Windermere Supergroup which is part of the North American Craton Margin (Gabrielse and Campbell, 1991; Nokleberg and others, 1997b, 1998). The largest deposits is at Coates Lake (Redstone); the other deposit in the belt is the June Creek (Baldwin-Shell) deposit (table 4) (Nokleberg and others 1997a, b, 1998).

Coates Lake (Redstone) sediment-hosted Cu-Ag Deposit

The Coates Lake (Redstone) sediment-hosted Cu-Ag deposit consists of chalcopyrite, bornite, digenite, chalcocite and covellite as disseminations stratabound in eight repetitive algal carbonate/evaporite sabkha sequences along a transgressive contact with underlying continental redbeds of the Redstone River Formation (Chartrand and others, 1989). The deposit contains estimated reserves of 37 million tonnes grading 3.9% Cu and 11.3 g/t Ag. Other deposits in the belt are at June Creek, Hayhook Lake, and Per.

Origin of and Tectonic Controls for Redstone Metallogenic Belt

The Coates Lake deposit is the largest and best-documented example of Kuperschiefer-type, syngenetic mineral deposit in Canada. Typically Kuperschiefer deposits are zonally distributed and contain disseminated sulfides at oxidation-reduction boundaries in anoxic marine sedimentary rock at the base of a marine or large-scale saline lacustrine transgressive cycle. The host strata either overlie or are interbedded with continental redbeds. The redbeds, along with characteristically-associated evaporites, are a probable source of evaporite-derived ore fluid and copper (Kirkham, 1996a).

The Redstone metallogenic belt of sediment-hosted Cu-Ag deposits and hosting Windermere Supergroup are interpreted as forming during a period of major Late Proterozoic rifting along the western continental margin of North America (Gabrielse and Campbell, 1991). The Coates Lake Group which hosts the Coates Lake deposit is an unconformity-bounded rift assemblage which occupies several fault-controlled embayments over a 300 km-long trend which is located along the eastern limit of Late Proterozoic strata in the Mackenzie Mountains (Jefferson and Ruelle, 1986).

Churchill Metallogenic Belt of Cu Vein Deposits(Belt CH) Northern British Columbia

The Churchill metallogenic Belt of Cu vein deposits occurs in the Muskwa Ranges assemblage in northern British Columbia (fig. 3; tables 2, 3) (Nokleberg and others, 1997b, 1998). This assemblage consists of a platformal succession, about 6-km-thick, of quartzite, carbonate rocks, and flysch which are tentatively correlated with the Purcell (Belt) Supergroup which was deposited along the passive continental margin of the North American Craton (Bell, 1968; Aitken and McMechan, 1991). The Muskwa Ranges assemblage consists of a lower sequence of platformal quartzite and carbonate rocks which is about 3.5 km thick, and an upper sequence of shaley flysch which is about 2.5 km thick. In this area are twelve significant Cu vein deposits which occur in clastic and impure carbonate rocks of the Aida and Gataga formations in the Racing River-Gataga River region (Taylor and Stott, 1973). The significant deposit is at Churchill. Other Cu vein deposits in the Churchill metallogenic belt are at Davis Keays, Gataga, and Fram.

Churchill (Davis Keays) Cu Vein Deposits.

The major Churchill (Davis Keays) Cu vein deposit occurs along the Magnum vein system. The deposit consists of chalcopyrite, pyrite, quartz, and ankerite in a zone which is 100 m wide (Preto and Tidsbury, 1971; Dawson and others, 1991). The deposit occurs in strongly folded Late Proterozoic dolomites and slates of the Aida Formation (with K-Ar isotopic age 780 Ma), and is intruded by diabase dikes and sills. Overlying Cambrian basal conglomerate contains clasts of mineralized vein material. The deposit age is interpreted as Late Proterozoic. From 1971 to 1974, 498,00 tonnes grading 3.43% Cu were produced. The grade is highly variable and discontinuous.

Origin of and Tectonic Controls for Churchill Metallogenic Belt

The Cu vein deposits in the Churchill metallogenic belt are associated with a northwest-striking diabase dike swarm which crosscuts folded sedimentary rocks in the Purcell (Belt) Supergroup which were deposited along the passive continental margin of the North American Craton. The Cu vein deposits are partly concordant with and intruded by genetically-related diabase dikes. However, no diabase dikes occur in the Late Proterozoic Windermere Group to the west, indicating an early Late Proterozoic age for dike emplacement and formation of associated Cu vein deposits (Dawson and others, 1991). The Churchill metallogenic belt is interpreted as forming in a major, Mesoproterozoic rifting event which is reflected in the sedimentary assemblages of the Purcell and Wernecke Supergroups and the Muskwa Ranges assemblage.

Monashee Metallogenic Belt of Sedimentary Exhalative (SEDEX) Zn-Pb-Ag Deposits (Belt MO) Southern British Columbia

The Monashee belt of sedimentary exhalative (SEDEX) Zn-Pb-Ag deposits (fig. 3; tables 3, 4), located in southern British Columbia in the southeastern Canadian Cordillera, is hosted in the Monashee cratonal terrane. The major SEDEX deposits (table 4) are Big Ledge, Ruddock Creek, Cottonbelt, and River Jordan (King Fissure), as well as the Neoproterozoic Mount Copeland porphyry Mo deposit which is herein included in the metallogenic belt because the porphyry systems are part of the Monashee cratonal terrane (Nokleberg and others 1997a, b, 1998). The SEDEX deposits and prospects are within the upper paragneiss part of the terrane. Estimated resources range from less than 1 million to 6.5 million tonnes.

Big Ledge SEDEX Zn-Pb Deposit

The Big Ledge SEDEX Zn-Pb deposit consists of sphalerite, pyrrhotite, galena, and pyrite in lenses (Høy, 1982a; MINFILE, 2002). The deposit contains estimated reserves of 6.5 million tonnes grading 4% Zn. The deposit is in a dark, pyrrhotite and pyrite-rich, graphitic, calcareous schist which extends along strike for approximately 10 km. The schist is part of paragneiss which is interpreted as the amphibolite-grade metamorphic equivalent of the Late Proterozoic Windermere Group.

Ruddock Creek SEDEX Zn-Pb Deposit

The Ruddock Creek SEDEX Zn-Pb deposit consists several layers with banded sphalerite, pyrrhotite, galena, pyrite and minor chalcopyrite and local barite and fluorite which occur in discontinuous lenses and layers along strike length for several kilometers (Dawson and others, 1991; Høy, 1982a, 2001; MINFILE, 2002). The deposit has estimated reserves of approximately 5.0 million tonnes grading 7.5% Zn, 2.5% Pb and is hosted in possibly Paleoproterozoic schist, calc-silicate gneiss, quartzite and marble.

Mount Copeland Porphyry Mo Deposit

The Mount Copeland porphyry Mo deposit consists of molybdenite, pyrite, pyrrhotite, bornite, chalcopyrite and galena which occur along the northern boundary of a large mass of nepheline syenite gneiss flanking the southern boundary of the Frenchman's Cap Dome, one of several gneissic domes flanking the eastern margin of the Shuswap Metamorphic Complex (McMillan, 1973; Okulitch and others, 1981; MINFILE, 2002). The deposit has estimated reserves of 180,000 tonnes grading 1.82% MoS_2 and production of 171,145 tonnes grading 0.75% MoS_2. The deposit is hosted in irregular lenses of aplite and pegmatite syenite. U-Pb zircon isotopic analysis suggests an age of 773 Ma. This age indicates the porphyry deposit formed in the early history of the Monashee cratonal terrane prior to fragmentation and migration.

Origin of and Tectonic Controls for Monashee Metallogenic Belt

The SEDEX Zn-Pb deposits in the Monashee metallogenic belt, which are interpreted as Broken Hill type Pb-Zn-Ag deposits by Høy (2001), consist of extensive, thin, sulfide layers which are folded and metamorphosed along with their predominantly calcareous and schistose host rock (Fyles, 1970; Høy, 1982a, 2000; Dawson, and others, 1991). A correlation of the SEDEX Zn-Pb deposits and host rocks of the Monashee terrane with those in the Kootenay terrane may exist (Dawson and others, 1991; Høy, 2001). The Monashee terrane is interpreted as a displaced fragment of the North American Craton which consists of a core of basement paragneiss (with a Late Archean and Paleoproterozoic isotopic age of 2.8 to 1.96 Ga), intruded by orthogneiss (2.1 Ga), and mantled by paragneiss which is intruded by a syenite pluton which may be as old as 1,852 Ma (Scammell and Brown, 1990; Nokleberg and others, 1994c, 1997c; Crowley, 1997). In the area of the Mount Copeland porphyry Mo deposit, minor occurrences of pyrochlore and columbite-tantalite in carbonatite associated with syenite gneiss (McMillan, 1973) suggest a genetic relationship of these alkaline intrusions to a rifting event which resulted in the separation of the Monashee terrane from the craton in the Late Proterozoic (Monger and Nokleberg, 1996).

Purcell Metallogenic Belt of SEDEX Zn-Pb-Ag Deposits (Belt PR) Southern British Columbia

The Purcell metallogenic belt of sedimentary exhalative (SEDEX) Zn-Pb-Ag deposits (fig. 3; tables 3, 4) occurs in the southern Canadian Cordillera and is hosted in sedimentary rocks of the Mesoproterozoic Purcell Supergroup. The sedimentary rocks of the supergroup comprise a dominantly passive margin depositional sequence of fine-grained, basinal clastic rocks at least 11 km thick. This basinal sequence thins eastward into platformal sedimentary rocks toward the North American Craton (Aitken and McMechen, 1991). The Purcell Supergroup is correlated with the Belt Supergroup in the western and northern USA. The major SEDEX deposit is Sullivan; other significant deposits in the belt are the Moyie (St. Eugene) and Vine Ag-Au polymetallic vein deposits (table 4) (Høy, 1991, 2001; Nokleberg and others 1997a, b, 1998).

Sullivan SEDEX Zn-Pb-Ag Deposit

The Sullivan SEDEX Zn-Pb-Ag deposit (fig. 7) consists of a laminated sulfide assemblage of galena, sphalerite and pyrite which has undergone metamorphic recrystallization, and tectonically-induced mechanical and chemical remobilization (Leitch and Turner, 1991, 1992; Lydon, 1995). The deposit occurs near a north-trending rift axis at an intersection with the east-west-trending, proto-Kimberley fault. The Sullivan deposit originally contained 170 million tonnes of ore with a grade of 5.5% Zn, 5.8% Pb, and 59 g/t Ag. About 70% of the deposit occurs in a massive pyrrhotite-galena-sphalerite vent complex which overlies a heavily tourmaline-altered hydrothermal upflow zone. The remaining 30% of the deposit occurs in concordant laminated pyrrhotite-sphalerite-galena "ore bands" which extend eastwards from the vent complex (Lydon, 1995). Ongoing hydrothermal activity from marine brines generated successive chlorite-pyrrhotite-muscovite and albite-chlorite-pyrite-sericite-calcite assemblages in ore zone and hanging wall and footwall, all coincident with gabbro dikes and sills. The deposit is hosted conformably within folded, Middle Proterozoic turbidite of the Early Aldridge formation of the Purcell Supergroup. The turbidites fill an intracontinental extensional rift marine basin which is extensively intruded by tholeiitic Mesoproterozoic Moyie Sills series. The sulfide deposition is interpreted as predating the Mine Sill series, part of the Moyie Sills series, and was accompanied by extensive boron (tourmaline) alteration of marine sedimentary origin. Related, smaller Zn-Pb-Ag deposits are at Fors, Stemwinder, North Star, and Vine.

Origin of and Tectonic Setting for Purcell Metallogenic Belt

The Purcell metallogenic belt of SEDEX Zn-Pb-Ag deposits (fig. 3; tables 3, 4) is hosted in the Purcell Supergroup which ranges up to 10 km thick to the west, but thins eastward into platformal sedimentary rocks. The Supergroup is overlain by shallow marine and non-marine rocks (Aitken and McMechan, 1991), is underlain by basement rocks older than 1.7 Ga, and is intruded by the tholeiitic Moyie Sills with a U-Pb zircon isotopic age of 1,467 Ma (Anderson and Davis, 1996). Up to 30% of outcrops of the turbidite sequence consists of the tholeiitic sills which were emplaced before significant consolidation of the sedimentary rocks. The sills are interpreted as forming during rifting (Høy, 1989; Lydon, 1995). The SEDEX Zn-Pb-Ag deposits of the Purcell metallogenic belt are interpreted as forming at the beginning of major period of mid-Purcell (middle Paleozoic) rifting which consisted of exhalation of Zn-Pb-Ag-bearing fluids and associated hydrothermal alternation which was followed by intrusion of the abundant Moyie Sills series. Several other similar metallogenic belts of Mesoproterozoic stratiform massive sulfide deposits occur in parts of the North American Craton Margin and are interpreted as forming during a major period of Middle Proterozoic rifting along the passive continental margin of the North American Craton (Stewart, 1975). These belts include: (1) Churchill belt of Cu vein deposits; (2) Clark Range belt of sediment-hosted Cu-Ag deposits; and (3) Gillespie belt of SEDEX deposits. The SEDEX deposits are interpreted as directly associated with mafic volcanic rocks and hydrothermal activity.

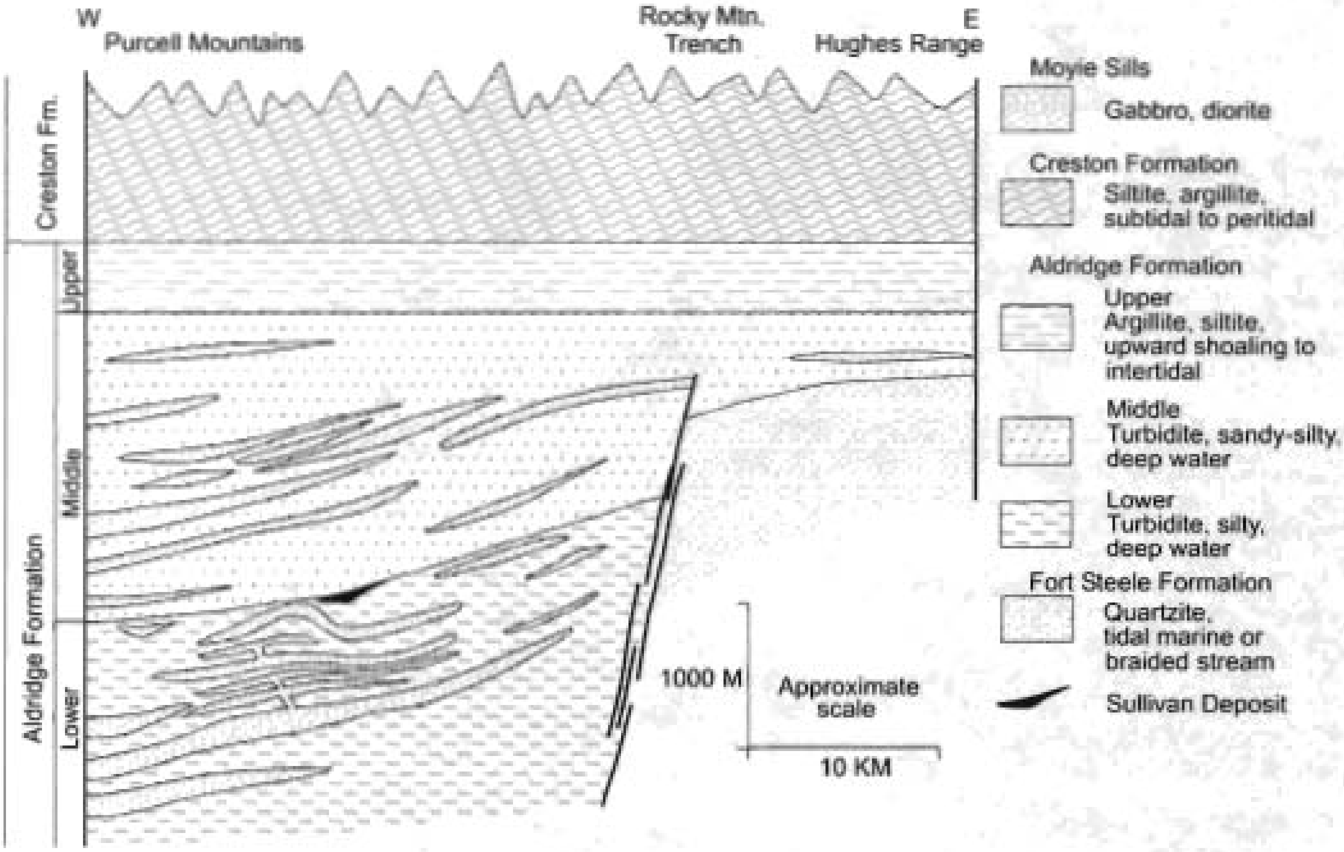


Figure 7. Sullivan sedimentary-exhalative Zn-Pb-Ag deposit, Purcell metallogenic belt, Canadian Cordillera. Schematic restored cross section. Adapted from Lydon (1995).

Clark Range Metallogenic Belt of Sediment-Hosted Cu-Ag Deposits Southern British Columbia (Belt CR)

The Clark Range metallogenic belt of sediment-hosted Cu-Ag deposits occurs in the Clark Range of southeastern British Columbia and southwestern Alberta (fig3; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt is hosted in the predominantly clastic rocks of the Appekuny, Grinnell, and Siyeh Formations of the lower Purcell Supergroup which was deposited along the passive continental margin of the North American Craton. The metallogenic belt contain numerous, minor occurrences of sediment-hosted Cu-Ag and less common Zn-Pb-Cu deposits (Kirkham, 1974; Morton and others, 1974; Collins and Smith, 1977; Binda and others, 1989). The sedimentary rocks of the Mesoproterozoic Purcell Supergroup comprise a dominantly passive margin depositional sequence of fine-grained, basinal clastic rocks at least 11 km thick. They thin eastward into platformal sedimentary rocks toward the North American Craton. The supergroup is correlated with the Belt Supergroup in the western and northern USA The metallogenic belt contains no significant mineral deposits (Nokleberg and others, 1997a, b).

Clark Range Sediment-Hosted Cu-Ag Deposits

The sediment-hosted Cu-Ag sulfide occurrences in the Clark Range metallogenic belt are most abundant in the Grinnell Formation. The deposits typically consist of erratically disseminated chalcocite, bornite, and less common Cu sulfides which are hosted in relatively permeable white quartz-arenite interlayered with red argillite. Larger Canadian occurrences include Kinshena Creek and Bull River, and an extensive occurrence in the Akamina syncline along the contact between the Grinnell and Siyeh Formations (Binda and others, 1989). None contain measured reserves or resources. The Grinnell Formation is the stratigraphic equivalent of the Revett Formation of Montana which hosts the important Spar Lake Cu (Ag) deposit (Hayes and others, 1989). In this area is a 75-km-long belt of sediment-hosted Cu-Ag and Zn-Pb occurrences that are located in the Spokane and Helena Formations in the eastern Belt basin of western Montana. These units are the equivalents to the Siyeh Formation in Canada (Lange and others, 1989).

Origin of and Tectonic Controls for
Clark Range Metallogenic Belt.

The Clark Range metallogenic belt is hosted by sedimentary rocks which are interpreted as part of Proterozoic through middle Paleozoic passive margin along the North American Craton (Nokleberg and others, 1994c, 1997b. c, 1998, 2000; Monger and others, 1996). The sediment-hosted Cu occurrences in the Clark Range metallogenic belt, which occur in quartz-arenite beds in dominantly red argillite, were interpreted by Kirkham (1974) as forming during late diagenetic mineralization of eolian beds in a sabkha sequence. In contrast, the occurrences are interpreted by Collins and Smith (1977) as the product of cyclically-controlled redox conditions during short-lived, fluvial to lacustrine episodes. Alternatively, Morton and others (1974) interpret the metal-bearing fluids forming from exhalations along faults.

Deposition of a prograding wedge of Purcell (Belt) sedimentary rocks is interpreted as the result of major Mesoproterozoic rifting along the passive continental margin of the North American Craton (Monger and others, 1972). A rift-related, exhalative origin for the sediment-hosted copper deposits in the Clark Range metallogenic belt is supported by analogous, similar deposits elsewhere in the North American Craton Margin: (1) Cap Mountains deposit in the southern Franklin Mountains, Northwest Territories (Aitken and others, 1973); (2) Churchill belt of Cu vein deposits; (3) Gillespie belt of SEDEX deposits; and (4) the Purcell belt of SEDEX deposits. Many of the metallogenic belts with SEDEX deposits are directly associated with mafic volcanic rocks and hydrothermal activity.

Cambrian through Silurian Metallogenic Belts (570 to 408 Ma)

Overview

The major Cambrian through Silurian metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 2 and 3. The major belts, although with disparate origins, are as follows. (1) In the Russian Southeast, Voznesenka (VZ) and the Kabarga (KA) belts, which contain Korean Pb-Zn and Ironstone (Superior Fe) deposits, are hosted in the Khanka continental-margin arc superterranes. These belts are interpreted as forming during marine sedimentation in rifted fragments of the Gondwandaland supercontinent. (2) In the same region, the South Khingan (SK), and Gar (GA) belts, which contain ironstone (Superior Fe), volcanogenic Fe, Cu massive sulfide, and stratiform Zn-Pb deposits, are hosted in the Bureya or Khanka continental-margin arc superterranes. These belts are interpreted as forming These belts are interpreted as forming during early Paleozoic sedimentation or marine volcanism in Manchurid and Altaid orogenic systems. (3) In the central part of the Russian Far East, Galam (GL) belts, Omulevka River (OR), Rassokha (RA), which contain Volcanogenic Fe and Mn; sedimentary, Austrian Alps W, Kipushi Cu-Pb-Zn, and Basaltic Cu, sediment-hosted Cu deposits, are interpreted as during early Paleozoic sea-floor spreading, regional metamorphism, or during subduction-related volcanism. (4) In the Russian Northeast, Dzhardzhan River (DZR) belt, which contains Southeast Missouri Pb-Zn, sediment-hosted Cu, and sandstone-hosted U deposits, is interpreted as forming during incipient rifting of early Paleozoic (Cambrian) continental-margin. (5) In the Canadian Cordillera, the Anvil (AN), Howards Pass (HP), and Kootenay (KO) belts, which contain SEDEX Zn-Pb-Ag deposits, are hosted in the North American Craton Margin, or in the Yukon-Tanana and Kootenay continental-margin terranes which are interpreted as having been rifted from the North American Craton Margin. These belts are interpreted as forming during rifting of early Paleozoic (Cambrian) North American Continental-Margin. And (6) in Southeastern Alaska, the Prince of Wales Island (PW) porphyry Cu and polymetallic vein deposits, which are hosted in the Alexander sequence of the Wrangellia superterrane, are interpreted as forming in a short-lived continental-margin arc. In the below descriptions of metallogenic belts, a few of the notable or significant lode deposits are described for each belt. Table 4, which is adapted and revised from Nokleberg and others (1997a), provides a complete listing of significant lode deposits in each metallogenic belt.

Metallogenic Belts Formed During Early Paleozoic Marine Sedimentation in Rifted Fragments of Gondwandaland Supercontinent

Voznesenka Metallogenic Belt of Korean Pb-Zn Deposits (Belt VZ) Southern Russian Southeast

The Voznesenka metallogenic belt of Korean Pb-Zn massive sulfide deposits (fig. 2; tables 3, 4) occurs in the southern part of the Russian Southeast. The belt is hosted in the Voznesenka terrane of the Khanka superterrane, a fragment of a Paleozoic active continental-margin arc (Androsov and Ratkin, 1990; Nokleberg and others, 1994c, 1997c; Khanchuk and others, 1996, 1998; Ryazantseva, 1988). The significant deposits are at Voznesenka-I and Chernyshevskoe (table 4) (Nokleberg and others

1997a, b, 1998). The massive sulfide ores generally occur conformable to organic-rich, bituminous limestones near a contact with overlying marl. Banded magnetite ore associated with algae bioherms is a peculiarity of the stratiform deposits of the Voznesenka metallogenic belt.

Voznesenka-I Korean Pb-Zn Deposit

The Voznesenka-I (Korean Pb-Zn deposit (fig. 8) (Androsov and Ratkin, 1990; Ryazantseva, 1988) consists of massive and thick-banded sphalerite and magnetite-sphalerite layers in bedded Early Cambrian limestone turbidite. The ore bodies are lenticular, 1-2 m thick, 20 to 100 m long, and occur in dolomitic limestone and marl. The sulfide bodies and host rocks are folded and regionally metamorphosed. The sulfide bodies were locally altered to skarn and greisen during emplacement of a Silurian granitic stock which intrudes the carbonate unit. The deposit is of medium size with an average grade of 4% Zn.

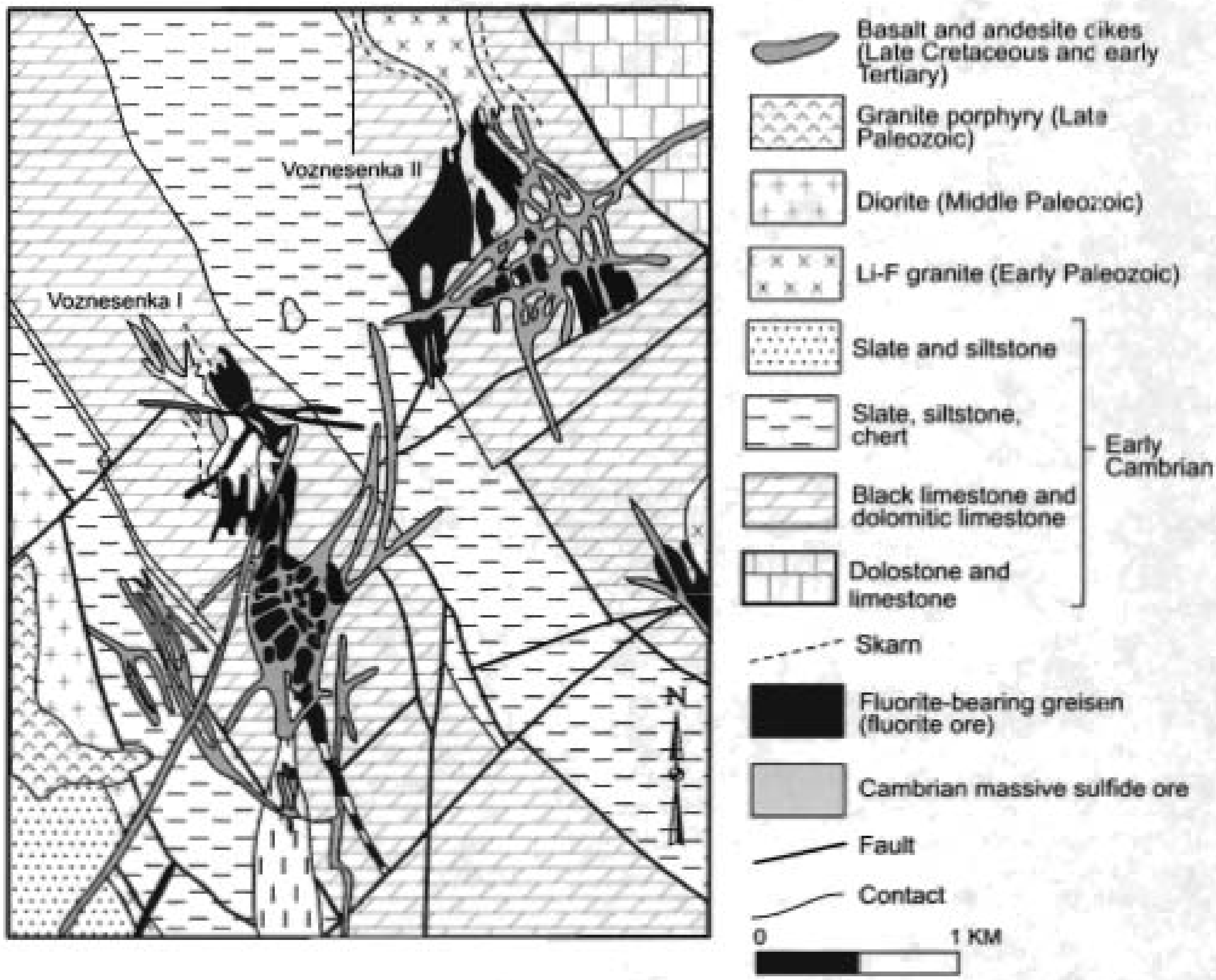


Figure 8. Voznesenka-I Korean Zn massive sulfide deposit (Voznesenka metallogenic belt) and Voznesenka-II fluorite greisen deposit, Yaroslavka metallogenic belt, Russian Southeast. Schematic geologic map. Adapted from Ratkin (1995).

Chernyshevskoe Korean Pb-Zn Deposit

The nearby Chernyshevskoe Korean Pb-Zn deposit (Bazhanov, 1988; Ryazantseva, 1988) consists of sheeted pyrrhotite-arsenopyrite-pyrite-galena-sphalerite bodies which occur at the contact of a limestone sequence with overlying Early Cambrian siltstone. Rare conformable zones of disseminated sulfide mineralization occur within the limestone away from the contact. The sulfide bodies are 1 to 2 m thick, with a surface exposure 100 to 200 m long. The deposit was drilled to a depth of about 100 m. The deposit is small with an average grade of 1.5-6.5% Pb and 0.7-2.5% Zn. Both the Voznesenka-I and Chernyshevskoe deposits were formerly interpreted as skarns and were previously not evaluated properly. Locally abundant sedimentary-exhalative siliceous rocks have anomalously high F, B, and Zn values.

Origin of and Tectonic Controls for Voznesenka Metallogenic Belt

The Cambrian through Silurian units of the Voznesenka terrane consists are (Nokleberg and others, 1994c, 1997c; Khanchuk and others, 1996, 1998): (1) Cambrian sandstone, pelitic schist, rhyolite, felsic tuff, and limestone and dolomite which together are up to several thousand meters thick, are intensely deformed; (2) Ordovician collision-related biotite and Li-F protolithionite granitoid rocks with Rb-Sr and Sm-Nd ages 450 Ma (Belyatsky and others, 1999); and (3) Ordovician to Early Silurian conglomerate and sandstone with questionable-age flora. The limestone turbidites hosting the Voznesenka-I and Chernyshevskoe Korean Zn-Pb deposits are interpreted as forming on the upper part of an Early Cambrian continental slope. The limestone turbidite and other Cambrian sedimentary and volcanic units of the Voznesenka terrane are interpreted as a fragment of a Late Proterozoic to early Paleozoic carbonate-rich sedimentary rock sequence which formed on a passive continental margin. Archaeocyathid fauna in Cambrian limestone is related to the Australia paleogeographic province. The Voznesenka terrane probably was a part of the passive continental margin of Gondwanaland (Khanchuk and others, 1998). Similar stratiform Cambrian Zn deposits occur in fragments of Gondwanaland in Africa and South America.

Kabarga Metallogenic Belt of Ironstone Superior Fe) Deposits (Belt KB) Southern Russian Southeast

The Kabarga metallogenic belt of ironstone (Superior Fe) deposits (fig. 2; tables 3, 4) occurs in the southern part of the Primorye province in the Russian Southeast and is hosted in the Kabarga terrane of the Khankha superterrane (Nokleberg and others, 1994c, 1997c). The belt is defined principally by a group of ironstone deposits at Ussuri which consist of beds of magnetite- and hematite-magnetite-bearing chert which occur in a sequence of Early Cambrian clastic-carbonate rocks which overlie Early Cambrian dolomite (Denisova, 1990; Nokleberg and others 1997a, b, 1998). Magnetite and hematite layers also occur along the layering planes between chert and intercalated with quartz-sericite-chlorite and quartz-sericite schist and dolomite. The upper part of the Fe deposit is oxidized, and contains Mn deposits, mainly pyrolusite, which occur in addition to the Fe deposits. Mineralogic and geochemical studies suggest an exhalative-sedimentary origin. The deposits are generally small, with Fe contents which range from 24 to 39%).

The Kabarga metallogenic belt of ironstone (Superior Fe) is hosted in the Kabarga terrane of Khanka superterrane (Nokleberg and others, 1994c, 1997c). The ironstone deposits occur in Cambrian siliceous limestone, limestone, graphitic pelitic shale, ferromanganese and phosphate layers, and dolomite. The rocks are intensively deformed. The stratigraphic thickness ranges up to 1 km. The older units of the Kabarga terrane, which underlie the deposits described above, consist of highly metamorphosed and deformed marble, calc-schist, gneiss, and quartzite which exhibit granulite and amphibolite-facies metamorphism, and yield a Rb-Sr whole-rock isotopic age of greater than 1,517 Ma. Younger units consist of Silurian sandstone, limestone, Silurian collisional-related granitoid plutons, Permian basalt, andesite, and rhyolite, and Early Triassic sandstone. The Khanka superterrane is interpreted as a fragment of a Paleozoic continental-margin arc (Nokleberg and others, 1994c, 1997c). In the Early Cretaceous, the Khanka superterrane was accreted to the eastern margin of Asia.

Metallogenic Belts Formed During Early Paleozoic Sedimentation or Marine Volcanism in Manchurid or Altaid Orogenic Systems

South Khingan Metallogenic Belt of Ironstone (Superior Fe) Deposits (Belt SK) Southern Russian Southeast

The South Khingan metallogenic belt of ironstone (Superior Fe) deposits (fig. 2; tables 3, 4) occurs in the southwestern parts of the Khabarovsk province in the Russian Southeast in the Malokhingansk terrane of the Bureya superterrane. The belt contains a group of significant deposits at South Khingan (table 4) (Nokleberg and others 1997a, b, 1998).

The South Khingan deposit (fig. 9) consists of Fe- and Mn-bearing beds which are composed of magnetite-, hematite-, and magnetite-hematite-bearing quartzite in beds 18 to 26 m thick which are interlayered with chlorite-dolomite breccia (Kazansky, 1972). Underlying sedimentary rocks contain braunite-haussmanite-rhodochrosite layers between 2 and 9 m thick. The Fe- and Mn-bearing layers are overlain by a dolomite sequence which is overlain in turn by shale, limestone, and dolomite which all occur in the lower portion of the Early Cambrian Khingan series. The deposit has not been developed because of the difficulties with ore concentration and steeply-dipping beds. The largest deposits at Kimkanskoe, Kastenginskoe, and South Khingan are estimated as containing approximately 3 billion tonnes of Fe and Mn minerals. Mineralogic and geochemical studies suggest an sedimentary-exhalative origin. The Early Cambrian Khingan series is part of the Bureya superterrane which is interpreted as a fragment of a continental-margin arc which was accreted to Sino-Korean Craton during the Paleozoic (Nokleberg and others, 1994c, 1997c). The superterrane contains Late Proterozoic and Devonian granitoid rocks with K-Ar isotopic ages of 604 and 301

Ma which locally form extensive plutons and batholiths. The metallogenic belt is interpreted as forming in volcanic and sedimentation basin along an unstable proto-continental margin, or in a fragment of Archean craton which was incorporated into an accretionary wedge terrane.

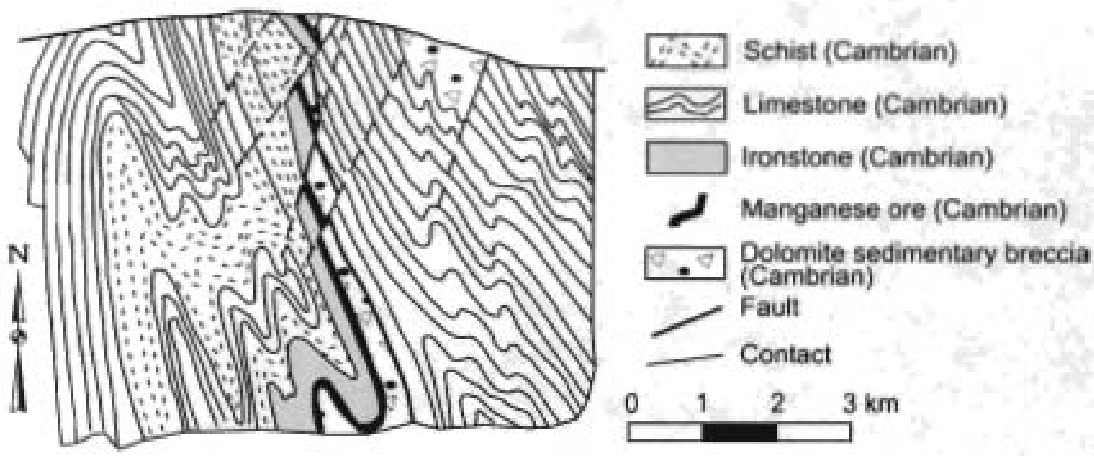


Figure 9. South Khingan ironstone deposit, South Khingan metallogenic belt, Russian Southeast. Schematic geologic map and cross section. Adapted from Korostelev and others (1990).

Gar Metallogenic Belts of Volcanogenic Fe Deposits and Stratiform Cu and Pb-Zn Deposits (Belt GR) Western Part of Russian Southeast

Two Gar metallogenic belts of volcanogenic Fe and stratiform Cu and Pb-Zn deposits (fig. 2; tables 3, 4) occur in the northwestern part of the Russian Southeast. The belts are hosted in the Mamyn continental-margin arc terrane (unit MM, fig. 2) (Nokleberg and others, 1994c, 1997c). The Fe deposits generally consist of lenses and beds of magnetite which is spatially associated with basalt and limestone. A large deposit occurs at Gar; coincidental with the Gar of volcanogenic Fe deposits is a metallogenic belt of Cu and Pb-Zn stratiform sulfide deposits (Nokleberg and others 1997a, b, 1998). The belt also contains (table 4): (1) small massive Cu sulfide deposits, as at Kamenushinskoe, which occur in rhyolite which underlies a sequence of magnetite-bearing basalt; and (2) a small stratiform Pb-Zn vein deposit at Chagoyan.

Gar Volcanogenic Fe Deposit

The large Gar volcanogenic Fe deposit (Zimin, 1985; Zimin and Konoplev, 1989) consists of sheeted iron ore bodies which occur in metamorphosed, Early Cambrian(?) felsic and mafic volcanogenic rocks with limestone lenses part of the Gar terrane. The iron ore beds occur chiefly in the upper Early Cambrian(?) section composed mainly of mafic volcanic rocks. The ore occurs within a section 220 to 250 m thick, but most of the ore, about 75 percent, occurs within an interval ranging from 156 to 184 m thick. The ore horizon occurs for 4 km along strike. The deposit has estimated reserves of 389.1 million tonnes grading 41.7% Fe. Total inferred reserves in the metallogenic belt are 4 billion tonnes (Zimin and Konoplev, 1989). The Gar deposit has not been mined. The deposit is intruded by early Paleozoic gabbro, diabase, and plagiogranite and is locally metamorphosed to skarn. Magnetite is the dominant ore mineral. Similar volcanogenic iron deposits occur north of the Gar deposit and need further exploration.

Kamenushinskoe Cu Massive Sulfide Deposit

The small Kamenushinskoe Cu massive sulfide deposit (P.N. Radchevsky, written commun., 1956, V.V. Ratkin, this study) consists of lenses, from 100 to 800 m long and 2 to 12 m thick, which occur conformable to bedding. Eleven ore bodies have been explored by drilling to a depth of 300 m. Pyrite is the most common ore mineral; however, some ore bodies consist of hematite-magnetite-pyrite ore. Chalcopyrite locally comprises up to 1 to 2%. The deposit is locally contact-metasomatized into skarn by Paleozoic granite. The deposit is interpreted as of sedimentary-exhalative origin which was associated with felsic seafloor volcanism. The Kamenushinskoe deposit occurs in Cambrian rhyolite of the Mamyn terrane. The rhyolite underlies a basaltic and limestone sequence which contains the volcanogenic Gar deposit.

Chagoyan Stratiform Pb-Zn Deposit

The Chagoyan stratiform Pb-Zn deposit (I.G. Khel'vas, written commun., 1963; V.V. Ratkin, this study) consists of a galena-sphalerite aggregate which occurs as cement between grains in sandstone. Veinlets are also common. The deposit is about 270 m long and 1.0 m thick, and is hosted in quartz-feldspar sandstone which underlies Cambrian(?) limestone and dolomite. Galena and sphalerite are the dominant ore minerals, with subordinate pyrite, pyrrhotite, and chalcopyrite. Post-ore dikes and stocks of Early Cretaceous diorite and granodiorite cut the deposit. The Mesozoic igneous rocks and the contained stratiform ore bodies locally exhibit hydrothermal alteration to quartz, sericite, and tourmaline. The deposit occurs on the northern bank of the Zeya River and is small. Average grades are 1.42% Pb, 5.16% Zn, and up to 3,000 g/t Ag. The deposit contains estimated reserves of 65 thousand tonnes zinc.

Origin of and Tectonic Controls for Gar Metallogenic Belts

The rocks hosting the two Gar metallogenic belts are interpreted as forming in a Late Proterozoic volcanic-tectonic basin in which marine basalt to rhyolite volcanism occurred (V.V. Ratkin, this study). The volcanogenic Fe deposits of the Gar metallogenic belt consist of sheeted Fe layers, mainly magnetite, which are hosted in metamorphosed Early Cambrian(?) felsic and mafic volcanic rocks and limestone. The stratiform Cu and Pb-Zn deposits of the Gar metallogenic belt are hosted in Cambrian rhyolite (Cu deposits) and quartz-feldspar sandstone (Pb-Zn deposits) which underlies Cambrian(?) basalt and calcareous rocks. These stratified units comprise part of the Mamyn continental-margin arc terrane (fig. 2). These stratigraphic units and stratiform deposits are (Nokleberg and others, 1994c, 1997c): (1) underlain by Archean(?) gneiss and schist, granite-gneiss, gabbro, and amphibolite which exhibit granulite facies metamorphism, and Proterozoic(?) and Early Cambrian sequence consists of greenschist, metasandstone, marble, quartzite, felsites, sandstone, and siltstone; and (2) are overlain by Silurian clastic rocks and Middle Devonian siltstone, sandstone, and limestone which are gently folded. The tectonic origins of the stratiform sulfide deposits are poorly understood and need further study.

Metallogenic Belts Formed During Early Paleozoic Sea-Floor Spreading, Regional Metamorphism, or During Subduction-Related Volcanism in Russian Far East Terranes

Galam Metallogenic Belt of Volcanogenic Fe, Volcanogenic Mn, and Sedimentary P Deposits (Belt GL) Central Part of Russian Far East

The Galam metallogenic belt of volcanogenic Fe, volcanogenic Mn, and sedimentary P deposits (fig. 2; tables 3, 4) occurs in the central part of the Russian Far East in the Galam accretionary wedge terrane (Shkolnik, 1973). The significant deposit is the Gerbikanskoe volcanogenic Fe deposit; other deposits are: the North-Shantarskoe, Nelkanskoe, Ir-Nimiiskoe-2, and Lagapskoe sedimentary P deposits; and the Ir-Nimiiskoe-1, Milkanskoe, Galamskoe, Gerbikanskoe, Kurumskoe, and Itmatinskoe volcanogenic Fe and Mn deposits (table 4) (Nokleberg and others 1997a, b, 1998). The Fe and Mn deposits occur in Cambrian beds and lenses with chert in seafloor basins and are interpreted as forming during seafloor hydrothermal activity which was associated with mafic volcanism.

The sedimentary P deposits are phosphorites which formed in limestone caps which formed in two stages on accreted seamounts, atolls, and guyots. The older stage consisted of siliceous deposition of phosphate coquina (inarticulate brachiopods, trilobites, etc) in the section of those atolls. Abrasion resulted in the formation of fragmentary trains, including phosphorite fragments. The younger stage consists of accumulations of phosphorite fragments. The deposits are interpreted as being subsequently deformed and metamorphosed during subsequent accretion of the Galam terrane.

Gerbikanskoe Volcanogenic Fe Deposit

The Gerbikanskoe volcanogenic Fe deposit (fig. 10) (Shkolnik, 1973) consists of two zones separated by a sequence of sandstone and siltstone. The two zones contain approximately 30 steeply-dipping sheets and lenses of magnetite and hematite. Individual bodies are several tens of m to 5 to 7 km long, and locally occur in a closely-spaced en-echelon pattern. Thickness varies from 5 to 50 m and is commonly 8 to 28 m. Fe-rich zones vary from banded to thinly-banded, lenticular-banded, and bedded, and consists of finely-dispersed hematite, magnetite, and rare pyrite and chalcopyrite. The deposit is large with an average grade of 42-43% Fe (soluble Fe 33-53%); 1.8% Mn, and 9.6% P.

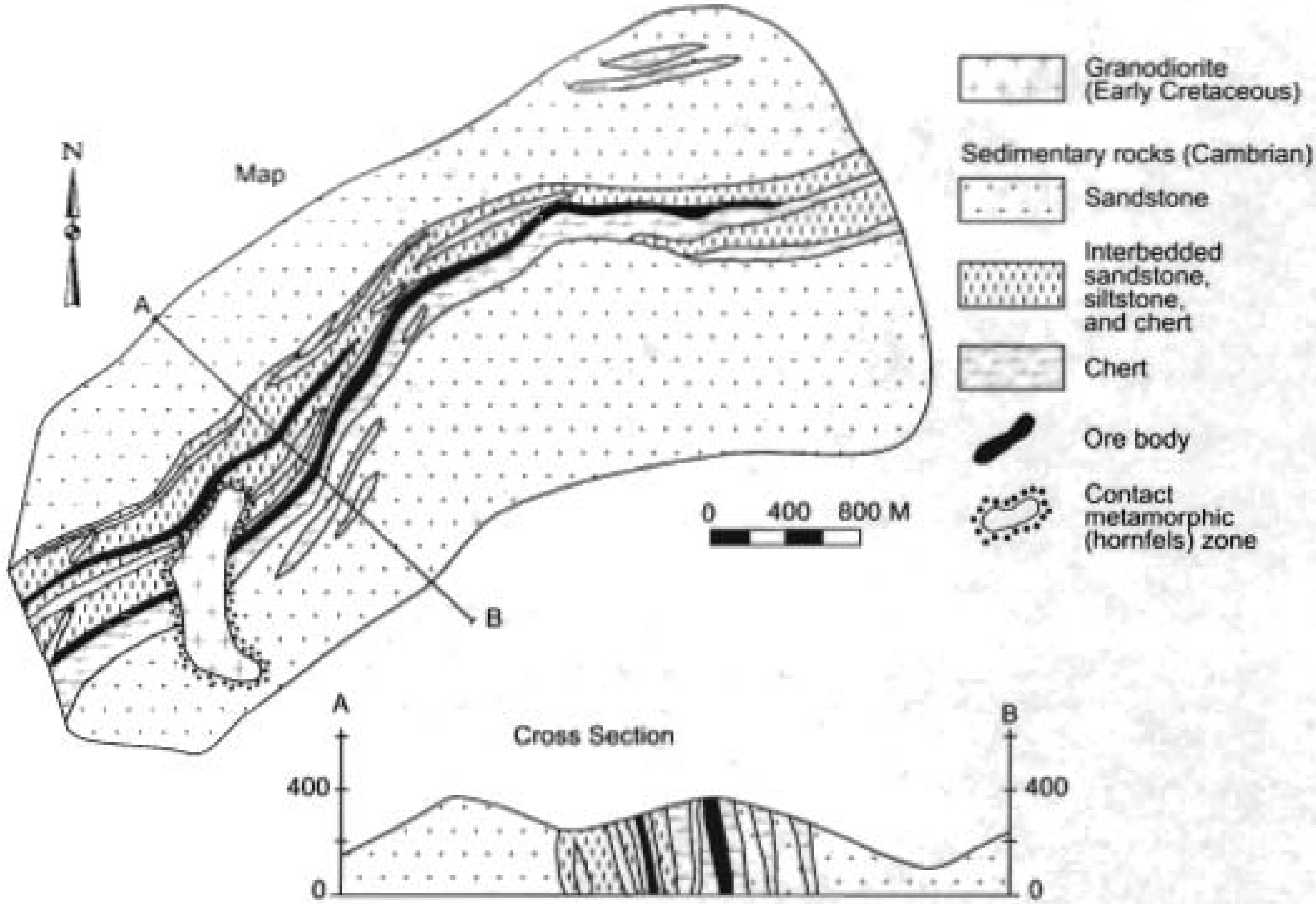


Figure 10. Gerbikanskoe volcanogenic Fe deposit, Galam metallogenic belt, Russian Southeast. Schematic geologic map and cross section. Adapted from Shkolnik (1973).

Origin of and Tectonic Controls for Galam Metallogenic Belt

The volcanogenic Fe deposits in the Galam metallogenic belt consist of numerous lenticular and sheeted magnetite bodies which consist of conformable, steeply-dipping bodies of complex composition. Magnetite bodies occur in a layer up to 600 m thick which consists of alternating, weakly metamorphosed Cambrian dark gray jasper, schist, shale, spilite, basalt, and basaltic tuff which is interlayered with rare sandstone, siltstone, sedimentary breccia, limestone, and dolomite. The volcanogenic Mn deposits consist of partly metamorphosed, steeply-dipping, lenticular and sheeted, bedded Mn bodies which occur in a diverse Lower Cambrian sequence of jasper, shale, schist, spilite, basalt, and basaltic tuff which overlays a carbonate reef complex with seamounts. The Fe and Mn deposits occur in long beds and lenses and are interpreted as forming during seafloor hydrothermal activity and associated with basaltic volcanism which was accompanied by chert deposition in seafloor depressions. The sedimentary P deposits are hosted in complex, steeply-dipping and folded sequence of jasper and volcanic rocks which represent a reef edifice. The deposits consist of carbonate beds which contain phosphorite-bearing breccia with Cambrian fossils. The sedimentary breccia is interpreted as forming in atoll fans and seamounts (Khanchuk, 1993).

The Galam terrane consists of a complexly-built accretionary prism with numerous regional-size olistoliths of early Paleozoic (Cambrian and Ordovician) marine basalt, chert, and clastic rocks (Khanchuk, 1993). The matrix consists of late Paleozoic turbidite and olistostrome. The early Paleozoic strata and overlying middle to late Paleozoic sedimentary rocks are interpreted as forming in a marine basin (Shkolnik, 1973; Khanchuk, 1993).

Omulevka River Metallogenic Belt of Austrian Alps W and Kipushi Cu-Pb-Zn Deposits (Belt OR) Northwest Part of Russian Northeast

The Omulevka River metallogenic belt of stratabound Austrian Alps W and Kipushi Cu-Pb-Zn deposits (fig. 2; tables 3, 4) occurs in the northwest part of the Russian Northeast (Shpikerman, 1998). The belt occurs between the Moma and Omulevka Rivers, and is hosted in the northeastern part of the Omulevka passive continental margin terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c). The belt is greater than 300 km long and ranges up to 100 km wide. The significant deposits are the Omulev stratabound Austrian Alps W deposit, and the Vesnovka Kipushi Cu-Pb-Zn deposit (table 4) (Nokleberg and others 1997a, b, 1998).

Omulev Austrian Alps W Deposit

The Omulev Austrian Alps W deposit (fig. 11) (Shpikerman and others, 1986) consists of veinlets in Middle Ordovician black, carbonaceous, calcareous siltstone. The main ore mineral is scheelite with local pyrite, antimony realgar, orpiment, galena, and chalcopyrite. The ore minerals are restricted to a conformable, thin layer which is intricately folded along with adjacent sedimentary rocks. The ore minerals and sedimentary rocks exhibit greenschist-facies metamorphism. The deposit occurs in the core of a large, open, northwest-trending anticline, and covers an area of about 100 km^2. The deposit is small and has an average grade of up to 1% WO_3.

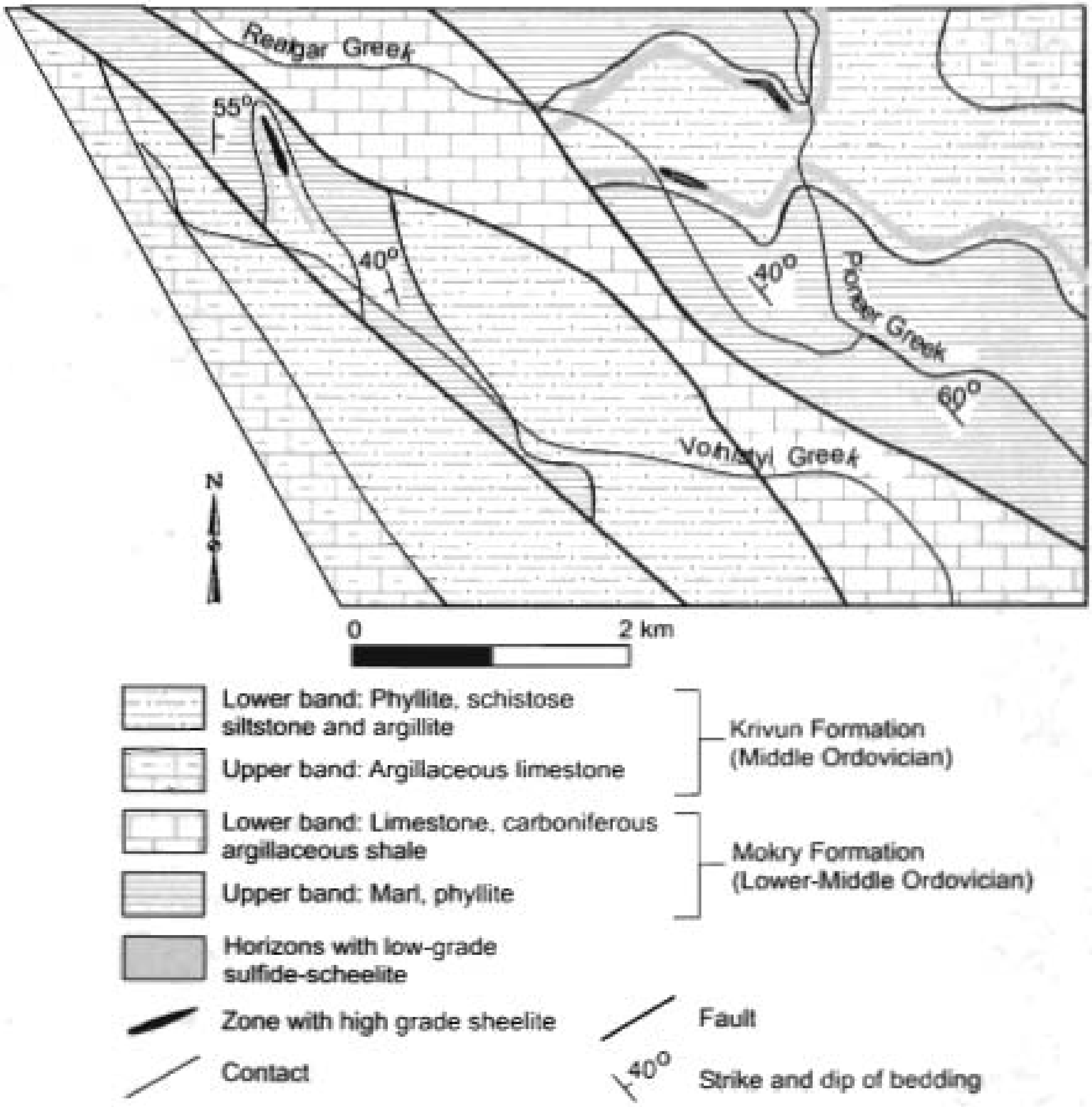


Figure 11. Omulev Austrian Alps W deposit, Omulevka River metallogenic belt, Russian Northeast. Schematic geologic map. Adapted fromShpikerman and others (1986).

Vesnovka Kipushi Cu-Pb-Zn Deposit

The Vesnovka Kipushi Cu-Pb-Zn deposit (Shpikerman, 1998) consists of veinlets and disseminated sulfides in Middle Ordovician limestone, shale, and siltstone. The ore bodies trend east-west and form metasomatic replacements conformable to bedding. The chief ore minerals are sphalerite, galena, chalcopyrite, and renierite(?). The calcareous siltstone which hosts the ore bodies is silicified and cut by calcite veins. Local tuff beds in these formations suggest which a volcanic island arc occurred along the margin of an Early and Middle Ordovician continental-margin sedimentary basin (Bulgakova, 1986).

Origin of and Tectonic Controls for Omulevka River Metallogenic Belt

The Omulevka River metallogenic belt of stratabound Austrian Alps W and Kipushi Cu-Pb-Zn deposits consists mainly of vein deposits which are hosted in the Omulevka passive continental margin terrane (Shpikerman, 1998).

The stratabound Austrian Alps W mineralization deposits are hosted in the lower part of the Middle Ordovician (Llanvirnian) Krivun Formation which ranges from 600 to 700 m thick and consists of flysch composed of rhythmically-interbedded black clay-carbonaceous limestone, calcareous siltstone and phyllite. The ore-bearing rock horizon ranges from 10 to 15 m thick and is composed of black calcareous siltstone with clastic, round grains of calcite (65-70%), quartz (20-30%), and graphite (3-5%). Metamorphism has produced a fine-grained granoblastic and lepidogranoblasic texture. Former interstitial clay is metamorphosed to a fine-grained epidote aggregate.

The Vesnovka and related Kipushi Cu-Pb-Zn deposits are hosted in the Middle Ordovician Minutka Formation which is about 325 m thick and consists of rhythmically interlayered black clay limestone and shale wit beds of siltstone and calcareous sandstone. The sulfide deposits are beds of sandstone and calcareous siltstone. The deposits and host rocks are interpreted as having been regionally metamorphosed in the Late Silurian for several reasons. (1) The Ordovician and Silurian sedimentary rocks of Rassokha terrane and the northern part of the Omulevka terrane are unconformably overlapped by Lower Devonian conglomerates, and pebbles of the metamorphic rocks occur in these conglomerates. And (2) a model Pb age of 410 to 432 Ma is obtained for the galena from the sulfide ores of the Omulevka Austrian Alps W deposit (Shpikerman, 1998).

Because the stratabound Austrian Alps W and Kipushi Cu-Pb-Zn deposits occur as veins and replacements, the Omulevka River metallogenic belt is interpreted as forming during regional metamorphism. The regional metamorphism is interpreted as occurring during accretion of the small Rassokha oceanic crust terrane to the North Asian Craton Margin (NSV) in the Late Silurian (Shpikerman, 1998). The host Omulevka continental margin terrane is interpreted as a rifted fragment of the North Asian Craton Margin (Nokleberg and others, 1994c, 1997c). Rifting is interpreted as occurring in the Late Devonian and Early Carboniferous.

Rassokha Metallogenic Belt of Basaltic Cu and Sediment-Hosted Cu Deposits (Belt RA) Northern Part of Russian Northeast

The Rassokha metallogenic belt of basaltic Cu and sediment-hosted Cu deposits (fig. 2; tables 3, 4) occurs in the northern part of the Russian Northeast (Shpikerman, 1998). The belt is 80 km long and 20 km wide and is hosted in the Rassokha passive continental-margin terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c). The metallogenic belt also contains sparse Pb-Zn vein deposits which occur in the Middle and Late Ordovician Bulkut Formation. This volcanic-rock-dominated unit consists of potassic trachybasalt, trachyandesite, basalt, and trachyte flows, interbedded tuff, siliceous shale, red sandstone, conglomerates and gray limestone, and hypabyssal shoshonite bodies. The Pb-Zn vein deposits are interpreted as forming during a period of post-volcanic, hydrothermal activity. The Bulkut Formation is interpreted as part of a distal(?) oceanic island arc volcanic assemblage. The significant deposit is the basaltic Cu and sediment-hosted Cu Agyndja deposit (table 4) (Nokleberg and others 1997a, b, 1998).

Agyndja Basaltic Cu and Sediment-Hosted Cu Deposit

The basaltic Cu and sediment-hosted Cu Agyndja deposit (Shpikerman and others, 1988) consists of disseminated and vein-like ore bodies, and sparse breccia ores which are hosted in amygdaloidal trachybasalt and sandstone of Middle to Late Ordovician age. The ore minerals are bornite, chalcocite, chalcopyrite, covellite, and local native copper. The lower part of the stratified deposit is commonly composed of mineralized trachybasalt which overlain by Cu-bearing sandstone. The Cu minerals in trachybasalt occur in amygdules and synvolcanic fissures in the upper portion of lava flows. The Cu minerals also occur both as cement and as clasts in sandstone. The deposit occurs over an area of about 100 km^2. Individual ore horizons are 1 to 30 m thick and trend northwest. The Cu sulfide deposits occur in submarine lava flows, subvolcanic porphyry intrusions, and shallow-water sandstones. The Agyndja deposit is large with an average grade of about 1% Cu.

Origin of and Tectonic Controls for Rassokha Metallogenic Belt

The Rassokha passive continental-margin terrane, which host the Rassokha metallogenic belt, consist of two structural complexes (Shpikerman, 1998). A lower complex consists mainly of Ordovician marine sedimentary and volcanic rock is about 5,000 m thick. The major lithologies are Cambrian sandstone and conglomerate with round clasts of serpentinite, trachybasalt, tuff, volcaniclastic sandstone, minor trachyte. The basaltic Cu and sediment-hosted Cu deposits of the Rassokha metallogenic belt are hosted in the Middle and Late Ordovician Agyndja Formation which contains sedimentary and volcanic rocks and ranges from 800 to 1000 m thick. The major lithologies in the formation are interbedded lava flows (10-30 m thick), mainly red porphyry trachybasalt, rare trachyte, trachyandesite, tuff, volcaniclastic sandstone, and conglomerate. Local limestone and dolomite with marine fauna occur (Shpikerman, 1998). The lower complex is intruded by sills of K-rich basalt, monzonite, and syenite porphyry which are interpreted as comagmatic with the flows. The igneous rocks are interpreted as forming during rifting of an island arc complex located close to a continent. The unconformably overlying upper complex consists of marine and abyssal sedimentary rock, including coarse clastic rock, carbonate, volcaniclastic rock, and black shale. Based on Devonian graptolites, the age of the upper complex ranges from Devonian to Triassic. The upper complex is interpreted as having been deposited along the middle Paleozoic passive continental margin in the Verkhoyansk fold belt (North Asian Craton Margin). The basaltic Cu and sediment-hosted Cu deposits of the Rassokha metallogenic belt are interpreted as forming during Ordovician rifting of an island arc (Shpikerman, 1998).

Metallogenic Belts Formed During Early Paleozoic Rifting of Continental Margins or in Continental-Margin Arc Terranes

Dzhardzhan River Metallogenic Belt of Southeast Missouri Pb-Zn, Sediment-Hosted Cu and Sandstone-Hosted U deposits (Belt DZ) Northern Part of Eastern Siberia

The Dzhardzhan River metallogenic belt of Southeast Missouri Pb-Zn, sediment-hosted Cu, and sediment-hosted U deposits (fig. 2; tables 3, 4) occurs in two areas in the northern part of eastern Siberia in the northeastern North Asian Craton Margin (Verkhoyansk fold belt, unit NSV; Nokleberg and others, 1994c; Shpikerman, 1998). The two parts of the belt trend for more than 400 km from the Dzardzhan River in the south to the Laptev Sea in the north. The Dzhardzhan River metallogenic belt contains sparse stratabound deposits in Vendian, Early Cambrian, Late Devonian, and Early Carboniferous sedimentary rocks. The major Southeast Missouri Pb-Zn deposits are at Manganiler and Aga-Kukan, and the major sediment-hosted U deposit is at Kyongdyoi (table 4) (Nokleberg and others 1997a, b, 1998).

Manganiler Southeast Missouri Pb-Zn and Deposit

The Manganiler Southeast Missouri Pb-Zn and similar deposits generally consist of layers of concordant, lenticular galena-sphalerite ore bodies which occur in Early Cambrian dolomite (Shpikerman, 1998). The ore bodies vary from 0.4 to 3.6 m thick and are up to 135 m long. Disseminated sulfides are locally replaced by massive, predominantly sphalerite in the lower portion of the deposit. The sulfides are banded locally. The major ore minerals are sphalerite and lesser galena. Subordinate ore minerals are pyrite, marcasite, and smithsonite. The occurrences also exist to the south, as at the Aga-Kukan deposit, is a Southeast Missouri Pb-Zn occurrence, and is hosted in Early Carboniferous limestone. Nearby Late Devonian sandstone and shale contain sediment-hosted Cu occurrences.

Kyongdyoi Sandstone-Hosted U Deposit

The Kyongdyoi sandstone-hosted U deposit consists of uraninite crust which occurs in Late Proterozoic (Vendian) and Early Cambrian sandstone and limestone (unit NSV, Verkhoyansk fold belt; Yu.M. Arsky and others, written commun., 1963). Uranium occurs in disseminated sulfides such as pyrite and sphalerite, and in bitumen (kerite) inclusions. The deposit occurs in various stratigraphic levels of anticlinal domes and in lens-shaped bodies which range from 0.3 to 2.3 m thick and from 100 to 400 m long. The uranium-bearing zone ranges up to 50 km long.

Origin of and Tectonic Controls for Dzhardzhan River Metallogenic Belt

The southeast Missouri Pb-Zn deposits of the Dzhardzhan River metallogenic belt occur two stratigraphic horizons, in the lower part of a Cambrian sedimentary rock sequence, and in the Early Carboniferous Aga-Kukan suite. The Lower Cambrian sedimentary rocks, about 110 m thick, consist of bituminous and clay limestone and sandstone, conglomerate, basalt flows, tuff (Natapov and Shuligina, 1991). The Early Carboniferous Aga-Kukan suite is about 150 m thick and consists of limestone and sandstone (Melnikov and Izrailev, 1975). The sediment-hosted Cu deposits are hosted in the Late Devonian and Early Carboniferous Artygan suite which is about 800 m thick and is stratigraphically beneath the Aga-Kukan suite. The suite is composed of red limestone, siltstone, and sandstone (Melnikov and Izrailev, 1975). The sandstone-hosted U deposits are hosted in Vendian sandstone which contain local bitumen (kerite).

The Southeast Missouri Pb-Zn and sediment-hosted U deposits in the Dzhardzhan River metallogenic belt are herein interpreted as forming during prolonged action of subsurface water in carbonate and sandstone along the passive margin of the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV; Shpikerman, 1998). The sediment-hosted Cu deposits are interpreted as forming during migration of Cu from the craton to a shallow sea during both Riphean and Late Devonian rifting of the North Asian Craton Margin. This unit is chiefly a thick wedge of continental margin deposits which range up to 20 km thick (Nokleberg and others, 1994c, 1997c). The sedimentary rocks of the Verkhoyansk fold belt are apparently tectonically detached from crystalline basement of craton. The fold belt is separated from the Siberian platform by the Late Cretaceous, west-verging Lena thrust belt (fig. 2).

Anvil Metallogenic Belt of SEDEX (SEDEX) Zn-Pb-Ag Deposits, Yukon Territory, Canada (Belt AN)

The Anvil metallogenic belt of sedimentary exhalative (SEDEX) Zn-Pb-Ag deposits (fig. 3; tables 3, 4) occurs in the Anvil district in the western Selwyn Basin, Yukon Territory, Canada. The deposits are hosted in the passive continental margin rocks of the North American Craton which represent the transition from shelf to off-shelf facies. The SEDEX deposits occur in calcareous and non-calcareous phyllites which are correlated (Jennings and Jilson, 1986) with Early Cambrian to Silurian strata in the Howards Pass region (Gordey and Anderson, 1993) which contain Early Silurian SEDEX deposits (Howards Pass metallogenic belt described below). The major deposits are in the Anvil district are the Faro, Vangorda Creek, Grum, Firth, DY, and Swim (table 4) (Nokleberg and others 1997a, b, 1998).

Anvil District SEDEX Zn-Pb-Ag Deposits

The Anvil district contains six pyrite-bearing, stratiform Zn-Pb-Ag (Au-Cu-Ba) deposits and two stratiform pyritic Cu-Zn occurrences which extend southeastward along strike for 45 km. The deposits and occurrences are hosted in distinctive, Early Cambrian graphitic phyllite which forms a district-wide metallotect. Ore from the three principal deposits (Faro, Vangorda, and Grum) consists of massive pyrite, pyrrhotite, sphalerite, galena and marcasite with patchy barite in a siliceous gangue. Higher ore grades are associated with barite. Pyrite-bearing massive sulfides are overlain by barite-bearing massive sulfides, and are underlain by pyrite-bearint quartzite which grades laterally into ribbon-banded graphitic quartzite and graphitic phyllite. The Faro deposit (fig. 12) occurs approximately 100 metres stratigraphically below the contact between phyllite and quartzite of the Early Cambrian Mount Mye Formation and calcareous rocks of the Cambrian and Ordovician Vangorda Formation. At the northern end, the deposit is intruded and contact metamorphosed by the Cretaceous Anvil batholith and related dikes. For the district, the combined, pre-mining reserves were 120 million tonnes grading 5.6% Zn, 3.7% Pb, and 45-50 g/t Ag (Jennings and Jilson, 1986). Faro, the largest deposit, ceased production in 1997. The Vangorda deposit, a smaller mine, containing 7.1 million tonnes of ore, was largely exhausted between 1990 and 1993 (Brown and McClay, 1993), and the Grum mine produced 16.9 million tonnes of ore from 1993 to 1996.

Origin of and Tectonic Controls for Anvil Metallogenic Belt

The Anvil metallogenic belt is hosted by sedimentary rocks of western Selwyn basin which are part of the Cambrian through Devonian passive margin of the North American Craton (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). The host sedimentary strata represent a transition from shelf to slope facies. The coincidence of southwestward thickening in the graphitic phyllite with a linear array of alkaline basalt volcanism centers suggests which rift-related synsedimentary faults may have served as conduits for the SEDEX fluids. However, demonstrable feeder zones have not been observed. The elongate sub-basins hosting the deposits are interpreted as forming during Middle Cambrian to Early Ordovician extension and faulting (Jennings and Jilson, 1986). The resulting structural conduits provided concentrated exhalative metalliferous brines in a reducing environment in which the deposits formed. Related extensional faulting and emplacement of Middle Ordovician alkalic basalt dikes, which occur along the eastern margin of Selwyn Basin and southward to Gataga Trough, may have served both as a tectonic control on the development of the sedimentary basins in the Anvil and Howards Pass areas, and a source of both heat and metalliferous brines.

The mineral assemblages, host rock age, and geologic setting for the Anvil metallogenic belt are similar to those for the Howards Pass and Kootenay metallogenic belts of the Canadian Cordillera (described below). All three metallogenic belts are interpreted as forming from Pb- and Zn-rich fluids resulting during rifting, volcanism, basinal subsidence, local marine transgression, and related hydrothermal activity along the passive continental margin of the North American Craton. Rifting is interpreted to have formed the Misty Creek Embayment in the Early to Middle Cambrian (Cecile, 1982), the Selwyn Basin in the Late Proterozoic to Ordovician (Gabrielse, 1963), and the Meilleur River Embayment in the Early to Middle Ordovician (Morrow, 1984), with the latter event marked by alkalic basaltic volcanism (Fritz and others, 1991). SEDEX occurrences also formed during these events mainly in the Anvil and Howards Pass metallogenic belts, and to a minor extent in the Misty Creek and Meilleur River embayments.

Howards Pass Metallogenic Belt of Sedimentary Exhalative Zn-Pb Deposits (Belt HP) Eastern Yukon Territory

The Howards Pass metallogenic belt of sedimentary exhalative (SEDEX) Zn-Pb deposits (fig. 3; tables 3, 4) occurs in the eastern Yukon Territory. The belt is hosted in the Selwyn Basin which constitutes part of a Cambrian to Devonian passive margin of the North American Craton Margin. The major deposits are at Howards Pass and Anniv (table 4) (Nokleberg and others 1997a, b, 1998).

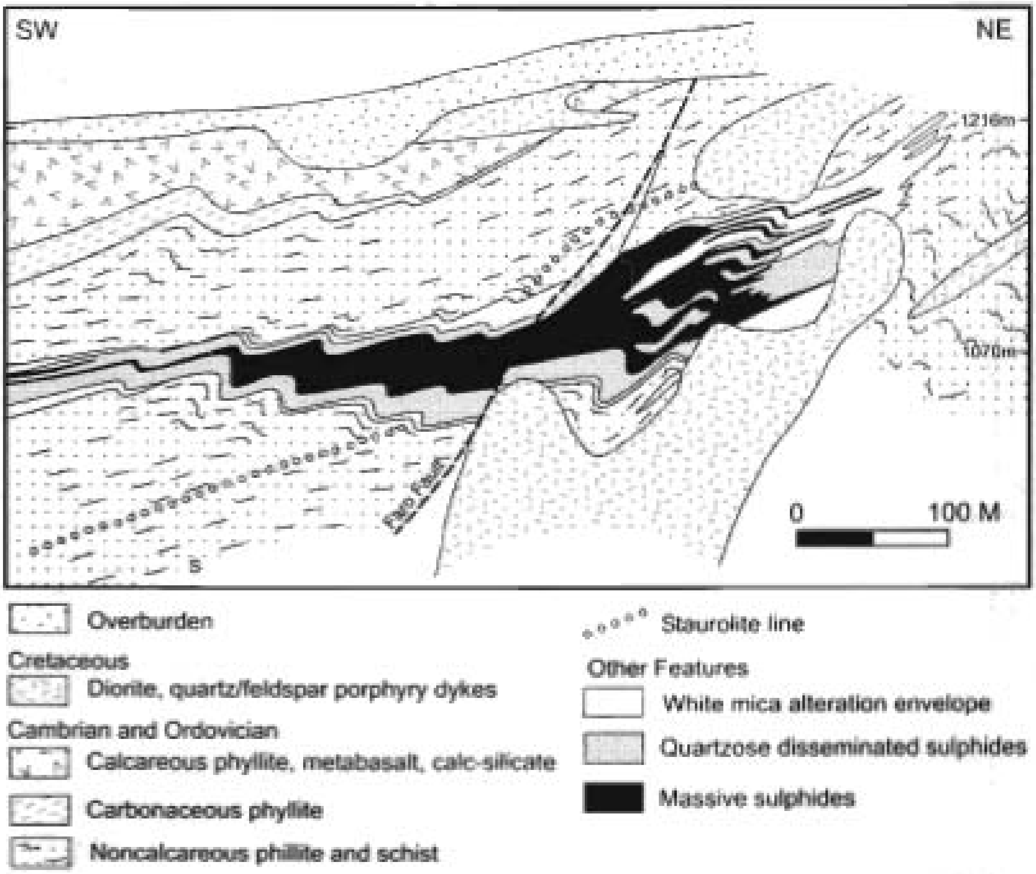


Figure 12. Faro sedimentary-exhalative Zn-Pb-Ag deposit, Anvil metallogenic belt, Canadian Cordillera. Schematic cross section. Adapted from Jennings and Jilson (1986).

Howards Pass (XY) Zn- Pb SEDEX Deposit

The Howards Pass (XY) sedimentary exhalative (SEDEX) Zn- Pb deposit (fig. 13) consists of fine-grained, well-bedded sphalerite and galena with pyrite as stratiform and stratabound massive bodies, up to 50 meters thick and 3 to 4 km long, which are interlaminated with carbonaceous, cyclical, limy mudstone and chert of the rift-related Early Silurian "Active Zone" of the Ordovician to Devonian Road River Group (Yukon Minfile, 1984; Abbott and others, 1986a, b; Abbott and others, 1994; MacIntyre, 1991). The deposit is one of three related Zn-Pb SEDEX deposits which occur in an elongate, 20 km-wide sub-basin in the eastern Selwyn Basin. The deposits are interpreted as forming at the base of the continental slope, about 10 km to 20 km seaward of a carbonate platform margin. Total reserves and resources are estimated at about 500 million tonnes grading 5% Zn, and 2% Pb (Placer Developments Ltd. Annual Report, June 1982).

Anniv (OP) SEDEX Zn- Pb Deposit

The Anniv (OP) SEDEX Zn- Pb deposit consists of sphalerite and galena which occur in saucer-shaped stratiform and stratabound bodies in Early Silurian cyclic, rift-related carbonaceous mudstone and chert of the Ordovician to Silurian Road River Group (Morganti, 1981; Yukon Minfile, 1984; EMR Canada, 1989; MacIntyre, 1991). The host rocks interpreted as part of a Cambrian and Devonian passive margin of the North American Craton Margin. The deposit averages 13 m thick (maximum 45 m) over a 1.5 km strike length.

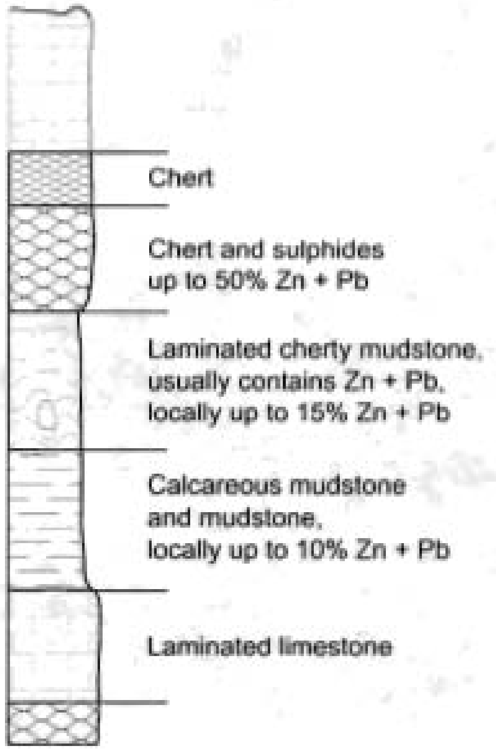


Figure 13. Howards Pass sedimentary exhalative Zn- Pb deposit, Howards Pass metallogenic belt, Canadian Cordillera. Schematic stratigraphic column illustrating major stratiform sulfide zones. Adapted from Morganti (1981).

Origin of and Tectonic Setting for Howards Pass Metallogenic Belt

The Zn-Pb SEDEX deposits of the Howards Pass metallogenic belt are hosted Selwyn Basin which contains a sequence of late Precambrian to Middle Devonian, turbiditic sandstone, deep water limestone, shale and chert. The basin is the offshore equivalent of the shallow-water carbonate and sandstone of Mackenzie Platform (Gordey and Anderson, 1993). A major SEDEX event was localized in eastern Selwyn Basin at Howards Pass where large stratiform bodies of Zn-Pb-Fe sulfides were deposited synchronously with Early Silurian (Norford and Orchard, 1983) carbonaceous and limy mudstone and chert. The Howards Pass metallogenic belt is interpreted as forming from Pb- and Zn-rich fluids resulting during rifting, volcanism, basinal subsidence, local marine transgression, and related hydrothermal activity (Goodfellow and Jonasson, 1986; Dawson and others, 1991). The fluids were discharged episodically into a stable, starved marine basin during restricted seawater circulation and resultant formation of sulphidic, anoxic bottom waters. The mineral assemblages, host rock age, and geologic setting for the Howards Pass metallogenic belt are similar to those for the Anvil and Kootenay metallogenic belts of the northern and southern Canadian Cordillera (described above and below, respectively). All three belts are interpreted as forming from Pb- and Zn-rich fluids resulting during rifting, volcanism, basinal subsidence, local marine transgression, and related hydrothermal activity along the passive continental margin of the North American Craton.

Kootenay Metallogenic Belt of Carbonate of Sediment-Hosted Deposits (Belt KO) Southern British Columbia

The Kootenay metallogenic belt of carbonate or sediment-hosted (SEDEX) Zn-Pb deposits (fig. 3; tables 3, 4) occurs in southeastern British Columbia. The deposits are hosted in metamorphosed and intensely deformed siliceous clastic, carbonate, volcanic, and plutonic rocks of the Kootenay metamorphosed continental margin terrane. This metamorphosed continental margin terrane occurs between the North America Craton Margin and to the east, and the accreted island arc Quesnellia terrane to the west (fig. 3). Some of the older sedimentary rock units, notably the middle Paleozoic Eagle Bay Assemblage in Kootenay and Shuswap regions of southeastern British Columbia, can probably be stratigraphically correlated with units in the North America Craton Margin (Monger and Nokleberg, 1996). The significant deposits in the metallogenic belt are the Mastadon, Jersey, Duncan Lake area, H.B. (Zincton), and Reeves-MacDonald (Reemac) deposits (table 4) (Nokleberg and others 1997a, b, 1998).

Mastadon SEDEX Pb-Zn(?) Deposit

The Mastadon SEDEX Pb-Zn (?) deposit consists of pyrite, arsenopyrite, sphalerite, galena and sulfosalts which occur in bands, lenses and stringers from 0.1 to 12 meters wide (Mining Review, 1992). The hanging wall part of deposit consists of disseminated sphalerite, galena and pyrite; footwall part of deposit consists of massive arsenopyrite, sphalerite and pyrite. Ore minerals are concentrated along the contact between phyllite and limestone. Au is refractory and associated with arsenopyrite. The deposit contains estimated production and reserves of 12.27 million tonnes grading 4.9% Zn, 2.3% Pb, and 62 g/t Au. The deposit is hosted in Early Cambrian Hamill Formation quartzite and Badshot Formation with limestone forming the footwall. The deposit origin is poorly understood.

Jersey SEDEX Pb-Zn Deposit

The Jersey deposit consists of fine grained sphalerite and galena with pyrite, pyrrhotite and minor arsenopyrite in five ore bands ranging from 0.30 to 9 meters thick (Fyles and Hewlett, 1959; Sangster, 1986; MacIntyre, 1991). Sulfides occur more abundantly in fold troughs relative to fold crests. Cd is associated with sphalerite, Ag with galena. The deposit has produced 7.7 million tonnes grading 3.49% Zn, 1.65% Pb, 3.08 g/t Ag. The deposit is hosted in the folded Reeves Member dolomite of the Early Cambrian Laib Formation, and may be a SEDEX Pb-Zn deposit.

H.B. (Zincton) Pb-Zn SEDEX Deposit

The H.B. (Zincton) Pb-Zn SEDEX deposit consists of pyrite and sphalerite which occur in narrow bands, irregular lenses or disseminations in dolomite of the Early Cambrian Reeves Formation (Sangster, 1986; MacIntyre, 1991; Hoy, 1982b; MINFILE, 2002). Local cross-zones contain fine-grained massive sulfides which commonly occur as matrix in a coarse breccia. The breccia zones are related to thrust faults and are interpreted as secondary structures. Much of the dolomite in the West orebody is altered to talc. The deposit has produced 6.7 million tonnes grading 3.91% Zn, 0.74% Pb, 4.42 g/t Ag.

Origin of and Tectonic Setting for Kootenay Metallogenic Belt

The Kootenay metallogenic belt of Zn-Pb SEDEX deposits is hosted in platformal, Early Cambrian carbonate rocks in the Kootenay metamorphosed continental margin terrane. The deposits commonly consist of bands and lenses of sphalerite, galena and pyrite both conformable and discordant to often isoclinally folded and regionally metamorphosed dolostone of the Badshot, Reeves and Laib formations. Along with their host rocks, these deposits were deformed prior to deposition of unconformably overlying strata of the Carboniferous Milford Assemblage (Monger and others, 1991). The age of the carbonate-hosed deposits is not known with certainty, and may be either SEDEX, or highly-deformed replacement deposits in Early Cambrian carbonate rock. The mineral assemblages, host rock age, and geologic setting for the Kootenay metallogenic belt are similar to those for the Anvil and Howards Pass metallogenic belts of the northern Canadian Cordillera as described above. All three belts are interpreted as forming from Pb- and Zn-rich fluids resulting during rifting, volcanism, basinal subsidence, local marine transgression, and related hydrothermal activity along the passive continental margin of the North American Craton. Episodic rifting in the Cambrian through Ordovician is interpreted as opening several sedimentary basins in the Canadian Cordillera, such as the Selwyn Basin, with related formation of Zn-Pb SEDEX deposits which are similar to those in the Kootenay metallogenic belt.

Prince of Wales Island Metallogenic Belt of Continental-Margin Arc-Related Deposits (Belt PW) Southeastern Alaska

The Prince of Wales Island metallogenic belt occurs in Southeastern Alaska and consists mainly of a suite of porphyry Cu-Mo, polymetallic vein, and skarn deposits (fig. 3; tables 3, 4) which occur mainly in alkalic Orodovian and Silurian plutons in the Alexander sequence of the Wrangellia superterrane. The deposits and metallogenic belt occur on central and southern Prince of Wales Island, and to a much lesser extent on Chichagof, Annette, and Gravina Islands in central- southeastern Alaska (Nokleberg and others, 1995a). These alkalic plutons range in age from Late Ordovician to Early Silurian. The plutons intrude the metamorphosed Devonian(?) St. Joseph Island Volcanics (Eberlein and others, 1983; D.A. Brew, oral commun., 1995), Early and Middle(?) Devonian Karheen Formation (Gehrels, 1992; D.A. Brew, oral commun., 1995), Middle to Late Ordovician to Early Silurian Descon Formation (Herreid and others, 1978; D.A. Brew, oral commun., 1995), and metamorphosed Late Proterozoic and Early Cambrian(?) Wales Group (Gehrels and Berg, 1992; D.A. Brew, oral commun., 1995). The plutons and metasedimentary rocks form the older part of the Alexander sequence in the region. The major granitic-magmatism-related deposits are represented by deposits in four areas: (1) several deposits in the McLean Arm porphyry Cu-Mo district; (2) the Klaka Inlet polymetallic skarn and vein deposit; (3) the Kassan Peninsula Cu-Fe skarn deposit; and (4) the major zoned mafic-ultramafic Cu-Au-PGE deposit at Salt Chuck (table 4) (Nokleberg and others 1997a, b, 1998).

McLean Arm Porphyry Cu-Mo District

The McLean Arm porphyry Cu-Mo district (fig. 14) contains a group of porphyry copper-molybdenum deposits which consist of precious metal stockworks and veins at Poison, Ickis, Veta, Apex, and Stone Rock Bay prospects in the central part of a northwest-trending belt of middle Paleozoic, multi- phase plutons composed of pyroxenite, syenite, quartz monzonite, and mixed intermediate-composition igneous rocks. The plutonic rocks intrude the clastic rocks of the Descon Formation on the extreme tip of southern Prince of Wales Island. The central part of the complex which contains the deposits is mainly syenite. The altered and mineralized syenite at Stone Rock Bay has a a U-Pb zircon age of 436 Ma (Gehrels, 1992). The sulfide deposits occur mainly in stockwork which occurs along joints and faults which strike 25° or 295° and dip steeply. The deposits and their host joints and faults appear to be related to a concentric alteration zone, of about 5 km2 area, with a carbonate-albite center, and an albite and sericite rim. The higher grade veins and stockwork range from 0.4 to 5.6% Cu, 0.01 to 0.08% Mo, and 2.1 to 11.0 g/t Au. Anomalous Ag, Pt, Bi, Te, and base metals also occur in the deposits (MacKevett, 1963; F.D. Forgeron and L.W. Leroy, written commun., 1971; T.K. Bundtzen, unpublished data, 1990; Nokleberg and others, 1995a). Soil sampling, trenching, and limited diamond drilling done in 1972 suggests a potential for 40 million tonnes of Cu-Mo ore at the Apex zone.

Polymetallic Vein, Skarn, and Disseminated Deposits in Paleozoic Plutons at Klakas Inlet and Kassan Peninsula

A suite of polymetallic vein, skarn, and disseminated deposits, which form part of the Prince of Wales Island metallogenic belt, are associated with Silurian or older alaskite and granodiorite in Klakas Inlet. The granodiorite, with a minimum K-Ar isotopic age of 428 Ma (Turner and others, 1977), contains sericite-altered veinlets of chalcopyrite, molybdenite, and galena in a 100 m^2 area. The deposit contains up to 0.23% Cu, 0.06% molybdenum, 0.05% Co, 0.05% Sn, and 0.01% W. The high Sn and W values occur adjacent to the main Cu and Mo deposits (Herreid and others, 1978).

A suite of polymetallic Cu vein, Cu-Fe (magnetite) skarn, and disseminated deposits also occurs in or near altered Late Ordovician to Early Silurian, intermediate-composition plutons on Kasaan Peninsula. About 607,690 tonnes of Fe and Cu ore were mined in this area prior to World War II (Warner and Goddard, 1961). Most of the deposits consist of irregular bodies of magnetite, chalcopyrite, and pyrite, and contain lesser amounts of sphalerite and galena. The deposits contain minor Au and Ag, and generally occur in skarn associated with alkali gabbro, diorite, and granodiorite. The plutonic rocks exhibit U-Pb zircon isotopic ages ranging from the Late Ordovician to the Early Silurian (Gehrels and Berg, 1992). The largest skarn deposit in the area occurs at the Mount Andrew-Mamie mine, the biggest Cu producer in the district (Bundtzen, 1978). The deposits in this area are associated with peripheral polymetallic veins and stockworks which contain chalcopyrite and pyrite, and Au values. Concentric magnetic anomalies in the area are interpreted by Warner and Goddard (1961) as reflecting as a buried porphyry Cu deposit.

Salt Chuck Zoned Mafic-Ultramafic Cu-Au-PGE Deposit

The Salt Chuck zoned mafic-ultramafic Cu-Au-PGE deposit (fig. 15) consists of irregularly and randomly distributed veinlets of bornite and associated minor chalcopyrite, chalcocite, covellite, native copper, and magmatic magnetite (Donald Grybeck and David A. Brew, written commun., 1985; Loney and others, 1987; Loney and Himmelberg, 1992; Foley and others, 1997). The deposit produced about 300,000 tonnes grading 0.95% Cu, 1.2 g/t Au, 5.8 g/t Ag, 2.2 g/t PGE (mainly Pd and Pt), and produced 610,400 g PGE from 1907 to 1941. The sulfides and oxides occur as disseminations and along cracks and fractures in pipe-like late Paleozoic or Mesozoic gabbro-clinopyroxenite stock intruding Silurian metagraywacke. Clinopyroxenite and gabbro grade irregularly into one another. Bornite, the principal sulfide; occurs mainly as interstitial grains in clinopyroxenite in amounts up to 15 percent. Extensive, late magmatic or hydrothermal epidote veins occur in gabbro and clinopyroxenite. Low-K, altered biotite from clinopyroxenite has a K-Ar isotopic age of 429 Ma. The deposit is interpreted to be magmatic, however, considerable hydrothermal remobilization of sulfides has occurred.

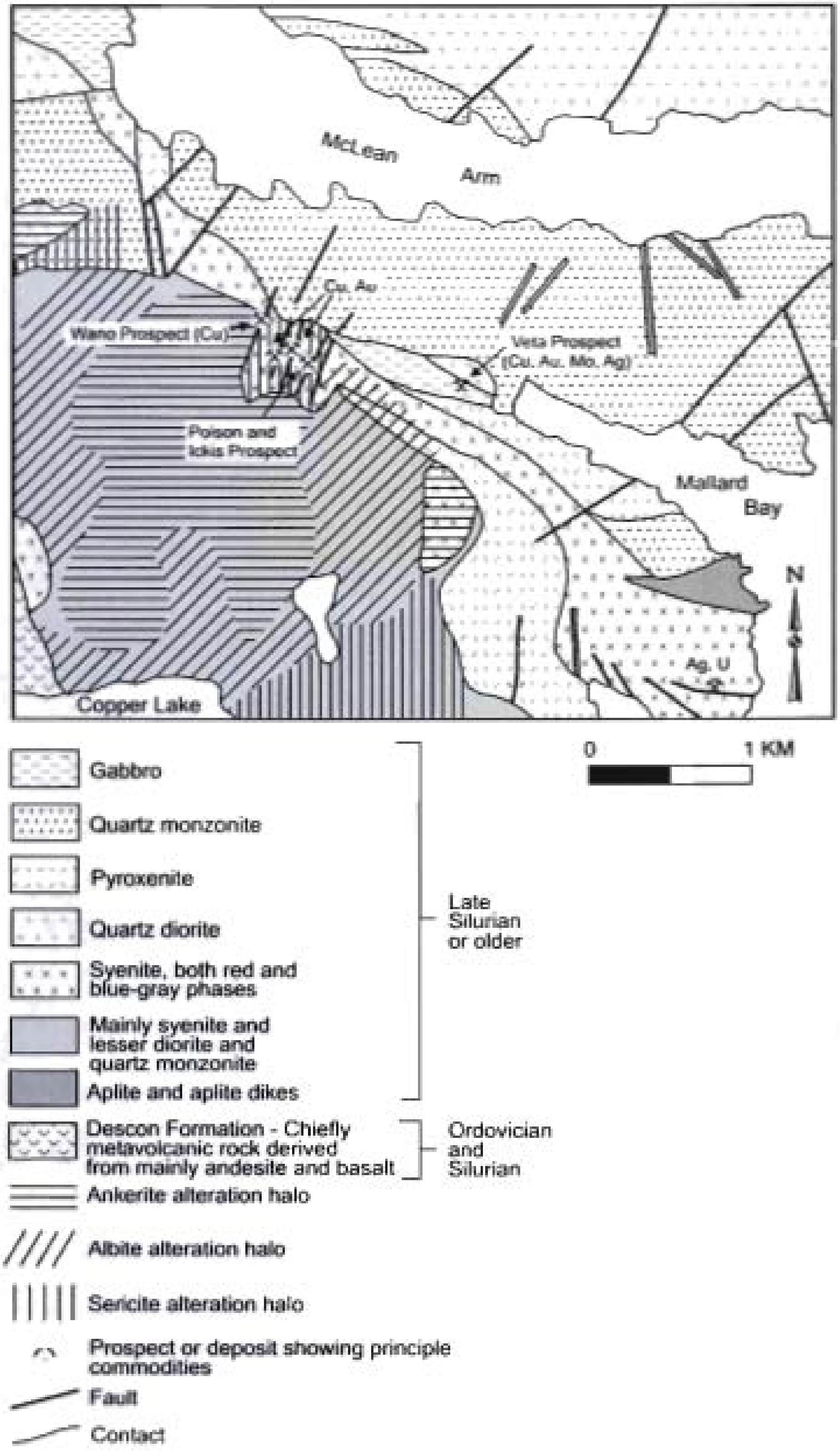


Figure 14. McLean Arm porphyry Cu-Mo district, Prince of Wales Island metallogenic belt, Southeastern Alaska. Adapted from MacKevett (1963), Gehrels (1992), T.K. Bundtzen, F.D. Forgeran, and L.W. LeRoy (written comm., 1993), and Nokleberg and others (1995).

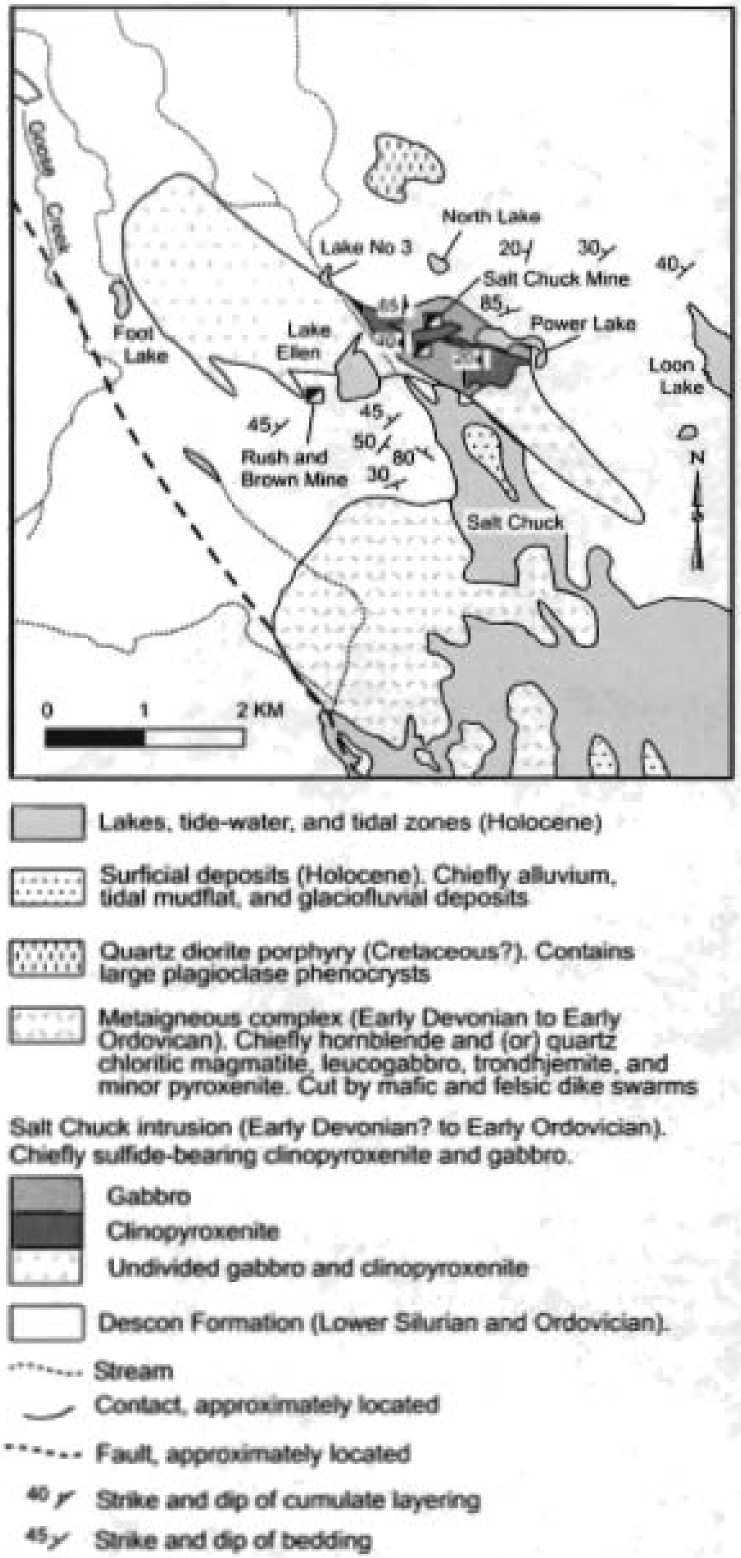


Figure 15. Salt Chuck zoned mafic-ultramafic Cu-Au-PGE deposit, Prince of Wales Island metallogenic belt, Southeastern Alaska. Schematic geologic map. Adapted from Loney and Himmelberg (1992).

The continental-margin arc-related deposits deposits of the Prince of Wales Island metallogenic belt are mainly hosted in Orodovician and Silurian granitoid rocks which intrude early Paleozoic stratified rocks of the Alexander sequence of the Wrangellia superterrane (Nokleberg and others, 1995a). The stratified rocks consist of felsic to mafic volcanic and associated marine sedimentary rocks. The known porphyry Cu and associated deposits occur in plutons which range from 472 to 432 Ma in age (Turner and others; 1977; Herreid and others, 1978; Eberlein and others, 1983; Gehrels, 1992; Gehrels and Berg, 1992). The zoned mafic-ultramafic Salt Chuck deposit, one of a series of mafic-ultramafic bodies intruding the Descon Formation (Loney and Himmelberg, 1992), has a K-Ar isotopic age of 429 Ma (Loney and others, 1987). This suite of deposits and host rocks are interpreted as forming during Ordovician and Silurian, subduction-related, island-arc magmatism in the Alexander sequence of the Wrangellia superterrane (Gehrels and Berg, 1994; Nokleberg and others, 1994c, 1995a, 1997c, Goldfarb, 1997). The granitoid plutons and associated plutons are herein interpreted as forming at intermediate levels of the arc, whereas the Salt Chuck zoned-mafic-ultramafic deposit is herein interpreted as forming from magmas which intruded into the deeper levels of the arc.

Middle and Late Devonian Metallogenic Belts (387 to 360 Ma; Figures 16, 17)

Overview

The major Middle and Late Devonian metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 16 and 17. The major belts are as follows. (1) In the Russian Southeast, the Yaroslavka (YA) belt, which contains F and Sn greisen deposits, is hosted in the Khanka continental-margin arc terrane. The belt is interpreted as forming during anatectic granitic plutonism which occurred during terrane accretion. (2) In the Russian Northeast, Northern Alaska, and the Canadian Cordillera, the Arctic (AT), Brooks Range (BR), Dawson (DA) Frances Lake (FR), Kedon (KE), Kootenay-Shuswap (KS), and Tracy (TR) belts contain deposits associated with felsic to mafic marine volcanism or with granitic magmatism. These belts are hosted in the North Asian or North American Cratons or Craton Margins, or in cratonal or continental-margin (arc) terranes which were derived from those craton margins. These belts are interpreted to be associated with formation of a short-lived continental-margin arc (Kedon arc in the Russian Northeast) along the margin of the North Asian Craton and Craton Margin and the North American Craton Margin. And (3) in Southern Alaska and the Canadian Cordillera, the Mount Sicker belt, which contains kuroko massive sulfide deposits, is hosted in the Wrangellia island-arc superterrane. This belt is interpreted as forming during subduction-related volcanism in the short-lived Sicker island arc.

In the Russian Northeast, Alaska, and Canadian Cordillera, the Berezovka River (BE), Cathedral (CA), Dempster (DE), Finlayson Lake (FL); Gataga (GA), Ingenika (IN), Liard (LI), Northern Cordillera (NCO), Macmillan Pass (MP), older part of Mystic (MY), Robb Lake (RL), Selennyakh River (SEL), Sette-Daban (SD), Southern Rocky Mountain (SRM), Tommot River (TO), Urultun and Sudar Rivers (URS), and Yarkhodon (YR) belts, which contain massive sulfide, bedded barite, carbonatite-related Nb, Ta, and REE, and related deposits, are hosted either in the North Asian or North American Craton Margins, or in passive continental margin terranes derived from those craton margins. These belts are interpreted as forming during late Late Devonian and (or) Early Mississippian rifting of either the North Asian or the North American Craton Margins (table 3), or during generation of low-temperature brines from adjacent shale basins. In the below descriptions of metallogenic belts, a few of the noteable or significant lode deposits (table 4) are described for each belt.

Metallogenic-Tectonic Model for Middle through Late Devonian (387 to 360 Ma; Figure 18)

During the Middle to Late Devonian (387 to 360 Ma), the major metallogenic-tectonic events were (fig. 18; table 3): (1) formation of a discontinuous continental-margin arc (Kedon arc in Russian Northeast) and contained metallogenic belts, and associated subduction zone along the North Asian and North American Craton Margins; (2) in the late Late Devonian, inception of rifting of the North Asian and North American Cratons and Craton Margins, resulting in formation of new terranes and associated metallogenic belts (table 3); and (3) formation of the Sicker arc and contained metallogenic belts, and associated subduction zone in the Wrangellia superterrane. Sedimentation continued along the North Asian and North American Craton Margins. Out of the field of view of figure 18 was formation of the Yaroslavka (YA) belt which contains F and Sn greisen deposits. The belt is hosted in the Voznesenka terrane in the Khanka continental-margin arc superterrane and is interpreted as forming during anatectic granitic plutonism which occurred during accretion of the Voznesenka terrane with other parts of the Khanka superterrane in the early Paleozoic.

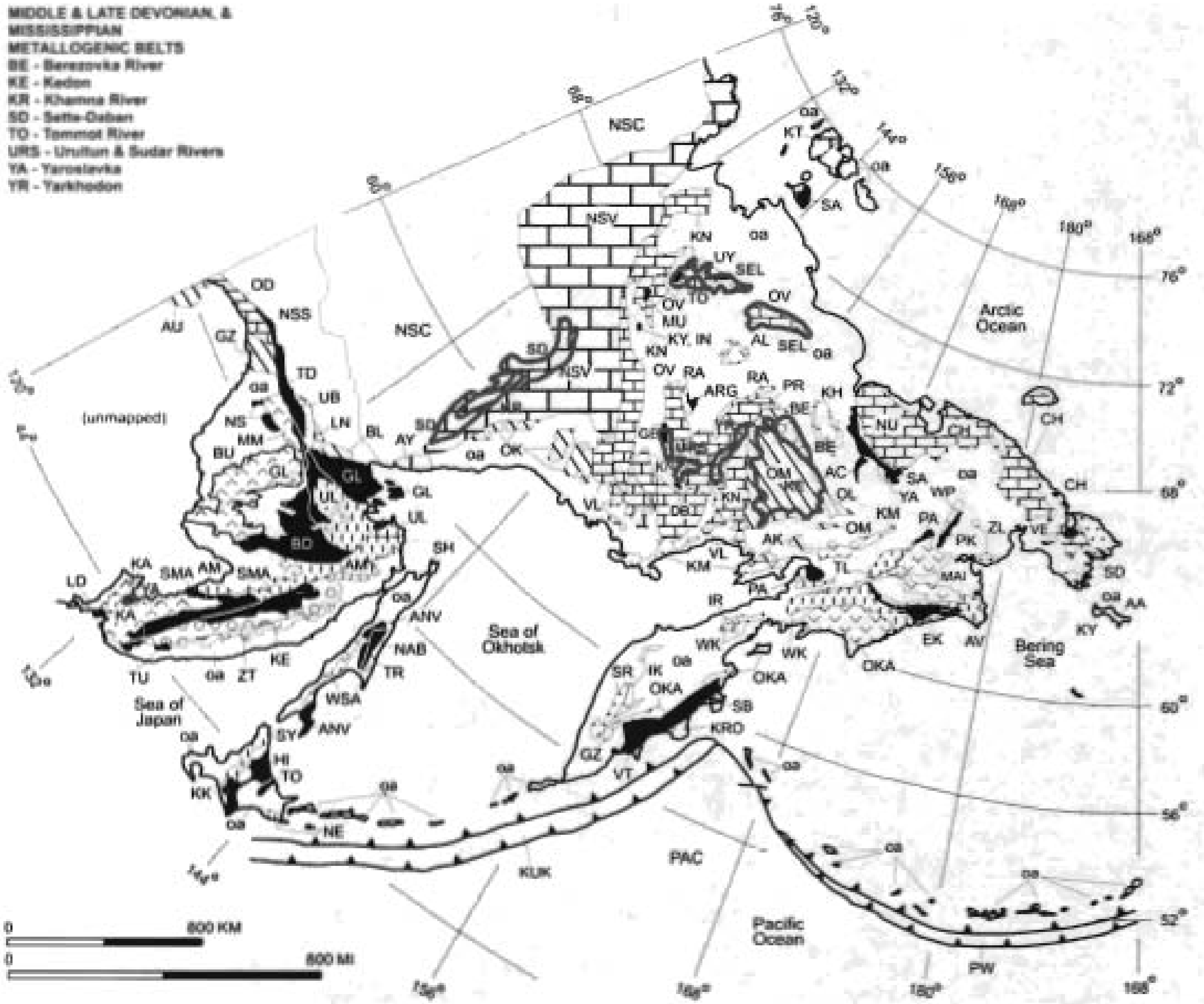


Figure 16. Generalized map of major Middle and Late Devonian and Mississippian metallogenic belts and terranes for Russian Far East, northern Japan, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 2 for explanation.

Specific Events for Middle Through Late Devonian

(1) In the early Paleozoic, on the basis of paleomagnetic data, the North Asian Craton and Craton Margin (NSC, NSV, KN) migrated to a position adjacent to the North American Craton and Craton Margin (NAC, NAM) along a pre-Devonian sinstral-slip suture.

(2) The Kedon continental-margin arc and associated subduction zone formed along the margin of the North Asian Craton and Craton Margin (NSC, NSV, KN) and along the margin of the North American Craton Margin (NAM). The relative positions of the two cratons (NSC, NAC) and their craton margin units (NSC, NSV, KN, NAM) are determined from paleomagtic data for the cratons (see Nokleberg and others, 2000). In the North Asian Craton Margin and outboard terranes, the arc is preserved today in:

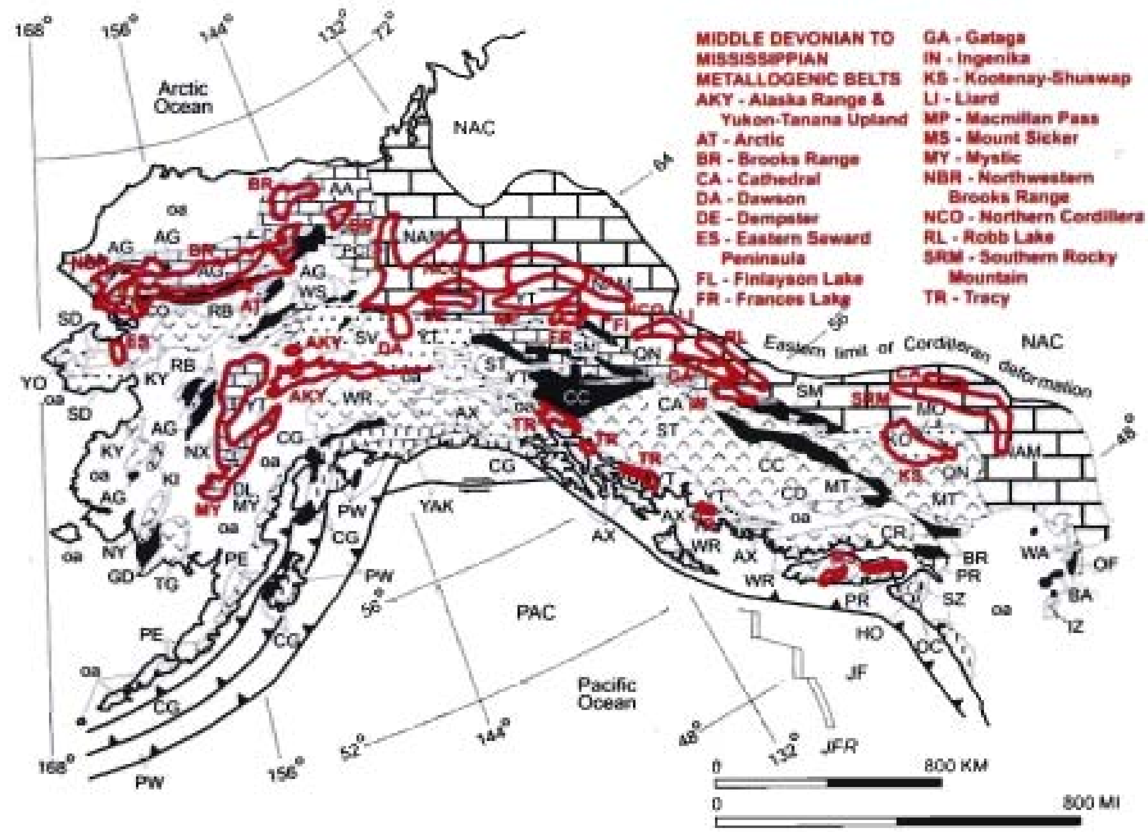


Figure 17. Generalized map of major Middle and Late Devonian metallogenic and Mississippian belts and terranes for Alaska, Canadian Cordillera, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 3 for explanation.

(1) sporadic occurrences of marine and continental volcanic and associated rocks and subduction-related granitic rocks in the southern part of the craton margin (NSV); (2) units which overlie parts of the Okhotsk (OK), Akekova (AK), Omolon (OM) cratonal terranes; (3) the Oloy (OL) and Yarakvaam (YA) island-arc terranes; and (4) the Beryozovka (BE) turbidite-basin terrane. Associated with this arc was the subduction of the older part of the Galam (GL) accretionary-wedge terrane along the margin of the North Asian Craton and Craton Margin (NSC, NSV), and subduction of the Angayucham and ancestral Pacific Oceans along the margin of the North American Craton Margin (NAM). Forming in part of the North Asian Craton Margin, from which the Omolon terrane was rifted, was the Kedon metallogenic belt which contains deposits related to felsic to mafic marine volcanism or to granitic magmatism in the Kedon arc.

In the Alaska and the Canadian Cordillera, the arc is preserved today in sporadic occurrences of marine volcanic and associated rocks and shallow- to deep-level subduction-related granitic rocks in various parts of the Arctic Alaska (AA), Coldfoot (CO), Ruby (RB), Seward (SD), Yukon-Tanana (YT), and Kootenay (KO) terranes. Occurring in this arc, now preserved in various continental-margin terranes, were the Arctic (AT), Brooks Range (BR), Dawson (DA), Frances Lake (FR), Kootenay-Shuswap (KS), and Tracy (TR) metallogenic belts, which contain deposits related to felsic to mafic marine volcanism or to granitic magmatism. The Devonian arc is interpreted as extending discontinuously from Arctic Alaska to northern California (Rubin and others, 1991; Mortensen, 1992; Smith and Gehrels, 1992; Nokleberg and others, 1994a; Plafker and Berg, 1994).

(3) In the late Late Devonian, rifting of the North Asian and North American Cratons and Craton Margins occurred. Derived from the North Asian Craton (NSC) and Craton Margin (NSV) were the Kotelnyi (KT), Omulevka (OV), Prikolyma (PR), Nixon Fork-Dillinger-Mystic (NX, DL, MY), Viliga (VL), and Zolotogorskiy (ZL) passive continental-margin terranes, the Avekova (AK), Kilbuck-Idono (KI), Okhotsk (OK), and Omolon (OM) cratonal terranes. Derived from the Devonian continental-margin arc which formed along the margins of the North Asian Craton Margin were the Beryozovka (BE), Oloy (OL), and Yarakvaam (YA) terranes (fig. 18). The newly-created terranes migrated into the Angayucham Ocean. Derived from the North American Craton Margin (NAM) were the Kootenay (KO) and Yukon-Tanana (YT) passive continental-margin terranes. The following metallogenic belts, which contain massive sulfide, carbonatite-related Nb, Ta, and REE, or related deposits, formed during rifting: Berezovka River (BE); Cathedral (CA), Dempster (DE), Finlayson Lake (FL); Gataga (GA), Ingenika (IN), Liard (LI), older part of Mystic (MY), Northern Cordillera (NCO), Macmillan Pass (MP), Robb Lake (RL), Selennyakh River (SEL), Sette-Daban (SD), Southern Rocky Mountain (SRM), Tommot River (TO), Urultun and Sudar Rivers (URS), and Yarkhodon (YR).

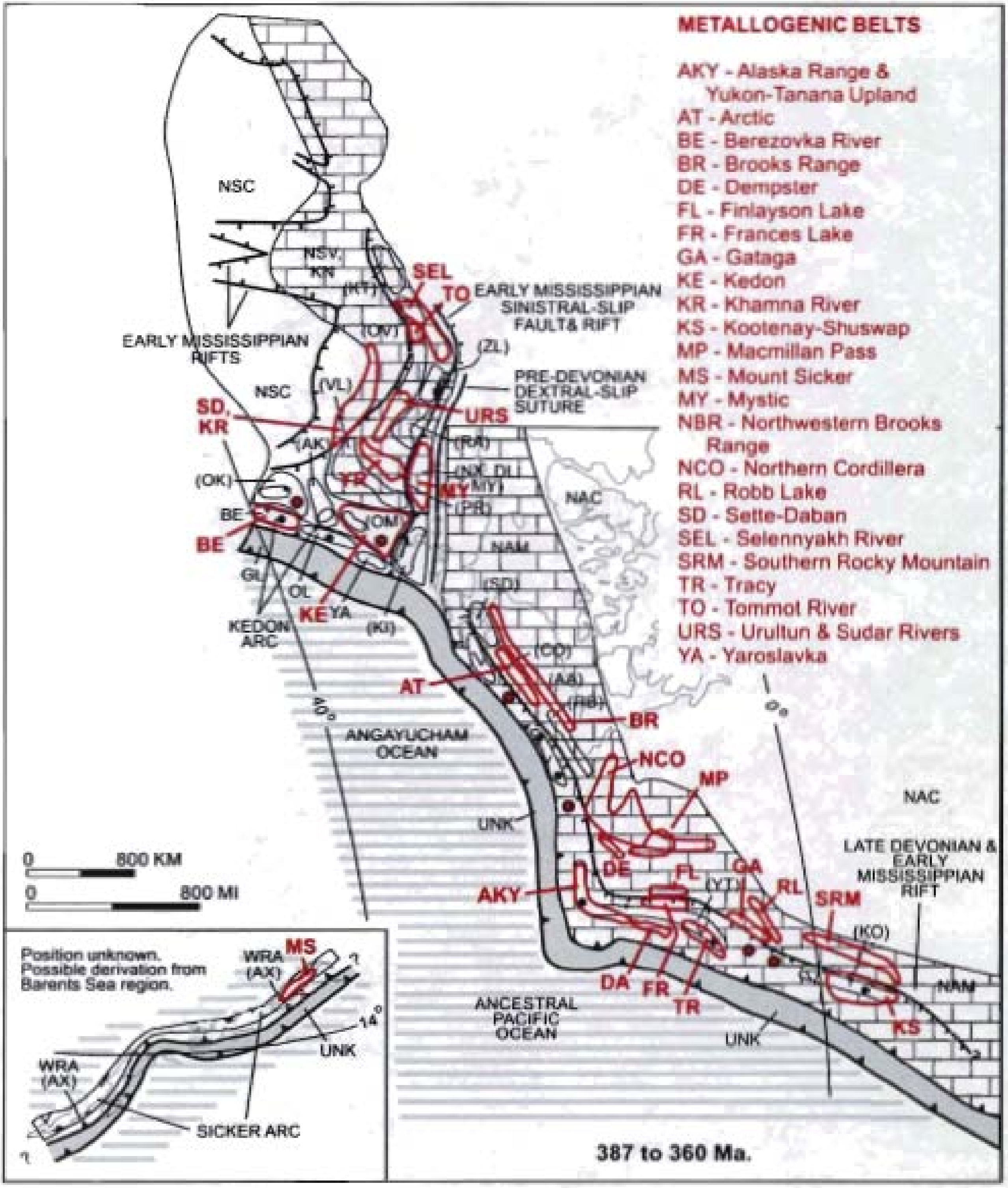


Figure 18. Middle through Late Devonian (387 to 360 Ma) stage of metallogenic-tectonic model and explanation. Refer to text for explanation of metallogenic-tectonic events, and to tables 3 and 4 for descriptions metallogenic belts and significant deposits. Adapted from Nokleberg and others (1997b, 1998, 2000).

EXPLANATION

TECTONIC ENVIRONMENTS AND GEOLOGIC UNITS

CRATONAL

Cratons (No patterns): **NAC**, North American; **NSC**, North Asian; **NSS**, Stanovoy block;

CRATON MARGIN

Craton Margins: **NAM**, North American; **NSV**, North Asian (Verkhoyansk foldbelt; **NSS**, North Asian (Stanovoy block)
Passive continental-margin terranes (derived from craton margins): **AA**, Arctic Alaska; **AP**, Artis Plateau; **CA**.

CONTINENTAL-MARGIN ARC, ISLAND ARC, OR TURBIDITE BASIN (Subduction-Related; includes forearc & backarc, and related turbidite basin deposits)

Continental-margin arcs: **al**, Aleutian; **at**, Alaska Range-Talkeetna Mountains; **bw**, Bowers Ridge; **ca**, Cascade; **ck**, Central Kamchatka; **cn**, Coast-North Cascade; **ej**, East Japanl; **ek**, East Kamchatka; **es**, East Sikhote-Alin; **gg**, Gravina-Nutzotin-Gambier; **io**, Indigirka-Oloy; **ka**, Kamloops; **kc**, Central Kamchatka; **kk**, Kamchatka-Koryak; **kh**, Kahiltna; **km**, Kuskokwim Mountains; **ko**, Khingan-Okhotsk; **ku**, Kuril; **mo**, Monakin; **no**, North Okhotsk; **oc**, Okhotsk-Chukotka; **ol**, Oloy; **os**, Oloy-Svyatov Nos; **pn**, Penzhina; **ns** Nelson; **sb** Spences Bridge; **sh** Shirshov Ridge; **sv**, Svyotoy-Nos; **tt**, Tahtsa-Twin

SUBDUCTION-ZONE OR ACCRETIONARY-WEDGE COMPLEX, OR OPHIOLITE

AG, Angayucham; **AM**, Amur River; **AC**, Aluchin; **AGR**, Argatas; **ANV**, Aniva; **AV**, Alkatvaam; **BA**, Baker; **BD**, Badzhal; **BR**, Bridge River; **CC**, Cache Creek; **CG**, Chugach; **DB**, Debin; **EA**, Easton; **EK**, Ekonay; **GB**, Garbyn'ya, **GD**, Goodnews; **GL**, Galam; **GS**, Grindstone; **HI**, Hidaka; **HO**, Hoh; **KB**, Khabarovsk; **KK**, Kamuikotan; **KLM**, Kiselevka-Manoma;

BACKARC SPREADING OR HOT-SPOT UNITS

am, Alpha and Mendeleev Ridges; **bs**, Bering Sea; **cr**, Columbia River; **kr**, Kuril; **sj**, Sea of Japan; **sp**, Sakhalin-Primorye

OCEANIC

Plates: **FAR**, Farallon; **JF**, Juan de Fuca; **KULA**, Kula; **PAC**,

POST-ACCRETION OVERLAP SEDIMENTARY AND VOLCANIC UNIT, SUBMARINE FAN, OR OCEAN BASIN DEPOSIT

ab, Amerasia Basin;**ar**, Anadyr; **atb**, Aleutian-Bowers; **bo**, Bowser; **bu**, Bureya; **cb**, Canada Basin; **cf**, Cordilleran

COLLAGE OF PREVIOUSLY ACCRETED TERRANES AND EXTINCT TERRANES, OVERLAP ASSEMBLAGES, AND BACKARC UNITS (names of units in parentheses)

COLL, Collages of various accreted terranes (some labeled);

CONTACTS AND FAULTS

(Dashed where concealed or approximately located; queried where unknown)

Contact
Thrust fault, barbs on upper plate
Strike-slip fault
Regional continental-rift. Barbs towards extended area
Subduction zone, barbs point toward subducting margin
Transform fault along oceanic ridge
Boundary of neotectonic block defined by modern seismicity

SYMBOLS

Oceanic ridges: GK, Gakkel, JFR, Juan de Fuca
Backarc spreading, barbs face spreading basin
Zone of active metamorphism and deformation of continental margin
B — B Zone of blueschist-facies metamorphism
Relative direction and motion of oceanic plate
DE Fault name abbreviation
(cb) Abbreviations for extensive extinct basin, previously accreted terranes, or inactive arcs in parentheses
Direction of tectonic migration or major oroclinal bending
Paleopole
14° Paleolatitude

PLUTONIC BELTS

Collisional granite belts: **ma**, Main; **no**, Northern; **om**, Omineca-Selwyn; **tr**, transverse; **wvk**, West Verkhoyansk
Subduction-related continental-margin plutonic rocks
Oceanic-ridge-related plutonic rocks: **sab**, Sanak-Baranof plutonic belt

FAULT NAMES

AD Adycha-Taryn
AL Aleutian megathrust
CA Central Sikhote-Alin
CC Cascadia megathrust
CO Contact
DE Denali
FS Frasier-Straight Creek
HA Harrison
KA Kaltag
KE Ketanga
KK Kuril Kamchatka megathrust
KO Kobuk-South Fork
LE Lena
LS Lyakhov-South Anyui
MO Mongol-Okhotsk
MY Myatisk
NF Nixon Fork
RL Ross Lake
QC Queen Charlotte-Fairweather
SH Sakhalin-Hokkaido
TE Teslin
TI Tintina
UL Ulban
UM Ulakhay

METALLOGENIC BELT

OH Metallogenic belt with abbreviation

(4) The Sicker island arc was active along most of the length of the Wrangellia superterrane (WRA), which at this time was composed only of the Alexander sequence (AX) of the Wrangellia superterrane. Associated with the Sicker arc was an unknown subduction zone (UNK). In the southern Canadian Cordillera today, the Sicker arc is defined by the Sicker Group which consists of Late Devonian arc-related volcanic and sedimentary strata, having a U-Pb zircon age of 367 Ma, and coeval intrusions (Muller, 1980; Parish and McNicoll, 1992). Occurring in the Alexander sequence (AX) was the Mount Sicker metallogenic belt of kuroko massive sulfide deposits which formed in the subduction-related, short-lived Sicker arc. Insufficient data exist to ascertain the relative positions of the Wrangellia superterrane (WRA) and associated subduction zone. On the basis of paleomagnetic, geologic, geochronologic, and faunal data, the Wrangellia superterrane (Alexander sequence, AX) may have been derived from the Russian platform (Baltica) in the Barents Sea region (Bazard and others, 1993, 1994) or possibly from Australia (Gebrels and Saleeby, 1987).

Yaroslavka Metallogenic Belt of Fluorite and Sn Greisen Deposits (Belt YA) Southern Part of Russian Southeast

The Yaroslavka metallogenic belt of fluorite and Sn greisen deposits (fig. 16; tables 3, 4) occurs in the southwestern part of the Primorye province of the Russian Southeast (Ryazantseva, 1998). The deposits occur in numerous early Paleozoic granitoid plutons which intrude Cambrian clastic and limestone units in the Vosensenka continental-margin arc terrane of the Khanka superterrane. The major fluorite greisen deposit is at Voznesenka-II; the major Sn greisen deposit is at Yaroslavka (table 4) (Nokleberg and others 1997a, b, 1998).

Voznesenka-II Fluorite Greisen Deposit

The major Voznesenka-II fluorite greisen deposit (fig. 19) (Androsov and Ratkin, 1990; Ryazantzeva, 1998) consists of fluorite which occurs above the apex of a 1.5 km-wide Late Cambrian intrusion of lithium-fluorine alaskite granite with Rb-Sr isotopic ages of about 512-475 Ma. The fluorite is interpreted as forming from metasomatic replacement and alteration of Early Cambrian, black organic limestone to greisen along a north-south-trending fault into which the alaskite granite intruded. An aggregate of muscovite and fluorite occurs at the periphery of the ore zone whereas the greisen occurs in the middle of the zone. The greisen is often brecciated into fragments of mica and fluorite, fluoritized limestone, greisen, and greisenized granite which are cemented by an aggregate of quartz, topaz, and micaceous-fluorite. The deposit is very large and contains an estimated 450 million tons fluorite ore averaging 30-35% CaF_2. The Voznesenka-II deposit has been mined since 1960's, is the sole producer of Russian fluorspar, and is currently one of the largest fluorine producers in the world.

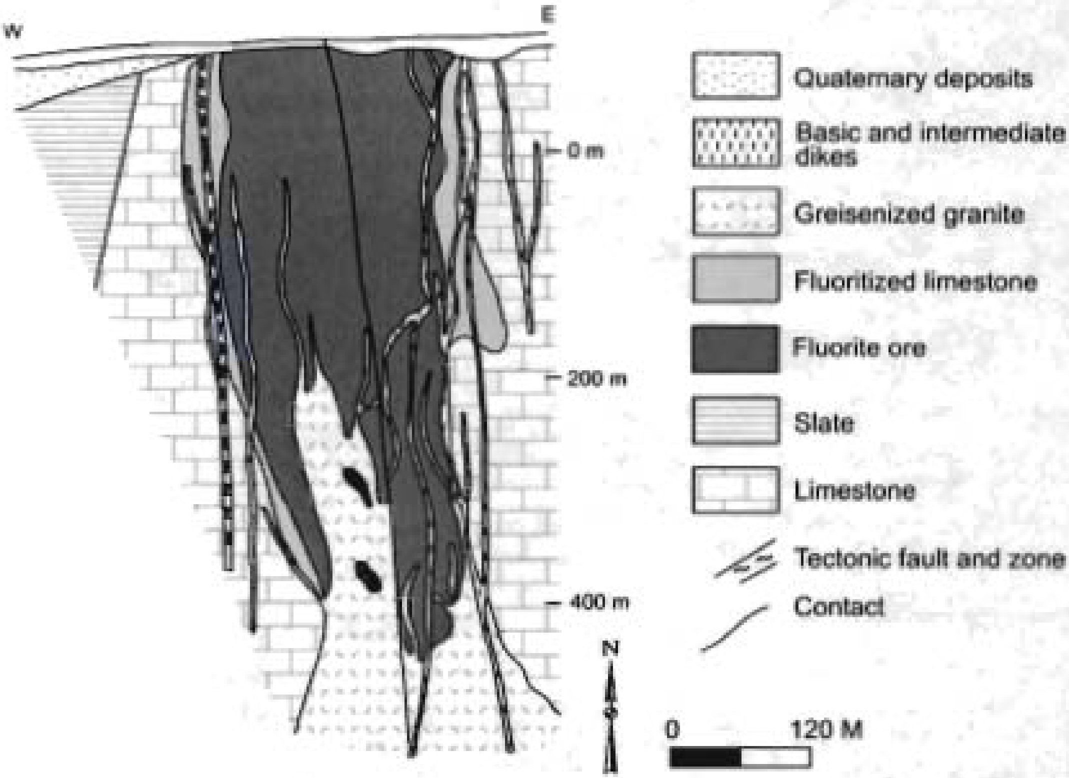


Figure 19. Voznesenka II F greisen deposit, Yaroslavka metallogenic belt, Russian Southeast. Schematic cross section through Glavnoe deposit. Adapted from Androsov and Ratkin (1990) and Ryazantzeva (1998).

The formation of the greisen fluorspar deposits is interpreted as related to intrusion of Late Cambrian leucogranite (Ryazantzeva and Shurko, 1992). The high fluorine content of the granitic intrusions is related to the presence of Precambrian accumulations of boron, fluorine, and sufur, and other metals in the zone in the host sedimentary rocks. Isotopic analyses of boron in tourmaline from leucogranite suggests which evaporites were the source for the boron, and which florine may be derived from associated dolomite.

Yaroslavka Sn Greisen Deposit

The major Yaroslavka Sn greisen deposit (fig. 20) (Govorov, 1977; Ryazantzeva, 1998) occurs mainly in greisen which mainly replaces skarn, limestone, and schist; and to lesser extent in granite and granite porphyry with a Rb-Sr isotopic age of 408 Ma and an initial Sr ratio of 0.7136 (Rayazantseva and others, 1994). Tin-bearing quartz and quartz-tourmaline veins, related to replacement of skarn by greisen, are classified into: (1) mineralized fracture zones; (2) ore veins; (3) veinlets and ore pods; and (4) saddle-shaped and sheeted ore. The Sn ores are classified into three types based on mineral associations: (1) tourmaline-quartz; (2) tourmaline-fluorite; and (3) sulfide-tourmaline-quartz with subordinate cassiterite-polymetallic and chlorite-sulfides. The sulfide minerals are dominantly pyrite, arsenopyrite, galena, and sphalerite. The deposit occurs along the contact of a early Paleozoic biotite granite (approximately 400 Ma) which intrudes Early Cambrian shale, siltstone, sandstone, and limestone. The pre-ore pyroxene-scapolite, vesuvianite-garnet, and epidote-amphibole skarn occurs in limestone and shale along the granite contacts, and in rare limestone inclusions within the granite. The deposit is of medium size. The average grade is 0.52% Sn. The deposit was mined from the 1950's through the 1970's. Over forty occurrences of and vein deposits are known in the Yaroslavka metallogenic belt.

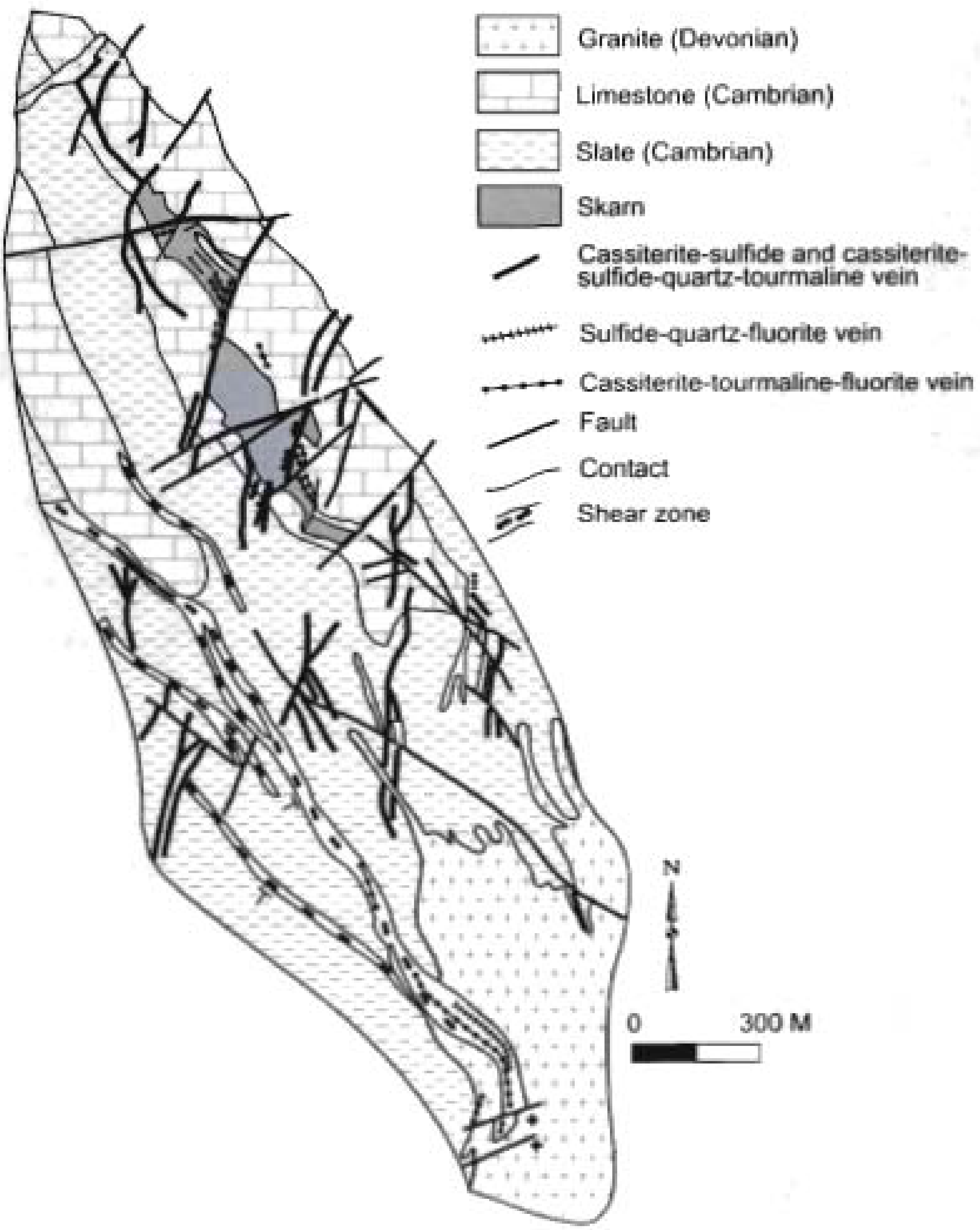


Figure 20. Yaroslavka Sn greisen deposit, Yaroslavka metallogenic belt, Russian Southeast. Schematic geologic map. Adapted from Govorov (1977) and Ryazantzeva (1998).

Origin of and Tectonic Controls for Yaroslavka Metallogenic Belt

The leucogranites hosting the Yaroslavka metallogenic belt of fluorite and Sn greisen deposits are lithium-fluorine-REE enriched (Ryazantseva, 1998). The extensive deposits occur in the apical parts of plutons, altered to quartz-mica-fluorite-REE greisen) which intruded Early Cambrian limestone of the Voznesenka passive continental-margin terrane. The leucogranites are interpreted as forming during anatectic melting of older granitic gneisses and Cambrian sedimentary rocks (Khetchikov and others, 1992) presumably during collision of the Voznesenka and Kabarga terranes in the early Paleozoic (Nokleberg and others, 1994c, 1997c; Khanchuk and others, 1996, 1998). The Voznesenka terrane hosting the Yaroslavka metallogenic belt consists of four major units. (1) Cambrian sandstone, pelitic schist, rhyolite, felsic tuff, and limestone and dolomite comprise a section up to several thousand meters thick with rhyolite which yields a Rb-Sr whole-rock isotopic age of 512 Ma. (2) Ordovician to Early Silurian conglomerate and sandstone which contains a questionable flora. (3) Early Devonian rhyolite and felsic tuff, Middle to Late Devonian rhyolite, felsic tuff, and rare basalt. And (4) Late Permian basalt, andesite, rhyolite, sandstone. The stratified Cambrian rocks are intensely deformed and intruded by collision-related Devonian granitoid rocks with isotopic ages of 440 to 396 Ma (Ryazantseva and others, 1994. The Cambrian sedimentary and volcanic units of the Voznesenka terrane are interpreted as a fragment of a Late Proterozoic to early Paleozoic carbonate-rich sedimentary rock sequence which formed on a passive continental margin. Archaeocyathid in Cambrian limestone is related to the Australia paleogeographic province. The Voznesenka terrane is interpreted as a fragment of the passive continental margin of Gondwanaland (Khanchuk and others, 1998).

Metallogenic Belts Formed in a Middle Paleozoic Continental Arc Along North Asian and North American Craton Margins

Kedon Metallogenic Belt of Au-Ag Epithermal Vein, Porphyry Mo, Fe Skarn, and Associated Deposits (Belt KE) Central Part of Russian Northeast

The Kedon metallogenic belt of Au-Ag epithermal vein, porphyry Mo, Fe skarn and associated deposits (fig. 16; tables 3, 4) occurs in the central part of the Russian Northeast. The belt is hosted in early and middle Paleozoic granite, and coeval rhyolite, andesite, trachyandesite, silicic tuff, and associated sedimentary rocks of the Omolon cratonal terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c). The areal extent of the Kedon metallogenic belt is approximately 40,000 km^2.

The Au-Ag epithermal vein deposits occur in subaerial extrusive rocks and subvolcanic equivalents, and in tuff of Middle Devonian through Early Carboniferous age. The significant deposits are at Olcha, Kubaka, and Zet (table 4) (Nokleberg and others 1997a, b, 1998). These deposits occur in trachyandesite-trachydacite volcanic rocks of Early Carboniferous age (Igor N. Kotlyar, written commun., 1995). Small deposits, such as at Tumannaya, Obyknovennoe, and Yolochka, occur in felsic volcanic rocks of Late Devonian age. Some epithermal vein deposits, as at Grisha, also occur in early(?) Paleozoic syenite. Porphyry Mo-Cu deposits, as at Vechernee and elsewhere, occur in middle Paleozoic, potassic granitoid rocks and subvolcanic rhyolites. Fe skarn deposits, as at Skarnovoe and elsewhere, occur in early Paleozoic granite which intrude Archean iron formation which provided Fe for the Fe skarn deposit (Fadeev, 1975). The available field, isotopic, and paleoflora data indicate that the magmatic rocks of the Kedon metallogenic belt formed mainly in the Middle Devonian through the Early Carboniferous (Lychagin and others, 1989).

Kubaka Au-Ag Epithermal Vein Deposit

The Kubaka Au-Ag epithermal vein deposit (fig. 21) (Savva and Vortsepnev, 1990; Stepanov and others, 1991; V.A. Banin, oral commun., 1993; I.N. Kotlar, written commun., 1986; Layer and others, 1994) consists of veins and zones of adularia-quartz and adularia-chalcedony-hydromica-quartz veinlets which contain fluorite, barite, and carbonate. The veins occur in a northwest-trending elongate caldera 4 km in diameter. The caldera lies transverse to the northeast trend of the main regional structural trend. The caldera is rimmed by Middle to Late Devonian volcanic rocks and volcanogenic sediments and is filled with Late Devonian to Early Carboniferous volcanic rocks. The Au-bearing veins occur within the caldera, and are localized in subvolcanic trachydacite in a stratified, Middle to Late Devonian volcaniclastic sequence composed of ignimbrite, pumiceous rhyolite to dacite, trachyandesite and rhyolite-dacite sills, and tephra and agglomerate tuff of various compositions. The veins die out in the overlying Early Carboniferous carbonaceous shale and siltstone. The most intensely mineralized veins trend about east-west and west-northwest. The host rocks are intensely silicified, adularized, and sericitized; with the development of much hydromica. Initial stage of mineralization was marked by a gold-chalcedony association with colloidal gold (with electrum and küstelite). A later adularia-quartz stage contains coarser, recrystallized native gold and scattered, disseminated pyrite, arsenopyrite, galena, freibergite, acanthite, aguilarite, naumannite, argentopyrite, and Au-Ag sulfides in fine-grained aggregates. Native gold predominates markedly over sulfide-bound gold. The Au:Ag ratio is 1:1 to 1:2. The deposit is medium size with proven reserves of about 100 tonnes Au and an average grade of about 17 g/t Au and 15.7 g/t Ag. Siince 1996, the Kubaka deposit has been developed under a joint venture agreement between the Kinross Gold Corporation of Canada and a consortium of Russian firms under the Omolon Mining Company. The joint venture is the first Western and Russian mining venture to succeed in the Russian Federation.

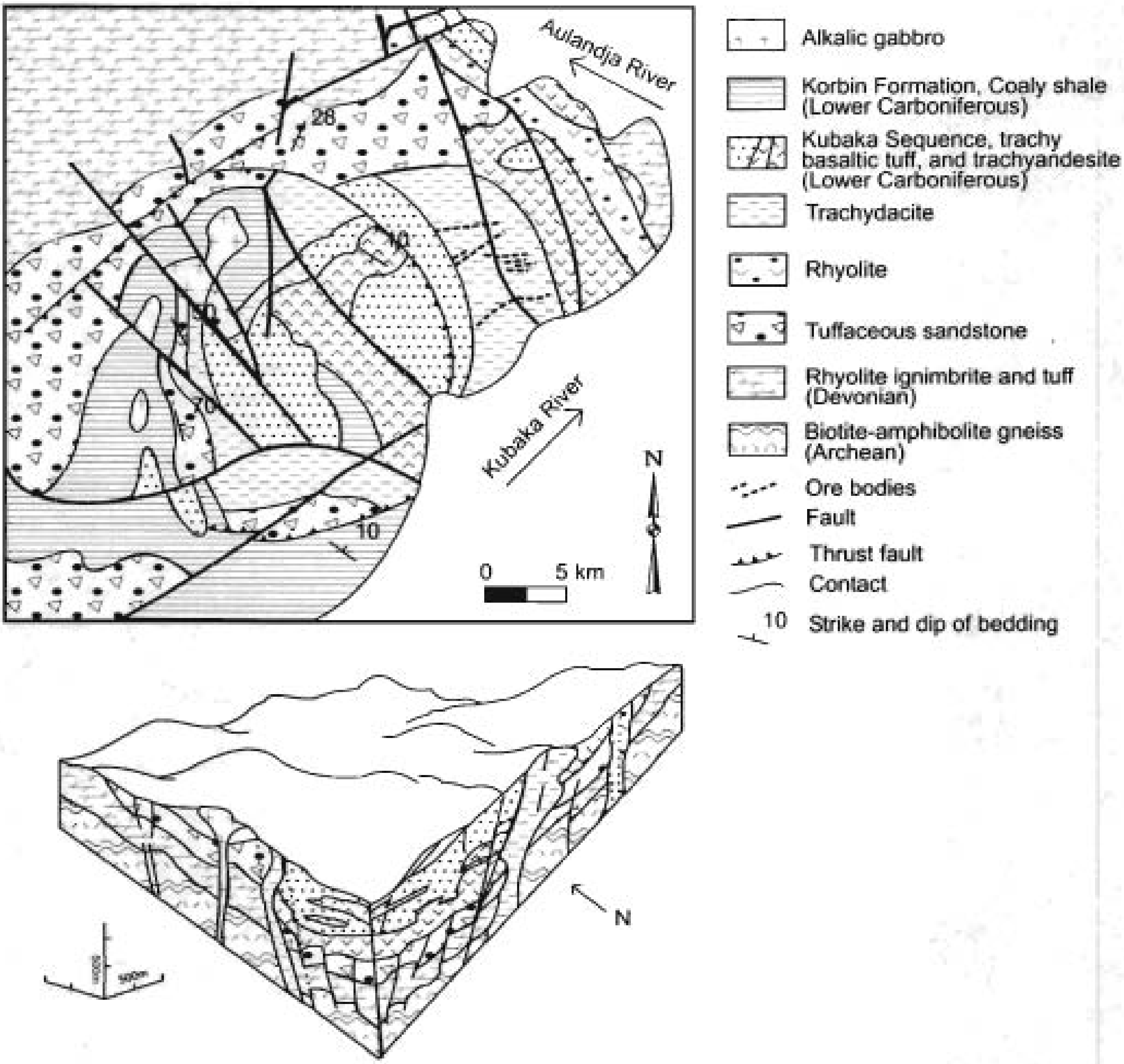


Figure 21. Kubaka Au-Ag epithermal vein deposit, Kedon metallogenic belt, Russian Northeast. Schematic geologic map and oblique view cross sections. Adapted from I.N.Kotlyar and N.E. Savva (written comm. 1994) and Sidorov and Goryachev (1994).

The stratified volcanic rocks and subvolcanic caldera rocks yield Rb-Sr isochron ages of are 332-344 Ma. Post-ore alkalic basalt dikes exhibit K-Ar isotopic ages of 124-155 Ma. Adularia from ore vein samples exhibit Ar-Ar ages which range from 110 to 175 Ma, with plateau ages ranging from 110-130 Ma. Cretaceous rhyolite and alkalic basalt dikes occur within and beyond the mineralized tectonic block. Basalt dikes cross the mineralized veins and are themselves cut by later, Au-poor quartz-carbonate veins and veinlets. The age of mineralization is interpreted as Late Devonian to Early Carboniferous because fragments of Au-bearing calcedonic quartz occur in the adjacent conglomerates which contain Early-Middle Carboniferous fossils.

Olcha Au-Ag Epithermal Vein Deposit

The Olcha Au-Ag epithermal vein deposit (Zagruzina and Pokazaniev, 1975; Pokazaniev, 1976a, b; I.N. Kotlar, written commun., 1984) consists of steeply dipping quartz, carbonate-quartz, and adularia-quartz veins and stockwork zones ranging from several tens of meters to 1,300 m long. The veins and stockworks are hosted in Middle to Late Devonian or Early Carboniferous volcanic rocks of the Kedon series. The veins occur along fractures, mainly in extrusive andesite breccia of a volcanic vent, and more rarely, in hypabyssal dacite-porphyry bodies and felsic extrusive rocks. The ore minerals include gold, chalcopyrite, argentite, polybasite, galena, sphalerite, pyrite, hematite, Mn-oxides, stromeyerite, tetrahedrite, native silver, and tellurides. The gangue minerals are quartz and adularia, with lesser calcite, dolomite, rhodochrosite, and barite. Au and Ag is associated with Hg, Cu, Mo, Pb, Zn, Mn, and As. The deposit exhibits propylitic and quartz-sericite alteration. The Au-Ag ore bodies are controlled by arcuate faults which occur around a volcano-tectonic depression over a basement composed of Archean metamorphic rocks and early Paleozoic(?) carbonate and clastic sedimentary rocks. Adularia from quartz veins has been dated by K-Ar isotopic studies as 268 Ma and by Rb-Sr isotopic studies as 251 Ma. More recent K-Ar dating of adularia from Au-bearing veins yields an age of 318 Ma. The deposit is medium size, and grade ranges from 0.5 to 273 g/t Au and 26.3 to 4,978 g/t Ag.

Origin of and Tectonic Controls for Kedon Metallogenic Belt

The Omolon cratonal terrane, which hosts the Kedon metallogenic belt, consists of a long-lived succession of Archean to Early Proterozoic crystalline basement, Middle Proterozoic through middle Paleozoic miogeoclinal sedimentary rocks (Nokleberg and others, 1994c, 1997c). The younger part of the stratigraphy consists of unconformably overlying, widespread, gently-dipping Middle and Late Devonian calc-alkalic lava, and rhyolite tuff, and Early Carboniferous trachyte, trachyandesite, and basalt which are interlayered with nonmarine sandstone, conglomerate, and siltstone. These rocks constitute the Kedon arc of Shpikerman (1998). The felsic-magmatism-related lode deposits and host rocks of the Kedon metallogenic belt are interpreted as forming in the Kedon continental-margin magmatic arc which formed in the Late Devonian. Subsequent to the Kedon arc, the Omolon terrane is interpreted having been rifted from the North Asian Craton (Nokleberg and others, 2000; Shpikerman, 1998).

Eastern Seward Peninsula (Kiwalik Mountain) Metallogenic Belt of Kuroko Massive Sulfide Deposits (Belt ES) Northwestern Alaska

The Eastern Seward Peninsula metallogenic belt of kuroko massive sulfide deposits occurs in the Kiwalik Mountain region of the Seward Peninsula in northwestern Alaska (fig. 17; tables 3, 4) (Nokleberg and others, 1997b, 1998, Sheet 4). The metallogenic belt is hosted in a thin, tectonically-transposed unit of middle Paleozoic(?) felsic schists and metavolcanic rocks of the Seward metamorphosed continental margin terrane (Nokleberg and others, 1994c, 1997c). Two small occurrences on the west flank of Kiwalik Mountain consist of chalcopyrite, galena, tetrahedrite, and sphalerite in layers and as disseminations. The layers range from 0.2 to 2 m thickand occur parallel to compositional layering in a 200 meter-thick section of metafelsite, "button schist", and metatuff. The Kiwalik Mountain belt are interpreted as the extension of the Arctic metallogenic belt of kuroko massive sulfide deposits described below (T.K. Bundtzen and Thomas Crafford, written commun., 1991).

Arctic Metallogenic Belt of Kuroko and Kipushi Massive Sulfide Deposits (Belt AT) Northern Alaska

The extensive Arctic metallogenic belt of major kuroko massive sulfide deposits (tables 3, 4), which contains the Ambler district, 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 in northern Alaska (fig. 17). The metallogenic belt is hosted in a sequence of metavolcanic and sedimentary rocks which occur in both the Coldfoot metamorphosed continental-margin terrane of the southern Brooks Range, and in the Nome Group in the southern Seward Peninsula in the Seward metamorphosed continental-margin terrane (Nokleberg and others, 1994c, 1997c; Schmidt, 1997b). The Arctic kuroko massive sulfide and the Ruby Creek Kipushi Cu-Pb-Zn (fig. 22)deposits occur in the Ambler district (Hitzman and others, 1986); other kuroko massive sulfide deposits of the district are at Smucker, Michigan Creek, BT, Jerri Creek, Sun, and Roosevelt Creek prospects (table 4) (Nokleberg and others 1997a, b, 1998).

Arctic Kuroko Massive Sulfide Deposit

The Arctic kuroko massive sulfide deposit (Wiltse, 1975; Sichermann and others, 1976; Hitzman and others, 1982; Schmidt, 1983; Schmidt, 1986, 1988; Hitzman and others, 1986) consists of stratiform, semi-massive to massive chalcopyrite and sphalerite accompanied by lesser pyrite, minor pyrrhotite, galena, tetrahedrite, arsenopyrite, and traces of bornite, magnetite, and hematite. The deposit occurs in a thick horizon which has an areal extent of about 900 by 1,050 m, and in two thinner horizons above the main horizon. The sulfides form multiple lenses up to 15 m thick over stratigraphic interval of 6 to 80 m. The gangue minerals are mainly calcite, dolomite, barite, quartz, and mica. Locally abundant chlorite, phlogopite-talc-barite, and pyrite-calcite-white mica occur in hydrothermally-altered wall rocks overlying, underlying, and interlayered with sulfide mineralization. The alteration is interpreted as occurring during rapid influx of cold seawater into a hot hydrothermal vent system. The deposit contains an estimated 37 million tonnes grading 4.0% Cu, 5.5% Zn, 0.8% Pb, 47 g/t Ag, 0.62 g/t Au. The deposit is hosted in part of the

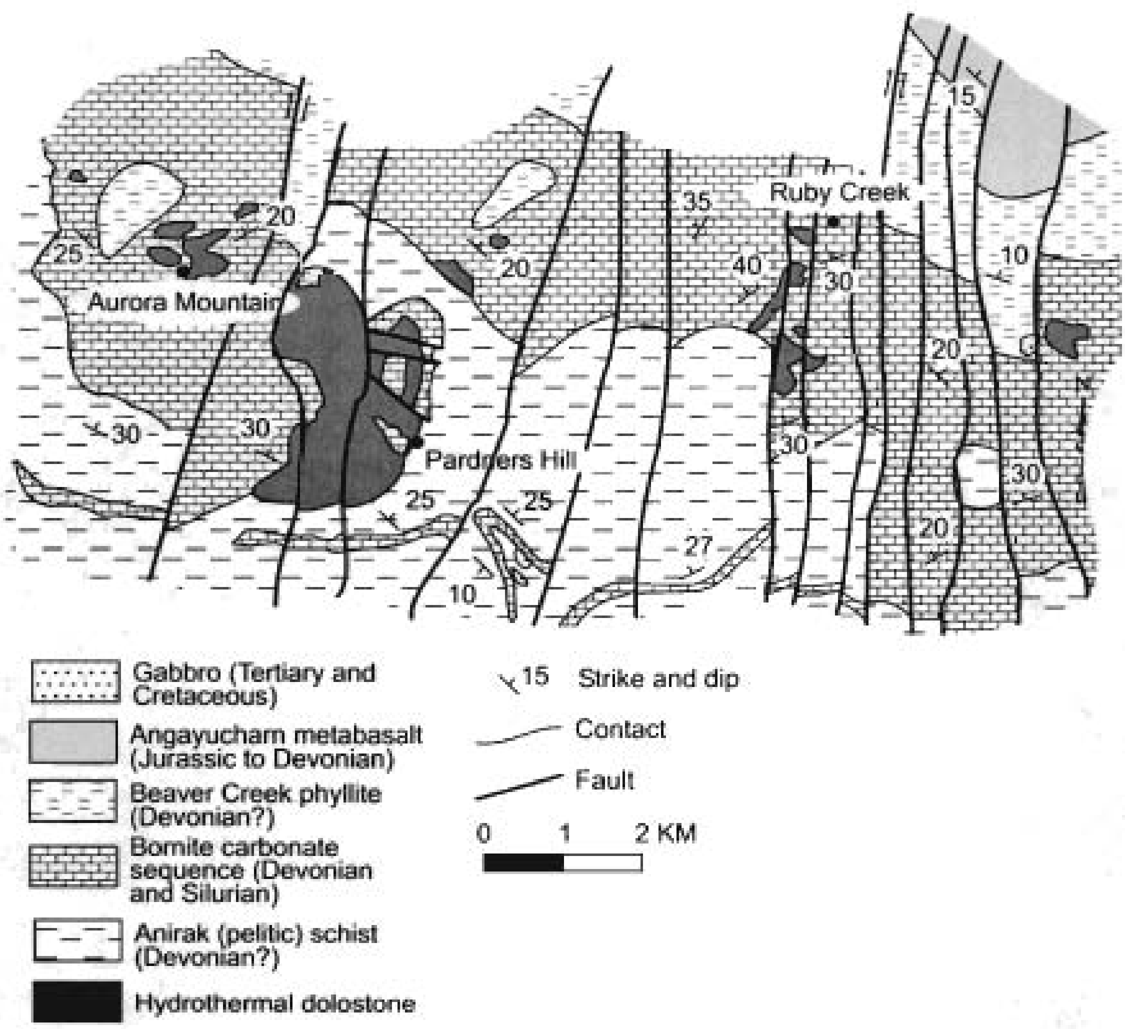


Figure 22. Ruby Creek (Bornite) Kipushi Cu-Pb-Zn deposit and related deposits, Cosmos Hills area, Arctic metallogenic belt, Northern Alaska. Schematic geologic map. Except where noted, all faults are downthrown to the east. Adapted from Hitzman (1986) and Schmidt (1997).

Devonian and Mississippian Ambler sequence. The main horizon of sulfides is hosted in mainly graphitic pelitic schist and metarhyolite porphyry derived from submarine ash-flow tuff.

Origin of and Tectonic Controls for Arctic Metallogenic Belt

The kuroko massive sulfide deposits in the Arctic metallogenic belt are hosted in, or occur 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; Newberry and others, 1997) which forms part of the informally named *Ambler schist belt* or Coldfoot metamorphosed continental margin terrane of the southern Brooks Range (Moore and others, 1992; Nokleberg and others, 1994c, 1997c). On the basis of local bimodal volcanic rocks, a back-arc rift environment is interpreted by some workers in the southern Brooks Range belt for the origin of kuroko massive sulfide deposits and host rocks (Hitzman, 1986; Newberry and others, 1997; Schmidt, 1986; Moore and others, 1994; Goldfarb, 1997). However, this belt shares many characteristics with the broadly coeval Eastern Alaska Range belt of kuroko massive sulfide deposits, described below, which is interpreted as forming in a submerged continental-margin arc environment (Lange and others, 1993). In addition, regional tectonic analyses interpret the Devonian submarine and associated volcanic rocks of the southern Brooks Range and the belt of Devonian granitoid plutons, which occur along the southern flank of the Brooks Range, are part of a discontinuous Devonian continental-margin arc which extended along the margin of the North American Cordillera (Rubin and others, 1991; Plafker and Berg, 1994; Goldfarb, 1997; Nokleberg and others, 2000). The Arctic metallogenic belt is herein interpreted as forming in the back-arc of the same continental-margin arc in which formed the Brooks Range metallogenic belt of granitic magmatism deposits, described below (fig. 17). With this interpretation, the SEDEX deposits formed later in the Late Mississippian and Early Pennsylvanian, and in a distinctly different tectonic environment. This interpretation differs from, Goldfarb (197) who interprets that the Arctic metallogenic belt as forming during a long-protracted, 100-m.y.-long event which included formation of SEDEX zinc-lead deposits in the Northwestern Brooks Range metallogenic belt (described below).

Brooks Range (Chandalar) Metallogenic Belt of Granitic Magmatism Deposits (Belt BR) Northern Alaska

The Brooks Range metallogenic belt of granitic magmatism deposits (fig. 17; tables 3, 4), mainly porphyry, polymetallic vein, and skarn deposits, occurs in the core of the Brooks Range in northern Alaska (Nokleberg and others, 1995a, 1997b, 1998). The metallogenic belt is hosted in the Coldfoot, Hammond, and North Slope terranes of the Arctic Alaska superterrane (Moore and others, 1992, 1994; Nokleberg and others, 1994c, 1997c). The belt is discontinuous, but extends for over 900 km along the length of the Brooks Range. The significant deposits in the belt are: the Mount Igikpak and Arrigetch Peaks polymetallic vein, Au quartz vein, Sn skarn, Cu-Pb-Zn skarn deposits; the Ann (Ernie Lake), Galena Creek, Porcupine Lake, and Romanzof Mountains polymetallic vein deposits; the Jim-Montana Cu-Zn skarn deposit; the Sukakpak Mountain Sb-Zu vein deposit; the Victor, Venus, Evelyn Lee, and Ebo porphyry Cu and Cu skarn deposits; the Geroe Creek porphyry Cu-Mo deposit; the Esotuk Glacier Pb-Zn skarn and fluorite vein deposit; and the Bear Mountain porphyry Mo deposit (table 4) (Nokleberg and others 1997a, b, 1998). These significant deposits occur in two groups described below: a major group in the central Brooks Range, and a minor group in the northeastern Brooks Range. In the northeastern Brooks Range, the belt is sometimes referred to as the Chandalar belt (Newberry and others, 1997a, b).

Vein, Skarn, and Porphyry Deposits Central Brooks Range

Significant deposits in the central Brooks Range part of the belt are at Mount Igikpak and Arrigetch Peaks, Sukakpak Mountain, Victor, and Geroe Creek. These deposits include polymetallic quartz veins containing base-metal sulfides, Sn skarns containing both disseminated cassiterite and base-metal sulfides, Cu-Pb-Zn skarns containing disseminated Fe and base-metal sulfides, and porphyry Cu and Mo deposits (Nokleberg and others, 1995a).

The Victor and associated porphyry Cu and Cu skarn deposits at Venus, Evelyn Lee, and Ebo (DeYoung, 1978; Donald Grybeck, written commun., 1984; Newberry and others, 1997a) consist of veinlet and disseminated chalcopyrite, bornite, molybdenite, and pyrite in schistose Devonian granodiorite porphyry which intrudes either the Silurian and Devonian Skajit Limestone or older marble, calc-schist, and pelitic schist. The skarn minerals are mainly garnet, magnetite, and diopside, and retrograde vein and replacement epidote, amphibole, chlorite, calcite, and quartz. The skarns were subsequently regionally metamorphosed during the Mesozoic. Skarns in marble adjacent to plutonic rocks contain vugs containing interstitial bornite, chalcopyrite, bornite, chalcocite, pyrite, magnetite, and some digenite. Zones in granitoid rocks up to 30 m wide contain up to 0.4% Cu. Grab samples of skarn contain up to 5.5% Cu, 0.41 g/t Au, and 0.29 g/t Ag.

The felsic-magmatism-related deposits in the central Brooks Range are hosted in a structurally complex and polymetamorphosed assemblage of Devonian or older carbonate rocks, including Silurian and Devonian polymetamorphosed limestone, calc-schist, quartz-mica schist, and quartzite, which is intruded by mainly Late Devonian gneissic granitoid rocks which together with the metasedimentary rocks constitute the Hammond passive continental margin terrane of the Arctic Alaska superterrane (Moore and others, 1992).

Skarn, Vein, and Porphyry Deposits Northeastern Brooks Range

Significant deposits in the Brooks Range metallogenic belt in the northeastern Brooks Range are a cluster of Pb-Zn skarn, fluorite vein, polymetallic vein, and porphyry Cu deposits at Esotuk Glacier, Porcupine Lake, Romanzof Mountains, and Galena Creek (Nokleberg and others, 1995a). This part of the belt is sometimes referred to as the Chandalar belt (Newberry and others, 1997a, b).

The Romanzof Mountains polymetallic vein and Pb-Zn skarn deposit (Brosge and Reiser, 1968; Grybeck, 1977; Sable, 1977; W.P. Brosge, oral commun., 1984; Newberry and others, 1997a) consists of numerous scattered mineral occurrences of polymetallic sulfides. The most common types of deposits are: (1) zones of disseminated galena, sphalerite, chalcopyrite and pyrite, locally with Au and Ag, in Devonian(?) granite; (2) Pb-Zn skarn in marble with disseminated magnetite, pyrite, pyrrhotite, sphalerite, and galena in gangue of carbonate, clinopyroxene, epidote, amphibole, beryl, tourmaline, and fluorite; (3) disseminated galena, sphalerite, chalcopyrite, and (or) molybdenite in quartz veins along sheared contact in in Devonian(?) granite; and (4) local fluorite greisen in in Devonian(?) granite. Grab samples contain up to 0.15% Sn. The skarns and quartz veins occur in Precambrian marble and calc-schist of the Neruokpuk Quartzite at the periphery of the Silurian or Early Devonian Okpilak (granite) batholith.

These felsic-magmatism-related deposits are hosted in a variety of Paleozoic and late Proterozoic metasedimentary rock which consist mainly of marble, calc-schist, limestone, quartzite, and greenstone of the North Slope passive continental margin terrane (part of the Arctic Alaska superterrane) where intruded by Devonian gneissose granite plutons (Newberry and others, 1997a). The paucity of deposits in the northeastern Brooks Range most likely reflects the limited geological exploration of the area. Although not part of this metallogenic belt, a nearby porphyry Mo deposit in this area at Bear Mountain consists of molybdenite- and wolframite-bearing Tertiary(?) granite porphyry stock (Barker and Swainbank, 1986). The stock intrudes the Late Proterozoic(?) Neruokpuk(?) Quartzite, and the Tertiary(?) isotopic age for the stock may be a reset Devonian age. If so, the Bear Mountain deposit would be part of the Brooks Range metallogenic belt.

Origin of and Tectonic Controls for Brooks Range Metallogenic Belt

Field, chemical, and isotope data indicate the granitic magmatism deposits in the Brooks Range metallogenic belt formed during intrusion of the Devonian gneissic granitoid rocks (Dillon and others, 1987; Nokleberg and others, 1995a). High initial Sr ratios (about 0.715), and Pb and Sm-Nd isotopic studies indicate the presence of an older, inherited crustal component (about 1,000 to 800 Ma) and involvement of Proterozoic or older continental crust in the genesis of the plutons (Dillon and others, 1987; Nelson and others, 1993; Miller, 1994; Moore and others, 1994). U-Pb zircon and Rb-Sr isotopic studies indicate intrusion from about 402 to 366 Ma (Dillon and other, 1987; Moore and others, 1994). Most of the gneissic granitoid plutons contain a moderately- to intensely-developed, subhorizontal to gently-dipping schistosity which formed at lower greenschist facies. K-Ar, and incremental Ar studies indicate which mid-Cretaceous greenschist metamorphism was superposed on older blueschist facies metamorphism (Dusel-Bacon and others, 1993; Moore and others, 1994).

These field, petrologic, chemical, and isotopic data indicate that the Brooks Range metallogenic belt and associated Devonian gneissic granitoid plutons formed along a Devonian continental-margin arc which developed above a subduction zone (Newberry and others, 1997a; Nelson and others, 1993; Miller, 1994; Moore and others, 1994; Nokleberg and others, 1995a, 2000). U-Pb zircon isotopic ages indicate that the Devonian gneissic granitoid rocks intruded about 30 to 40 m.y. after the eruption of the submarine volcanic rocks which host the kuroko massive sulfide deposits to the west in the Arctic metallogenic belt (Newberry and others, 1997a; Nokleberg and others, 1997a) described above. Herein the Brooks Range metallogenic belt is interpreted as the axial arc part of a continental-margin arc in which the Arctic metallogenic belt of kuroko massive sulfide and associated deposits formed in the back arc. Regional tectonic analyses also suggest that the Devonian igneous of the Brooks Range are part of a discontinuous Devonian continental-margin arc which extended along the margin of the North American Cordillera (Rubin and others, 1991; Nokleberg and others, 1994c, 1997c, 2000; Plafker and Berg, 1994; Goldfarb, 1997). An alternative interpretation by Goldfarb and others (1997, 1998) proposes which some of the deposits in the Arctic metallogenic belt formed during subsequent rifting, as indicated by Pb isotope data reported by Dillon and others (1987).

Alaska Range and Yukon-Tanana Upland Metallogenic Belt of Kuroko Massive Sulfide Deposits (Belt AKY) Central and East-Central Alaska

The Alaska Range and Yukon-Tanana Upland metallogenic belt of kuroko massive sulfide deposits (fig. 17; tables 3, 4) occurs in the central and eastern Alaska Range in the southern part of the Yukon-Tanana metamorphosed continental margin terrane. The massive sulfide deposits extend for 350 km along strike on the northern flank of the Alaska Range, and constitute one of the longer belts of massive sulfide deposits in Alaska. The significant deposits are WTF, Red Mountain, Sheep Creek, Liberty Bell, Anderson Mountain, Miyaoka, Hayes Glacier, McGinnis Glacier, and in several deposits in the Delta district (table 4) (Newberry and others, 1997; Nokleberg and others 1997a, b, 1998).

Bonnifield District of Kuroko Massive Sulfide Deposits

In the Bonnifield district along the Wood River drainage, the best-studied deposits are at Anderson Mountain and WTF, and Red Mountain. Twenty sulfur isotopic analyses from seven stratiform deposits in the Bonnifield district indicate enrichment by heavier sulfur during deposition, typical of many volcanogenic massive sulfide deposits (Gilbert and Bundtzen, 1979; Newberry and others, 1997). One lead isotopic analysis from the Anderson Mountain deposit yielded a single-stage lead age of 370 Ma (Devonian).

Anderson Mountain Kuroko Massive Sulfide(?) Deposit

The Anderson Mountain kuroko massive sulfide(?) deposit (Gilbert and Bundtzen, 1979; Curtis J. Freeman, written commun., 1984; Newberry and others, 1997a) consists of massive sulfide layers with pyrite, chalcopyrite, galena, sphalerite, enargite, and arsenopyrite in gangue of quartz, sericite, chlorite, calcite, barite and siderite. The deposit is hosted in metamorphosed marine tuffaceous rhyolite and metamorphosed calcareous clastic rocks which are correlated with the Moose Creek Member of the Mississippian(?) Totatlanika Schist. Numerous high-angle faults cut the deposit. The massive sulfide beds lie on an irregular paleosurface in footwall with domal sulfide accumulations. The absence of footwall alteration and stringer mineralization suggests off-vent deposition. Grab samples contain up to 19% Cu, up to 5% Pb, 28% Zn, and 171 g/t Ag. High geochemical values of As, Sb, Hg, and W may be derived from underlying schist.

WTF and Red Mountain Kuroko Massive Sulfide Deposit

The WTF and Red Mountain Kuroko massive sulfide deposits (Gilbert and Bundtzen, 1979; David R. Gaard, written commun., 1984) consist of massive pyrite, sphalerite, galena, and chalcopyrite in a quartz-rich gangue. The sulfides are hosted in in felsic metavolcanic rock derived from crystal and lapilli tuff, minor flows, and metasedimentary rock. The stratiform massive sulfide layers occur on both sides of a large, east-west trending syncline. The massive sulfide layers at Red Mountain occur in a proximal setting on the south limb of the anticline, and occur in a sulfide-silica exhalite which ranges up to 130 m thick. An older, southern horizon contains sphalerite and coarse pyrite in black chlorite schist. The WTF deposit occurs on the north limb of the antiform and consists of a thin blanket of fine-grained sulfides which are interpreted as having formed in a distal setting relative to the vent. The WTF deposit contains an estimated 1.10 million tonnes grading 0.15% Cu, 2.5% Pb, 7.9% Zn, 270 g/t Ag, and 1.9 g/t Au. The deposits occur immediately below the Sheep Creek Member and above the Mystic Creek Member of the Mississippian(?) Totatlanika Schist.

Delta District of Kuroko Massive Sulfide Deposits

The best-known kuroko massive sulfide deposits of the Alaska Range and Yukon-Tanana Upland metallogenic belt are part of the Delta district in the eastern part of the Alaska Range (fig. 23). The district and large massive sulfide deposits have been described by several authors (Nauman and others, 1980; Lange and Nokleberg, 1984; C.R. Nauman and S.R. Newkirk, written commun., 1984; Lange and others, 1990, 1993; Newberry and others, 1997a). The district comprises an area of about 1,000 km^2. The district contains about 26 deposits, many of which are stratiform or transposed and some of which are replacement deposits which occur along four regional trends. The deposits consist of varying amounts of pyrite, chalcopyrite, galena, sphalerite, and lesser malachite and bornite. The gangue minerals are mainly quartz, carbonate, and white mica. Hydrothermal alteration consists of chlorite, quartz, sericite, pyrite, and Zn-Ag-Au sulfide minerals. The massive sulfides and adjacent disseminated sulfide layers occur in zones which average 500 m long, 200 m wide, and 15 m thick. The deposits are hosted in metamorphosed Devonian spilite, andesite, and keratophyre suite, which initially formed in flows, tuff, and breccia, and in metamorphosed shallow- to deep-marine sedimentary rocks; now mainly quartz schist, quartz-chlorite-feldspar schist, calc-schist, and marble. The host rocks are part of the extensive Devonian and Mississippian Yukon-Tanana terrane. Intruding the deposits are numerous tholeiitic greenstone sills which are interpreted as Triassic(?) to Cretaceous(?). The largest deposit contains an estimated 18 million tonnes grading 0.3 to 0.7% Cu, 1 to 3% Pb, 3 to 6% Zn, 34 to 100 g/t Ag, 1 to 3.4 g/t Au.

Origin of and Tectonic Controls for Alaska Range and Yukon-Tanana Upland Metallogenic Belt

The Alaska Range and Yukon-Tanana Upland metallogenic belt of kuroko massive sulfide deposits is hosted in Devonian metavolcanic and interlayered metasedimentary rocks of the southern Yukon-Tanana terrane which which is interpreted as a fragment of metamorphosed Devonian and Mississippian continental-margin arc (Lange and others, 1990, 1993; Nokleberg and others, 1994c, 1997, 2000). The metavolcanic rocks, which host most of the major base and precious metal deposits, are derived from a volcanic suite which varies in composition from spilite to andesite to keratophyre. Most studies of kuroko massive sulfide deposits interpret a back-arc or arc-related rift origin for the deposits (Sawkins, 1990); however, in the eastern Alaska Range, the lack of coeval mafic plutonic or volcanic rocks appears to preclude a rift origin. The Yukon-Tanana terrane in east-central Alaska, Southeastern Alaska, and the Canadian Cordillera, and the correlative Kootenay terrane in southern British Columbia are interpreted to be fragments of the herein, informally named, Kootenay arc, a discontinuous Devonian continental-margin arc which extended along the margin of the North American Cordillera from Arctic Alaska to California (Grantz and others, 1991; Rubin and others, 1991; Mortensen, 1992; Plafker and Berg, 1994; Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996; Nokleberg and others, 2000). Fragments of the Kootenay arc include several metallogenic belts which host kuroko massive sulfide and related deposits (Nokleberg and others, 1997a, b, c): (1) The Arctic metallogenic belt in the Coldfoot terrane in Arctic Alaska; (2) the Frances Lake metallogenic belt (Murphy and Piercey, 1999) in the Yukon-Tanana terrane in the southern Yukon Territory; (3) the Tracey metallogenic belt in the Yukon-Tanana terrane in Southeastern Alaska and western British Columbia; and (4) the Kootenay-Shuswap belt in the Kootenay terrane in the southern Canadian Cordillera.

Dawson Metallogenic Belt of Volcanogenic Pb-Zn-Cu Massive Sulfide and SEDEX Pb-Cu-Zn-Ba Deposits (Belt DA) Northwestern Yukon Territory

The Dawson metallogenic belt of volcanogenic Pb-Zn-Cu massive sulfide and SEDEX Pb-Cu-Zn-Ba occurrences is located in the Yukon-Tanana terrane in the southern Yukon Territory (fig. 17; tables 2, 3) (Nokleberg and others, 1997b, 1998). Stratiform massive sulfide occurrences exist in three sequences within the terrane. With more detailed study, each of the three sequences and contained massive sulfide deposits might be designated as separate metallogenic belts.

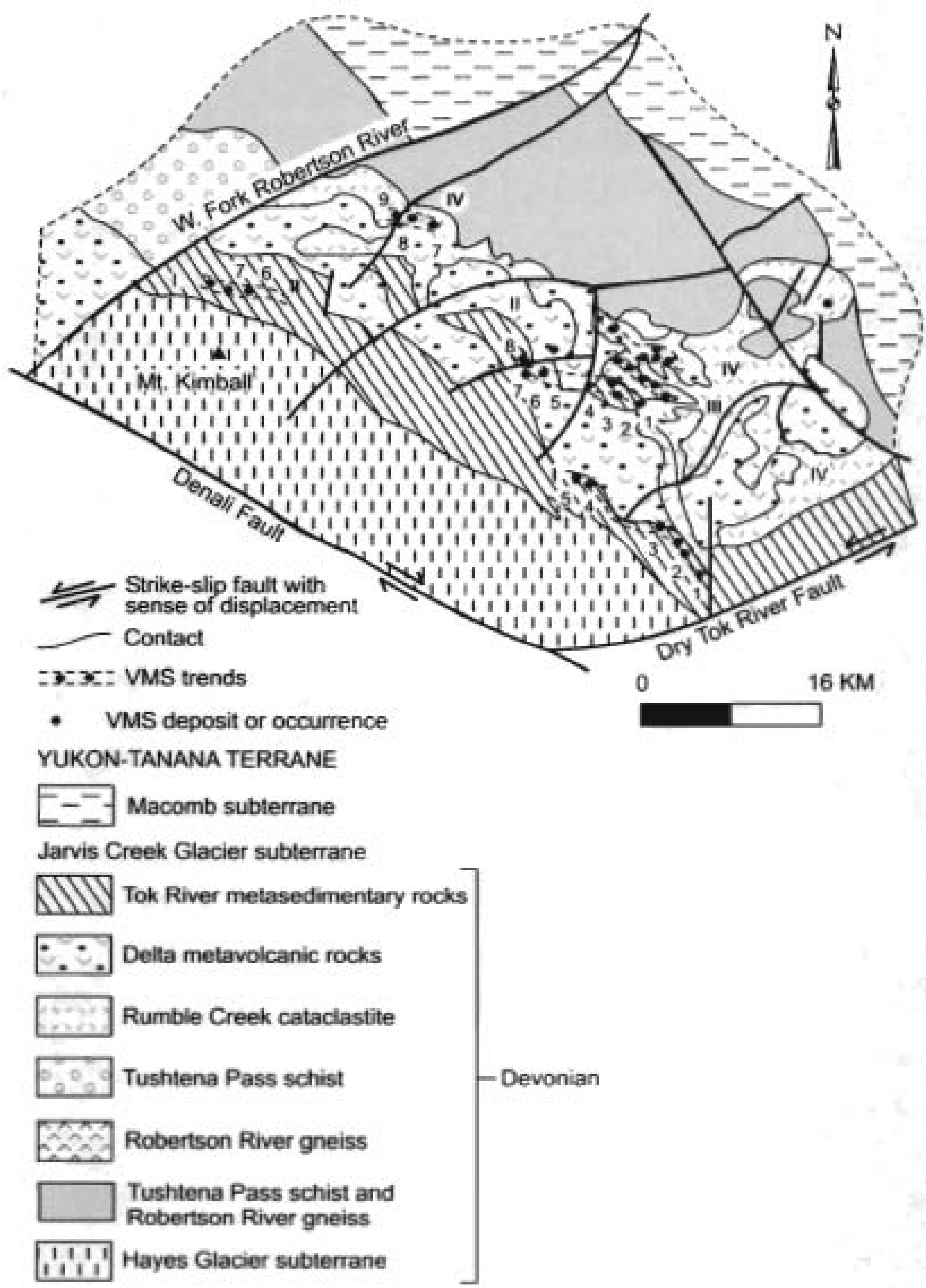


Figure 23. Delta district of kuroko massive sulfide deposits, Alaska Range and Yukon-Tanana Upland Metallogenic East-Central Alaska. Schematic geologic map. Roman numerals denote mineralization trends; arabic numerals denote deposits within a trend. Deposits: PP-LZ Trend (I), 1-LBB, 2-PPD, 3-UPP, 4-LZ East, 5-LZ, 6-RC East, 7-RC; DD-Rum Trend (II), 1-LBB, 2-Rum South, 3-Rum North, 4-Lower Rum, 5-DDS, 6-DDX, 7-DDY, 8-DDN; PG-Trio-HD Trend (IV), 7-PGX, 8-PG, 9-PGW; VMS-volcanogenic massive sulfide. Modified from Lange and others (1993).

Besshi Cu-Zn-Pb massive sulfide occurrences, such as Lucky Joe (Mortensen, 1992), are hosted in Devonian and Mississippian mafic metavolcanic and carbonaceous metasedimentary rocks. The occurrences are Kuroko and Besshi deposits which are associated with calc-alkaline and tholeiitic volcanic rocks, respectively. The host rocks are part of the Late Proterozoic to early Paleozoic Nisling assemblage which consists of continental margin metasedimentary rocks. These deposits and host rocks are correlated with similar, larger deposits of the Delta district in Alaska Range and Yukon-Tanana Upland metallogenic belt of Kuroko volcanogenic massive sulfide deposits described above. These extensive middle Paleozoic volcanics and granitoids are interpreted by and as part of a extensive continental-margin arc in the Late Devonian and Early Mississippian which formed along the margin of the North American Craton Margin (Lange and others, 1985; Mortensen, 1992; Nokleberg and others, 2000).

Small pyrite-bearing Pb-Zn-Ba lens-shaped occurrences, as at Mickey (Mortensen, 1992), are hosted in carbonaceous schist and quartzite and Middle Mississippian felsic metatuff. These deposits are interpreted as SEDEX Zn-Pb deposits may be correlated with similar-age SEDEX deposits of the Gataga metallogenic belt 1,000 km to the southeast, across the Tintina fault (fig.17) (Johnston and Mortensen, 1994). However, the Dawson metallogenic belt is hosted in the Yukon-Tanana terrane which is interpreted as a rifted fragment of the North American Craton Margin (Mortensen, 1992; Monger and Nokleberg, 1996; Nokleberg and others, 2000) whereas these metallogenic belts to the east containing SEDEX deposits are hosted in a Devonian-Mississippian clastic wedge deposited on the North American Craton Margin (Nokleberg and others, 1997b, 1998, Sheet 4). The host rocks for this part of the Dawson metallogenic belt are part of the Nasina assemblage which consists of Late Devonian to Middle Mississippian mafic to felsic metavolcanic rocks, quartzite, schist, and metaplutonic rocks. The tectonic origin of this group of deposits is unclear.

Pyrite-bearing Kuroko Pb-Zn-Cu (Au-Ba) massive sulfide occurrences, as at Lone Star (Mortensen, 1992), are hosted in middle Permian felsic metavolcanic rocks. The host rocks are part of the Klondike schist and associated units which consist mainly of middle Permian felsic metavolcanic and metaplutonic rocks (Mortensen, 1992). Structurally interleaved with the metavolcanic rocks are blueschist and eclogite which are interpreted as remnants of a former subduction zone which was tectonically linked to the volcanic arc which formed the metavolcanic rocks and associated occurrences.

Frances Lake Metallogenic Belt of Volcanogenic Zn-Cu-Pb Massive Sulfide Deposits (Belt FR) Southern Yukon Territory

The Frances Lake metallogenic belt of volcanogenic massive sulfide deposits (fig. 17; tables 3, 4) occurs in the southeastern Yukon Territory and is hosted in Early Mississippian felsic metavolcanic rocks and meta volcaniclastic units in the Yukon-Tanana terrane. The kuroko massive sulfide deposits, which occur northeast of the Tintina Fault and southwest of Finlayson Lake, are interpreted as equivalent to: (1) smaller kuroko massive sulfide occurrences in the Dawson metallogenic belt (as at Mickey) which occur southwest of the Tintina fault and are hosted in the Nasina Assemblage (Johnston and Mortensen 1994); and (2) major kuroko volcanogenic massive sulfide deposits which occur across the Tintina fault in the Alaska Range and Yukon-Tanana Upland metallogenic belt in East-Central Alaska. The significant deposits are at Kudz Ze Kayah and Wolverine (table 4). Local Besshi and Cyprus volcanogenic massive sulfide deposits also occur in the belt.

Kudz Ze Kayah Kuroko Massive Sulfide Deposit

The Kudz Ze Kayah kuroko Zn-Cu-Pb massive sulfide deposit consists of pyrite-bearing massive sulfide bodies which are associated with deformed, subvolcanic domes or thick sills which occur within felsic metavolcanic units. The deposit contains mineable reserves of 11.3 million tonnes grading 5.9% Zn, 0.98% Cu, 1.5% Pb, 133 g/t Ag, and 1.34 g/t Au (Mining Review, summer, 2000). The deposit and similar occurrences are hosted in felsic metavolcanic rocks of the Late Devonian to Middle Mississippian Nasina Assemblage which constitutes the middle structural sequence of the Yukon-Tanana terrane (Mortensen, 1992).

Wolverine-Lynx Kuroko Massive Sulfide Deposits

The Wolverine-Lynx kuroko Zn-Cu-Pb-Ag-Au massive sulfide deposits consist of massive sulfides in a fragmental rhyolite unit which is capped by an extensive magnetite iron formation and limy exhalite. The deposit contains estimated reserves (Wolverine and Lynx) of 6.2 million tonnes grading 12.66% Zn, 1.3% Cu, 1.5% Pb, 350 g/t Ag, and 371 g/t Au (Mining Review, summer 2000).The deposit occurs in the Yukon-Tanana terrane about 135 km southeast of Ross River, Yukon Territory. It is hosted by interbedded felsic volcanics and argillite of Devonian and Mississippian age.

Origin of Tectonic Setting for Frances Lake Metallogenic Belt

The eastern Frances Lake belt of kuroko massive sulfide deposits is hosted subvolcanic felsic domes or sills (Johnston and Mortensen, 1994) which form lensoidal metavolcanic units which interfinger with fine-grained quartzite and carbonaceous schist of the Devonian and Mississippian Nasina Assemblage or Nisutlin subterrane of the Yukon-Tanana terrane. The Nasina Assemblage consists of carbonaceous quartzite, quartz-mica schist, marble, mafic and felsic metavolcanic rocks and lesser amounts of metaplutonic rocks. These units are interpreted as part of the extensive Kootenay continental-margin igneous arc which formed along the margin of the North American Craton Margin, subsequent to rifting of the Yukon-Tanana and related terranes (Mortensen, 1992; Nokleberg and others, 2000). Remnants of the extensive middle Paleozoic Kootenay continental margin arc and associated lode deposits extend for several thousand km in various metamorphosed continental margin terranes in Northern Alaska, East Central Alaska, the northern and southern Canadian Cordillera, and Southeastern Alaska (Rubin and others, 1991; Plafker and Berg, 1994; Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996; Nokleberg and others, 2000). Fragments of the

Kootenay arc include the following metallogenic belts, in addition to the Frances Lake belt, which host kuroko massive sulfide and related deposits (Nokleberg and others, 1997a, b, c): (1) The Arctic metallogenic belt hosted in the Coldfoot terrane in Arctic Alaska; (2) Alaska Range and Yukon-Tanana Upland metallogenic belt hosted in the Yukon-Tanana terrane in central and eastern Alaska; (3) Tracy metallogenic belt hosted in the Yukon-Tanana terrane in Southeastern Alaska and western British Columbia; and (4) Kootenay-Shuswap metallogenic belt hosted in the Kootenay terrane in the southern Canadian Cordillera.

Tracy Metallogenic Belt of Kuroko Massive Sulfide Deposits (Belt TR) Southeastern Alaska and Western British Columbia

The Tracy metallogenic belt of kuroko massive sulfide deposits (fig. 17; tables 3, 4) extends from Southeastern Alaska into western British Columbia and is hosted in Devonian and Mississippian interlayered metavolcanic and metasedimentary rocks of the Yukon-Tanana terrane. In this region, the Yukon-Tanana metamorphosed continental margin terrane occurs as two, colinear, narrow fault-bounded fragments which extend discontinuously north-northeast for several hundred km west of the Stikinia island-arc terrane. The significant deposits are at Alamo, Ecstall, Packsack, Red River, Scotia, Sumdum, and Sweetheart Ridge (table 4) (Nokleberg and others 1997a, b, 1998).

Sumdum Kuroko Zn-Cu Massive Sulfide Deposit

The Sumdum kuroko Zn-Cu massive sulfide deposit consists of massive lenses and disseminated zones containing pyrrhotite, pyrite, chalcopyrite, sphalerite, and lesser bornite, malachite, azurite, and galena in bodies up to 15 m wide (Brew and Grybeck, 1984; Kimball and others, 1984). The deposit contains an estimated 24 million tonnes grading 0.57% Cu, 0.37% Zn, and 10.3 to 103 g/t Ag, assuming deposit continues beneath the Sumdum Glacier. The zones occur parallel to layering along the crest and flanks of an isoclinal fold in Paleozoic or Mesozoic metasedimentary schist and gneiss at the western edge of the informally named Coast plutonic-metamorphic complex of Brew and Ford (1984). Local sulfide-bearing veins(?) and fault breccia, which may postdate the stratabound deposit, may represent remobilization of the original deposit.

Ecstall Kuroko Zn-Cu Massive Sulfide Deposit.

The Ecstall kuroko Zn-Cu massive sulfide deposit, which consists of pyrite, chalcopyrite, sphalerite, pyrrhotite, marcasite, and galena, occurs in two tabular massive stratabound lenses in Middle Devonian schist, quartzite which are intruded by granitoid gneiss. These units are part of the Nisling assemblage of the Yukon-Tanana terrane in the Coast Plutonic Complex of British Columbia, Canada (EMR Canada, 1989; Hoy, 1991; Allrick and others, 2001; MINFILE, 2002). The deposit contains estimated reserves of 6.9 million tonnes grading 0.65% Cu, and 2.5% Zn. The deposit occurs in a metavolcanic sequence which is overprinted by an intense hydrothermal alteration assemblage of chlorite, sericite, and silica.

Origin of and Tectonic Controls for Tracy Metallogenic Belt

The Tracy metallogenic belt of kuroko massive sulfide deposits is hosted in metavolcanic and interlayered metasedimentary rocks of the Cambrian to Devonian Nasina and Nisling assemblages and equivalent rocks of the Yukon-Tanana terrane. The assemblage consists of carbonaceous quartzite, quartz-mica schist, marble, mafic and felsic metavolcanic rocks and lesser amounts of metaplutonic rocks. Locally large parts of the terrane occur in pendants and screens within plutons of the Coast Plutonic Complex. These units are interpreted as part of the extensive continental-margin igneous arc which formed along the North American Craton Margin, prior to rifting of the Yukon-Tanana and related terranes (Nokleberg and others, 1994c, 1997c). Remnants of the extensive middle Paleozoic Kootenay continental margin arc and associated lode deposits extend for several thousand km in various metamorphosed continental margin terranes in Northern Alaska, East Central Alaska, the northern Canadian Cordillera, and Southeastern Alaska (Rubin and others, 1991; Plafker and Berg, 1994; Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996; Nokleberg and others, 2000). Fragments of the Kootenay arc include several metallogenic belts hosting the kuroko volcanogenic massive sulfide and related deposits (Nokleberg and others, 1997a, b, c): (1) The Arctic metallogenic belt in the Coldfoot terrane in Arctic Alaska; (2) Alaska Range and Yukon-Tanana Upland metallogenic belt in the Yukon-Tanana terrane in central and eastern Alaska; (3) the Tracy metallogenic belt hosted in the Yukon-Tanana terrane in Southeastern Alaska and western British Columbia; and (4) the Frances Lake belt in the Yukon-Tanana terrane in the southern Yukon Territory; and (5) the Kootenay-Shuswap belt in the Kootenay terrane in the southern Canadian Cordillera, and the Frances Lake metallogenic belt in the southern Yukon Territories.

Mount Sicker Metallogenic Belt of Kuroko Volcanogenic Massive Sulfide Zn-Cu-Pb-Au-Ag Deposits (Belt MS) Vancouver Island

The Mount Sicker metallogenic belt of kuroko massive sulfide Zn-Cu-Pb-Au-Ag deposits (fig 17; tables 3, 4) occurs in southwestern British Columbia on Vancouver Island. The belt is hosted by the Late Devonian to Early Permian Sicker Group, a sequence of arc-related volcanic and sedimentary strata in the southern Alexander sequence of the Wrangellia superterrane. The significant deposits are at Mount Sicker near Duncan (Lenora-Tyee, Twin J, Lara, Copper Canyon), and Myra Falls (Buttle Lake, Lynx, H-W, Battle; table 4) (Nokleberg and others 1997a, b, 1998).

Mount Sicker (Lenora-Tyee, Twin J, Lara, Copper Canyon) Kuroko Massive Sulfide Zn-Cu-Pb-Au-Ag Deposit

The Mount Sicker (Lenora-Tyee, Twin J, Lara, Copper Canyon) kuroko massive sulfide Zn-Cu-Pb-Au-Ag deposit consists of massive pyrite, chalcopyrite, sphalerite, galena with barite hosted in Late Devonian felsic volcanic tuffs of the McLaughlin Ridge Formation (Juras, 1987; Sicker Group; Hoy, 1991; Robinson and others, 1994). The combined estimated reserves and production for the Lenora-Tyee-Twin J deposit are 594,852 tonnes grading 2.46% Cu, 3.85% Zn, 0.37% Pb, 117.0 g/t Ag, and 2.5 g/t Au. Estimated reserves for the Lara deposit are 529,000 tonnes grading 1.01% Cu, 5.87% Zn, 1.22% Pb, 100.1 g/t Ag, and 4.73 g/t Au. Estimated reserves for the Copper Canyon deposit are 32.4 million tonnes grading 0.75% Cu, 8.57 g/t Ag, and 1.17 g/t Au (Dawson and others, 1991).

Myra Falls (Buttle Lake, Myra, Lynx, H-W, Battle) Kuroko Massive Sulfide Zn-Cu -Au-Ag Deposit

The Myra Falls (Lynx-Myra, Price, H-W, Battle) kuroko volcanogenic massive sulfide Zn-Cu -Au-Ag deposit (fig. 24)consists of massive sphalerite, chalcopyrite, pyrite and lesser galena and barite with minor tennantite, bornite, pyrrhotite, digenite, covellite and stromeyerite which occur in a number of lenses along an east-west trend (Juras, 1987; Juras and Pearson, 1991; Dawson and others, 1991; Hoy, 1991; George Cross Newsletter no. 30, February 12, 1993; Pearson, 1993). The deposits contain an estimated combined production and reserves of 30.3 million tonnes grading 2.23g/t Au, 54.5g/t Ag, 2.12% Cu, and 7.1% Zn. The deposit is hosted within felsic volcanics of the Late Devonian Myra Formation in the Sicker Group. The deposits occur at two stratigraphic levels; the H-W horizon, at the base of the Myra Formation, and the Lynx-Myra-Price horizon, in the central portion of the Myra Formation. Under the H-W deposit, the stratigraphic footwall consists of greater than 300 m of basaltic andesite of the Price Formation which in tensely altered to to quartz-sericite-pyrite.

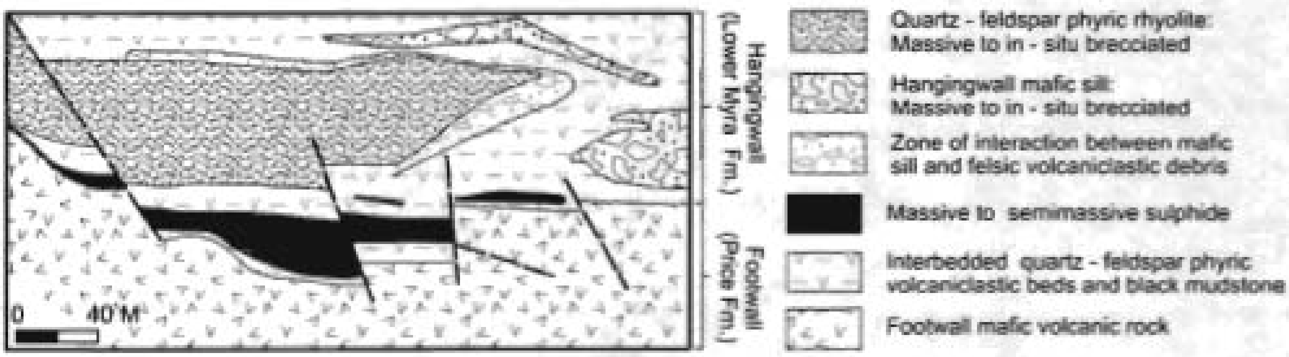


Figure 24. H-W kuroko massive sulphide Zn-Cu -Au-Ag deposit, Mount Sicker metallogenic belt, Canadian Cordillera. Schematic cross section. Adapted from Barrett and Sherlock (1996b).

Origin of and Tectonic Controls for Mount Sicker Metallogenic Belt

The kuroko volcanogenic massive sulfide Zn-Cu-Pb-Au-Ag deposits in the Mount Sicker metallogenic belt occur mainly in fragmental basaltic andesite, lesser dacite and andesite, intermediate pillow lava, and epiclastic volcanic rock. The host rock and deposit distribution are defined by three fault-bounded uplifts. The volcanic rocks are 310 to 440 m thick and exhibit an U-Pb zircon isotopic age of 370 Ma (Juras, 1987). Underlying pillow basaltic flows of the Price Formation formed during a non-explosive effusive event which was succeeded by rifting, felsic volcanism, and formation of massive sulfide deposits. The volcanic rocks are overlain by Carboniferous sedimentary rocks which contain bioclastic crinoidal limestone in the Buttle Lake Formation. Significant kuroko massive sulfide deposits occur in felsic volcanics of the upper part of the Sicker Group in domal culminations. The calc-alkaline volcanic rocks hosting the Mount Sicker metallogenic belt are interpreted as part of the minor, middle Paleozoic Sicker island arc which forms the oldest part of the Alexander sequence of the Wrangellia superterrane (Monger and Nokleberg, 1996; Nokleberg and others, 1994c, 1997c). In this paper, following Nokleberg and others (1994c, 2000), the Wrangellia superterrane is subdivided into three sequences, from west to east to southeast, the Peninsular, Wrangellia, and Alexander sequences. These sequences are interpreted as form the once continuous core of the superterrane and have been subsequently tectonically dismembered.

Kootenay-Shuswap Metallogenic Belt of Volcanogenic Zn-Pb-Cu-Ag-Au Massive Sulfide Deposits(Belt KS) Southern British Columbia

The Kootenay-Shuswap metallogenic belt of volcanogenic Zn-Pb-Cu-Ag-Au massive sulfide deposits (fig. 17; tables 3, 4) occurs in Southern British Columbia. The belt is hosted in is a discontinuous assemblage of metamorphosed and intensely deformed siliceous clastic, carbonate, volcanic, and plutonic rocks of the Kootenay terrane in the Shuswap region. This metamorphosed continental margin terrane occurs between the North America Craton Margin to the east, and the accreted island arc Quesnellia terrane to the west (fig. 17). The belt contains Kuroko, Besshi, Cyprus, SEDEX Zn-Pb, Southeast Missouri, and bedded barite deposits (table 4) (Nokleberg and others (1997a, b). Four types of volcanogenic massive sulfide deposits are recognized by Preto and Schiarriza (1985).The significant deposits in the metallogenic belt are the Cyprus-type Chu Chua and Harper Creek Cyprus massive sulfide deposits, the kuroko-type Homestake and Rea (Hilton) kuroko sulfide deposits, the Goldstream Besshi massive sulfide deposit, the Adams Plateau Zn-Pb-Ag SEDEX deposits (Spar, Lucky Coon, King Tutt, Mosquito King), and the Rexspar (Birch Island) felsic plutonic U-REE deposit (Nokleberg and others 1997a, b, 1998).

Homestake and Rea Gold Kuroko Zn-Pb-Cu-Au-Ag Deposits

The Homestake kuroko Zn-Pb-Cu-Au-Ag deposit consists of two tabular sulfide-barite horizons which occur in intensely quartz-sericite-pyrite altered sericite schist derived from felsic to mafic tuffaceous units of the Devonian Eagle Bay Assemblage (Dawson and others, 1991; Høy, 1991). Sulfide minerals are tetrahedrite, galena, sphalerite, pyrite, and chalcopyrite. Estimated reserves are 919,420 tonnes grading 248 g/t Ag, 2.5% Pb, 4% Zn, 0.55% Cu, and 275,500 tonnes grading 36.7% Ba. The deposit is overlain by intermediate to felsic volcanics of Eagle Bay Assemblage. The Rea Gold volcanogenic sulfide deposit occurs about 4 km to the norwest, and contains contains mining reserves of 376,385 tonnes grading 2.2% Pb, 2.3% Zn, 6.1 g/t Au, and 76 g/t Ag.

Goldstream Besshi Cu-Zn-Ag Deposit

The Goldstream Besshi Cu-Zn-Ag volcanogenic massive sulfide deposit occurs in the eastern part of the Kootenay terrane and consists of massive pyrrhotite, chalcopyrite and sphalerite often exhibiting gneissic texture with sub-rounded quartz, phyllite and carbonate inclusions (Høy, 1991; MINFILE, 2002). The deposit occurs as a thin, conformable sheet (400 x 1500 x 1-3m thick) and as several other horizons in sericite quartzite and calcareous and chloritic phyllite in the lower Index Formation of the Cambrian Lardeau Group. The host metavolcanic-phyllite unit consists of mafic tholeiitic volcanic rocks, massive greenstone, chloritic phyllite, ultramafic pods and dark calcareous to pelitic schist. In 1983 and 1984, 427,886 tonnes were mined averaging 8.9 g/t Au, 4.43% Cu, and 0.12% Zn. Production restarted in 1992; estimated reserves are 3.2 million tonnes grading 4.5% Cu, 3.1% Zn, and 20 g/t Ag.

Harper Creek and Chu Chua Cu-Zn-Ag-Au Deposits

The Harper Creek Cu-Ag-Au volcanogenic massive sulfide deposit consists of disseminated pyrite, pyrrhotite and chalcopyrite with minor molybdenite, galena, sphalerite, and tetrahedrite which occur in tabular zones in mafic metavolcanic rocks and quartz-sericite phyllite of the Devonian Eagle Bay Formation (Preto and Schiarizza, 1985; Schiarizza and Preto, 1987; Høy, 1997. The deposit occurs in two parts: (1) the East Zone with reserves of 42.5 million tonnes grading 0.39% Cu, 2.4 g/t Ag, and 0.044 g/t Au; and (2) the West Zone with reserves of 53.5 million tonnes grading 0.42% Cu, 2.6 g/t Ag and 0.047 g/t Au. The deposit has estimated reserves of 96 million tonnes grading 0.41%Cu, 2.5g/t Ag, 0.04g/t Au, and 0.016% Mo. A skarn or porphyry origin was interpreted by Schiarizza and Preto (1987) with a relation to Devonian intrusive rocks which are now metamorphosed to orthogneiss and are interpreted as derived from bimodal, calcalkaline volcanic rocks. The deposit is herein interpreted as a kuroko massive sulfide deposit.

The Chu Chua Cyprus Cu-Zn volcanogenic massive sulfide consists of pyrite with chalcopyrite and minor sphalerite which occur in two major and several smaller stratiform massive sulfide lenses associated with pyritic, cherty sediments and pillow basalt of the late Paleozoic (Devonian to Permian) Fennel Formation (McMillan, 1980; Schiarizza and Preto, 1987). Chalcopyrite and sphalerite occur interstitially to pyrite. Basalt is locally extensively altered to talc and carbonate in structures interpreted as vents. The deposit contains estimated reserves of 2.5 million tonnes grading 2% Cu, 0.5% Zn, 0.5 g/t Au, 9 g/t Ag. The deposit is interpreted as a Cyprus(?) massive sulfide deposit (Høy, 1991).

Adams Plateau SEDEX Zn-Pb-Ag Deposits

Several SEDEX Zn-Pb-Ag deposits, which occur in the Adams Plateau area, are hosted in clastic metasedimentary sequences of probable Cambrian age and lower Eagle Bay Assemblage (Schiarizza and Preto, 1987; Høy, 1991) in the Kootenay terrane, and Devonian and older magmatic arc rocks in the Yukon-Tanana terrane in the Canadian Cordillera. The assemblage is correlative in part with the Nisutlin Assemblage of the Yukon-Tanana terrane (Wheeler and McFeely, 1991). The significant deposits are two previously-producing, small mines at Mosquito King and Lucky Coon.

Origin of and Tectonic Setting for Kootenay-Shuswap Metallogenic Belt

A diverse group of volcanogenic and related mineral deposits occur in the Kootenay-Shuswap metallogenic belt. Because of a wide range of age of host rocks and deposits, this metallogenic belt may be divided into two metallogenic belts, one of Cambrian age and the other of Devonian and Mississippian age.

The Kuroko massive sulfide deposits in the Kootenay-Shuswap metallogenic belt are hosted in Devonian and Mississippian felsic to intermediate metavolcanic units. The calc-alkaline igneous-arc rocks are interpreted as part of the extensive middle Paleozoic continental-margin arc which extends for several thousand km along the North American Craton Margin (Grantz and others, 1991; Rubin and others, 1991; Plafker and Berg, 1994; Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). Fragments of the continental-margin arc include several metallogenic belts hosting the kuroko massive sulfide and related deposits (Nokleberg and others, 1997a, b, c): (1) The Arctic metallogenic belt hosted in the Coldfoot terrane in Arctic Alaska; (2) Alaska Range and Yukon-Tanana Upland metallogenic belt hosted in the Yukon-Tanana terrane in central and eastern Alaska; and (3) the Frances Lake and Finlayson Lake metallogenics belt hosted in the Yukon-Tanana terrane in the southern Yukon Territory.

The Cyprus massive sulfide deposits in the Kootenay-Shuswap metallogenic belt are hosted in Devonian mafic volcanic and associated metasedimentary rocks. The deposits and host oceanic assemblages, together with SEDEX sulfide deposits and their host rocks, occur in imbricated thrust sheets within other assemblages in the Kootenay terrane. These oceanic assemblages and deposits, which are interpreted to have formed in the back-arc of the Kootenay arc, and were subsequentally structurally emplaced within shelf and continental-margin arc parts of the Kootenay terrane during accretion of the outboard Slide Mountain oceanic terrane in the Jurassic (Monger and Nokleberg, 1996; Nokleberg and others, 2000).

The Besshi Cu-Zn-Ag deposits in the Kootenay-Shuswap metallogenic belt are hosted in Cambrian tholeiitic metavolcanic and associated rocks which constitutes the older part of the Kootenay terrane. The Besshi Cu-Zn-Ag deposits in the Kootenay-Shuswap metallogenic belt are herein interpreted as forming in a short-lived Cambrian continental-margin arc.

The Adams Plateau SEDEX Zn-Pb-Ag deposits in the Kootenay-Shuswap metallogenic belt are hosted in Cambrian metasedimentary rocks. The deposits are correlated with similar SEDEX deposits in the Kootenay metallogenic belt to the east, and with deposits in the Anvil and Howards Pass metallogenic belts to the north in the Selwyn Basin of the northern Canadian Cordillera. All three metallogenic belts are interpreted as forming from Pb- and Zn-rich fluids during rifting, volcanism, basinal subsidence, local marine transgression, and related hydrothermal activity along the passive continental margin of the North American Craton.

Metallogenic Belts Formed During Middle Paleozoic Rifting of North Asian Craton Margin

Khamna River Metallogenic Belt of Carbonatite-Related Nb, Ta, and REE Deposits (Belt KR) Southern Part of Eastern Siberia

The Khamna River metallogenic belt of carbonatite-related Nb, Ta, and REE deposits (tables 3, 4) occurs in the southern part of eastern Siberia in the North Asian Craton Margin (fig. 16; Verkhoyansk fold belt, unit NSV) (Nokleberg and others, 1994c). The belt strikes north-south, is about 300 km long, and varies from 20 to 60 km wide. The significant deposits are at Khamna and Gornoye Ozero (table 4) (Nokleberg and others 1997a, b, 1998). These deposits consist of pyrochlore, orthite, perovskite, and monozite which occur in halos adjacent to or around alkalic igneous rocks. The Khamna River metallogenic belt is similar to the Tommot River metallogenic belt, described below, occurs in the passive continental margin Omulevka terrane of the Kolyma-Omolon superterrane in the western part of the Russian Northeast.

Khamna Carbonatite-Related REE Deposits

The Khamna deposit (Elyanov and Moralev, 1973; N.D. Kobtseva and T.G. Devyatkina, written commun., 1988) consists of steep fluorite-carbonate veins and stockworks which occur in Late Proterozoic metasomatic carbonate in the vicinity of dikes and stocks of probable Late Devonian alkalic syenite and alkalic magmatic breccia. The veins range from 0.1 to 1.5 km long and from 1.4 to 30 m thick. Individual stockworks are 100-500 m^2 in size. The main ore minerals are bastnaesite, parisite, and galena. Disseminated mineralization also occurs. The average grade is 0.2-1.93% REE; 0.03-0.26% Nb_2O_5. The syenite exhibits U-Th-Pb isotopic ages of which range from 240 to 417 Ma (V.I. Shpikerman and N.A. Goryachev, this study).

Gornoye Ozero Carbonatite-Related REE Deposit

The major Gornoe Ozero Nb-Ta-REE deposit (fig. 25) (Korostylyov, 1982; N.D. Kobtseva and T.A. Devyatkina, written commun., 1988) occurs in a middle Paleozoic (Late Devonian) ellipsoid intrusion of alkalic rocks, with a surface area of 10.3 km^2. The alkalic intrusion exhibits a zoned structure. The core consists of nepheline-cancrinite syenite and small relic pyroxenite and melteigite pockets. Carbonatite comprises up to 90% of the intrusion and occurs mostly in the periphery. The host rocks are limestone, shale, and siltstone of the middle Riphean Lakhandin suite which is altered to fenite near the intrusion. The carbonatite consists of dominate calcite, along with ankerite-calcite and dolomite-calcite. Other parts of the carbonatite contain aegirine, amphibole, chlorite, pyroxene, magnetite, biotite and barite. Relatively older parts of the intrusion contain pyroxenite are in association with perovskite, magnetite, spinel and apatite. Pyrochlore, apatite and magnetite occur in syenite which formed after pyroxenite. The relatively younger carbonatite formed during two stages: (1) an earlier stage of pyrochlore-hatchettolit; and (2) a later stage of REE minerals including bastnasite, parisite and monazite, and also pyrochlore and columbite). The average grade is 0.35% REE oxides; 0.09-0.36% Nb_2O_5; 0.011% Ta_2O_5. The complex exhibits K-Ar isotopic ages of 280 to 350 Ma and the age of mineralization is interpreted as probably 290 Ma.

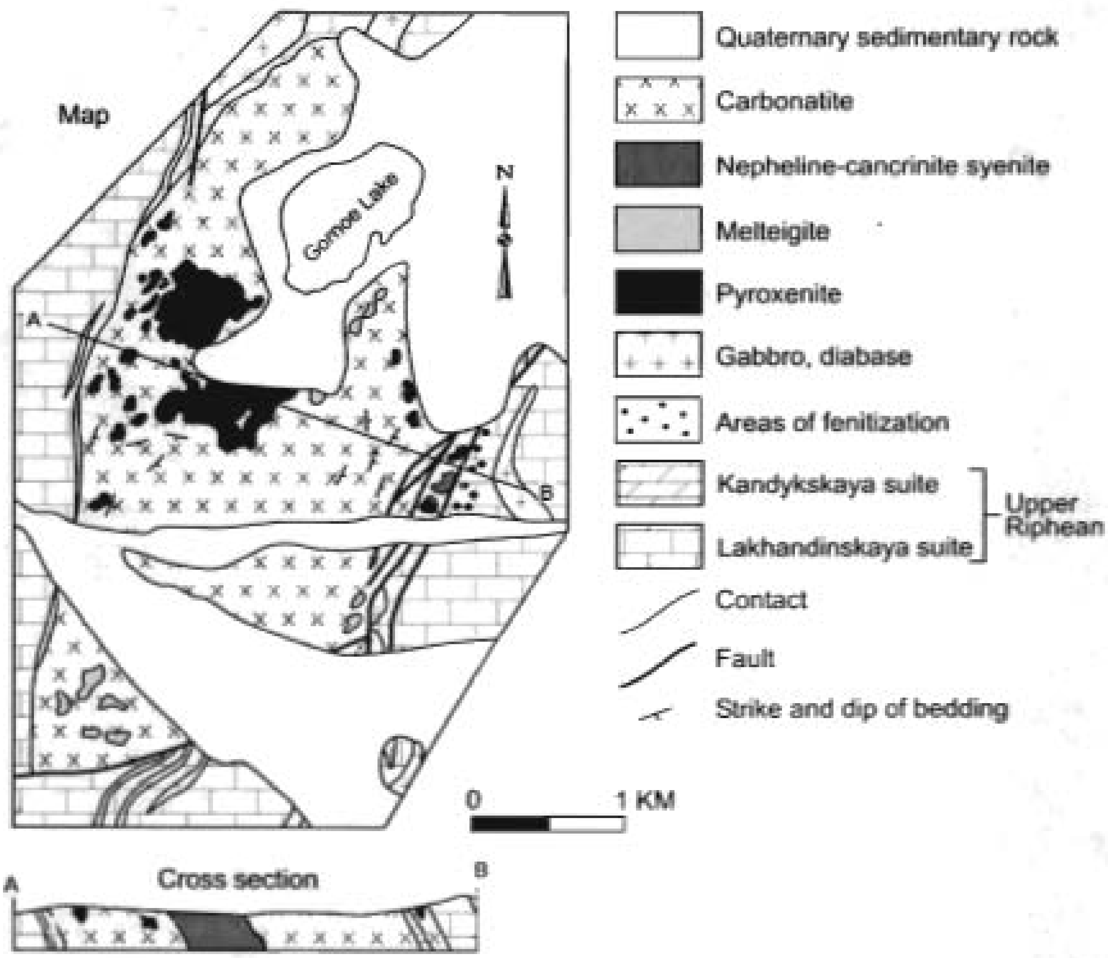


Figure 25. Gornoye Ozero carbonatite-related REE deposit, Khamna metallogenic belt, Russian Southeast. Adapted from Korostelev (1982).

Origin of and Tectonic Controls for Khamna River Metallogenic Belt

The carbonatites and alkalic igneous rocks of the Khamna River metallogenic belt intrude Late Proterozoic and early Paleozoic sedimentary deposits of the folded margin of the North Asian Craton Margin (Shpikerman, 1998; Verkhoyansk fold belt, unit NSV). U-Pb isotopic studies of the carbonatites and ores yield an age of 417 to 240 Ma, and K-Ar isotopic studies yield an age of 350 to 280 Ma (Elyanov and Moralev, 1973). Because coeval, rift-related basaltic rocks formed in adjacent areas neighboring areas, the Khamna River metallogenic belt is interpreted as forming during rifting of the North Asian Craton during the Late Devonian to Early Mississippian. The sedimentary rocks of the Verkhoyansk fold belt are apparently tectonically detached from crystalline basement of craton. The fold belt is separated from the Siberian platform by a Late Cretaceous, west-verging thrust belt.

Sette-Daban Range Metallogenic Belt of Southeast Missouri Pb-Zn, Sediment-Hosted Cu, and Basaltic Cu Deposits (Belt SD) Southern Part of Eastern Siberia

The Sette-Daban Range metallogenic belt of Southeast Missouri Pb-Zn, sediment-hosted Cu, and basaltic Cu deposits (fig. 16; tables 3, 4) occurs in the southern part of eastern Siberia (Nokleberg and others, 1994c, 1997c; Shpikerman, 1998) in the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV). The metallogenic belt trends south to north for more than 700 km along the Sette-Daban Mountain Range. The deposits, of Late Proterozoic to Early Carboniferous age, occur at different stratigraphic levels of the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV). The major Southeast Missouri Pb-Zn deposits are at Lugun, Sakyryr., Segenyakh, and Urui; the major sediment-hosted Cu deposit is at Kurpandzha; and the major basaltic Cu deposit is at Dzhalkan (table 4) (Nokleberg and others 1997a, b, 1998). The Southeast Missouri Pb-Zn deposits are the dominate deposit type in the metallogenic belt. The Southeast Missouri Pb-Zn deposits at Urui and Lugun occur in Vendian dolomite of the Udom Formation and the Southeast Missouri Pb-Zn-fluorite occurrences at Segennyak and Sakyryr are hosted by Late Silurian dolomite of the Oron Formation. The sediment-hosted Cu deposits are associated with basaltic Cu deposits which usually occur at the same or nearby stratigraphic levels. The sediment-hosted Cu deposits are hosted in Late Devonian and Early Carboniferous sandstone and shale.

Sardana Missouri Pb-Zn Deposit

The Sardana Missouri Pb-Zn deposit (fig. 26) (Kuznetsov and Yanshin, 1979; Ruchkin and others, 1979; Kutyrev and others, 1989) consists of disseminated, banded, massive, and breccia and ore and stringers which occur within and adjacent to a dolomite bioherm which ranges from 50-80 m thick. The bioherm is hosted in the Late Proterozoic (Late Vendian) dolomite of the Yudom Formation. The ore bodies are lenticular, ribbon-like, and cylindrical in form, and are mostly confined to the overturned limb of a syncline. The limb dips eastward at 75-85°. The ore bodies range up to 40 m thick and are 200 to 300 m long at depth. Drilling indicates additional ore bodies occur at a depth of 200 to 300 m. Most of the ore is associated with metasomatic, sugar-textured dolomite and zebra (brown and white striped) dolomite. The main ore minerals are sphalerite, galena, calcite, and dolomite, and subordinate ore minerals are pyrite, marcasite, arsenopyrite, quartz, and anthraxolite. Oxidized ore minerals include smithsonite, cerussite, anglesite, goethite, hydrogoethite, and aragonite. Low-grade disseminations occur in Late Proterozoic (Late Vendian) dolomite for many kilometers in both limbs, and in the axis of a north-south-trending syncline which is 3 km wide and more than 10 km long. The deposit is medium to large with reserves of more than 1.0 million tonnes Pb+Zn, and a Pb:Zn ratio of 1:3-4. The dolomite of Yudom Formation is 200 m thick and transgressively overlies Late Proterozoic (Late Riphean) quartz and quartz-feldspar sandstone and siltstone which in turn is conformably overlain by Early Cambrian variegated clay and carbonate rocks. The deposit intruded by sparse diabase and dolerite dikes.

Urui Southeast Missouri Pb-Zn Deposit

The Urui Southeast Missouri Pb-Zn deposit (Ruchkin and others, 1977; Volkodav and others, 1979; Bogovin and others, 1979; N.D. Kobtseva and T.G. Devyatkina, written commun., 1988) consists of stratified ribbon-like deposits, from 2-3 to 40 m thick and 0.5 to 1.2 km long, which occur in metamorphosed Late Proterozoic (Vendian) dolomite. The ore bodies are conformable to host rocks and strike 30-45°NW; and commonly wedge out at a depth of 30-40 m. The deposits vary from massive, pocket-stringer-disseminated, to banded. Galena and sphalerite are the m ain ore minerals; pyrite, marcasite, arsenopyrite are secondary; and pyrrhotite, chalcopyrite, and electrum are scarce. Calcite, quartz, and anthraxolite also occur. The deposit is medium to large with an average grade of 9.9-25.6 Pb; 6.4-21.3% Zn; 6.8-200 g/t Ag; up to 10 g/t Ge. The deposit is associated with a significant recrystallization of dolomite and formation of peculiar zebra dolomite rocks. The general structural pattern of deposit controlled by monoclinal strike of sedimentary rocks to the west and by numerous post-ore faults which trend roughly east-west and strike northwest. Local Paleozoic diabase dikes in area.

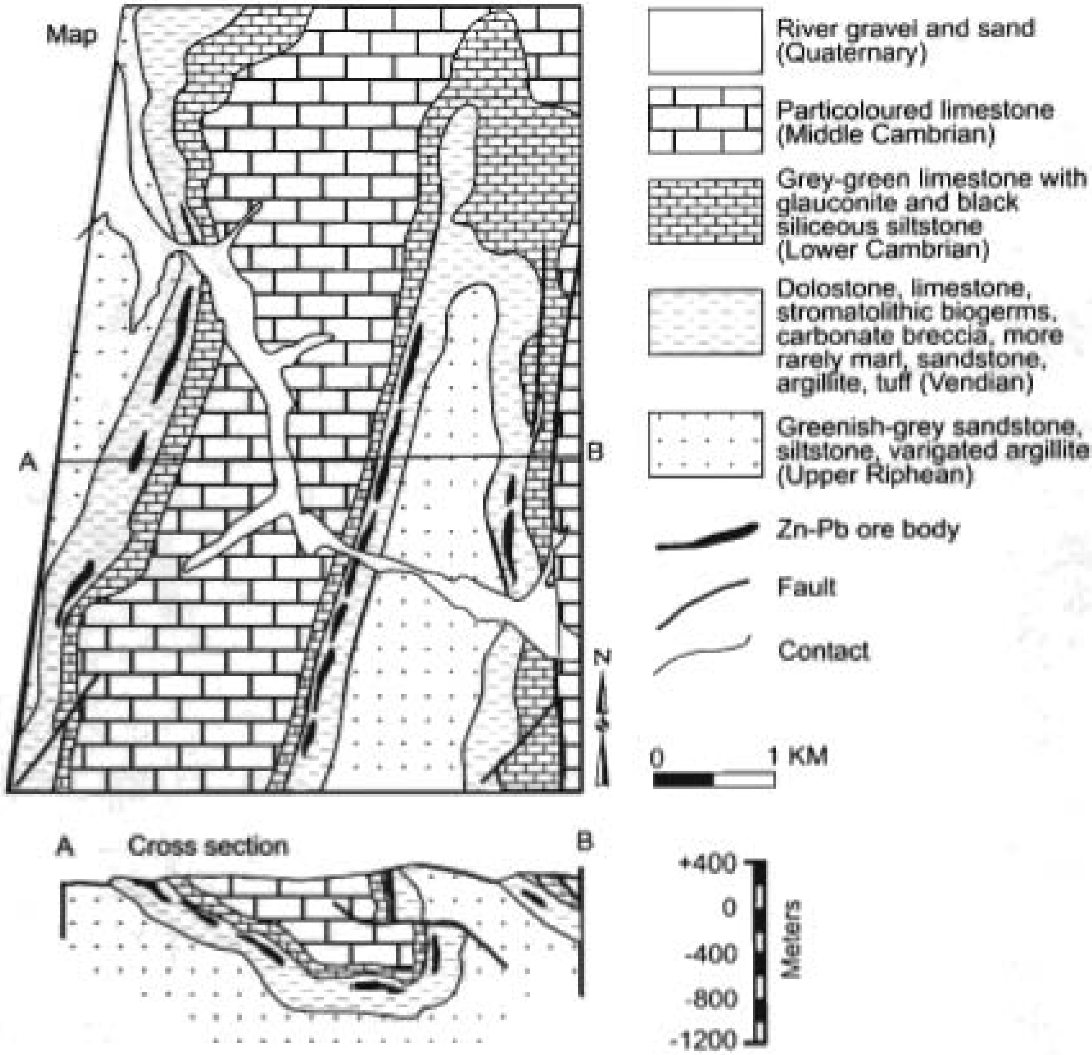


Figure 26. Sardana Southeast Missouri Pb-Zn deposit, Sette-Daban metallogenic belt, Russian Northeast. Schematic geologic map and cross section. Adapted from Shpikerman (1998) using materials of A.I. Starnikov and A.V. Prokopiev.

Kurpandzha Sediment-Hosted Cu Deposit

The Kurpandzha Southeast sediment-hosted Cu deposit (Kutyrev, 1984; Ioganson, 1988) consists of more than three stratified horizons of finely disseminated to massive copper ore which is hosted in Late Devonian to Early Carboniferous coastal and deltaic sandstone. The main ore minerals are chalcocite, bornite, chalcopyrite, and pyrite. Ore bodies range from 0.2 up to 4 m thick and up to 1.5 km long. The host polymictic sandstone contains pyroclasts of volcanic rock. The deposit occurs in a stratigraphic interval from 50 up to 300 m thick which is underlain by Famennian basalt which also contains copper mineralization. The deposit occurs within a major syncline which has an amplitude of up to 4 km. Ore bodies and host rocks strike at 40 to 70° on syncline limbs.

Dzhalkan Basaltic Cu Deposit

The well-known basaltic Cu deposit at Dzhalkan (Kutyrev, 1984; Kutyrev and others, 1988) occurs in a Famennian amygdaloidal basalt flow and near the Kurpandzha sediment-hosted Cu deposit. The deposit consists of disseminated Cu in a sequence of basalt flows with a total thickness of 180 m. The deposit is mostly confined to horizons which range from 0.5 to 2.0 m thick and contain both cinders and amygdules at the top of flows. The ore minerals include native copper and cuprite, with lesser bornite, chalcocite, and chalcopyrite. Epidosite (epidote-quartz) wallrock alteration occurs locally. The ore bodies range from 0.3 to 1.0 m thick and up to 100 m long. Areas of copper mineralization are separated by unmineralized areas of up to several kilometers. The deposit is small with average grades of 0.3 up to 4.5% Cu. The basalt flows erupted into shallow water and subaerial environments. The host basalts are folded, with fold limbs dipping 40 to 60°.

Origin of and Tectonic Controls for
Sette-Daban Range Metallogenic Belt

The Sette-Daban metallogenic belt occurs within the Sette-Daban horst/anticlinorium in the southwestern part of the North Asia Craton Margin (the Verkhoyansk fold belt, unit NSV; Shpikerman, 1998). The local units which host the Sette-Daban metallogenic belt consist of mainly thick, shelf carbonate and clastic rocks, and volcaniclastic deposits of Riphean, Vendian, and Cambrian age with a combined thickness of up to 13 km. The major lithologies are limestone, dolomite, marl, mudstone, shale, mudstone, siltstone, sandstone, quartzite, conglomerate, basalt, tuff, Cu-bearing sandstone, and Cu-bearing basalt. Rare mafic and ultramafic dikes occur. The units are metamorphosed to lower greenschist facies. The sulfide deposits, as at Sardana, are interpreted as syngenetic.

The Southeast Missouri Pb-Zn deposits are located in the upper part of the Oron Formation of Ludlovian age (350-500 m thick) which consists of large black and thin bedded dolomites and hydrogenic dolomite breccia. Hiod unit is overlapped by the Hurat Formation which consists mainly of marl. The Southeast Missouri Pb-Zn deposits of the Sette-Daban Range metallogenic belt are interpreted as forming from artesian thermal waters which circulated through the carbonate rocks of the North Asia passive continental margin. The sediment-hosted Cu deposits of the Sette-Daban belt are hosted in volcanic sedimentary rocks of Givetian, Fronian, Famenian and Turonian age. The significant deposits are in the upper Famenian and Turonian Menkule suite which ranges from 100 to 550 m thick and contains coastal-marine and continental sandstone, tuffaceous sandstone, siltstone, and dolomite. The basaltic Cu and sediment-hosted Cu deposits are interpreted as forming during rifting, mainly in the Middle Devonian to Early Carboniferous (Shpikerman, 1998).

Selennyakh River Metallogenic Belt of
Southeast Missouri Pb-Zn, Stratabound Hg and Au,
and Pb-Zn Vein Deposits (Belt SEL)
Northwestern Part of Russian Northeast

The Selennyakh River belt metallogenic belt of diverse lode deposits, including Mississippi Zn-Pb, stratabound Hg and Au, and Pb-Zn vein deposits (fig. 16; tables 3, 4) occurs in the northwestern part of the Russian Northeast (Shpikerman, 1998). The metallogenic belt is hosted in the Omulevka terrane of the Kolyma-Omolon superterrane in early through late Paleozoic, passive continental margin carbonate and shale (Nokleberg and others, 1994c, 1997c; Shpikerman, 1998). The significant deposits are (table 4) (Nokleberg and others 1997a, b, 1998): (1) stratabound Hg deposits such the Gal-Khaya carbonate-hosted Hg deposit; (2) small Southeast Missouri type Pb-Zn occurrences as at Kondakovskoe; (3) Pb-Zn vein deposits as at Chistoe; and (4) Au quartz vein deposits as at Khatynnakh-Sala. This metallogenic belt, which needs further study, occurs along a sublatitudinal strike for more than 600 km (fig. 16).

Gal-Khaya Carbonate-Hosted Hg Deposit

The Gal-Khaya carbonate-hosted Hg deposit (Babkin, 1975) consists of a zone of quartz-carbonate breccia and veins which occurs along the contact of Early Silurian limestone and calcareous shale. The zone is 600 m long, 60 to 80 m wide, dips 75°, and is concordant to host rock bedding. The ore occurs in cylindrical ore shoots, mainly in carbonate breccia cemented with calcite and quartz-calcite. The main ore mineral is cinnabar. Also present are metacinnabar, galkhaite (Hg, Cu, Zn; As, Sb), stibnite, realgar, orpiment, pyrite, chalcopyrite, fluorite, barite, native gold, tennantite, sphalerite, bornite, chalcocite, covellite, malachite, and azurite. Gangue minerals include quartz, calcite, dolomite, barite, dickite, kaolinite, and bitumen (anthraxolite). The (syngenetic) deposit is interpreted as forming in the Late Devonian or Carboniferous (Shpikerman, 1998), or as an epigenetic deposit which formed in the Late Cretaceous (Galkin, 1968).

Kondakovskoe Southeast Missouri Pb-Zn Occurrence

The Kondakovskoe Southeast Missouri Pb-Zn deposit (Bakharev and others, 1988) consists of sulfide disseminations and pockets in Devonian limestone which is locally metamorphosed to marble. The deposit is localized along the southern contact of the Early Cretaceous Ulakhan-Siss granodiorite intrusion. The mineralized layer is several hundred meters long and consists of two mineral assemblages: (1) galena-sphalerite; and (2) less common pyrite-tetrahedrite. The deposit contains up to 0.1% Cd, 0.05-1% Pb, 0.08-1.5% Zn, and 0.01-0.3% Sb.

Chistoe Pb-Zn Vein Deposit

The Chistoe Pb-Zn vein deposit (Shpikerman, 1998) consists of a galena vein which occurs in a shear zone in Ordovician limestone locally metamorphosed to marble. The vein varies from 10 to 20 m thick and is about ten meters long. The ore minerals include galena, which is predominant, and also pyrite, sphalerite, chalcopyrite, cerussite, and smithsonite. Oxidized minerals are locally abundant.

Khatynnakh-Sala Au Quartz Vein Deposit

The Khatynnakh-Sala Au quartz vein deposit (Nekrasov, 1959, 1962; O.G. Epov and others, written commun., 1964) occurs in anticlinal domes and is controlled by bedding-plane faults. The ore bodies include 30 veins, lenses, lenticular bodies, and stockworks. The veins are generally not more than 1 m thick, generally 15-20 m long, and not more than 30-40 m long. Most of the veins and host rocks are isoclinally folded. The host rocks include Ordovician and Silurian amphibole-mica-carbonate shale and limestone locally metamorphosed to marble. Two levels of intensely sulfidized shale, from 0.4-6 m thick and up to 250 m long, also occur in the deposit. Post-mineralization diabase and diorite porphyritic dikes are present, which are probably Late Jurassic-to-Early Cretaceous in age. Besides pyrite and pyrrhotite, the ore minerals are arsenopyrite, galena, fahlore, sphalerite, and gold. Gangue minerals constitute 95% of the deposit and include quartz, albite, ankerite, barite, and fluorite. Pyrite is altered to pyrrhotite, and metamorphic actinolite, zoisite, biotite, sphene replace gangue minerals along with recrystallization of quartz. A late Paleozoic age is interpreted for the deposit and associated metamorphism. The deposit averages 0.2 to 2 g/t Au.

Origin of and Tectonic Controls for Selennyakh River Metallogenic Belt

The Selennyakh River metallogenic belt is hosted in the Omulevka passive continental margin terrane. The local units which host the Selennyakh River metallogenic belt consist of a continuous succession of Ordovician, Early Carboniferous, and Permian sedimentary rocks which are about 10,000 to 12,000 km thick. The major lithologies are continental-shelf carbonate rocks with layers of deep-marine limestone and shale. The stratabound Hg and Au deposits, which are the major element of the Selennykh River belt, are hosted in Middle Ordovician and Lower Silurian limestone and dolomite which ranges from 300 to 500 m thick. The ore-bearing carbonate stratum is overlapped by calcareous shale (Shpikerman, 1998). Local middle Paleozoic mafic and syenite intrusions also occur. The younger, Carboniferous and Permian stratiform deposits are interpreted as forming during a short-lived rifting event within the Omulevka terrane.

The diversity of deposit types in the Selennyakh River metallogenic belt is interpreted as the result of a complex metallogenic history (Shpikerman, 1998) of the terrane which consisted of: (1) subsurface mineralization occurring in artesian thermal basins associated with Late Devonian rifting, thereby forming Southeast Missouri Zn-Pb and stratabound Hg deposits; and (2) subsequent formation of veins during intrusion and regional metamorphism of the stratabound deposits, thereby forming Hg, Au, and Pb-Zn vein deposits. The local units which host the Selennyakh River metallogenic belt consist of a continuous succession of Middle Ordovician to Middle Devonian sedimentary rocks which are about 10,000 to 12,000 km thick. The major lithologies are continental-shelf carbonate rocks with layers of calcareous shale. Local, rift-related, middle Paleozoic alkali-mafic and syenite intrusions also occur and have ^{40}Ar-^{39}Ar isotopic ages of 300 and 141±07 Ma, respectively (Trunilina and others, 1996). The host Omulevka terrane is interpreted as a rifted fragment of the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV; Nokleberg and others, 1994c, 1997c; Shpikerman, 1998).

Tommot River Metallogenic Belt of Carbonatite-Related Nb, Ta, and REE Deposits (Belt TO) North-Central Part of Russian Northeast

The small Tommot River metallogenic belt of carbonatite-related Nb, Ta, and REE deposits occurs in the north-central part of the Russian Northeast (fig. 16; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt is hosted in the passive continental margin Omulevka terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c), extends almost 50 km, and varies between 20 to 30 km wide. The Tommot River metallogenic belt is herein correlated with the Khamna River metallogenic belt which is hosted in the North Asian Craton Margin (unit NAV, Verkhoyansk fold belt). This interpretation suggests that the Omulevka terrane is a faulted fragment of the North Asian Craton Margin.

Tommot REE Deposit

The one significant deposit in the belt at Tommot (Nekrasov, 1962; L.M. Parfenov, P.W. Layer, written commun., 1994) consists of REE, Ta, and Nb minerals which occur in fenite, metasomatic alkalic pegmatite, and aegirine granite and in country rock adjacent to a zoned Late Devonian (?) alkalic gabbroic-syenite pluton. These igneous rocks intrude early Paleozoic slate. The 20 ore bodies at the deposit include metasomatic veins and lenses which vary from several to 25 m thick and range up to a hundred meters long. The most important elements in the deposit are Y, Ce, La, Ta, and Nb. Some rock samples contain 0.1-0.2% Y; 0.1-0.5% Zn; and 0.01-0.5% Nb. K-Ar isotopic studies indicate a Permian to Carboniferous age whereas U-Pb isotopic studies indicate an age of 368 Ma (Nekrasov, 1962).

Origin of and Tectonic Controls for Tommot River Metallogenic Belt

The intrusion of alkalic igneous rocks which host the Nb, Ta and REE deposits of the Tommot River metallogenic belt are interpreted as forming during Late Devonian rifting of the North Asian Craton and the formation of the Omulevka Omulevka passive continental margin terrane (Nokleberg and others, 1997b, 1998). The alkalic igneous rocks, that host the Tommot River metallogenic belt, are part of a sequence of Mississippian igneous rocks in the terrane. The Omulevka terrane is herein interpreted as rifted fragment of the Paleozoic passive continental margin of North Asian Craton (Nokleberg and others, 1994c, 1997c, 2000) which in the Khamna River area contains a possibly similar belt of carbonatite-related Nb, Ta, and REE deposits.

Urultun and Sudar Rivers Metallogenic Belt of Southeast Missouri Pb-Zn, Carbonate-Hosted Hg, Basaltic Cu, and Volcanogenic Mn Deposits (Belt URS) West-Central Part of Russian Northeast

The Urultun and Sudar Rivers metallogenic belt of Southeast Missouri Pb-Zn, volcanogenic-sedimentary Mn, basaltic Cu, bedded barite, and carbonate-hosted Hg deposits (fig. 16; tables 3, 4) occurs in three discontinuous fragments which extend northwesterly for 170 km in the west-central part of the Russian Northeast (Shpikerman, 1998. The southeastern portion of the belt is in the Sudar River basin, and the northwestern portion of the belt is in the Late Taskan and Urultun Rivers. The deposits occur in various parts of the Paleozoic Sudar rift sequence in the Omulevka passive continental margin terrane (Nokleberg and others, 1994c, 1997c). Southeast Missouri Pb-Zn-fluorite deposits, as at Urultun, are most prevalent, and occur in Late Ordovician through Middle Devonian strata (Shpikerman, 1987, 1988). The significant deposits are the Urultun Southeast Missouri Pb-Zn deposit; the Uochat carbonate-hosted Hg deposit, the Batko basaltic Cu deposit, the Lyglykhtakh volcanogenic Mn deposit, and the Prizovoe bedded barite deposit (table 4) (Nokleberg and others 1997a, b, 1998).

Urultun Southeast Missouri Pb-Zn Deposit

The Urultun Southeast Missouri Pb-Zn deposit (fig. 27) (Shpikerman, 1987, 1998) consists of disseminated veinlets and brecciated ore which occur in Early Devonian dolomite overlain by Middle Devonian (Givetian) marl. The ore bodies are composed of dolomite, calcite, fluorite, galena, sphalerite, and anthraxolite. Barite, pyrite, and cinnabar are present locally. The deposit is interpreted as forming in two stages: (1) an early sphalerite-fluorite stage which resulted in disseminated metasomatic ore; and (2) a galena-fluorite-calcite stage which resulted in brecciated and veinlet ores. The ore-bearing dolomite sequence is up to 240 m thick and occurs along a synclinal limb of a fold which generally trends northwesterly. Two to five conformable ore horizons, varying in thickness from 1 to 10 m, occur in the dolomite sequence. The ore bodies are sporadic within a given horizon. The deposit occurs over an area of about 20 by 4 km. This and other deposits and host rocks are stratigraphically overlapped by deep-sea argillaceous and carbonaceous sedimentary rocks. The deposit contains an estimated resource of 23 million tonnes with an average grade of about 2.85% Pb, 6.74% Zn, and 10% fluorite.

Carbonate-Hosted Hg Deposits

The carbonate-hosted Hg deposits of the Urultun and Sudar Rivers metallogenic belt are interpreted as forming in the same event as the Southeast Missouri Pb-Zn deposits. The significant deposit at Uochat (Babkin, 1975) consists of disseminated, cinnabar-bearing veinlets which occur in brecciated Early(?) Devonian dolomite along a major north-south-trending fault. The deposit is about 20 m long and 4 to 7 m thick. The main ore mineral is cinnabar, which occurs with calcite in masses and irregular veinlets. Pyrite, quartz, sphalerite, and anthraxolite also occur. The deposit formed in several stages: (1) pre-ore silicification; (2) pre-ore calcite alteration; (3) deposition of cinnabar and calcite; and (4) post-ore deposition of calcite. The deposit is small.

Basaltic Cu, Volcanogenic Mn, and Bedded Barite Deposits

The stratabound basaltic Cu deposits occur in rift-related trachybasalt flows of the Givetian Formation which formed in a shallow marine environment. The significant deposit is at Batko.

The Batko basaltic Cu deposit (Shpikerman and others, 1991) consists of disseminated and irregular masses of sulfides which occur in subalkalic, amygdaloidal basalt flows up to 200 m thick, within folded red beds of Middle Devonian (Givetian) age. The ore minerals are bornite, chalcocite, and covellite. The deposit occurs at the tops of the basalt flows. The adjacent trachybasalt is intensely epidotized and carbonatized. The upper mineralized horizon is no more than 2-3 m thick. The deposit is small with grab samples which contain up to 3.1% Cu and 13.7 g/t Ag. Ag and Ba are associated with the Cu.

The stratiform volcanogenic Mn deposits, as at Lyglykhtakh, and the bedded barite deposits occur in folded Early Carboniferous (Mississippian) through Late Permian siliceous shales, cherts and siliceous-carbonate rocks which are intercalated with tuff and diabase bodies. The Prizovoe bedded barite deposit occurs in the Early and Middle Carboniferous Batko Formation. Associated stratiform rhodochrosite deposits, at Lyglykhtakh and elsewhere in the Sudar and nearby river basins, occur in the lower part of the Late Permian Turin Formation. Stratigraphic breaks may exist between these formations of sedimentary rocks.

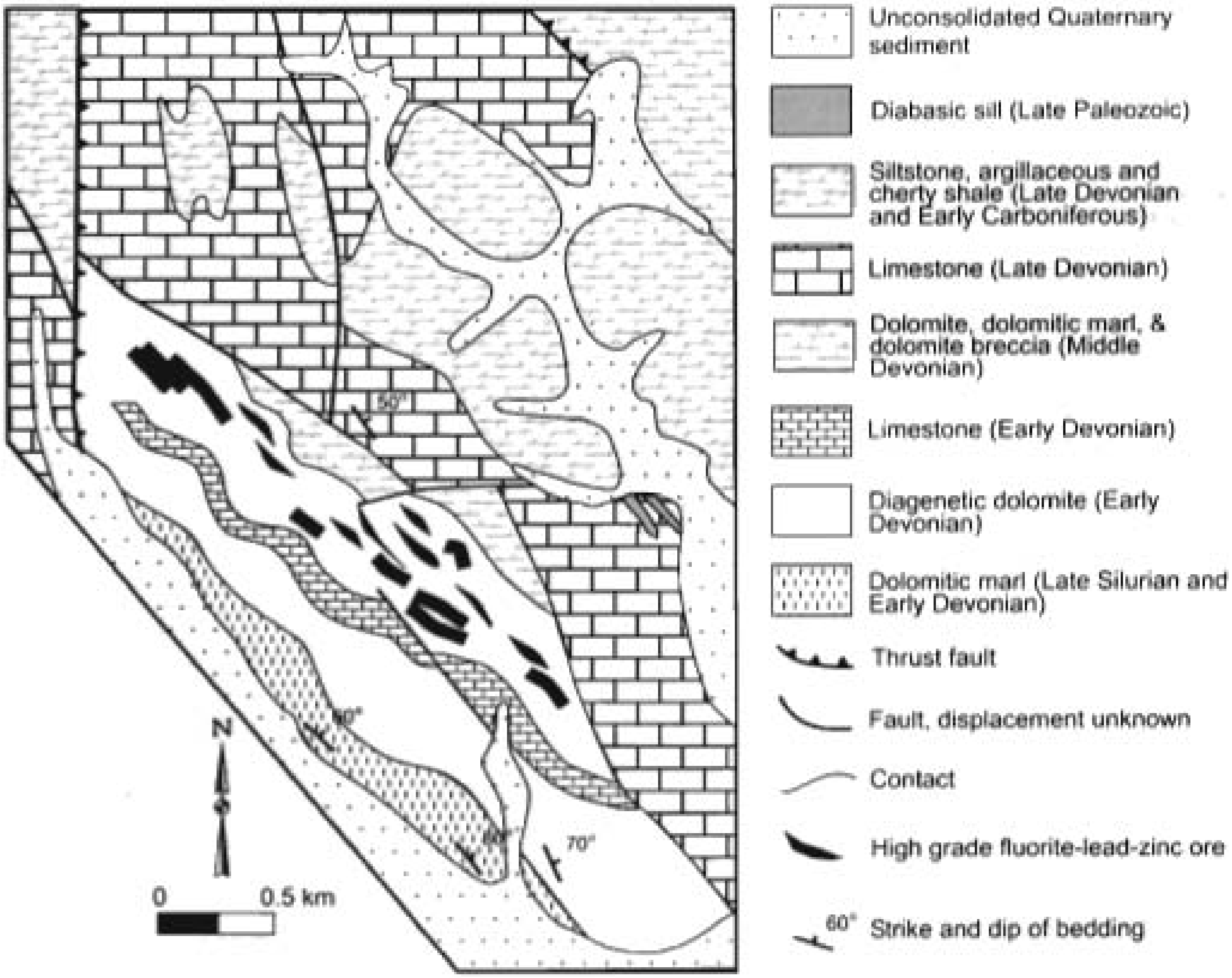


Figure 27. Urultun Southeast Missouri Pb-Zn deposit, Urultun and Sudar Rivers metallogenic belt, Russian Northeast. Generalized geologic map of the Bitum-Sdvig area of stratabound F-Pb-Zn deposit. Adapted from Shpikerman (1987).

Origin of and Tectonic Controls for Urultun and Sudar Rivers Metallogenic Belts

Both the Southeast Missouri Pb-Zn and carbonate-hosted Hg deposits are interpreted as forming in a middle Paleozoic thermal artesian paleobasin in a major petroleum area (Shpikerman, 1998). Early and middle Carboniferous rifting is interpreted as the source of mineralizing fluids. Similarly, the deep-marine sedimentary and mafic volcanic rocks which host the basaltic Cu, volcanogenic Mn, and associated deposits of the Urultun and Sudar Rivers metallogenic belt are interpreted either as allochthonous blocks of oceanic-floor sedimentary rocks, or as sedimentary and volcanic rocks which were deposited during Devonian rifting of the North Asian Craton Margin to form the Omulevka terrane (Nokleberg and others, 1994c, 1997c). Characteristic pyroclastic debris in the sedimentary rocks indicates which submarine volcanism and was associated with these SEDEX deposits. This interpretation is supported by anomalous values of Pb, Zn, Cu, Ag, and Hg in the host rocks. In spite of the variety of mineral deposit types in this belt, a genetic relation is interpreted between most of the deposits. The sedimentary-exhalative accumulation of Mn and barite ores, and anomalous Pb, Zn, Cu, Ag, and Hg concentrations are interpreted as forming during deposition of the Southeast Missouri Pb-Zn deposits in artesian horizons. The younger parts of the Omulevka terrane consists of Carboniferous and Permian fossiliferous tuff, chert, shale, limestone, siltstone, and sandstone, and Triassic fossiliferous siltstone, mudstone, marl, and shaley limestone.

Yarkhodon Metallogenic Belt of Southeast Missouri Pb-Zn Deposits (Belt YR) West-Central Part of Russian Northeast

The Yarkhodon metallogenic belt of Southeast Missouri Pb-Zn-barite deposits occurs mainly in the Yarkhodon River basin in the west-central part of the Russian Northeast (fig. 16; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt is hosted in the Yarkhodon subterrane in the eastern part of the Prikolyma passive continental margin terrane. The belt is 330 km long and up to 50 km wide. Most of the deposits occur in the same stratigraphic level of the Yarkhodon Formation of Givetian age and are hosted in diagenetic dolomite and dolomitized limestone. Rare deposits occur in Proterozoic dolomite. The depositional environment for the original limestone is interpreted as a carbonate bank formed on a passive continental shelf. The significant deposits are at Slezovka and Gornoe.

Slezovka Southeast Missouri Pb-Zn Deposit

The Slezovka Southeast Missouri Pb-Zn deposit (A.V. Artemov and others, written commun., 1976; Davydov and others, 1988) consists of vein, disseminated, and breccia sulfides which occur in Middle Devonian a mineralized dolomite sequence which occurs in a sequence of clastic sedimentary rocks and carbonate rocks. The deposit contains up to five mineralized beds, each 3 to 5 m thick which separated by barren interbeds ranging from 3 to 10 m thick. The ore minerals are mainly galena, sphalerite, pyrite, and barite. The deposit is cut by quartz and calcite veinlets. The deposit is small.

Origin of and Tectonic Controls for Yarkhodon Metallogenic Belt

The Yarkhodon subterrane of the Prikolyma passive continental margin terrane, which hosts the Yarkodon metallogenic belt, consists of the follow major units: (1) Givetian limestone, dolomite, marl, and siltstone; (2) Famennian to Early Permian argillite, siltstone, volcaniclastic sandstone, rhyolite tuff, and basalts. The sedimentary rocks are very thick are interpreted as forming along continental-slope base of a rift-related trough within a passive continental-margin area. The Prikolyma terrane is interpreted as a rift-related fragment of the North Asia Craton (unit NSC; Nokleberg and others, 1994c, 1997c). The Southeast Missouri Pb-Zn-barite deposits of the Yarkodon metallogenic belt are interpreted as forming during rifting during the Late Devonian through the Mississippian.

Berezovka River Metallogenic Belt of Kuroko Massive Sulfide Deposits (Belt BE) Central Part of Russian Northeast

The Berezovka River metallogenic belt of kuroko massive sulfide and sulfide vein deposits in the Berezovka River basin in the west-central part of the Russian Northeast (fig. 16; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt is hosted in the Late Devonian through Late Permian turbidite deposits which are part of the Beryozovka turbidite basin terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c). The northwest-trending belt is 120 km long and up to 100 km wide. The belt occurs in four areas separated by units of post-accretionary volcanic rocks. In addition to kuroko massive sulfide deposits, the belt also contains numerous stratiform vein and veinlet-disseminated Au- and Ag-bearing Ba-Pb-Zn deposits. The significant deposit at Berezovskoe and other similar deposits are hosted in the Tynytyndzhin formation of Late Devonian (Frasnian and Famennian) age.

Berezovskoe Kuroko Massive Sulfide Occurrence

The Berezovskoe deposit consists of tuffaceous sandstone and siltstone, and rhyolite and basalt flows (Gorodinsky and others, 1974; N.A. Bobrov, written commun., 1976; Shpikerman, 1998). The Berezovskoe deposit consists of quartz-sulfide veins and stratiform barite-sulfide bodies which are conformable to bedding in the host rocks. The major sulfide minerals are galena and sphalerite. Some of the vein deposits are interpreted as forming during late Mesozoic magmatism which remobilized and redeposited the volcanic-rock-hosted massive sulfide deposits (Davydov and others, 1988). Because of a bimodal assemblage of basalt and rhyolite has recently been recognized in the Devonian rocks of the Berezovka terrane (Dylevsky, 1992), potential exists for the discovery of new stratiform massive sulfide deposits.

Origin of and Tectonic Controls for Berezovka River Metallogenic Belt

The Beryozovka turbidite basin terrane occurs in a series of tectonic sheets which are thrust southward over the northern margin of the Omolon terrane (Nokleberg and others, 1994c, 1997c). The Beryozovka terrane consists of: (1) a basal section of deep- and shallow-marine basalt, rhyolite, siliceous siltstone, chert, sandstone, and conglomerate which formed in a rift setting and which contains Late Devonian conodonts and radiolarians, and Early Carboniferous forminiferas, conodonts, and macrofossils; and (2) Middle and Late Carboniferous to Early Jurassic chert, siltstone, mudstone, and shale with pelitomorphic limestone layers and argillaceous-calcareous concretions. The Late Devonian Kuroko massive sulfide deposits and associated bimodal volcanic rocks are herein interpreted as forming during rifting which was the earliest interpreted event for the Beryozovka terrane (Nokleberg and others, 1994c, 1997c).

Metallogenic Belts Formed During Middle Paleozoic Rifting of North American Craton Margin or in Low-Temperature Brines Along Craton Margin

Mystic Metallogenic Belt of SEDEX Bedded Barite and Southeast Missouri Pb-Zn Deposits (Belt MY) West-Central Alaska

The Mystic metallogenic belt of SEDEX massive bedded barite and Southeast Missouri Pb-Zn deposits occurs in West-Central Alaska (fig. 17; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt is hosted in the Mystic and Nixon passive continental margin terranes (Nokleberg and others, 1994c, 1997c). The significant deposits are at Gagaryah and Reef Ridge. The belt also contains younger a younger Besshi massive sulfide(?) deposit at Shellebarger Pass. In addition, very high Cu background values (350 to 450 ppm Cu) occur in Late Triassic basalt, and several small syngenetic Cyprus-type chalcopyrite deposits occur within interstices of pillow structures and in aquagene tuff of the Mystic terrane in the McGrath quadrangle (T.K. Bundtzen, written commun., 1992).

Bedded Bariteand Southeast Missouri Pb-Zn Deposit

A sedimentary-exhalative (SEDEX) bedded barite deposit is hosted Gagaryah at in Late Devonian (Frasnian) shales and clastic rock host barite mineralization in the Lime Hills D-4 Quadrangle (Bundtzen and Gilbert, 1991). The deposit consists of nodular, laminated, composite, and massive, light gray barite in Frasnian (early Late Devonian) shale, limestone, and minor chert of Mystic Terrane. The deposit extends along strike for 640 meters, has an average thickness of 20 meters, and an estimated down-dip extension of 300 meters. The deposit contains slightly elevated levels of Av, V, Sr (in celestite), but no lead or zinc. Sulfide isotopic analyses of +20 and +24 determined from nodular and massive barite respectively. The deposit contains 2.3 million tonnes grading 51% barite. The barite is interpreted as deposited syngenetically into host shale basin with barite rapidly precipitating from low temperature hydrothermal fluids distal from exhalative vents. Barite nodules and spheroids are also commonly encountered in either Devonian or Mississippian strata at other localities in the Mystic terrane to the northeast.

A Southeast Missouri Pb-Zn deposit at Reef Ridge consists of stringers of brown sphalerite and minor galena in hydrothermal breccia in carbonate rocks of the Silurian and Devonian Whirlwind Creek Formation in the Nixon Fork terrane (Harold Noyes, written commun., 1984). The deposit extends along strike for 2,000 m and ranges up to 15 m thick. The sulfides pinch and swell along strike. The deposit is the best known of ten similar nearby occurrences, and contains bout 181,000 tonnes of 15% combined Zn and Pb.

Shellebarger Pass Besshi Massive Sulfide(?) Deposit

The younger Shellebarger Pass Besshi massive sulfide(?) deposit (Reed and Eberlein, 1972; Bundtzen and Gilbert, 1983) consists of a very fine grained mixture of mainly pyrite and marcasite and lesser sphalerite, chalcopyrite, galena, and pyrrhotite in a gangue of siderite, calcite, quartz, and dolomite. The sulfides and gangue occur in massive, lenticular sulfide bodies, as replacements of carbonate-rich beds, and as fracture fillings, mainly in chert and siltstone. The host rocks are a Triassic and (or) Jurassic age sequence of chert, dolomite, siltstone, shale, volcanic graywacke, conglomerate, aquagene tuff, and overlain by an upper sequence of pillow basalt, agglomerate, and breccia. At least six individual sulfide bodies are known. The main sulfide bodies may be proximal to basaltic flow fronts. The highest chalcopyrite concentrations occur in the basal parts of bodies. Minor sphalerite occurs in or near the hanging wall. Extensive hydrothermal alteration occurs in the footwall, but is to absent in hanging wall. The basalt displays high background Cu values of 250 to 300 g/t. The deposit contains an estimated several hundred thousand tonnes of unknown grade. Individual samples contain up to 5% Cu and average about 2% Cu and 1% Zn.

Origin of and Tectonic Controls for Mystic Metallogenic Belt

The Mystic metallogenic belt is hosted in the Mystic and Nixon passive continental margin terranes which consist of a complexly deformed but partly coherent, long-lived stratigraphic succession, including Devonian through Pensylvanian carbonate and clastic sedimentary rock, Permian flysch and chert, and Triassic(?) pillow basalt (Nokleberg and others, 1994c, 1997c): Recent studies report early to middle Paleozoic fauna in these terranes that are typical of taxa that occur in similar age units in the Kolyma region in the Russian Northeast and suggest that these three terranes were rifted from the Siberian continent (North Asian Craton Margin) (Blodgett and Brease, 1997; Blodgett, 1998; Fryda and Blodgett, 1998; Dumoulin and others, 1998, 1999; Blodgett and Boucot, 1999). The Mississippian and older parts of these terranes and a stratigraphy that is similar to the North Asian Craton Margin (NSV). Accordingly, these Mississippian and older parts of these terranes and their Mississippian and older lode SEDEX bedded barite deposits and metallogenic belts are herein interpreted as being derived from rifting of the North Asian Craton Margin (NSV) (Nokleberg and others, 2000). Coeval metallogenic belts with similar origin deposits residing in the Russian Northeast include the Urultun and Sudar Rivers, Selennyakh River, and Sette-Daban, and Yarkhodon belts (table 3). The tectonic origin of the younger Triassic(?) Besshi(?) and Cyprus massive sulfide deposits in the Mystic metallogenic belt, as at Shellebarger, is not clear.

Northern Cordillera Metallogenic Belt of Southeast Missouri Zn-Pb Deposits (Belt NCO) Central Yukon Territory

The Northern Cordillera metallogenic belt of Proterozoic and early Paleozoic Southeast Missouri Zn-Pb deposits (fig. 17; tables 3, 4) occurs in the east-central Yukon-Territory and western Northwest Territories and is hosted in an extensive pericratonic platformal sequence in the North American Craton Margin. The major Proterozoic deposits are at Gayna River and Goz Creek. The major early Paleozoic deposit is at Bear-Twit; other examples are at Gayna River, Goz Creek area (Barrier Reef), and Rusty Springs (Termuende) (table 4) (Nokleberg and others 1997a, b, 1998).

Gayna River Southeast Missouri Zn-Pb Deposit.

The Gayna River Southeast Missouri Zn-Pb deposit consists of sphalerite with minor pyrite and galena which occur in breccias and as tabular replacement bodies in Late Proterozoic shallow water carbonate of the Little Dal Group (Mackenzie Mountain Assemblage; Hardy, 1979; Aitken, 1991; Hewton, 1982; EMR Canada, 1989). Sphalerite and lesser galena occur as disseminations in breccias which formed as slumps over the flanks of stromatolitic reefs. Sphalerite is also concentrated in solution-collapse and fault-related crackle breccias. The Gayna River district contains 18 deposits and more than 100 occurrences. Several deposits exceed 1 million tonnes grading 10% combined Zn and Pb.

Goz Creek (Barrier Reef) Southeast Missouri Zn-Pb Deposit

Deposits in the Goz Creek area consist of sphalerite with minor galena, pyrite and boulangerite which occur as fracture and breccia filling and disseminations (EMR Canada, 1989; Dawson and others, 1991; Fritz and others, 1991). The deposit contains estimated reserves of 2.49 million tonnes grading 11% combined Zn and Pb. The deposits occur in both stratigraphically and tectonically controlled zones in pervasively silicified sandy dolostone. Smithsonite occurs as weathering product of sphalerite. The deposit age is interpreted to be Late Proterozoic. Other Southeast Missouri Pb-Zn districts hosted by Late Proterozoic dolostone include Nadaleen Mountain, south of Goz Creek, and Coal Creek Dome, north of Dawson.

Bear-Twit Southeast Missouri Zn-Pb District.

The Bear-Twit Southeast Missouri Zn-Pb district consists of galena and sphalerite with minor tetrahedrite which occur in brecciated dolomitized shallow water (reef) carbonates of the Early Devonian Whittaker, Delorme and Camsell Formations (Dawson, 1975; Archer Cathro and Associates, unpublished company report, 1978; EMR Canada, 1989). The deposit contains estimated reserves of 8 million tonnes grading 5.4% Zn, 2.6% Pb, and 0.5 g/t Ag. The deposit occurs in cross-cutting fractures, breccia matrices, fossil replacement, and also as disseminations in dolomite. The deposit age is interpreted as Early Devonian. In the Godlin Lakes region, are numerous deposits are hosted by orange-weathering ferroan dolostone of the Early Cambrian Sekwi Formation (Dawson, 1975). The Rusty Springs deposit in northwestern Yukon is an Ag-rich Southeast Missouri Pb-Zn deposit hosted by brecciated dolostone of the Middle Devonian Ogilvie Formation.

Origin of and Tectonic Controls for Northern Cordillera Metallogenic Belt

The deposits in the Northern Cordilleran metallogenic belt are classic Southeast Missouri Pb-Zn deposits composed of sphalerite, galena, and pyrite, with a gangue of dolomite, quartz, calcite and barite, and lesser gypsum, fluorite, chalcopyrite, and pyrobitumen. These minerals occur in vugs, pores, burrows, various sedimentary and tectonic breccias, and minor to major fractures. Secondary dolomite commonly accompanies mineralization. Zn: Pb ratios average 10:1, and Ag and Fe contents are low. The deposit form is highly irregular and usually discordant on a local scale, but stratabound on a district scale. The deposit sizes range from a few tens of thousands to about 10 million tonnes, and grades range from 3 to 10% combined Zn and Pb in larger deposits to about 50% combined Zn and Pb in small bodies (Dawson and others, 1991). Remote location and lack of infrastructure has limited drilling and development to only a few of the several hundred known occurrences.

The Late Proterozoic to Middle Devonian passive part of the North American Craton Margin consists of a miogeoclinal sedimentary prism which is segmented into two contrasting facies belts. To the northeast are shallow water sandstone, dolostone and limestone which define the Mackenzie Platform, whereas to the southwest are turbiditic sandstone, deep-water limestone, shale and chert which define the Selwyn Basin. Sedimentary lithofacies exerted a primary control upon the localization of pre-accretionary sediment-hosted mineral deposits. Minor occurrences of Southeast Missouri Pb-Zn deposits are a common feature of carbonate rocks of all ages in the North American miogeocline; however, significant deposits commonly are localized along the carbonate-shale facies changes near the tectonically-unstable, western margin of Late Proterozoic to early Paleozoic platformal carbonate successions.

The apparent spatial relationship of mineralization to extensional structures suggests formation of the Southeast Missouri Zn-Pb deposits during major rifting and basinal subsidence along the passive North American Craton Margin. These structures include rift-induced, synsedimentary and block faulting, uplift, basinal subsidence, resultant facies changes, reefal development, development of karsts, brecciation, and basinal brine migration (Dawson and others, 1991). The common association of hydrocarbons with Zn-Pb deposits in carbonate rocks suggests a genetic relationship between mineralization and oil maturation, migration, and entrapment (Jackson and Beales, 1967). Although the timings of mineral deposition commonly are not well known (Sangster, 1986), the two major age groups of Southeast Missouri Zn-Pb deposits are herein interpreted as forming during two major periods of incipient rifting of the North American Continental Margin, the Late Proterozoic and early Paleozoic.

Other metallogenic belts in the Canadian Cordillera, which contain stratiform or stratabound massive sulfide deposits which are hosted in parts or rifted fragments of the North American Craton Margin, are (in order of decreasing age): (1) Monashee belt of Late Proterozoic SEDEX deposits; (2) Redstone belt of Late Proterozoic sediment-hosted Cu deposits (3) Cathedral belt of Cambrian Southeast Missouri Zn-Pb deposits; (4) Churchill belt of Late Proterozoic Cu vein deposits; (5) Kootenay belt of Cambrian SEDEX deposits; and (6) Anvil belt of Cambrian through Silurian SEDEX deposits. An important distinction occurs between some of the metallogenic belts. Many metallogenic belts with SEDEX deposits are directly associated with mafic volcanic rocks and hydrothermal activity whereas the metallogenic belts containing Southeast Missouri Zn-Pb deposits are not.

Dempster Metallogenic Belt of SEDEX Ba,
Sedimentary-Exhalative (SEDEX),
SEDEX Ni-Zn-PGE-Au, and Kuroko Zn-Pb-Cu
Massive Sulfide Deposits (Belt DE)
Northwestern Yukon Territory

The Dempster metallogenic belt of SEDEX Ba, SEDEX Ni-Zn-PGE-Au, and Kuroko Zn-Pb-Cu massive sulfide deposits occurs in the northwestern Yukon Territory (fig. 17; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt is hosted in the North American Craton Margin in a sequence Devonian and Mississippian clastic strata which are part of the Earn assemblage, in the region north of Tintina Fault and south of Dawson Fault. The significant deposits are the Rein SEDEX, Marg Kuroko massive sulfide, and the Nick SEDEX deposits.

Rein SEDEX Ba Deposits

The Rein and several other large SEDEX deposits in the region contain barite, barytocalcite, and witherite and are hosted in Early to Middle Devonian (late Emsian to early Eifelian) sedimentary rocks which crop our near Dempster Highway (M.J. Orchard, written communication, 1985). None of the occurrences has measured reserves. The upper Earn Assemblage includes beds between the Tombstone and Robert Service thrust faults previously interpreted to be Mesozoic, including the Keno Hill quartzite, which host the large polymetallic silver vein district of Keno Hill in the Tombstone metallogenic belt.

Marg Kuroko Volcanogenic Zn-Pb-Cu Deposit

The Marg kuroko Zn-Pb-Cu-Au-Ag massive sulfide deposit consists of pyrite, sphalerite, chalcopyrite and galena with minor arsenopyrite and tetrahedrite which occur in a quartz and barite gangue (Eaton, written commun., Archer, Cathro, and Associates, 1989; Yukon Minfile, 1991). The deposit occurs in four stacked massive sulfide lenses which occur at the contact of quartz-sericite-chlorite phyllite and graphitic phyllite. The deposit contains an estimated 2.097 million tonnes grading 5.0% Zn, 2.7% Pb, 1.8%Cu, 65g/t Ag, 1.2 g/t Au. The host rocks are tectonically interleaved with, and overlain by the Keno Hill quartzite of the Late Earn Assemblage, part of a Devonian and Mississippian clastic wedge (Mortensen and Thompson, 1990; Turner and Abbott, 1990). The felsic metavolcanic rocks are interpreted as part of a Carboniferous continental-margin arc form along the North American Craton Margin.

Nick SEDEX Ni-Zn-PGE-Au Deposit

The Nick SEDEX Ni-Zn-PGE-Au deposit consists of pyrite, vaesite, melnikovite-type-pyrite, sphalerite and wurtzite which occur in a gangue of phosphatic-carbonaceous chert, amorphous silica and intergrown bitumen (Hulbert and others, 1992; Yukon Minfile, 1992). The deposit has reserves of 900,000 tonnes grading 5.3% Ni, 0.73% Zn, and 0.8 g/t PGE, along with minor Au. The deposit forms a thin, conformable unit at the contact between Middle and Late Devonian Earn Group. The deposit extends laterally over a 80 km^2 basin (Hulbert and others, 1992). The host rocks are the basinal sedimentary part of a Devonian and Mississippian clastic wedge exposed in an east-west trending syncline. The basin is interpreted as a local trough or embayment on the eastern margin of the Selwyn Basin. The only known deposits similar to this rare SEDEX deposit are the Ni-Mo sulfide beds of the Yangtze Platform, China (Coveney and others, 1994).

Origin of and Tectonic Controls for Dempster Metallogenic Belt

In the Middle Devonian, a dramatic change in sedimentation patterns occurred throughout the North American Craton Margin when continental shelf platform assemblages of carbonate and clastic rocks were drowned and starved of clastic sediments before being inundated by mainly turbidite and chert-rich clastic rocks derived from the west and north. The abrupt change from passive-margin to variably coarsening-upward clastic sedimentation represented by the Earn Assemblage is interpreted as the result of local block uplift as a consequence of regional extension or strike-slip faulting (Gordy, 1991; Gordey and Anderson, 1993), or as interpreted herein, related to syndepositional faults which bounded a westerly trending, rift-related trough. The formation of the Dempster metallogenic belt and the similar Macmillan Pass and Gataga metallogenic belts is interpreted as occurring during deposition of the clastic wedge.

Macmillan Pass Metallogenic Belt of Zn-Pb-Ag-Ba SEDEX Deposits, Central Yukon Territory (Belt MP)

The Macmillan Pass metallogenic belt of SEDEX Zn-Pb-Ag-Ba deposits (fig. 17; tables 3, 4) occurs in the central Yukon Territory and is hosted in the Devonian and Mississippian sedimentary rocks of Earn Group, part of the North American Craton Margin in the northern Canadian Cordillera. The significant deposits are at Cathy (Bar, Walt, Hess), Gravity (BA), Jeff (Naomi, Baroid), Macmillan Pass (Tom, Jason Main, Jason East), Moose (Spartan, Racicot), Oro (Buc, Mar, Dar, Tang), and Tea (Brock) (table 4) (Nokleberg and others 1997a, b, 1998).

Tom, Jason Main, and Jason East Pb-Zn-Ag-Ba SEDEX Deposits

Tom, Jason Main, and Jason East SEDEX Pb-Zn-Ag-Ba deposits occur in two or more stratigraphic intervals in the Middle to Late Devonian lower Earn Group, interpreted as part of a Devonian and Mississippian clastic wedge in the MacMillan Pass area. The deposits are interpreted as spatially related to syndepositional faults bounding a rift-related trough filled with fine- to coarse-grained siliceous turbiditic clastic rocks(MacIntyre, 1991; Mining Review, 1992). Estimate reserves are 9.3 million tonnes grading 7.5% Pb, 6.2% Zn, and 69.4 g/t Ag for the Tom deposit, and 14.1 million tonnes grading 7.09% Pb, 6.57% Zn, and 79.9 g/t Ag for the Jason deposits (MacIntyre, 1991; Mining Review, 1992). The distribution of ore facies consists of: (1) a Cu- and Ag-rich footwall stockwork which is overlain by Pb- and Zn- rich massive sulfide facies; (2) an upward and lateral gradation into a Zn- and Fe-rich, laminated sulfide facies; and (3) a distal gradation into Ba-rich ore. This distribution is interpreted as forming during a zonal deposition from low-temperature brines exhaled into an anoxic sub-basin (McClay and Bidwell, 1986; Large, 1983). The Jason deposits, 5 km southwest of Tom, possess similar ore facies but occur closer to a graben margin and are characterized by slump and debris flows and discordant, replacement ore textures.

Moose Ba SEDEX Deposit

The Moose Ba SEDEX deposit consists of finely laminated barite which occurs in two beds from 25 to 45 meters thick and exposed for 200 to 250 meters along strike (Dawson and Orchard, 1982; Yukon Minfile, 1992). The deposit has estimated reserves of 3.0 million tonnes grading 84% $BaSO_4$, 12% to 14% SiO_2. The deposit occurs near the base of a shale member of the Middle to Late Devonian lower Earn Group, immediately above an underlying chert pebble conglomerate. The host rocks are interpreted as part of a Devonian and Mississippian clastic wedge.

Origin of and Tectonic Setting for MacMillan Pass Metallogenic Belt

The MacMillan Pass metallogenic belt of Zn-Pb-Ag-Ba SEDEX deposits is hosted mainly in Late Devonian (Frasnian) units of the North American Craton Margin (Dawson and Orchard, 1982). Most of the SEDEX deposits in the metallogenic belt are related to syndepositional faults which bound a westerly trending, rift-related trough filled with turbiditic siliceous clastic rocks of the lower Earn Group (Abbott, 1986b). The Devonian and Mississippian Earn Group, which hosts the metallogenic belt, represents a dramatic change in sedimentation patterns. The change consisted of drowning of shelf carbonate-clastic platforms and subsequent inundation by turbidite- and chert-rich clastic rock derived from the west and north (Gordey and others, 1991). The abrupt change from passive continental margin sedimentation to variable, coarsening-upward clastic sedimentation is interpreted as the result of local block uplift as a consequence of regional extension related to rifting or strike-slip faulting (Gordey, 1992), or a consequence of ensialic arc magmatism, uplift and foreland clastic wedge deposition (Gabrielse and others, 1982).

Finlayson Lake Metallogenic Belt of SEDEX Zn-Pb-Ag-Cu-Au Deposits (Belt FL) Southern Yukon Territory

The Finlayson Lake metallogenic belt of SEDEX Zn-Pb-Ag-Cu-Au deposits (fig. 17; tables 3, 4) occurs in the Selwyn Basin of the North American Craton Margin in the Yukon Territory. The significant deposits at Maxi and Matt Berry (table 4) (Nokleberg and others 1997a, b, 1998) are hosted in deformed sedimentary rocks of the Road River Group. The stratigraphic position and age of the host rocks at Maxi are better known than at Matt Berry.

Maxi SEDEX Zn-Pb-Ag Occurrence

The Maxi SEDEX Zn-Pb-Ag occurrence consists of galena, sphalerite, and quartz which occur as penetratively-deformed and transformed lamellae and bands in black phyllite in the basal Road River Group (Blusson, 1978). The sulfides are commonly coarse-grained and concentrated in minor fold hinges, indicating mobilization during pre-Late Devonian, regional metamorphism. A second stage of folding and thermal metamorphism is interpreted as related to Cretaceous granitoid plutons in the area (Blusson, 1978). No reserves or resources are reported.

Matt Berry SEDEX Pb-Zn Deposit

The Matt Berry SEDEX deposit consists of massive galena, sphalerite, pyrrhotite and chalcopyrite which occur with minor antimony-silver minerals (Ostler, 1979; Bremner and Ouellette, 1991). The deposit contains estimated reserves of 533,434 tonnes grading 6.81% Pb, 4.8% Zn, and 102.9 g/t Ag (Northern Miner, August 5, 1980). The sulfides are concentrated with quartz, in fold noses, and in discontinuous en-echelon lenses over a strike length of 500 m. The rocks have undergone at least three periods of deformation and metamorphism, including thermal metamorphism along the contacts of a Cretaceous granitoid pluton. The deposits constitute a zone of sulfide lenses up to 10 m thick hosted by deformed black phyllite and quartz-sericite phyllite, probably of the Paleozoic Road River Group in eastern Selwyn Basin, Yukon. The copper and antimony minerals are interpreted as related to local Cretaceous intrusive activity which overprints the Paleozoic SEDEX mineralization which formed along a Devonian and Mississippian passive continental margin.

Origin of and Tectonic Setting for Finlayson Lake Metallogenic Belt

The Maxi and Matt Berry deposits are interpreted as originally stratiform SEDEX sulfides deposits which were deposited with black shale in the Ordovician and Silurian Road River Group and are provisionally correlated with the adjacent Howards Pass metallogenic belt to the northeast. The Maxi and Matt Berry deposits were attenuated, deformed, remobilized, and contact metamorphosed during mid-Cretaceous magmatism, uplift and deformation.

Liard Metallogenic Belt of Southeast Missouri Ba-F Deposits (Belt LI) Northern British Columbia

The Liard metallogenic belt of Southeast Missouri Ba-F deposits occurs in northern British Columbia and is hosted mainly in early to middle Devonian shelf carbonate rocks in the North American Craton Margin (fig. 17; tables 3, 4) (Nokleberg and others, 1997b, 1998). The deposits are epigenetic stockworks, breccia-fillings, replacements, and (or) veins which exhibit stratigraphic and structural controls similar to those of Southeast Missouri Zn-Pb deposits. The large deposits exhibit a southward lateral gradation towards several, small Zn-Pb vein and breccia occurrences which are hosted in a dolomite-barite-fluorite gangue (Dawson, 1983). The Ba-F deposits are herein interpreted as analogous to Southeast Missouri Pb-Zn deposits. However, local epigenetic barite deposits occur in the area without fluorspar and Pb-Zn sulfides.

Leguil Creek Bedded Ba Deposit

The Leguil Creek (Letain) bedded Ba deposit consists of three stratabound zones of veins and lenses of barite which are hosed in Cambrian to Devonian shale and siltstone (MINFILE, 2002). The barite and host rocks are gently folded. Discordant, fault-controlled barite vein zones range from 1 to 4 m thick. Barite sulphur isotopic analysis indicate a Devonian age of mineralization (K.M. Dawson, unpublished data, 1995). A SEDEX barite origin, similar to that for the adjacent Gataga SEDEX metallogenic belt, with subsequent tectonic remobilization, is herein proposed.

Lower Liard Southeast Missouri Ba-F and Muncho Lake Ba Deposits

The Lower Liard Southeast Missouri Ba-F deposit consists of fluorite with barite, witherite, barytocalcite, quartz and calcite which occurs as veins, lenses and breccia-fillings at the contact between limestone of the Middle Devonian Dunedin Formation and shale of the Besa River Formation (EMR Canada, 1989; MINFILE, 2002). Fission-track dating suggests a

Mississippian age of mineralization (MINFILE, 2002). Massive stratabound Ba deposits, which occur in the same region at Muncho Lake, northern British Columbia, are not hosted by the same strata, and may be spatially related to fluorite-free barite replacements and breccias. The Muncho Lake Ba deposit in northern British Columbia consists of mssive, stratabound barite which is devoid of fluorite. The barite layer overlies the Waknash Formatoin and is bedded and contains local abundant sandstone, and may exhibit evaporite textures (Dan Hora, written commun., 2000). Also occurring in the area area barite veins (Butnerchuk and Hancock, 1997; MINFILE, 2002).

Origin of and Tectonic Setting for Liard Metallogenic Belt

The Liard metallogenic belt of Southeast Missouri(?) Ba-F deposits is hosted in Devonian passive continental margin sedimentary rocks of the North American Craton Margin. The deposits exhibit characteristics similar to Southeast Missouri Pb-Zn deposits in the Robb Lake metallogenic belt of Southeast Missouri Pb-Zn deposits (described herein), and to the Gataga metallogenic belt of SEDEX deposit (described herein). Sulphur isotope analyses exhibit heavy values for barite sulfur in all three metallogenic belts (K.M. Dawson, unpublished data, 1995). These data and a similar geologic setting suggest a genetic relation between the two deposit types and three metallogenic belts. A similar rifting origin is interpreted for all three metallogenic belts. The rifting is interpreted as occurring during the Late Devonian and Early Mississippian rifting event when the Yukon-Tanana and Kootenay metamorphosed continental margin terranes separated from the North American Craton Margin (Nokleberg and others, 1994c, 1997c, 2000; Monger and Nokleberg, 1996). During the rifting, volcanism, plutonism, related hydrothermal activity, and sedimentary exhalations occurred in the North American Craton Margin and in the Yukon-Tanana and Kootenay terranes (Paradis and others, 1998).

Gataga Metallogenic Belt of Zn-Pb-Ag-Ba SEDEX Deposits (Belt GA) Northern British Columbia

The Gataga metallogenic belt of Zn-Pb-Ag-Ba SEDEX deposits (fig. 17; tables 3, 4) occurs in northeastern British Columbia. The deposits are hosted in basinal sedimentary strata of the Kechika Trough, a southeastern extension of Selwyn Basin (Fritz and others, 1991). The belt contains eight significant deposits and extends for 180 km southeastward from Driftpile Creek to Akie River. The deposits are localized in inferred euxinic sub-basins in a structurally controlled trough which was partly flanked by carbonate reefs (MacIntyre, 1982, 1998). The significant deposits are at Akie, Cirque (Stronsay), and Driftpile Creek (Saint, Roen; table 4) (Nokleberg and others 1997a, b, 1998). The deposits and host rocks are part of a sequence of Late Devonian (Famennian) turbiditic shale and cherty argillite of the Earn Group (Pigage, 1986; Paradis and others, 1998).

Cirque (Stronsay) Deposit

The Cirque (Stronsay) Zn-Pb-Ag-Ba SEDEX deposit (fig. 28), the largest in the Gataga belt, consists of stratiform, laminar banded, massive barite with pyrite, galena and sphalerite which occur in turbidite shale, chert, and cherty argillite of the Late Devonian Gunsteel Formation (Jefferson and others, 1983; Gorzynski, 1986). The host rocks are siliceous and contacts between sulfide bodies and sediments are sharp. The deposit forms a 1000 by 300 m tapering, wedge-shaped lens which is about 10 to 60 m thick. The Cirque and adjacent South Cirque deposits contain estimated reserves of 52.2 million tonnes grading 8% Zn, 2% Pb, and 47 g/t Ag (Mining Review, 1992).

Driftpile Creek SEDEX Zn-Pb-Ag-Ba Deposit.

The three sulfide bodies at the Driftpile SEDEX Zn-Pb-Ag-Ba deposit consist of stratiform pyrite, sphalerite, galena, and barite in siliceous black turbiditic shale of Famennian (Late Devonian) age (Paradis and others, 1998). The deposit has estimated reserves of 18.1 million tonnes grading 2.38% Zn+Pb (Insley, 1991; Paradis and others, 1995). The sulfide bodies occur in three stratigraphic levels in the Gunsteel Formation of the Earn Assemblage in different thrust-bounded panels. The host sedimentary rocks are interpreted as part of a Devonian-Mississippian clastic wedge.

Origin of and Tectonic Setting for Gataga Metallogenic Belt

The SEDEX Zn-Pb-Ag-Ba deposits of the Gataga metallogenic belt are interpreted as forming during deposition of basinal clastic rocks of the Earn Assemblage during the early to late Famennian over a time span of not more than 7 million years. This relatively brief episode occurred during or immediately after a period of continental-margin arc formation and subsequent rifting of the North American Craton Margin in the early Mississippian (Paradis and others, 1998). The rifting is interpreted to have influenced sedimentation and volcanism in the Yukon-Tanana and Kootenay terranes (Nokleberg and others, 1994c, 1997c;

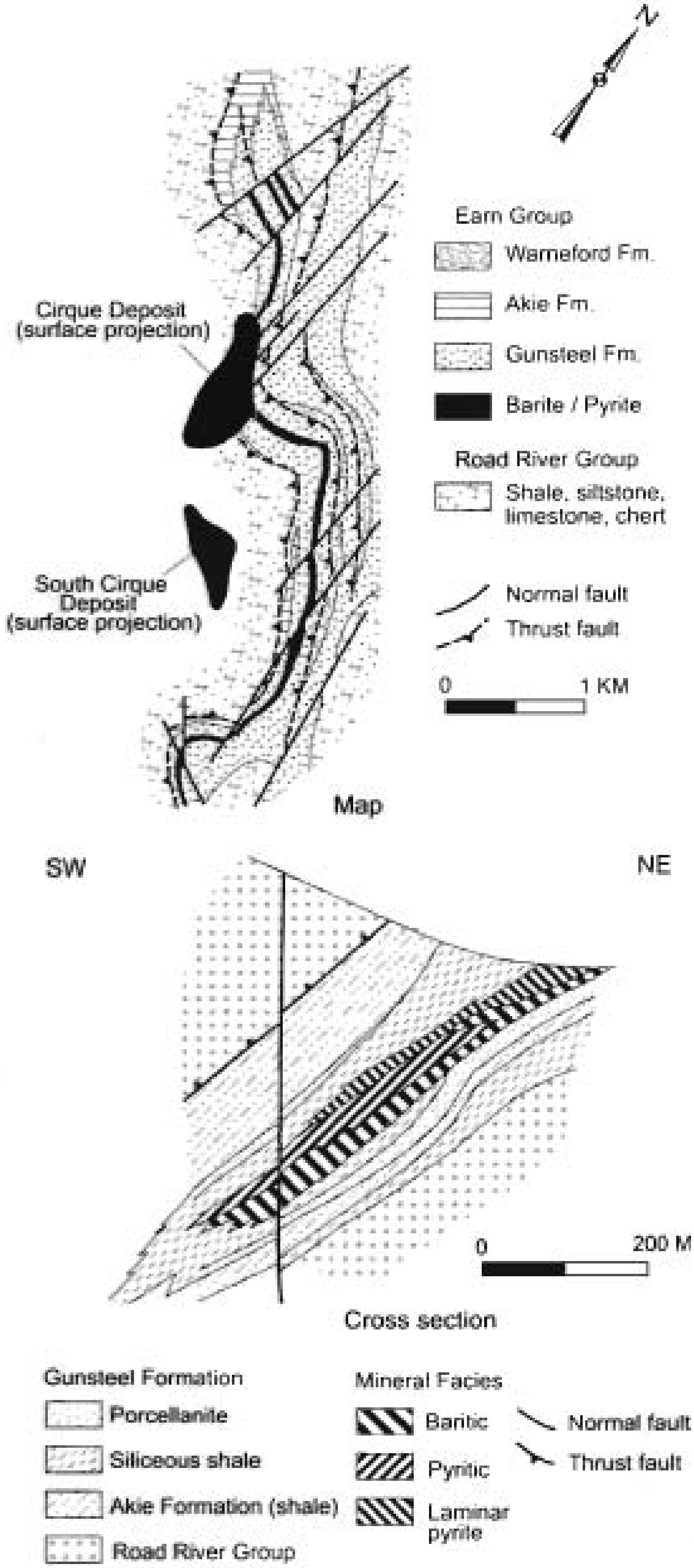


Figure 28. Cirque (Stronsay) sedimentary-exhalative Zn-Pb-Ag-Ba deposit, Gataga metallogenic belt, Canadian Cordillera. Schematic map and cross section. Adapted from Jefferson and others (1983).

Monger and Nokleberg, 1996; Nokleberg and others, 2000). The SEDEX deposits of the Gataga metallogenic belt are interpreted as forming during a relatively brief period immediately after rifting (Paradis and others, 1998; this study). However, other metallogenic belts containing Devonian-Mississippian SEDEX deposits are interpreted as forming over a longer age range, from Frasnian (early Late Devonian) at Macmillan Pass to Tournasian (Early Mississippian) in the Cassiar terrane.

Robb Lake Metallogenic Belt of Southeast Missouri Zn-Pb Deposits (Belt RL) Northern British Columbia

The Robb Lake metallogenic belt of Southeast Missouri Zn-Pb deposits occurs in northern British Columbia (fig. 17; tables 3. 4) (Nokleberg and others, 1997b, 1998; Nelson and others, 2002) and is hosted in the Proterozoic to Devonian passive continental units of the Rocky Mountains which constitute part of North American Craton Margin. The Southeast Missouri Pb-Zn deposits in the Robb Lake metallogenic belt occur in secondary breccias of either solution or tectonic origin in folded dolostones mainly of the Silurian and Devonian Muncho-McConnel Formation (Taylor and others, 1975; Nelson and othes, 2002). Occurrences also are located in the underlying Silurian Wokkpash and overlying Devonian Stone,Dunedin, Pine Point, and Slave Point Formations (Macqueen and Thompson, 1978; Nelson and others, 1999; Paradis and others, 1999). The significant deposit is at Robb Lake.

Robb Lake Southeast Missouri Zn-Pb Deposits

The Robb Lake deposit consists of sphalerite, galena and pyrite which occur primarily in tabular and lenticular zones parallel to bedding in dolomite collapse breccias of the Silurian and Devonian Muncho-McConnel Formation (EMR Canada, 1989; Dawson and others, 1991; Mining Review, 1992; Nelson and others, 2002). The deposit occurs on the west limb and crest of a large south plunging anticline. The deposit occurs in an 8 km^2 area, and consists of a series of interconnected, bedding-parallel and crosscutting breccia bodies with a matrix of dolomite, sphalerite, galena, pyrite, quartz, calcite, and pyrobitumen, and peripheral veins and stockwork. (Nelson and others, 2002). Estimated reserves are 7.1 million tonnes grading 4.7% Zn and 1.5% Pb (Mining Review, summer, 2000). A significantly larger, but less defined resource for the district and belt is an estimated 20.1 million tonnes grading 5.1% combined Pb and Zn (Dawson and others, 1991).

Origin of and Tectonic Controls for Robb Lake Metallogenic Belt

The southern part of the Robb Lake metallogenic belt occurs along a Devonian carbonate facies front in shales of the Besa River Formation to the west for 250 km, extending from Mount Burden on the south to the CTV and DODO deposits near Tuchodi Lakes on the north. The stratigraphic setting for these occurrences, that consists of a carbonate front adjacent to the major Great Slave Lake basin, is interpreted as analogous to that at Pine Point (Nelson, 1991). Some occurrences in the northern part of the Robb Lake metallogenic belt contains fluorite, barite, and pyrobitumen and are poor in sphalerite, galena, and pyrite. This feature suggests continuity with the southern end of the Liard metallogenic belt of Southeast Missouri Ba-F deposits which occurs in similar Devonian host rocks (Nelson and others, 2002). The timing of mineralization is poorly constrained, but is interpreted as pre-early Tertiary (pre-Laramide) on the basis of rotated geopetal structures (Manns, 1981) or as Devonian or Missippian on the basis of isotopic studies (Nelson and others, 2002).

The Robb Lake metallogenic belt exhibits characteristics similar to the Liard metallogenic belt of Southeast Missouri(?) Ba-F deposits (described above), and to the Gataga Lake metallogenic belt of SEDEX deposit (described above). Sulphur isotope analyses exhibit heavy values for barite in all three metallogenic belts (K.M. Dawson, unpublished data, 1995). These data and a similar geologic setting suggest a genetic relation between the two deposit types and three metallogenic belts. A similar rifting origin is interpreted for all three metallogenic belts. A major period of Late Devonian and Early Mississippian rifting along the North American Craton Margin is interpreted with rifting away of the Yukon-Tanana and Kootenay continental margin terranes and formation of the Robb Lake and coeval metallogenic belts (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996; Nokleberg and others, 2000). Nelson and others (2002) propose a somewhat contrasting interpretation of back-arc and intra-arc spreading, and exhalative activity for the genesis of the Robb Lake and related, coeval metallogenic belts. This back-arc and intra-arc spreading would be coeval with the slightly older Kootenary arc as interpreted by Nokleberg and others (2000).

Ingenika Metallogenic Belt of Southeast Missouri Zn-Pb-Ag-Ba Deposits, and Manto Zn-Pb-Ag Deposits (Belt IN) Northern British Columbia

The Ingenika metallogenic belt of Southeast Missouri Zn-Pb-Ag-Ba deposits and manto Zn-Pb-Ag deposits occurs in central British Columbia. The belt is hosted in Late Proterozoic to Devonian carbonate-dominated strata of the proximal pericratonic Cassiar terrane (fig. 17; tables 2, 3) (Nokleberg and others, 1997b, 1998). The significant deposits are in the Wasi Lake area at Susie, Beveley, and Regent.

Westlake Area (Susie, Beveley, Regent) Southeast Missouri Zn-Pb-Ag-Ba Deposits

The Susie, Beveley and Regent Southeast Missouri Zn-Pb-Ag-Ba deposits consist of sphalerite, galena and barite in four zones of vein and breccia-filling which are hosted in Late Proterozoic to Devonian platformal dolostones (EMR Canada, 1989; Ferri and others, 1992). The deposits contain estimated resources of 2.82 million tonnes grading 2.24% Zn, 1.42% Pb, and 36.3 g/t Ag. The deposit age is interpreted as Cambrian to Devonian, similar to the host rocks. A series of probably early Tertiary foliated felsic dikes occur along the top of Bevely Mountain. The dikes range up to 200 m wide.

Origin of and Tectonic Setting for Ingenika Metallogenic Belt

The Southeast Missouri Zn-Pb-Ag-Ba deposits and Manto Zn-Pb-Ag deposits in the Ingenika metallogenic belt possess an ore mineral assemblage and morphology characteristic of manto replacement (Nelson, 1991). The deposits in the belt are interpreted as forming during deposition of metal from low temperature brines which may have originated within an adjacent shale basin. The Ingenika metallogenic belt is herein interpreted as a displaced part of the Cathedral metallogenic belt of Southeast Missouri Zn-Pb-Ag deposits (Dawson, 1996a; Nokleberg and others, 1997b, 1998) which occurs mainly in the western margin of the North American Craton Margin. Rock sequences in the Cassiar terrane are similar to those in the western North American Craton Margin to the south, thereby suggesting a dextral, northward displacement of Cassiar terrane about 700 km along the Tintina-Rocky Mountain Trench fault system in the Late Cretaceous and early Tertiary, as proposed by Gabrielse (1985). Restoration of this displacement would juxtapose the Ingenika and Cathedral metallogenic belts of Southeast Missouri Pb-Zn deposits.

Cathedral Metallogenic Belt of Southeast Missouri Zn-Pb-Ag Deposits Southern British Columbia (Belt CA)

The Cathedral metallogenic belt of Southeast Missouri Zn-Pb-Ag deposits occurs in southern British Columbia (fig. 17; tables 2, 3) (Nokleberg and others, 1997b, 1998). The metallogenic belt is hosted in the Middle Cambrian Cathedral and Jubilee Formations which contain dominantly carbonate rocks which are part of a shallow-water, carbonate-clastic shelf which was deposited along the passive continental margin of the North American Craton Margin. The deposits in the Cathedral metallogenic belt contain the only Southeast Missouri Pb-Zn deposits in the Canadian Cordillera with significant production. The significant deposit is at Monarch (Kicking Horse).

Monarch (Kicking Horse) Southeast Missouri Zn- Pb Deposit

The Monarch Southeast Missouri Zn-Pb-Ag deposit extends along strike for of over 1,370 m in folded, brecciated and dolomitized limestone of the Cathedral Formation (Høy, 1982; MINFILE, 2002). The deposit consists of argentiferous galena, sphalerite, and pyrite which occur as fillings in north-south striking, vertical fissures along the east limb of an anticline. Combined production and reserves are 820,000 tonnes grading 5.63% Pb, 8.85% Zn, 31 g/t Ag. The deposit age is interpreted as Middle Cambrian. Minor similar occurrences are at Hawk Creek, Steamboat and Shag, to the southeast of the Monarch (Kicking Horse) deposit.

Origin of and Tectonic Controls for Cathedral Metallogenic Belt

The age of mineralization for the Cathedral metallogenic belt is not known precisely, and the genesis of Southeast Missouri-type deposits is debatable. Faults, breccias and other open spaces in the host shelf limestone are filled by an assemblage of sulfide minerals and calcite-dolomite-fluorite gangue. The ore metals probably were transported and deposited by low temperature brines which may have originated within the adjacent shale basin. The Cathedral metallogenic belt is correlated with the Devonianl(?) Ingenika metallogenic belt in central British Columbia, described above. This relation suggests dextral, northward displacement of about 700 km along the Tintina fault system (Gabrielse (1985).

Southern Rocky Mountains Metallogenic Belt of Stratabound Barite-Magnesite-Gypsum Deposits (Belt SRM) Southern British Columbia

The Southern Rocky Mountains metallogenic belt of stratabound barite-magnesite-gypsum deposits (fig. 17; tables 3, 4) occurs in southeastern British Columbia and is hosted in passive continental margin sedimentary rocks of the North American Craton Margin. The significant deposits are at Brisco, Forgetmenot Pass, Kootenay River Gypsum, Lussier River (United Gypsum), Marysville, Mount Brussilof, Parson, and Windermere Creek (Western Gypsum) (table 4) (Nokleberg and others 1997a, b, 1998). Most of the deposits range in age from Cambrian to Devonian; a few formed in the Triassic (Nokleberg and others, 1997a, b). Most of the magnesite and barite deposits in the belt are hosted primarily in Cambrian carbonate units. In southeastern British Columbia, the belt contains a major group of gypsum mines which are hosted in Devonian strata. Also occurring in the belt are local magnesite, and Zn-Pb deposits, as at Kicking Horse.

Windermere Creek (Western Gypsum) Chemical-Sedimentary Gypsum Deposit

The Windermere Creek (Western Gypsum) chemical-sedimentary gypsum deposit consists of gypsum and anhydrite which underlie basal carbonate strata of the Devonian Burnais Formation (British Columbia Department of Mines and Petroleum Resources, 1991; MINFILE, 2002). The deposit and related occurrences form a belt which extends 80 km from Windermere Creek southeastward to Kootenay River and Lussier River. Estimated reserves range from 7 to 12 million tonnes of ore grading 90% gypsum. About 6.8 million tonnes of ore has been produced at four open-pit operations. A synsedimentary evaporite origin is interpreted for the deposits and for gypsum in concordant beds in dolostone of the Late Triassic Whitehorse Formation at Forgetmenot Pass.

Marysville and Mount Brussilof (Baymag) Chemical–Sedimentary Magnesite Deposits

These chemical-sedimentary magnesite deposits consist of conformable, interbedded magnesite which is hosted within quartzites of the upper 100 m of the Early Cambrian Cranbrook Formation (Grant, 1987; Simandl and Hancock, 1999; MINFILE, 2002). The thickest beds range up to approximately 15 meters thick and are exposed over a strike length of 5.5 km. The average grade is 40 to 45% MgO. Chemical-sedimentary magnesite forms extensive replacements of carbonates of the Middle Cambrian Cathedral Formation at the Mount Brussilof (Baymag) deposit (Grant, 1987; Simandl and Hancock, 1991; MINFILE, 2002). Estimated reserves are 40.7 million tonnes grading 92.4% to 95% MgO.

Parson and Brisco Barite Vein and Gypsum Deposits

The Parson barite vein deposit consists of barite and lesser gypsum in vein and breccia fillings in Early Cambrian quartzite which is underlain by dolostone and shale (Leitch, 1991; MINFILE, 2002). The mine at Parson produced 75,000 tonnes of barite at unspecified grade from two parallel veins between 1957 and 1988. The Brisco vein and breccia deposit occurs in a breccia zone in Ordovician dolostone (Reesor, 1973; MINFILE, 2002). Between 1947 and 1973 the mine at the deposit produced 140,000 tonnes grading 98% barite. In both cases, early Paleozoic replacement is interpreted.

Origin of and Tectonic Setting for Southern Rocky Mountains Metallogenic Belt

The Southern Rocky Mountains metallogenic belt contains a diverse age group of large, stratabound and stratiform deposits of gypsum-anhydrite, barite, and magnesite. From oldest to youngest, the ages and modes of formations of the significant deposits are: (1) early Paleozoic replacement for formation of Parson Ba vein deposit; (2) Cambrian synsedimentary deposition of stratiform Marysville chemical-sedimentary magnesite deposit; (3) Middle Cambrian replacement for formation of Mount Brussilof chemical-sedimentary magnesite deposit; (4) Ordovician replacement for formation of Brisco Ba vein deposit; and (5) Devonian synsedimentary deposition of stratiform Windermere Creek chemical-sedimentary gypsum deposit. A few deposits are also interpreted as forming in either the late Paleozoic or Triassic (Nokleberg and others, 1997a, b). From this short list, at least two major origins exist, either stratiform evaporate-related deposits, or replacement vein deposits which formed over a long geologic history. With further study, the Southern Rocky Mountains metallogenic belt may be divided into several metallogenic belts which formed during several tectonic events which affected the passive continental margin sedimentary rocks of the North American Craton Margin.

Mississippian Metallogenic Belts (360 to 320 Ma; Figures 16, 17)

Overview

The Mississippian metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 16 and 17. The major belt was the Northwestern Brooks Range (NBR) belt of SEDEX Zn-Pb and bedded barite deposits which is hosted in the Arctic Alaska superterrane. This belt is interpreted as forming during Mississippian-Pennsylvanian back-arc spreading along North American Craton Margin. Continuing on from the Middle and Late Devonian were the Berezovka River (BE), Selennyakh River (SEL), Sette-Daban (SD), Urultun and Sudar Rivers (URS), Kedon (KE), Yarkhodon (YR), Northern Cordillera (NCO), Macmillan Pass (MP), Finlayson Lake (FL), and Gataga (GA) metallogenic belts. In the below descriptions of metallogenic belts, a few the noteable or significant lode deposits (table 4) are described for each belt.

Metallogenic-Tectonic Model for Mississippian (360 to 320 Ma; Figure 29)

During the Mississippian (360 to 320 Ma), the major metallogenic-tectonic events were (table 3): (1) separation of North Asian and North American Cratons and Cratons Margins along a series of oblique-sinistral rifts; (2) ending of rifting of fragments from cratons and their margins and formation of associated metallogenic belts; (3) continuation of the Sicker arc and associated subduction in the Wrangellia superterrane. Sedimentation continued along the North Asian and North American Craton Margins.

Specific Events for Mississippian

(1) From the late Devonian and to the Early Mississippian, rifting occurred along the eastern margin of the North Asian Craton Margin (NSV, KN). This event formed the Kotelnyi (KT), Omulevka (OV), Prikolyma (PR), Nixon Fork-Dillinger-Mystic (NX, DL, MY), Viliga (VL), and Zolotogorskiy (ZL) passive continental-margin terranes, the Avekova (AK), Kilbuck-Idono (KI), Okhotsk (OK), and Omolon (OM) cratonal terranes, and the Beryozovka (BE), Oloy (OL), and Yarakvaam (YA) terranes. Before the rifting, these terranes were parts of either the North Asian Craton (NSC), the North Asian Craton Margin (NSV), or the Devonian continental-margin arc which formed along the margins of the North American and North Asian Craton Margins (fig. 29). The newly-created terranes remained into the Angayucham Ocean. Derived from the North Asian Craton (NSC) and Craton Margin (NSV) were the Kotelnyi (KT), Omulevka (OV), Prikolyma (PR), Nixon Fork-Dillinger-Mystic (NX, DL, MY), Viliga (VL), and Zolotogorskiy (ZL) passive continental-margin terranes, the Avekova (AK), Kilbuck-Idono (KI), Okhotsk (OK), and Omolon (OM) cratonal terranes. Derived from the Devonian continental-margin arc which formed along the margins of the North Asian Craton Margin were the Beryozovka (BE), Oloy (OL), and Yarakvaam (YA) terranes (fig. 29). Derived from the North American Craton Margin (NAM) were the Kootenay (KO) and Yukon-Tanana (YT) passive continental-margin terranes. Accompanying the rifting was formation of the Northwestern Berezovka River (BE), Brooks Range (NBR), Dempster (DE), Finlayson Lake (FL), Gataga (GA), Northern Cordillera (NCO), Macmillan Pass (MP), older part of Mystic (MY), Selennyakh River (SEL), Sette-Daban (SD), Southern Rocky Mountain (SRM), Tommot River (TO), and Urultun and Sudar Rivers (URS) metallogenic belts which all contain massive sulfide, carbonatite-related Nb, Ta, and REE, and related deposits.

(2) Movement along a series of oblique-sinistral rifts resulted in the separation of North Asian and North American Cratons and Cratons Margins.

(3) The Kedon continental margin arc and associated subduction zone continued activity along the margin of the North Asian Craton and Craton Margin (NSC, NSV) until about the late Early Mississippian. Associated with the arc was subduction of the older part of the Galam (GL) accretionary wedge terrane. Remnants of the arc are preserved in the in part of the North Asian Craton and Craton Margin (NSC, NSV, KN (2) units which overlie parts of the Okhotsk (OK), Akekova (AK), Omolon (OM) cratonal terranes; (3) the Oloy (OL) and Yarakvaam (YA) island-arc terranes; and (4) the Beryozovka (BE) turbidite-basin terrane.

(4) The Sicker island arc, which formed in the Devonian along most of the length of the Wrangellia superterrane (WRA) ceased activity. Insufficient data exist to ascertain the relative positions of the Wrangellia superterrane.

Metallogenic Belt Formed During Mississippian-Pennsylvanian Back-Arc Spreading Along North American Craton Margin

Northwestern Brooks Range Metallogenic Belt of SEDEX Zn-Pb, Bedded Barite, Kuroko Massive Sulfide, and Sulfide Vein Deposits (Belt NBR) Northwestern Alaska

The major Northwestern Brooks Range metallogenic belt of large SEDEX Zn-Pb-Ag (SEDEX), kuroko massive sulfide, bedded barite, and sulfide vein deposits (fig. 17; tables 3, 4) occurs in northwestern Alaska. The metallogenic belt is hosted in the Kagvik sequence in the Endicott Mountains passive continental margin terrane of the Arctic Alaska superterrane (Nokleberg and others, 1994c, 1997c). The belt extends along strike for more than 200 km. Locally associated with the SEDEX deposits are vein sulfide deposits. The larger SEDEX Zn-Pb-Ag deposits are at Lik and the Red Dog Creek deposit, a world-class mine of zinc and lead (Schmidt, 1997a), and the Drenchwater Creek kuroko-massive sulfide deposit (Nokleberg and Winkler, 1982; Lange and others, 1985). Other deposits in the belt are the Hannum Creek metamorphosed SEDEX Zn-Pb? deposit, the Omar Kipushi Cu-Pb-Zn deposit, the Frost, Story Creek, and Whoopee Creek Cu-Zn-Pb-Ba sulfide vein deposits, and the Nimiuktuk bedded barite deposit (table 4) (Nokleberg and others 1997a, b, 1998).

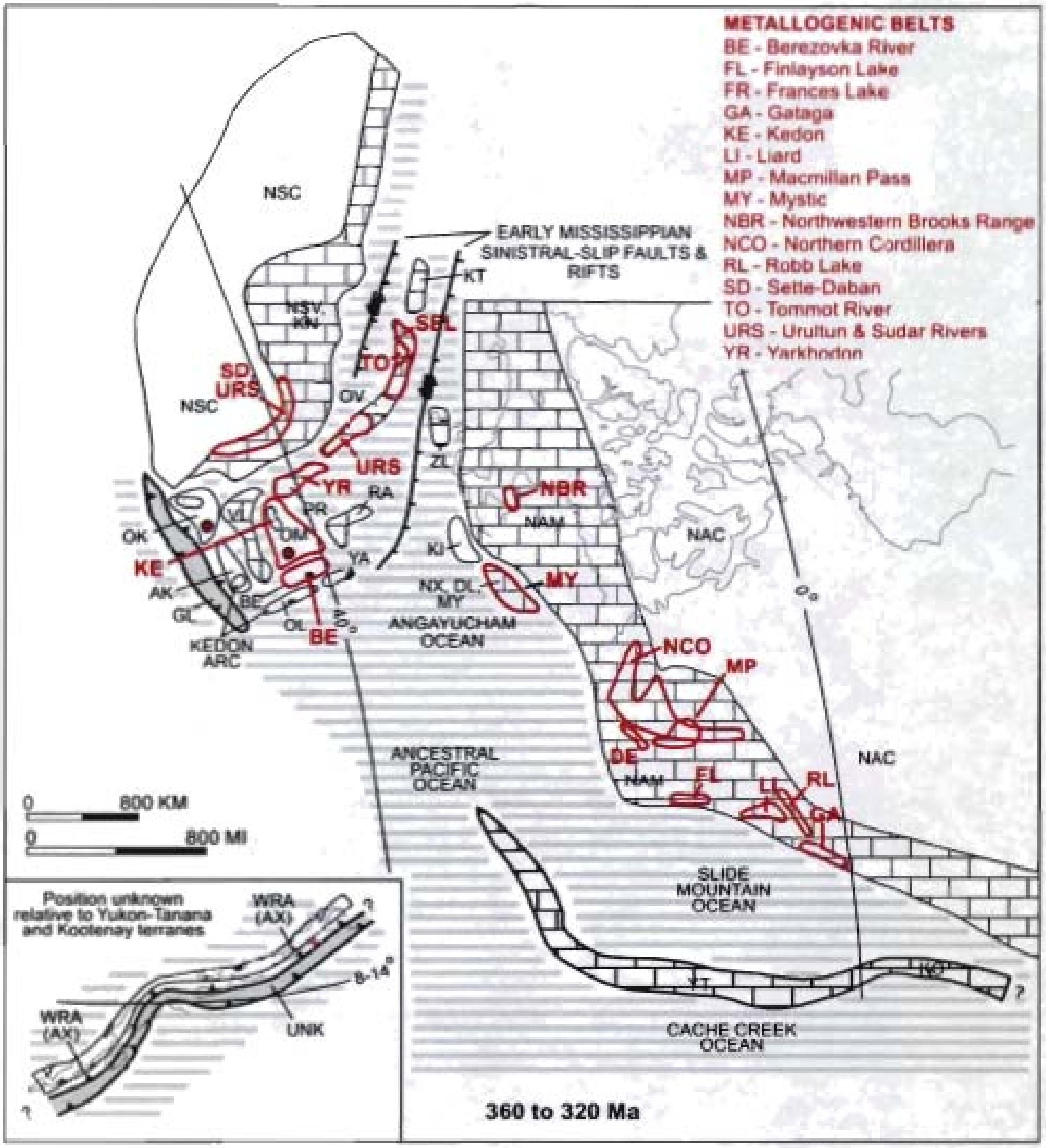


Figure 29. Mississippian (360 to 320 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

Red Dog Creek SEDEX Zn-Pb Deposit

The Red Dog Creek SEDEX Zn-Pb-Ag deposit (fig. 39) (Tailleur, 1970; Plahuta, 1978; Booth, 1983; Joseph T. Plahuta, L.E. Young, J.S. Modene, and D.W. Moore, written commun., 1984; Lange and others, 1985; Moore and others, 1986; Schmidt, 1997a; Schmidt and Zierenberg, 1988; Bundtzen and others, 1996) consists of disseminated and massive sphalerite, galena, pyrite, and barite in Mississippian and Pennsylvanian shale, chert, and silica exhalite of the Kuna Formation. The deposit is 1,600 m long and up to 150 m thick and occurs near the base of the Kuna Formation. Barite-rich lenses, up to 50 m thick locally cap the deposit. The sulfide minerals occur as: disseminated sulfides in organic-rich siliceous shale; coarse-grained sulfide veins; fine-grained, fragmental-textured to indistinctly bedded sulfides; and silica exhalite lenses. Minor hydrothermal alteration consists of silicification and decarbonatization of shale. A small, propyliticaliy altered diorite plug or hydrothermally altered pyroxene andesite flow occurs at north end of deposit. Prior to mining, which began in 1990, the Main deposit was estimated to contain 85 million tonnes grading 17.1% Zn, 5% Pb, and 82 g/t Ag. By the end of 1999, the four SEDEX deposits at Red Dog (Main, Aggaluk, Hill Top, Anarrag) contained an estimated 142.3 million tonnes grading 15.8% Zn, 4.3% Pb, and 83 g/t Ag (Swainbank and Szumigla, 2000) The host rocks and deposit are extensively structurally imbricated along many subhorizontal thrust faults. Graywacke of the Cretaceous Okpikruak Formation structurally underlies deposit.

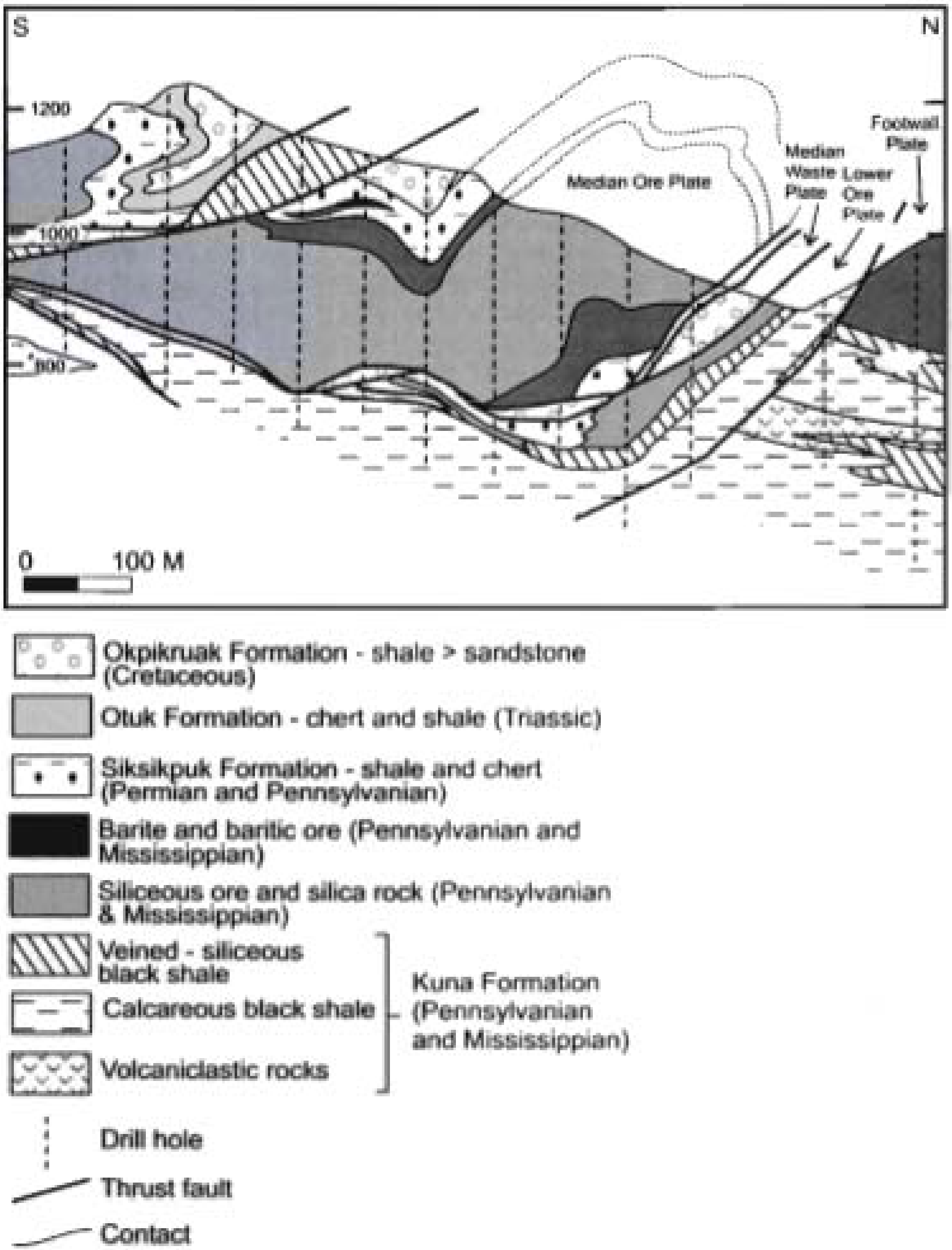


Figure 30. Red Dog Creek sedimentary exhalative Zn-Pb-barite deposit, Northwestern Brooks Range metallogenic belt, Northern Alaska. Schematic geologic cross section through the Main deposit showing the structural interpretation of thrust plates and the overturned fold related to thrust faults. Section along N 40 E. Adapted from Schmidt (1997).

Drenchwater Creek SEDEX Zn-Pb and (or) Kuroko Massive Sulfide Deposit

The Drenchwater Creek SEDEX Zn-Pb and (or) kuroko massive sulfide deposit consists of disseminated and massive sphalerite, galena, pyrite, and barite in Mississippian shale, chert, tuff, and quartz-exhalite of the Kagvik sequence (Nokleberg and Winkler, 1982; Lange and others, 1985). Volcanic sandstone and keratophyre are locally abundant. The sulfides occur as disseminations in chert, disseminations and massive aggregates in quartz-exhalite, and as sparse, remobilized disseminations in sulfide-quartz veins crosscutting cleavage in shale and chert. Locally extensive hydrothermal alteration of chert and shale is accompanied by extensive replacement by kaolinite, montmorillonite, sericite, prehnite, fluorite, actinolite, chlorite, calcite, and quartz. Grab samples contain more than 1% Zn, 2% Pb, and 150 g/t Ag. The deposit ranges up to 1,800 m long and up to 50 m thick. The host rocks and deposit are extensively faulted and structurally imbricated by many thrust faults which dip moderately south

Origin of and Tectonic Controls for Northwestern Brooks Range Metallogenic Belt

The Northwestern Brooks Range metallogenic belt of Zn-Pb-Ag SEDEX, bedded barite, kuroko massive sulfide, and vein deposits is hosted 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 keratophyre, named the Kuna Formation by Mull and others (1982). The Kuna Formation is the basal unit of the Kagvik sequence of Churkin and others (1979) and the Kagvik terrane of Jones and others (1987), and part of the DeLong Mountains terrane of the Arctic Alaska superterrane of Moore and others (1994). This unit, and younger, late Paleozoic and early Mesozoic 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; Schmidt, 1997a). Herein, the SEDEX Zn-Pb-Ag, bedded barite, and kuroko volcanogenic massive sulfide deposits in the Northwestern Brooks Range belt are interpreted as forming during a short-lived period of Late Mississippian and Early Pennsylvanian rifting or back-arc spreading that was possibly associated with a short-lived continental-margin arc.

South of the main east-west-trending belt of SEDEX Zn-Pb-Ag and bedded barite deposits are a group of sulfide vein deposits at Story Creek, Whoopee Creek, and Frost, and a Kipushi Cu-Pb-Zn deposit at Omar. The vein deposits generally consist of sphalerite and galena in association with quartz and minor carbonate gangue in veins and fractures (Ellersieck and others, 1982; Mayfield and others, 1983; Schmidt, 1997b). The vein deposits occur in the middle Paleozoic continental-margin sedimentary rocks of the Arctic Alaska superterrane. The veins and fractures occur in 1.5-3-km long linear zones which cross tightly folded strata, indicating an epigenetic origin (Schmidt, 1997b). No tonnage and grade data are available. Insufficient data preclude assignment of these deposits to a specific mineral deposit type. The vein deposits are interpreted by some workers as the possible feeders to the Zn-Pb SEDEX deposits and as having possibly formed during dewatering of the same source basin (Schmidt, 1993). However, this interpretation is contradicted by the field relation in which the vein deposits cross tightly-folded strata, indicating formation of veins after Cretaceous deformation of the strata.

Pennsylvanian Metallogenic Belts (320 to 286 Ma; Figures 31, 32)

Overview

The major Pennsylvanian metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 29 and 30. The major belts are as follows. (1) In the Russian Southeast, the Laoelin-Grodekovsk (LG) belt, which contains granitic-magmatism-related deposits, is hosted in the Laoelin-Grodekovsk island-arc terrane. This belt is interpreted as forming during subduction-related granitic plutonism that formed the Laoelin-Grodekovsk island arc, part of Khanka superterrane. (2) In the Russian Northeast, the Aluchin (AC) and Ust-Belaya (UB) belts contain podiform Cr deposits and are hosted mainly in fragments of ophiolites that are preserved in the Aluchin, and Penzhina-Anadyr subduction-zone terranes, respectively. The Aluchin belt is interpreted as forming in Oceanic lithosphere preserved in Aluchin subuction zone that was tectonically linked to Alazeya island arc. The Ust-Belaya belt is interpreted as forming in Oceanic lithosphere preserved in Penzhina Anadyr subuction zone that was tectonically linked to Koni-Murgal continental margin and island arc. (3) In northwestern Alaska, the Northwestern Brooks Range metallogenic belt, which contains SEDEX Zn-Pb-Ag., kuroko volcanogenic massive sulfide, bedded barite, and sulfide vein deposits, continued to form. (4) In Southern Alaska, the Alaska Range-Wrangell Mountains (ARW) and Ketchikan (KK) belts, which contain granitic-magmatism-related deposits and kuroko massive sulfide deposits, are hosted in the Wrangellia superterrane, and are interpreted as forming in the short-lived Skolai island arc. In the below descriptions of metallogenic belts, a few of the noteable or signficant lode deposits (table 4) are described for each belt.

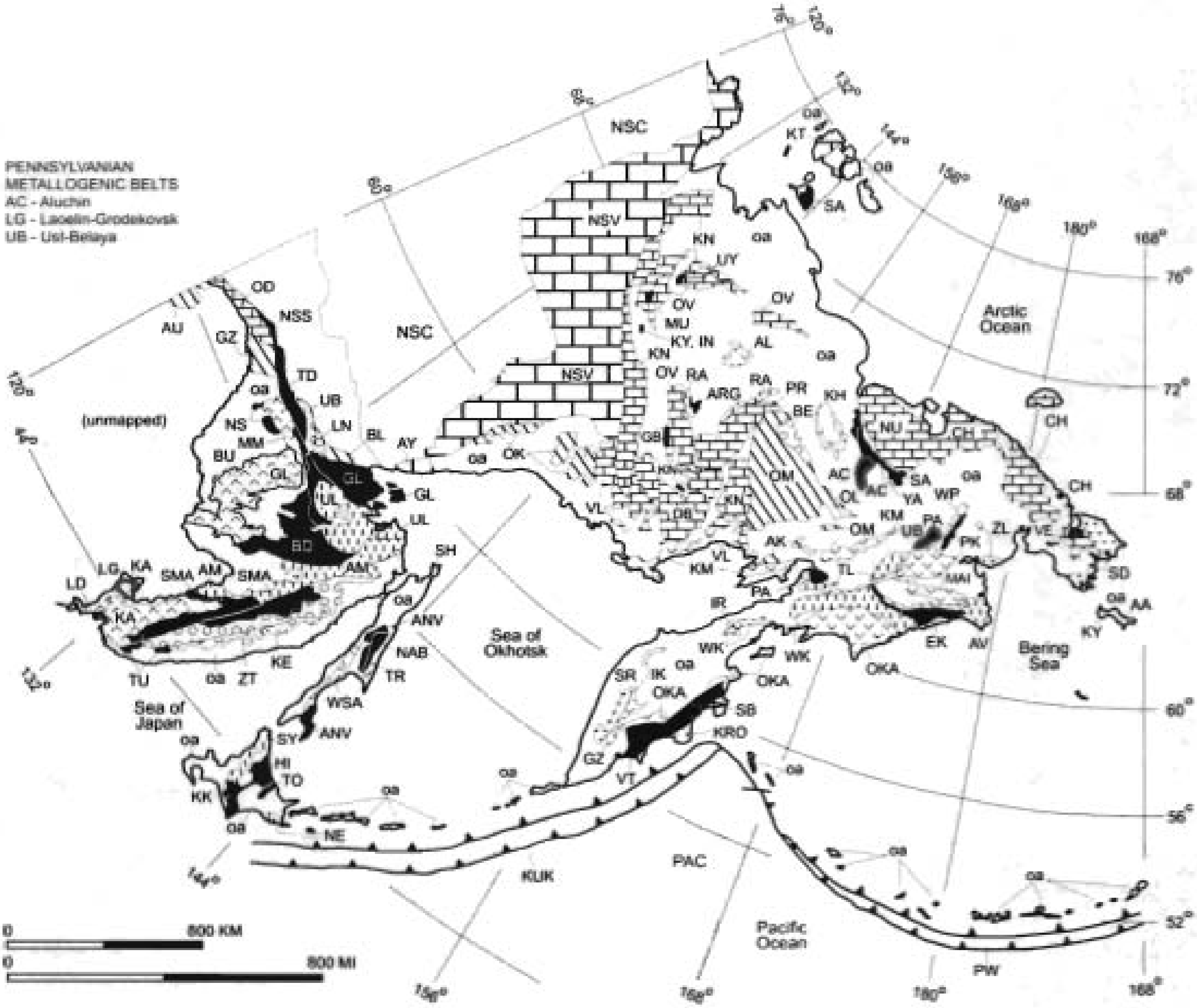


Figure 31. Generalized map of major Pennsylvanian metallogenic belts and terranes for Russian Far East, northern Japan, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 2 for explanation.

Metallogenic-Tectonic Model for Pennsylvanian (320 to 286 Ma; Figure 33)

During the Pennsylvanian (320 to 286 Ma), the major metallogenic-tectonic events were (table 3): (1) inception of the older parts of Stikinia-Quesnellia arc (Stikinia and Quesnellia terranes) and associated subduction zone in the Yukon-Tanana (YT) and Kootenay (KO) terranes in an area offshore of the North American Craton Margin (NAM); and (2) formation of the Skolai island arc and associated metallogenic belt, and associated subduction zone in the Wrangellia superterrane. Sedimentation continued along the passive continental margins of North Asia and North America. Out of the field of view of figure 33 was formation of the Laoelin-Grodekovsk (LG) metallogenic belt, which contains granitic-magmatism-related deposits and which formed in the Laoelin-Grodekovsk island-arc terrane.

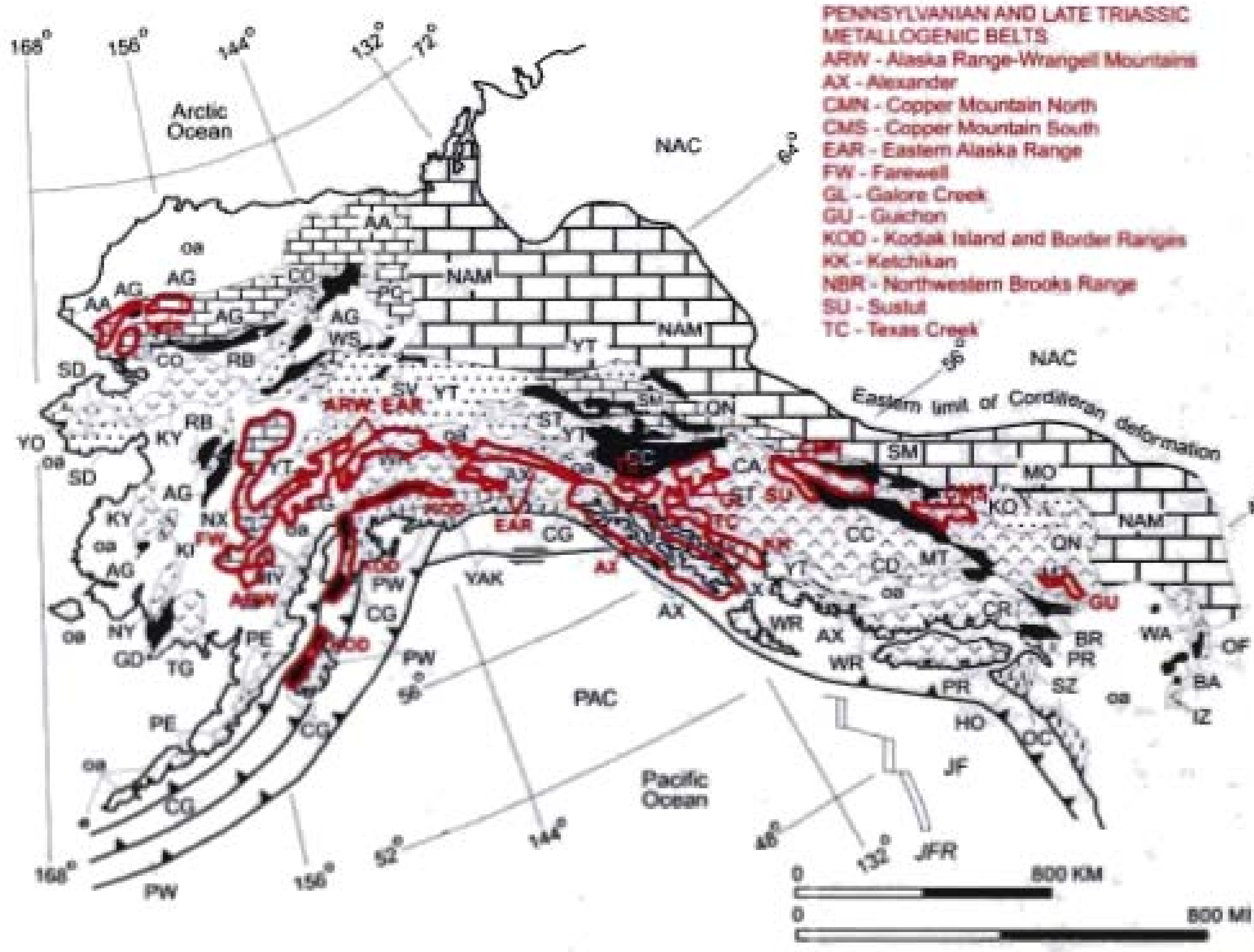


Figure 32. Generalized map of major Pennsylvanian and Late Triassic metallogenic belts and terranes for Alaska, Canadian Cordillera, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 3 for explanation.

Specific Events for Pennsylvanian

(1) Along the margin of the North Asian Craton (NSC), dextral-slip occurred along the Mongol-Okhotsk suture (*MO*), resulting in displacement of its southern margin relative to the Mongol-Okhotsk Ocean.

(2) Between the North Asian and North American Cratons, sporadic sea-floor spreading is interpreted as having enlarged the ancestral Pacific Ocean and formed the Oimyakon, Angayucham, and Goodnews Oceans. Forming during this event were the Aluchin (AC), and Ust-Belaya (UB) metallogenic belts which contain podiform Cr deposits and are hosted mainly in fragments of ophiolites which are now preserved in the Aluchin, and Penzhina-Anadyr, subduction-zone terranes. Fragments of the Oimyakon Ocean are preserved in the Debin and Garbyn'ya terranes (fig. 33). Fragments of the Angayucham and Goodnews Oceans are preserved in the Angayucham and Goodnews terranes, respectively (fig. 33).

Within the Angayucham Ocean were the Kilbuck-Idono cratonal terrane (KI), derived from the North Asian Craton (NSC), and the Nixon Fork-Dillinger-Mystic passive continental-margin terranes (NX, DL, MY), derived from the North Asian Craton Margin (NSV). During this time span, before accretion to the present North American continent, the Nixon Fork-Dillinger-Mystic terrane may have experienced several post-rifting events which formed additional units, such as the siliciclastic rocks of the Sheep Creek Formation and the Mt. Dall Conglomerate.

(3) The intraoceanic Omulevka Ridge, which separated the Oimyakon and ancestral Pacific Oceans, consisted of the Omulevka (OV), Prikolyma (PR), and Omolon (OM) terranes. These terranes were previously rifted from North Asian Craton and Craton Margin in the Early Mississippian. The Paleozoic Yarakvaam (YA), Oloy (OL), and the Alazeya (AL) island-arc terranes, together with the Beryozovka turbidite-basin terrane (BE), are interpreted as parts of an active island arc on an extension of the Omulevka Ridge.

(4) Along the margin of the Angayucham Ocean, between the North Asian and North American Cratons and Craton Margins, was the Taymyr Peninsula collage (TA; Vernovskiy and others (1998) which is interpreted as a series of Late

Proterozoic ophiolite, island-arc, and passive continental-margin terranes which were displaced along dextral-slip faults along the margin of the

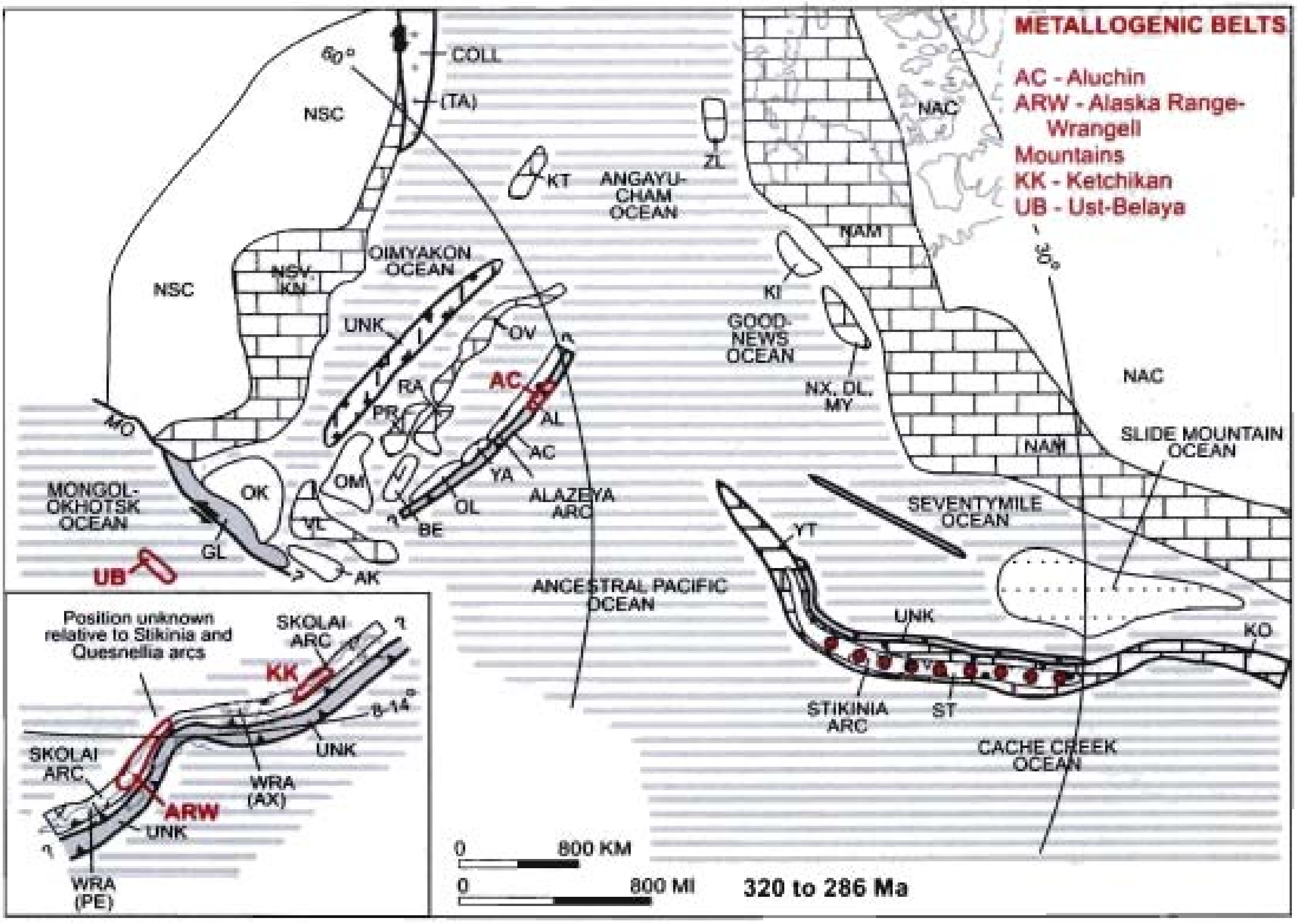


Figure 33. Pennsylvanian (320 to 286 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

North Asian Craton (NSC) and North Asian Craton Margin (NSV, KN) (Zonenshain and others, 1990; Vernikovsky and others, 1998).

(5) Fragments of the North American Craton Margin (NAM), including the Yukon-Tanana (YT) and Kootenay (KO) terranes, which formed offshore during Early Mississippian rifting, occurred offshore from the North American Craton Margin (NAM). Towards the North American Craton Margin were the Slide Mountain and Seventymile Oceans. An extensive but thin submarine fan was deposited in the Slide Mountain Ocean (Anvil Ocean of Templeman-Kluit, 1979) between the Yukon-Tanana (YT) and Kootenay (KO) continental-margin terranes and the North American Craton Margin (NAM).

(6) At an unknown location, the Skolai island arc was active along the length of the Wrangellia superterrane (WRA). Associated with the arc was a presumed (unknown) subduction zone (UNK). The Skolai arc deposits consist mainly of Early to Middle Pennsylvanian plutons and Pennsylvanian and Permian marine volcanic and volcaniclastic rocks that are interpreted as forming at high latitudes (Nokleberg and others, 1994b, 2000). Forming with the arc was the Alaska Range-Wrangell Mountains (ARW) metallogenic belt which contains granitic-magmatism-related deposits and the Ketchikan (KK) metallogenic belt which contains kuroko massive sulfide deposits. The basement for the Skolai arc may in part be the Alexander terrane which contains a fragment of an early and middle Paleozoic continental-margin arc (Nokleberg and others, 1994b). Insufficient data exist to ascertain the relative positions of the Wrangellia superterrane (WRA; and contained Skolai arc), and its associated subduction zone, with respect to the Stikinia and Quesnellia island-arc terranes and their associated subduction zones. Fauna in the Slana Spur and Eagle Creek (former Mankommen) Formations of the eastern Alaska Range indicate a high-latitude environment (Petocz, 1970).

(7) Subsequently in the Permian, the major part of the Stikinia-Quesnellia arc overlapped part of the Yukon-Tanana terrane after weak initiation of the arc in the Mississippian. This arc, defined by Permian granitic plutons in the Yukon-Tanana

terrane, and by the Stikine Assemblage in the Stikinia terrane, may have been tectonically linked to subduction of part of the Seventymile Ocean. Evidence in the Yukon Territory favors the Stikine part of the arc facing toward the North American Craton Margin (NAM; Monger and Nokleberg, 1996). Along strike, the extension of the arc occurs in the Harper Ranch Group of the Quesnellia (QN) island arc terrane. Part of the arc was probably linked tectonically to subduction of part of the Cache Creek Ocean (Monger and Nokleberg, 1996).

(8) Fauna of the Quesnellia and Stikinia terranes (QN and ST) are closest to those southwestern United States and northern Andean regions; the terranes probably formed along the continental margin at lower latitudes than their present positions. Estimates suggest which Stikinian fauna were located anywhere from near 0 to 8,000 km away from the craton (Belasky and Runnegar, 1994).

Metallogenic Belt Formed in Late Paleozoic Island Arc Terrane in Russian Southeast

Laoelin-Grodekovsk Metallogenic Belt of Porphyry Cu-Mo and Au-Ag Epithermal Vein Deposits (Belt LG) Southern Part of Russian Southeast

The Laoelin-Grodekovsk metallogenic belt of porphyry Cu-Mo and Au epithermal vein deposits (fig. 31; tables 3, 4) occurs in the late Paleozoic Laoelin-Grodekovsk island-arc terrane in the southern part of the southern Russia Far East. The porphyry Cu-Mo deposits and Au-Ag epithermal vein deposits occur in, or are associated with a thick Permian marine sequence of felsic and mafic volcanic rocks which may also be favorable for undiscovered kuroko massive sulfide deposits. Small lenses of sphalerite ore occur conformable to shales in this sequence. The principal deposit porphyry Cu-Mo deposit is at Baikal, and the significant Au-Ag epithermal vein deposit is at Komissarovskoe (table 4) (Nokleberg and others 1997a, b, 1998). The region and metallogenic belt is poorly exposed and poorly studied.

Baikal Porphyry Cu-Mo Prospect

The Baikal porphyry Cu-Mo prospect (Petrachenko and Petrachenko, 1985) consists of veinlets and disseminations along contacts of gabbro-diorite and gabbro-syenite, both within and adjacent to the intrusive rocks. The mineralization occurs over an area of 150-200 m^2 in hydrothermally altered biotite-K-feldspar rock which is surrounded in turn by propylitic epidote-chlorite alteration. The ore minerals are chalcopyrite, bornite, pyrite, and molybdenite. The hydrothermally altered area exhibits anomalous Au. The host rocks are metamorphosed Silurian and Devonian sedimentary and siliceous volcanic rocks, and Permian(?), subalkaline, gabbro-diorite, gabbro-syenite, and granite porphyry which intrude the sedimentary sequence. The gabbro-diorite highly alkaline. The gabbro-syenite and granite porphyry hosting the deposit are K-enriched. The deposit is small. Because the ore is highly oxidized, the Cu is content low (0.01%. Cu. Molybdenum grade is about 0.01%.

Komissarovskoe Au-Ag Epithermal Deposit

The Komissarovskoe Au-Ag epithermal deposit (A.N. Rodionov, written commun., 1991) consists of low-grade, short Au-Ag-pyrite veins which occur in dacite volcanic rocks, presumably part of a Permian volcanic sequence. The veins contain minor galena and sphalerite, occur in metasomatic sericite-biotite-quartz bodies in fracture zones, and are conformable to, and crosscut bedding. The epithermal deposits may be related to areas of higher carbon contents in thin-bedded siltstone and argillite. Associated Au placer deposits occur in adjacent parts of China. The deposit is small. Average grades are 1.92 g/t Au and 49-52 g/t Ag.

Origin of and Tectonic Controls for Laoelin-Grodekovsk Metallogenic Belt

The Laoelin-Grodekovsk metallogenic belt of porphyry Cu-Mo and Au-Ag epithermal vein deposits is hosted by the Laoelin-Grodekovsk island-arc terrane which consists chiefly of two units (Nokleberg and others, 1994c, 1997c). (1) A lower tectonic mélange unit is composed of fragments of Early Silurian granite-pebble-bearing conglomerate, sandstone, siliceous mudstone and lesser interbedded basalt, andesite, rhyolite, and tuff. The sedimentary are locally intensely deformed and metamorphosed to middle amphibolite facies. And (2) an upper unit is composed of Permian basalt, andesite, rhyolite, conglomerate, sandstone, mudstone, and shale and lesser interbedded limestone lenses which contain Late Permian Tethyan fusulinids. The structural thickness is about several thousand meters. The Permian rocks are intruded by zoned dunite-clinopyroxenite-gabbro intrusions which form Alaskan-Uralian zoned mafic-ultramafic plutons, and local tonalite and plagiogranite. The zoned dunite-clinopyroxenite-gabbro intrusions may be favorable for undiscovered zoned mafic-ultramafic Cr-PGE deposits (V.V. Ratkin, this study). The Permian igneous rocks that host Laoelin-Grodekovsk metallogenic belt are part of the younger Permian sequence of the Laoelin-Grodekovsk terrane that is interpreted a Permian island arc (Nokleberg and others, 2000).

Metallogenic Belts Formed In Late Paleozoic Oceanic Lithosphere Preserved in Subduction Zones Terranes in Russian Northeast

Aluchin Metallogenic Belt of Podiform Cr Deposits (Belt AC) Central Part of Russian Northeast

The Aluchin metallogenic belt of podiform Cr deposits (fig. 31; tables 3, 4) occurs in the Big Anui River basin in the central part of the Russian Northeast. The belt is hosted in the Aluchin ophiolite terrane of the Kolyma-Omolon superterrane (fig. 31) (Nokleberg and others, 1994c, 1997c). The podiform Cr deposits, as at Teleneut, are hosted by dunite and serpentinite, and occur in the north-eastern and southern portions of the metallogenic belt in a large, linear mass of dunite and harzburgite which extends for over 100 km (Nokleberg and others 1997a, b, 1998).

Teleneut Podiform Cr Deposit

The Teleneut podiform Cr deposit (Aksenova and others, 1970) occurs in serpentinite rocks at the southern end of the Aluchin alpine-type ultramafic body where ultramafic rocks crop out on the surface as a fault-bound lens which is 7 km long by 2.5 km wide with a north-south trend. The ultramafic rocks consist of serpentinite (70%) and subordinate little-altered dunite and pyroxenite. The Teleneut podiform Cr occurrence occurs in the central part of the lens which contains mostly serpentinite. The chromite occurrence 1500 m long and 700 m wide along a north-south trend. The occurrence contains rare disseminations and massive accumulations with up to 70% chromite. The structure is usually banded or lensoidal, or rarely massive. The main ore minerals are chromite, magnetite and spinel which are associated with Ni, Fe, and Cu sulfides, and pentlandite, millerite, bravoite, violarite, pyrrhotite and chalcopyrite. Sulfides occur both in high-chromite-ores and in low-chromite ores and listvenites. Sulfide grains usually occur between chromite grains and serpentinite-altered silicates and are xenomorphic.

Origin of and Tectonic Controls for Aluchin Metallogenic Belt

The ultramafic rocks hosting the deposits of the Aluchin metallogenic belt are part of a faulted succession of the Aluchin subduction-zone terrane (AC) which consists chiefly of (Lychagin and others, 1989; Byalobzhesky and others, 1990; Seslavinskiy and Ged'ko, 1990) of: (1) dismembered ophiolites of presumed middle Paleozoic age, including harzburgite, pyroxenite, dunite, lherzolite, gabbro, plagiogranite, a mafic dike suite, basalt, and local glaucophane schist; (2) tectonic lenses of Middle Carboniferous to Early Permian island-arc clastic-tuffaceous deposits, basalt, and andesitic basalt which are intruded by diorite and tonalite; and (3) unconformably overlying Late Triassic (Norian) shallow-marine volcanic and sedimentary rocks, and Early Jurassic clastic deposits which contain pebbles of the underlying diorite and tonalite. In the inner part of the Kolyma-Omolon superterrane, the subduction zone linked to the Alazeya arc can be traced beneath Cenozoic deposits along a horseshoe-like magnetic high (Parfenov, 1995c). The Aluchin subduction-zone terrane is interpreted as a small part of an elongate subduction zone which was tectonically linked to the mainly Late Triassic and Early Jurassic Alazeya island arc (Nokleberg and others, 2000).

Ust-Belaya Metallogenic Belt of Podiform Cr Deposits (Belt UB) Northeastern Part of Russian Northeast

The Ust-Belaya metallogenic belt of podiform Cr deposits (fig. 3; tables 3, 4) occurs in the Ust-Belaya dunite-harzburgite subterrane of the Penzhina Anadyr accretionary wedge-oceanic terrane in the northeastern part of the Russian Northeast (Nokleberg and others, 1994c, 1997a, b, c, 1998). The one significant deposit at Ust-Belaya consists of zones of closely spaced, banded chromite (10-30% chromite) which occur as lenses, schlieren, and vein-like bodies of disseminated and massive chromite (Silkin, 1983). The chromite occurs in layers up to 1,300 m long and 400 m wide in the dunite of the Ust-Belaya alpine-type ultramafic body. The chromite occurrences extend northward for 13 km along a belt more than 2 km wide. The chromite is of economic, low- and medium-Cr metallurgical grade (Silkin, 1983). Associated PGE placer deposits are dominated by Os, Ir, and Ru minerals which are typical of dunites and harzburgites, particularly in the Koryak Highlands (Dmitrenko and others, 1990).

Origin of and Tectonic Controls for Ust-Belaya Metallogenic Belt

The Ust-Belaya metallogenic belt is hosted in ophiolite which is a tectonic fragment in the Ust'belaya accretionary wedge or subduction zone subterrane which forms the northern part of the Penzhina-Anadyr' terrane (fig. 31). This Ust-Belaya subterrane consists mainly of a large early Paleozoic ophiolite with an areal extent exceeding 1,000 km^2. Extensive zones of chromite deposits are confined to dunites which occur together with peridotite, metagabbro, amphibolite, and gabbro. The subterrane consists of the following tectonic sheets which are distinguished by contrasting lithologies (Nokleberg and others, 1994c, 1997c). (1) The Otrozhnaya sheet is composed of an ophiolite which contains metamorphosed ultramafic rocks, gabbro, diabase, basalt, and volcanic breccia, and an overlying sequence of chert, calcareous sandstone, tuff, and limestone which yield Middle and Late Devonian and Early Carboniferous faunas. The Otrozhnaya sheet is intruded by diabase, plagiogranite, and diorite dikes which yield K-Ar ages of 180 to 304 Ma. (2) An unnamed sheet is composed of serpentinite mélange. (3) The Mavrina sheet is composed of shallow-marine sandstone and siltstone and interlayered conglomerate and limestone which yield a Middle Jurassic fauna. And (4) an uppermost sheet is composed of interlayered sandstone, siltstone, and mudstone which yield an Late Jurassic to Early Cretaceous fauna. The Penzhina-Anadyr' terrane is interpreted as accretionary wedge or subduction zone unit which contains fragments of oceanic lithosphere, now preserved as ophiolites. The Penzhina-Anadyr' subduction zone terrane is tectonically linked to the Late Jurassic part of the Kony-Murgal island-arc terrane (Nokleberg and others, 2000).

Metallogenic Belts Formed in Late Paleozoic Skolai Island Arc in Wrangellia Superterrane

Alaska Range-Wrangell Mountains Metallogenic Belt of Granitic Magmatism Deposits (Belt ARW) Central and Eastern-Southern Alaska

The Alaska Range-Wrangell Mountains metallogenic belt of granitic magmatism deposits (fig. 32; tables 3, 4) (mainly porphyry, polymetallic vein, and skarn deposits) occurs in the Alaska Range and the Nutzotin and Wrangell Mountains in central and eastern-southern Alaska (Nokleberg and others, 1995a). The metallogenic belt is hosted in the late Paleozoic part of the Wrangellia sequence of the Wrangellia island-arc terrane which contains late Paleozoic volcanic and granitoid rocks (Nokleberg and others, 1994c, 1997c). The significant deposits are the Rainy Creek Cu-Ag skarn deposit, and the Chistochina deposits, and smaller occurrences or prospects as the Rainbow Mountain and Slate Creek porphyry Cu deposits (table 4) (Nokleberg and others 1997a, b, 1998). Farther to the southeast in the Nutzotin and Wrangellia Mountains, similar small, subvolcanic intrusions occur in the Permian and Pennsylvanian Slana Spur, Hazen Creek, and Station Creek Formations, and in the Tetelna Volcanics (Richter, 1975; MacKevett, 1978).

Rainy Creek Cu-Ag Skarn District

The Rainy Creek Cu-Ag skarn deposit (Rose, 1966; Lange and others, 1981; Nokleberg and others, 1984, 1991) comprises a zone about 10 km long and up to 5 km wide which contains scattered garnet-pyroxene skarn bodies which have disseminated to small masses of chalcopyrite and bornite, minor sphalerite, galena, magnetite, secondary Cu-minerals, and sparse gold. The deposits occur in faulted lenses of marble of the Pennsylvanian and Permian Slana Spur Formation adjacent to late Paleozoic(?) metagabbro, metadiabase, and hypabyssal meta-andesite intrusive rocks. Local disseminated sulfides also occur in meta-andesite. The sulfide-bearing bodies and adjacent wall rocks are locally intensely faulted. Grab samples contain up to 5.6% Cu, 300 g/t Ag, 1.2 g/t Au, 0.07% Zn.

Chistochina District

The Chistochina porphyry Cu and polymetallic vein deposit (Richter, 1966; Rainier J. Newberry, written commun., 1985) contains several small areas containing galena, pyrite, chalcopyrite, tetrahedrite, and gold in quartz veins, small masses, and disseminations in margins of the Pennsylvanian and Permian Ahtell quartz diorite pluton and in adjacent volcanic and sedimentary rocks of the Pennsylvanian and Permian Slana Spur Formation. The quartz veins range up to 10 m wide, locally contain massive barite, calcite, and cerussite, and occur over an area about 5 km long and 3 km wide. The district also contains small Cu-Au and Pb-Zn skarns. Grab samples contain up to 20% Pb, 1.4% Cu, 21 g/t Ag, 1.4 g/t Au.

Origin of and Tectonic Controls for Alaska Range-Wrangell Mountains Metallogenic Belt

The Alaska Range-Wrangell Mountains metallogenic belt is hosted by granitoid plutons and associated volcanic rocks of the Pennsylvanian and Early Permian Skolai arc (Nokleberg and others, 1984, 1985; 1995a; Nokleberg and Lange, 1985, 1994d; Plafker and others, 1989). The Skolai arc forms a lithologically variable suite of volcanic and plutonic rocks which is discontinuously exposed in the Wrangellia and Alexander sequences of the Wrangellia supertermae which extends from eastern-southern Alaska into adjacent parts of the western Canada Cordillera. The granitoid rocks in this arc are Early to Middle Pennsylvanian plutons of granodiorite and granite which were preceded by gabbro and diorite, and succeeded by shoshonite (Beard and Barker, 1989; Barker, 1994). U-Pb zircon isotopic age studies reveal ages of 290 to 316 Ma (late Paleozoic) for this suite of plutons and volcanic rocks (Richter and others, 1975a; Barker and Stern, 1986; Aleinikoff and others, 1987; Gardner and others, 1988; Plafker and others, 1989). Common Pb isotopic compositions for the granitoid rocks yield low radiogenic Pb values and suggest derivation from a mixture of oceanic mantle and pelagic sediment leads, without an older continental component (Aleinikoff and others, 1987). Rb-Sr isotopic data, and REE volcanic and plutonic whole-rock chemical analyses suggest an intra-oceanic island arc origin (Barker and Stern, 1986; Beard and Barker, 1989; Barker, 1994; Miller, 1994). A marine origin for the Skolai arc is supported by submarine deposition of the volcanic flows, tuff, and breccia, and associated volcanic graywacke and argillite (Richter and Jones, 1973; Bond, 1973, 1976). The principal data for an island arc origin are: (1) the absence of abundant continental crustal detritus in late Paleozoic stratified rocks; (2) little or no quartz in the volcanic rocks and associated shallow-intrusive bodies; (3) high-latitude fauna; and (4) isotopic data summarized above.

Ketchikan Metallogenic Belt of Kuroko Massive Sulfide Deposits (Belt KK) Southeastern Alaska

The Ketchikan Metallogenic Belt of kuroko massive sulfide deposits occurs in Southeastern Alaska (fig. 32; tables, 3, 4) (Nokleberg and others, 1997b, 1998). The belt strikes north-south, is about 300 km long, and varies from 20 to 60 km wide. The significant kuroko massive sulfide deposit at Moth Bay consists of discontinuous lenses and layers of massive pyrite and pyrrhotite, minor chalcopyrite and galena, and local disseminated pyrite (Berg and others, 1978; Newberry and others, 1997). The deposit contains an estimated 91,000 tonnes grading 7.5% Zn and 1% Cu and an additional 181,000 tonnes grading 4.5% Zn and 0.75% Cu. The host rocks are light brown-gray, upper Paleozoic or Mesozoic muscovite-quartz-calcite schist, subordinate pelitic schist and quartz-feldspar schist, and possibly metachert. Layers and lenses of massive sulfides, up to 1 m thick, occur parallel to compositional layering in the schist.

The Moth Bay deposit is hosted in the former Taku terrane, now designated as part of late Paleozoic sedimentary and volcanic rocks of the Wrangellia sequence of the Wrangellia superterrane which consists of a poorly-understood sequence of mainly Permian and Triassic marble, pelitic phyllite, and felsic metavolcaniclastic and metavolcanic rocks which are overlain by Late Jurassic to mid-Cretaceous units of the Gravina belt (Gehrels and Berg, 1994). The Ketchikan metallogenic belt and host rocks are herein interpreted as a fragment of a late Paleozoic Skolai island arc which formed early in the history of the Wrangellia superterrane (Nokleberg and others, 1994c; 2000).

Late Triassic Metallogenic Belts (230 to 208 Ma; Figure 32)

Overview

The major Late Triassic metallogenic belts in the Alaska and the Canadian Cordillera are summarized in table 3 and portrayed on figure 32. No major Late Triassic metallogenic belts exist in the Russian Far East. The major belts in Alaska and the Canadian Cordillera are as follows. (1) In the same region is the Farewell belt of gabbroic Ni-Cu-PGE deposits that is hosted in the Dillinger, Mystic, and Nixon Fork passive continental margin terranes. The tectonic origin of this belt is uncertain. (2) In Southern Alaska, three belts are interpreted as forming in the middle Mesozoic Talkeetna-Bonzana island arc in Wrangellia Superterrane. These belts are the: (a) the Kodiak Island and Border Ranges (KOD) belt of podiform Cr deposits, that is interpreted as forming in the roots of the Talkeetna-Bonzana arc; and (b) Eastern and Western Alaska Range (EAR) belt of gabbroic Ni-Cu, Besshi massive sulfide, and related deposits, and the Alexander (AX) belt of massive sulfide and related deposits. Both belts are interpreted as forming during back-arc rifting of the Talkeetna-Bonzana arc preserved in the Wrangellia island-arc superterrane. And (3) in the Canadian Cordillera, the Copper Mountain (North; CMN), Copper Mountain (South; CMS), Galore (GL), Guichon (GU), and Texas Creek (TC) belts which all contain granitoid magmatism-related deposits, are interpreted as forming in the axial parts of the Stikinia-Quesnellia island arcs. The Stikinia and Quesnellia island-arc terranes are interpreted as forming on the deformed continental margin strata of Yukon-Tanana terrane which was previously rifted from the North American Craton Margin (Gehrels and others, 1990; Monger and Nokleberg, 1996; Nokleberg and others, 1994c, 1997c, 2000). Mineralization in all these belts continued into the Early Jurassic. And (4) also in the Canadian Cordillera, the Sustut metallogenic belt of basaltic Cu deposits, that is hosted in the Stikinia island arc terrane, formed in the upper oxidized parts of an island arc volcanic pile during shallow burial metamorphism and diagenesis. In the below descriptions of metallogenic belts, a few of the noteable signficant lode deposits (table 4) are described for each belt.

Metallogenic-Tectonic Model for Late Triassic (230 to 208 Ma; Figure 34)

During the Late Triassic (Carnian to Norian - 230 to 208 Ma), the major metallogenic-tectonic events were (table 3): (1) inception of continental-margin arcs and associated subduction along the North Asian Craton Margin; (2) continued formation of the Stikinia and Quesnellia island arcs and inception of subduction-related Talkeetna and Bonanza island arc in the Wrangellia superterrane, and associated metallogenic belts in these island arc systems; and (3) beginning of sinistral-slip imbrication of the Stikinia-Quesnellia island arc and metallogenic belts, and associated subduction zones. Sedimentation continued along the passive continental margins of North Asia and North America.

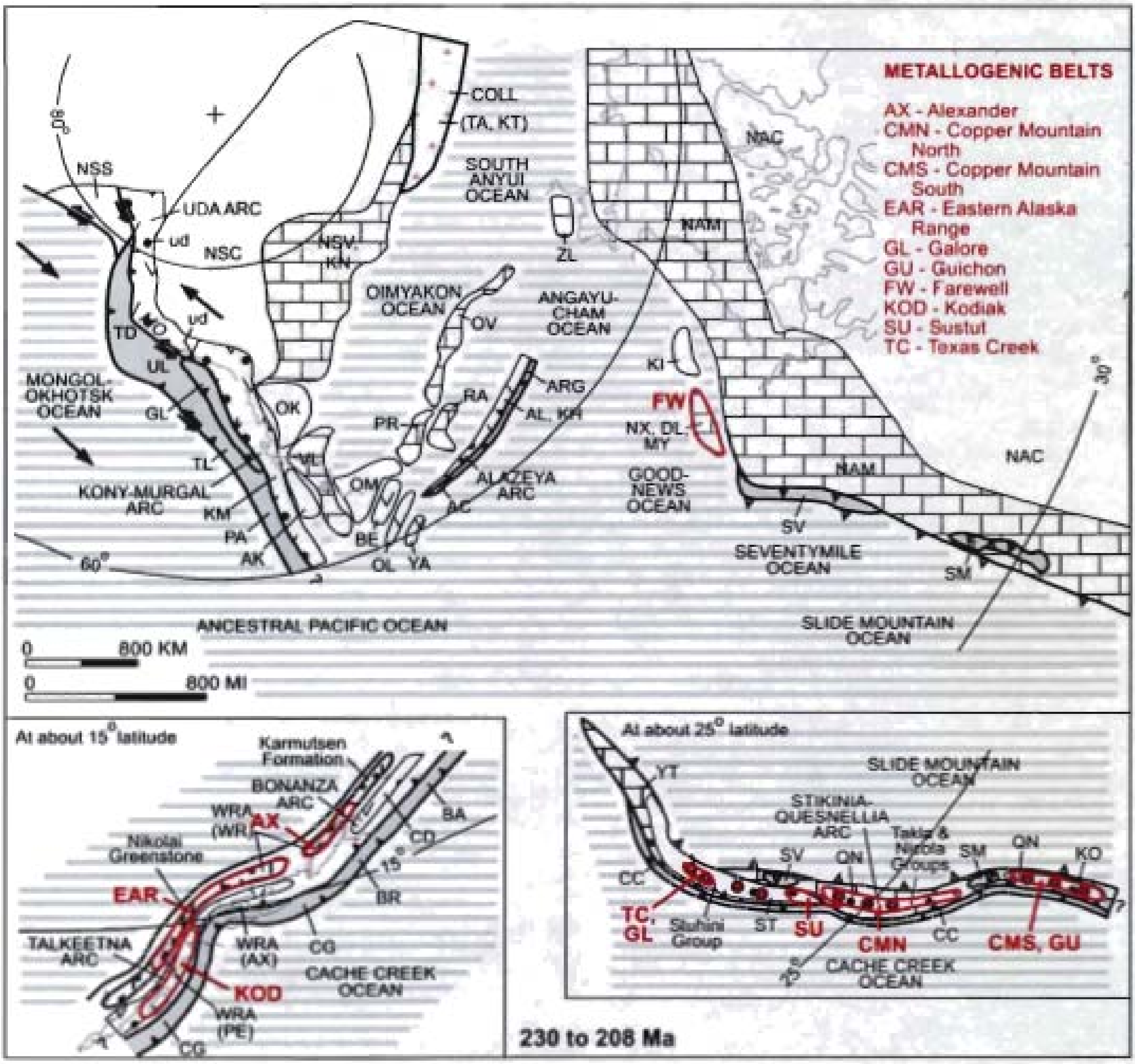


Figure 34. Late Triassic (Carnian through Norian - 230 to 208 Ma) stage of tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

Specific Events for Late Triassic (Carnian through Norian)

(1) The continental-margin Uda arc, defined by the Uda volcanic-plutonic belt (ud) and associated units, commenced activity and was associated with subduction and sinistral transpression of the Mongol-Okhotsk Ocean plate to form the Turkuringra-Dzhagdi (TD), Ulban (UL), and older part of Galam (GL) terranes. Both subduction and sinistral transpression occurred along the Mongol-Okhotsk suture (*MO*).

(2) The extensive Kony-Murgal island arc (KM) commenced activity as an offshore extension of the Uda arc. Associated with the arc was subduction of part of the ancestral Pacific Ocean plate to form the Talovskiy (TL) and Penzhina-Anadyr (PA) terranes. Inboard of the Kony-Murgal arc, the Okhotsk (OK) cratonal terrane was accreted to the North Asian Craton (NSC) and Craton Margin (NSV), together with the Viliga (VL) passive continental-margin terrane, and the Omolon (OM) and Avekova (AK) cratonal terranes. The Kony-Murgal terrane (KM) contains Triassic, Jurassic, and Neocomian Boreal fauna (Dagis and others, 1979; Dagis and Dagis, 1984; Zakharov and others, 1984). The Viliga terrane contains Carboniferous, Permian, Triassic, and Jurassic Boreal fauna.

(3) The Alazeya arc, consisting of the Alazeya (AL) and Khetachan (KH) island-arc terranes, continued activity and moved toward the Omulevka Ridge. Associated with the Alazeya arc was subduction of part of the Ancestral Pacific Ocean to form the Aluchin (AC) and Argatas (ARG) accretionary-wedge terranes. These terranes can be traced by magnetic anomalies under extensive Cenozoic deposits of the Russian Northeast (Parfenov and others, 1999). Behind the arc were fragments of prior Devonian to Pennsylvanian island arcs, including the Beryozovka turbidite-basin (BE), and the Oloy (OL), and Yarakvaam (YA) island-arc terranes.

(4) The Kotel'nyi passive continental-margin terrane (KT) was accreted and became part of the Taimyr Peninsular collage (TA). Within the Angayucham, Goodnews, and Seventymile Oceans were previously rifted terranes, including the Kilbuck-Idono cratonal (KI), and the combined Nixon Fork-Dillinger-Mystic passive continental-margin terrane (NX, DL, MY). During this time span, before accretion to the North American continent, the Dillinger, Mystic, and Nixon Fork terranes may have experienced several post-rifting events which formed additional units, such as the Triassic basaltic rocks which occur in the Tatina River area. Coeval mafic-ultramafic sills and dikes and cogenetic alkali-olivine basalt flows host gabbroic Ni-Cu-PGE deposits of the Farewell (FW) metallogenic belt.

(5) The complex Stikinia-Quesnellia island arc and associated subduction zones were active. The Stuhini Group is preserved in the Stikinia (ST) terrane, whereas the Takla and Nicola Groups are preserved in the Quesnellia (QN) terrane. Forming with the Stikinia-Quesnellia island arc were the Copper Mountain (North; CMN), Copper Mountain (South; CMS), Galore (GL), Guichon (GU), and Texas Creek (TC) belts which contain granitic magmatism-related deposits. Also in the Stikinia island arc terrane is the Sustut (SU) metallogenic belt of basaltic Cu deposits that is interepreted as forming in in the upper oxidized parts of an island arc volcanic pile during shallow burial metamorphism and diagenesis. The Stikinia-Quesnellia arc is interpreted as forming stratigraphically on the Yukon-Tanana (YT) and Kootenay (KO) terranes, previously rifted fragments of the North American Craton Margin (NAM; Mihalynuk and others, 1994). On the outboard side of the arcs was subduction of part of the Cache Creek Ocean plate to form the Cache Creek terrane (CC). The Cache Creek terrane and similar subduction-zone assemblages, which were tectonically linked to the Talkeetna and Bonanza arcs, along with the Chugach (CG), possibly Bridge River (BR), and Baker (BA) terranes, all contain exotic Permian Tethyan faunas in carbonate blocks in matrices of mainly early Mesozoic age. The Cache Creek terrane contains detritus probably derived from the Stikinia-Quesnellia arc (Monger and Nokleberg, 1996).

(6) Parts of the Seventymile (SV) and Slide Mountain (SM; Anvil Ocean of Templeman-Kluit, 1979) Ocean plates were obducted onto the Yukon-Tanana (YT) and Kootenay (KO) terranes, and onto the North American Craton margin (NAM). Part of the obduction occurred by the Late Triassic and (or) Early Jurassic when granitic plutons of the Stikinia-Quesnellia arc intruded across an intervening fault.

(7) The beginning of dextral-slip imbrication of the Stikinia-Quesnellia arc occurred along the Tally Ho shear zone (Hansen and others, 1990; Hart, 1995; inset, fig. 34). Alternatively, the present-day configuration of the Stikinia-Quesnellia island-arc and associated subduction zone terranes may have formed by oroclinal warping and counter-clockwise rotation of the Stikinia-Quesnellia arc in response to a combination of oblique convergence, and arc migration toward the companion subduction zone of the Cache Creek terrane (fig. 34) (Mihalynuk and others, 1994). Migration of the Stikinia-Quesnellia arc and associated terranes toward North America was accomplished by subduction and (or) obduction of the Seventymile terrane along the continental margin.

(8) The Talkeetna and Bonanza arcs formed along the length of the Wrangellia superterrane. Forming with the arcs were: (a) the Kodiak Island and Border Ranges (KOD) metallogenic belt which contains podiform Cr deposits and is interpreted as forming in the roots of the arc; (b) the Eastern and Western Alaska Range (EAR) metallogenic belt which contains gabbroic Ni-Cu, Besshi massive sulfide, and related deposits; and (c) the Alexander (AX) metallogenic belt which contains deposits related to felsic to mafic marine volcanism. The Talkeetna arc is preserved in the Late Triassic(?) and Jurassic Talkeetna Formation and coeval granitic plutonic rocks of the Peninsular sequence (PE) of the Wrangellia superterrane (WRA), and the Bonzana arc is preserved in the Cadwallader island-arc terrane (CD). Associated with the island arcs was subduction of part the Cache Creek Ocean plate to form the Chugach (CG), possibly Bridge River (BR), and Baker (BA) terranes. These terranes locally contain early Mesozoic blueschist (Plafker and others, 1994).

(9) During subduction of the Cache Creek Ocean plate to form the Talkeetna, Bonanza, and Stikinia-Quesnellia arcs, limestone blocks containing mainly Permian Tethyan faunas were accreted, locally in thick and extensive blocks in the subduction-zone complexes of the Chugach (CG) and Cache Creek (CC) terranes (Monger and Berg, 1987; Monger and Nokleberg, 1996). Tethyan faunas are generally interpreted as being derived from the late Paleozoic and early Mesozoic Tethys Ocean, remnants of which occur in the present-day Mediterranean region, Middle East, Himalayas, Southeast Asia, eastern China, Russian Southeast, and Japan (Monger and Ross, 1971; Monger and others, 1972; Stevens and others, 1997).

(10) In the Wrangellia superterrane (WRA), back-arc rifting or hot-spot activity formed the widespread basalt fields of the Nikolai Greenstone and Karmutsen Formation (Barker and others, 1989; Richards and others, 1991; Lassiter and others, 1994). The mafic magmatism forming those rocks was first interpreted as forming in a rift setting (Barker and others, 1989). Alternatively, the mafic magmatism may have formed in a short-lived mantle-plume setting similar to which in Java (Richards and others, 1991; Lassiter and others, 1994).

Metallogenic Belt Formed During Early Mesozoic Rifting? in Alaskan Passive Continental-Margin Terranes

Farewell Metallogenic Belt of Gabbroic Ni-Cu-PGE Deposits (Belt EAR) Western Alaska

The Farewell metallogenic belt of gabbroic Ni-Cu-PGE deposits (fig. 32; tables 3, 4) is hosted in the the Dillnger, Nixon Fork, and Mystic subterranes of the Farewell composite terrane of Decker and others (1994) in Western Alaska. The belt contains the Farewell gabbroic Ni-Cu district (Foley and others, 1997; Bundtzen and others, 2003a, b; Bundtzen, Sidorov, and Chubarov, 2003) in the west-central Alaska Range. The deposits in the district are hosted in the informally-named Farewell mafic-ultramafic suite that consists of differentiated, tholeiitic, peridotite, clinopyroxenite, and gabbro sills, and cogenetic alkali-olivine basalt flows that intrude or overlie: (1) silty limestone and shale of the Cambrian to Ordovician Lyman Hills Formation; and (2) calcareous sandstone and shale of the Permian-Pennsylvanian Sheep Creek Formation. The mafic-ultramafic suite are enstatite rich, orthopyroxene poor, and contain Ti-chromitite. REE and other trace element data from the Farewell suite suggests a magma mixing model with local crustal contamination. $^{40}Ar/^{39}Ar$ isotopic ages for three sills range from 225.6-to-233.7 Ma (Norian). The Farewell district contains three prospects at Gargaryah, Roberts, and Straight Creek.

Roberts PGM Prospect

The Roberts PGM prospect consists of disseminated to semi massive pyrrhotite, chalcopyrite, pentlendite, speerylite, and bravoite that occur in the lower part of an enstatite-rich ultramafic sill that intrudes the Lyman Hills Formation. Surface channel sampling yields grades of up to 16.9 g/t PGE, 1.48 g/t Au, 2.27% Ni, 1.31% Cu, and 0.14% Co. A 5-meter-thick drill interval yields grades of up to 4.13 g/t PGE, 0.67% Ni, 0.32% Cu, and 298 ppm Co. The Straight Creek and Gargaryah River deposits, discovered in 2001, consists of sills with up to 1.59 g/t PGE, 1.00% Co, 0.87% Ni, and 250 ppm Co. Several sills containing these PGE-Ni-Cu-Co prospects in the Farewell district exhibit a strong magnetic signature with maximum intensities of up to 4,300 milligals. Trace element data obtained for the sill intrusions hosting the prospects and PGE element ratios (Pt, Pd, Ir, Rh, Ru, Os) are similar to those reported from sulfide-bearing mafic intrusions in the Paxson-Canwell Glacier in the Eastern Alaska Range, and Kluane Lake area in the Yukon Territory. These deposits are part of the Eastern Alaska Range metallogenic belt, described below, that is hosted in the Wrangellia superterrane.

Origin of and Tectonic Controls for Farewell Metallogenic Belt

The Farewell metallogenic belt is hosted in the Dillinger, Mystic, and Nixon Fork passive continental margin terranes of Nokleberg and others (1997c) (Dillinger, Mystic, and Nixon Fork subterranes of the Farewell (composite) terrane of Decker and others, 1994 and Bundtzen and others, 1997). North of the Farewell district in the Dillinger terrane are similar, deformed mafic-ultramafic sills in the Nixon Fork terrane at St. Johns Hill (McGrath quadrangle) and in the Babybasket Hills (Medfra quadrangle). Geological mapping and paleontological data indicate that the Nixon Fork and Dillinger terranes were coeval, continental margin platform sections that were overlain by the Mystic terrane. These three terranes are interpreted as having been rifted from the North Asian Craton Margin in the Late Devonian and Early Mississippian (Blodgett and Brease, 1997; Blodgett, 1998; Fryda and Blodgett, 1998; Dumoulin and others, 1998, 1999; Blodgett and Boucot, 1999) when the North Asian and North American Cratons (and their margins) are interpreted as having been adjacent (Nokleberg and others, 2000). The early to middle Paleozoic fauna in the Dillnger, Nixon Fork, and Mystic terranes are typical of taxa that occur in similar age units in the Kolyma region of the North Asian Craton Margin (Verkhoyansk fold belt) in the Russian Northeast.

The tectonic origin of the Farewell metallogenic belt is uncertain. The Late Triassic gabbroic Ni-Cu deposits of the Farewell metallogenic belt and host rocks are similar to the deposits and host rocks of the Late Triassic Eastern Alaska Range metallogenic belt, now located a few hundred km to the east in Southern Alaska. However, available paleomagnetic data (table 3 in Nokleberg and others (2000)), indicate that the Wrangellia superterrane, that hosts the Eastern Alaskan Range metallogenic belt, was within a few degrees of the Late Triassic paleoequator. In contrast, the three subterranes (Dillnger, Nixon Fork, and Mystic), constituting the Farewell terrane, are interpreted as having been located several thousand km away, near the North American Craton Margin (fig. 34) (Nokleberg and others, 2000). Additional work is needed to determine the tectonic origin of the Farewell metallogenic belt, contained deposits, and host rocks. Herein, the Farewell metallogenic belt is interpreted as forming during incipient Late Triassic rifting of Dillinger and adjacent passive continental margin terranes

Metallogenic Belts Formed in Middle Mesozoic Talkeetna-Bonzana Island Arc in Wrangellia Superterrane

Kodiak Island and Border Ranges Metallogenic Belt of Podiform Cr Deposits (Belt KOD) Southern Coastal Alaska

The Kodiak Island and Border Ranges metallogenic belt of podiform Cr deposits and one gabbroic Ni-Cu deposit (fig. 32; tables 3, 4) occurs along the northern margin of Kodiak Island, on the Kenai Peninsula, and along the northern flank of the Chugach Mountains in southern coastal Alaska (Foley, 1985; Foley and others, 1997). This belt occurs discontinously along a strike distance of several hundred kilometers from Kodiak Island pn the southwest to the eastern Chugach Mountains on the east. The metallogenic belt is hosted in the Border Ranges ultramafic-mafic assemblage which forms the southern part of the Talkeetna part of the Talkeetna-Bonzana island arc in Wrangellia superterrane (Burns, 1985; Plafker and others, 1989; Nokleberg and others, 1994c, 1997c, 2000). The significant deposits are at Halibut Bay, Claim Point, Red Mountain, and Bernard and Dust Mountains; a possibly related gabbroic Ni-Cu deposit at Spirit Mountain (table 4) (Nokleberg and others 1997a, b, 1998).

Red Mountain Podiform Cr Deposit

The Red Mountain podiform Cr deposit (fig. 35) (Guild, 1942; Bundtzen, 1983b; Burns, 1985; Foley and Barker, 1985; Foley and others, 1985, 1997) consists of layers and lenses of chromite in dunite tectonite; the layers and lenses range up to several hundred meters long and 60 m wide. The largest chromite layer is about 190 m long and up to 1.5 m wide, and more than 10 smaller ore bodies exist. The host Late Triassic to Early Jurassic dunite tectonite is interlayered with subordinate pyroxenite in zones about 60 m thick. Serpentinite is locally abundant along contacts of bodies. Exploration and development occurred sporadically from about 1919 to the 1980's. Several hundred meters of underground workings and trenches were constructed. An estimated 26,000 tonnes of ore, ranging from 38 to 42% Cr_2O_3, was produced from 1943 to 1957. The two largest remaining deposits are estimated to contain 87,000 tonnes grading about 25 to 43% Cr_2O_3. An additional, low-grade deposit contains an estimated 1.13 million tonnes Cr_2O_3. The nearby Windy River chromite placer deposit, which occurs downstream from Red Mountain deposit, in hosted in glaciofluvial sand and gravel deposits and is estimated to contain 15.6 million m^3 grading about 1.33% Cr_2O_3.

Origin of and Tectonic Controls for Kodiak Island and Border Ranges Metallogenic Belt

The Kodiak Island and Border Ranges metallogenic belt of podiform Cr and associated deposits occurs in the Late Triassic to Early Jurassic Border Ranges ultramafic and mafic assemblage (Burns, 1985; Plafker and others, 1989; DeBari and Coleman, 1989; Foley and others, 1997). The assemblage is a major belt of ultramafic tectonite, cumulate gabbro, and norite which occurs along the southern, faulted margin of the Peninsular sequence of the Wrangellia island arc superterrane directly north of the Border Ranges fault system (unit WR, fig. 32) (MacKevett and Plafker, 1974; Burns, 1985; Plafker and others, 1989; Nokleberg and others, 1994c, 1997c). In this region, the ultramafic and mafic rocks are interpreted as the deep-level root of the Late Triassic to Jurassic Peninsular sequence (Talkeetna part of the Talkeetna-Bonanza island arc) of the Wrangellia superterrane (Burns, 1985; Debari and Coleman, 1989). This sequence consists of the Late Triassic(?) and Early Jurassic marine andesite volcanic rocks of the Talkeetna Formation and the Middle Jurassic plutonic rocks of the Alaska-Aleutian Range batholith. The age of the Talkeetna part of the Talkeetna-Bonanza island arc is interpreted as about 180 to 217 Ma (Newberry and others, 1986a; Roeske and others, 1989). These data indicate that the Kodiak Island and Border Ranges metallogenic belt are a deep-level suite of lode deposits formed in the root of the Talkeetna-Bonanza island arc along the margin of the Wrangellia superterrane (Nokleberg and others, 1994d, 2000).

Eastern Alaska Range Metallogenic Belt of Gabbroic Ni-Cu Deposits, Besshi Massive Sulfide, and Related Deposits (Belt EAR) Southern Alaska and Northwestern Canadian Cordillera

The Eastern Alaska Range metallogenic belt of gabbroic Ni-Cu, Besshi massive sulfide, and related deposits (fig. 32; tables 3, 4) occurs in the eastern Alaska Range and Wrangell Mountains in southern Alaska and in the northwestern Canadian Cordillera (Foley, 1982; Foley and others, 1997) and is equivalent to the Kluane- Nikolai belt (Mortensen and Hulbert, 1991; Hulbert, 1995; Hulbert and Carne, 1995). Bundtzen and others (2000) named this belt as the Kluane-Nikolai mafic-ultramafic belt.

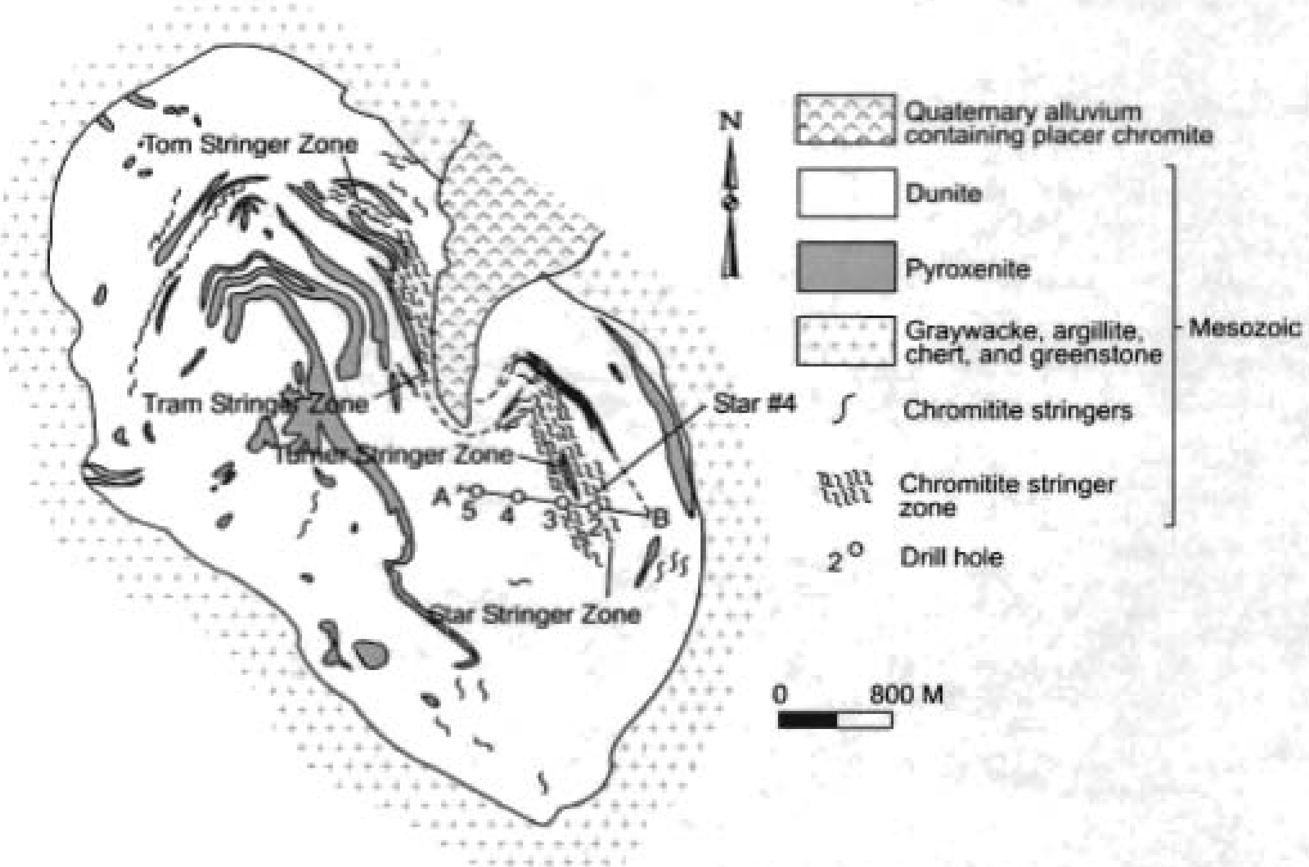


Figure 35. Red Mountain podiform Cr deposit, Kodiak Island and Border Ranges metallogenic belt, Southern Alaska. Schematic geologic map showing locations of the larger chromite deposits. Modified from Guild (1942), and Foley and others (1997).

In Alaska, Barker (1987) first recognized that the differentiated, Triassic sill-like plutons contained significant PGE in addition to Cu and Ni. These mafic-ultramafic bodies are the focus of intense exploration for PGE. The metallogenic belt occurs in the Wrangellia sequence of the Wrangellia superterrane. This sequence contains the areally extensive, Late Triassic Nikolai Greenstone and coeval mafic and ultramfic sills, dikes, and plutons (Nokleberg and others, 1994c, 1997c). The significant deposits are at Denali, Fish Lake, and Wellgreen (table 4) (Nokleberg and others 1997a, b, 1998). The metallogenic belt is hosted in Late Triassic marine pillow basalt and interlayered marine clastic metasedimentary rock of the Wrangellia sequence of the Wrangellia superterrane.

Denali Cu-Ag Besshi(?) Massive Sulfide Deposit

The Denali Cu-Ag Besshi(?) massive sulfide deposit (Stevens, 1971; Seraphim, 1975; Smith, 1981) contains at least six stratiform bodies of very fine grained and rhythmically layered chalcopyrite and pyrite laminations in thin-bedded, shaly, carbonaceous, and limy argillite enclosed in the Late Triassic Nikolai Greenstone. The largest body is about 166 m long and 9 m wide, and extends at least 212 m below surface. The massive sulfide layers contain abundant Cu and up to 13 g/t Ag. The sulfide deposits and host rocks are metamorphosed at lower greenschist facies and locally moderately folded. The deposit contains several hundred meters of underground workings which were developed from 1964 to 1969, but never put into production. The deposit is interpreted as forming in a submarine volcanic environment of a reducing or euxinic marine basin containing abundant organic matter and sulfate reducing bacteria.

Fish Lake Gabbroic Ni-Cu Deposit

The Fish Lake gabbroic Ni-Cu deposit (Stout, 1976; Nokleberg and others, 1984; I.M. Lange and W.J. Nokleberg, written commun., 1985; Nokleberg and others, 1991) consists disseminated and wispy-layered chromite, in serpentinized olivine cumulate. The deposit occurs in a zone up to 15 km long along strike, and ranges up to 2 km wide. Isolated grab samples contain greater than 0.5% Cr and up to 0.3% Ni, and local anomalous Cu and Ni in stream-sediment and rock samples. The gabbroic Ni-Cu deposit is hosted in small- to moderate size gabbro plutons and local cumulate mafic and ultramafic rocks. The mafic and ultramafic rocks intrude the Nikolai Greenstone and older rocks, and are interpreted as co-magmatic with the mafic magmas which formed the Middle and Late Triassic Nikolai Greenstone (Nokleberg and others, 1994d, 2000).

Wellgreen Gabbroic Ni-Cu Deposit

The Wellgreen gabbroic Ni-Cu deposit (fig. 36) (Campbell, 1976; Hulbert and others, 1988; EMR Canada, 1989; Mining Review, 1991) consists of massive pyrrhotite, pentlandite, chalcopyrite and magnetite lenses which are scattered along the footwall contact of a steeply dipping fault zone in gabbroic rocks of the Late Triassic Quill Creek Complex. In the Yukon Territory, the belt includes the Canalask deposit at White River (Bremes, 1994) in which Cu-Ni sulfides generally occur as disseminations in mafic dikes and peridotite. The deposit is medium size and has estimated reserves of 50 million tonnes grading 0.36% Ni, 0.35% Cu, 0.51g/t Pt, 0.34 g/t Pd. The deposit occurs in a 130-km-long belt of Ni-Cu-Co-PGE occurrences which, along with host gabbroic bodies, are interpreted as Late Triassic.

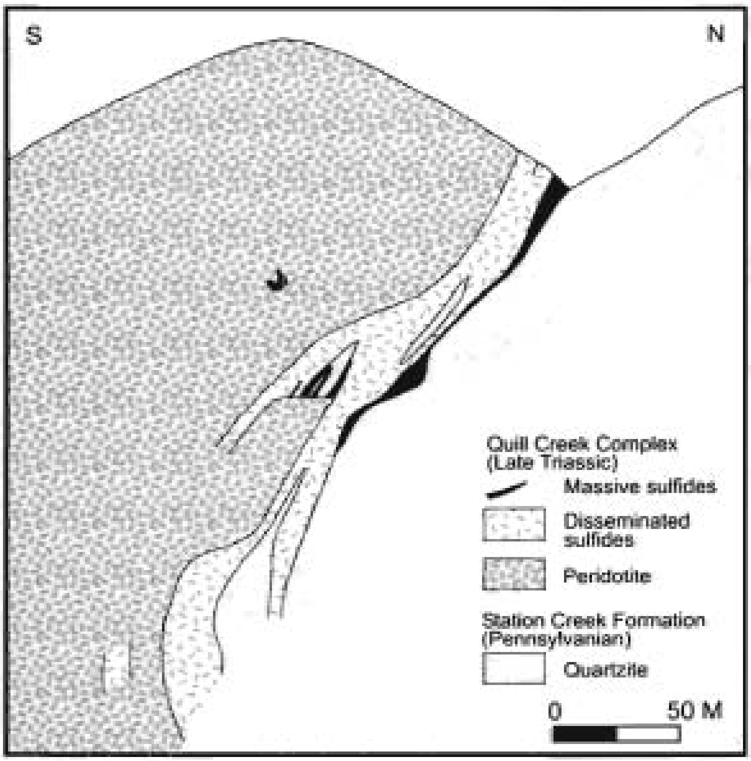


Figure 36. Wellgreen gabbroic Ni-Cu deposit, Eastern Alaska Range metallogenic belt. Schematic cross section through East Zone. Adapted from Hulbert and others (1998).

Origin of and Tectonic Controls for Eastern and Western Alaska Range Metallogenic Belt

The gabbroic Ni-Cu and PGE deposits in the Eastern Alaska Range metallogenic belt are hosted in gabbro and ultramafic sills and plutons which are interpreted as coeval with, and genetically related to the mainly Late Triassic Nikolai Nikolai Greenstone (Nokleberg and others, 1994d). The Nikolai Greenstone, which forms a major part of the Wrangellia superterrane, consists mainly of massive, subaerial, amygdaloidal basalt flows, lesser pillow basalt flows, and thin beds of argillite, chert, and mafic volcaniclastic rocks which are up to 4,350 m thick (Nokleberg and others, 1994c, d, 2000). The flows are predominantly intermixed aa, pahoehoe, and pillow basalt flows with minor interlayered chert and argillite (Nokleberg and others, 1994d);

individual flows range from 5 cm to more than 15 m thick. The Late Triassic mafic volcanic and sedimentary rocks of the Nikolai Greenstone also host the Besshi massive sulfide deposit at Denali.

In the southwesternmost Yukon Territory, the Wellgreen and associated deposits of the Eastern and Western Alaska Range metallogenic belt occur in gabbroic bodies which intrude the Pennsylvanian Skolai assemblage, part of the Wrangellia sequence of the Wrangellia superterrane (Campbell, 1960; Read and Monger, 1976; Nokleberg and others, 1994c, 1997c; Hulbert, 1994). The Skolai assemblage is overlain by mainly Late Triassic basalt of the Nikolai Greenstone and by Late Triassic carbonate rock (Nokleberg and others, 1994c, 1997c). In this area, the gabbro bodies hosting the Wellgreen deposit, and similar gabbroic Ni-Cu deposits in the same area, are also interpreted as coeval with the Late Triassic Nikolai Greenstone. This suite of mafic flows and related units, and mafic and ultramafic shallow intrusive to plutonic rocks are interpreted as forming during either a short-lived period of back-arc rifting or hot spot (oceanic plume) activity within the Talkeetna-Bonanza island arc in Wrangellia superterrane (Nokleberg and Lange, 1985a; Nokleberg and others, 1985a; 1987, 1994c, d, 2000; Plafker and others, 1989).

Also occurring in part of the Eastern Alaska Range metallogenic belt in the Yukon Territory are generally subeconomic volcanic redbed Cu deposits which are hosted in the predominantly subaerial tholeiitic basalt of the Late Triassic Karmutsen Formation, part of the Wrangellia sequence of the Wrangellia superterrane (Read and Monger, 1976). Significant volcanic redbed Cu-Ag deposits at Silver City and Johobo consist of stratabound lenses of native Cu, chalcocite, bornite, chalcopyrite and pyrite (Sinclair and others, 1979; Carriere and others, 1981). The origin of these deposits is not well understood. Kirkham (1996a, b) proposed that the deposits formed during early-stage burial metamorphism, analogous to diagenesis in sedimentary Cu deposits. Also in the Yukon Territory, the Eastern and Western Alaska Range metallogenic belt contains sparse stratiform gypsum deposits, as at Bullion Creek, which are hosted in limestone of the Late Triassic Nizina Formation, also part of a structurally displaced fragment of the Alexander sequence of the Wrangellia superterrane (Monger and others, 1991; Nokleberg and others, 1994c, 1997c).

Alexander Metallogenic Belt of Volcanogenic Cu-Pb-Zn and Carbonate-Hosted Massive Sulfide Deposits, Southeastern Alaska (Belt AX)

The Alexander metallogenic belt of volcanogenic and carbonate-hosted massive sulfide and associated deposits (fig. 32; tables 3, 4) occurs for about 750 km along the length of Southeastern Alaska. The metallogenic belt is hosted in the early Paleozoic (and older) to Late Triassic Alexander sequence of the Wrangellia superterrane (Nokleberg and others, 1994c, 1997c). The belt contains volcanic- and carbonate-hosted massive sulfide deposits, and bedded barite deposits. The significant deposits in the belt (tables 3, 4): are the Windy Craggy massive sulfide deposit (Alsek River area, British Columbia): the Glacier Creek, Greens Creek, Khayyam, Kupreanof Island, Niblack, and Orange Point kuroko massive sulfide deposits (Dawson and others, 1991; Nokleberg and others, 1994c, 1997a, b, 1998, 2000; Newberry and others, 1997); the Castle Island, Haines, and Lime Point bedded barite deposits (Nokleberg and others, 1994c, 1997a, b, 1998; Schmidt, 1997b); and the Moonshine carbonate-hosted massive sulfide deposit (Herreid and others, 1978; Nokleberg and others 1997a, b, 1998).

Windy Craggy Cu-Co Massive Sulfide Deposit

The world-class Windy Craggy deposit (fig. 37) occurs in the Tatshenshini River area, northern British Columbia, Canada, and consists of one or more pyrrhotite, pyrite and chalcopyrite massive sulfide bodies which are hosted in Late Triassic submarine, tholeiitic to calcalkaine basalt flows, with lesser intercalated siltstone, chert, argillite, and limestone, and numerous diorite dikes and sills which cut footwall units (EMR Canada, 1989; Schroeter and Lane, 1991; G. Harper, written commun., 1992; MacIntyre and others, 1993). Both zones have adjacent sulfide stringer stockworks. The deposit contains reserves of 265 million tonnes grading 1.44% Cu, 0.07% Co and 0.20 g/t Au. Five additional stratiform Cu occurrences were discovered in the area in 1992. The deposit age is interpreted as Late Triassic on the basis of Norian conodonts in limestone from the deposit (M. Orchard, written commun., 1983). The host rocks are intruded by calc-alkaline diorite sills and dikes, and overlain by calc-alkaline pillow basalt at least 1,500 m thick. The large, Cu-bearing pyrite-pyrrhotite massive sulfide bodies are folded, faulted, and sheared. The deposit is transitional between Cyprus and Besshi volcanogenic massive sulfide deposit types.

Greens Creek Kuroko Zn-Pb-Cu Massive Sulfide Deposit

The Greens Creek Kuroko Zn-Pb-Cu massive sulfide deposit (fig. 38) occurs on Admiralty Island and consists of sphalerite, galena, chalcopyrite, and tetrahedrite in a pyrite-rich matrix. The sulfides occur in massive pods, bands, laminations, and disseminations, and are associated with pyrite-carbonate-chert exhalite (Berg, 1984; Wells and others, 1986; Brew and others, 1991; Newberry and others, 1997). The structural hanging wall contains chlorite- and sericite-bearing metasedimentary rocks. The structural footwall contains black graphitic argillite. "Black ore" forms an extensive blanket deposit, and is composed of fine-grained pyrite, sphalerite, galena, and Ag-rich sulfosalts in laminations in black carbonaceous exhalite and argillite. "White ore" occurs along edges of massive sulfide pods and is composed of minor tetrahedrite, pyrite, galena, and sphalerite in laminations, stringers, or disseminations in massive chert, carbonate rocks, or sulfate-rich exhalite. Local veins occur below the massive sulfides and contain bornite, chalcopyrite, and gold. The veins may constitute brine conduits. The sulfides and host rocks are underlain by serpentinized mafic volcanic flows and tuffs. An incremental Ar age of 211 Ma was obtained for hydrothermal mariposite from a small massive sulfide occurrence near Greens Creek (Taylor and others, 1995). The host rocks are part of a Triassic suite of metasedimentary and metavolcanic rocks in the Wrangellia sequence which overlies the early to middle Paleozoic rocks of Alexander sequence. Both are part of the Wrangellia superterrane (Nokleberg and others, 1994c, 1997c). The host rocks are tightly folded into a southeast-plunging, overturned antiform. The deposit is interpreted as forming during marine exhalation in a Triassic back-arc or wrench fault extensional basin during deposition of the arc. From 1989-1999, the Greens Creek mine produced 299,480 tonnes zinc, 122,400 tonnes lead, 1,896 tonnes silver, and 10,617 kg gold from 2,924,294 tonnes of ore (Swainbank and Szumigala, 2000).

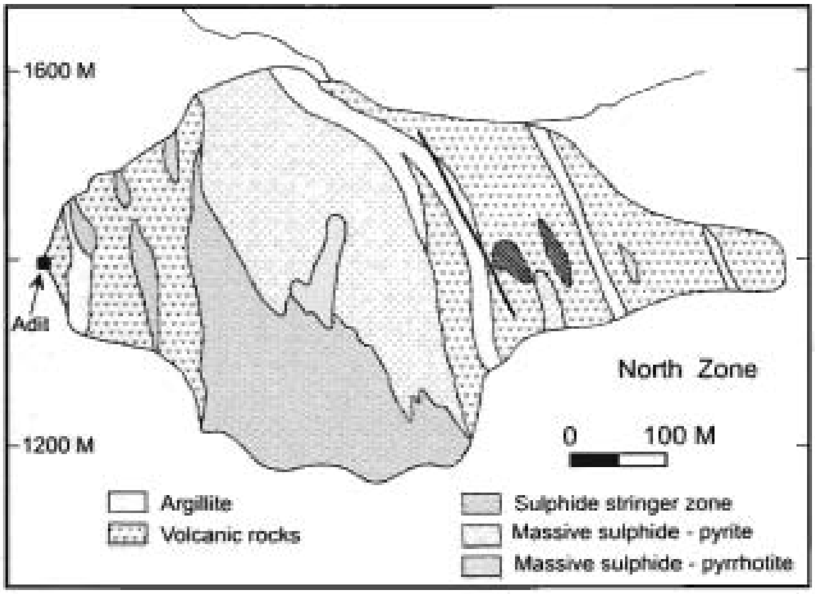


Figure 37. Windy Craggy Cyprus massive sulfide deposit, Alexander metallogenic belt, northern British Columbia, Canadian Cordillera. Schematic cross section through North Zone. Adapted from Downing and others (1990).

Castle Island Bedded Barite Deposit

The Castle Island bedded barite deposit consists of lenses of massive barite interlayered with metamorphosed limestone of probable Triassic age, and with metamorphosed calcareous and tuffaceous clastic rock (Berg and Grybeck, 1980; Berg, 1984; Grybeck and others, 1984; Brew and others, 1991). Sulfide-rich interbeds contain sphalerite, galena, pyrite, pyrrhotite, bornite, tetrahedrite, and chalcopyrite. The deposit produced 680,000 tonnes of ore grading 90% barite. Sulfide-rich layers contain up to 5% galena and sphalerite, and 100 g/t Ag.

Origin of and Tectonic Controls for Alexander Metallogenic Belt of Massive Sulfide Deposits

The deposits in the Alexander metallogenic belt of massive sulfide and associated deposits (tables 3, 4) are hosted in a variety of rocks. At the Windy Craggy deposit, the basalt flows hosting the massive sulfide deposit consist of a thick unit of dominantly alkaline to sub-alkaline composition, and abundant interleaved, craton-derived clastic sedimentary rocks which are more characteristic of a Besshi-type deposit. Hosting the Greens Creek and other kuroko massive sulfide deposits are suites of Triassic metasedimentary rocks, argillite, and siliceous metavolcanic rocks. Hosting the Castle Island bedded barite deposit is Triassic(?) limestone, and calcareous and tuffaceous clastic rocks. The Triassic units constitute the younger part of the Wrangellia sequence in Southeastern Alaska which in this area overlies the early to middle Paleozoic Alexander sequence; together the two sequences form the Wrangellia superterrane in the region (Nokleberg and others, 1994c, d, 1997c, 2000)

In Southeastern Alaska, in addition to marine basalt, the Triassic part of the Wrangellia sequence contains siliceous (meta)volcanic rocks (rhyolite and tuff), limestone, argillite, and conglomerate in a relatively narrow belt on the eastern side of the terrane (Gehrels and Berg, 1994). In contrast, in southern Alaska, the Triassic part of the Wrangellia sequence consists of thick unit of marine and subaerial basalt in the Nikolai Greenstone, and lesser limestone (Nokleberg and others, 1994c, 1997c). In southern British Columbia on Vancouver Island, similar thick marine basalt forms the Karmutsen Volcanics (Nokleberg and others, 1994c, 1997c).

The Triassic strata and contained massive sulfide deposits of the Alexander metallogenic belt are interpreted as forming in a back-arc rift environment on the basis of (Dawson, 1990; Gehrels and Berg, 1994; Nokleberg and others, 1994c, 1997c): (1) the presence of bimodal volcanic rock (basalt and rhyolite); (2) a variety of deposit types (Cyprus to Besshi, kuroko, and carbonate-hosted massive sulfide deposits, and bedded barite deposits) which are generally related to rifting; and (3) the occurrence of turbiditic clastic rocks. On the basis of geochemical data, either back-arc rifting or hot-spot activity is interpreted to have formed the widespread basalt fields of the Nikolai Greenstone and Karmutsen Formation and coeval mafic and ultramafic sills and plutons (Barker and others, 1989; Richards and others, 1991; Lassiter and others, 1994). Herein, back-arc rifting is interpreted as the tectonic environment for the Triassic strata and contained massive sulfide deposits. The rifting is tectonically linked to the coeval Bonzana-Talkeetna island arc which occurs along the length of the Wrangellia superterrane for several thousand km (Nokleberg and others, 2000).

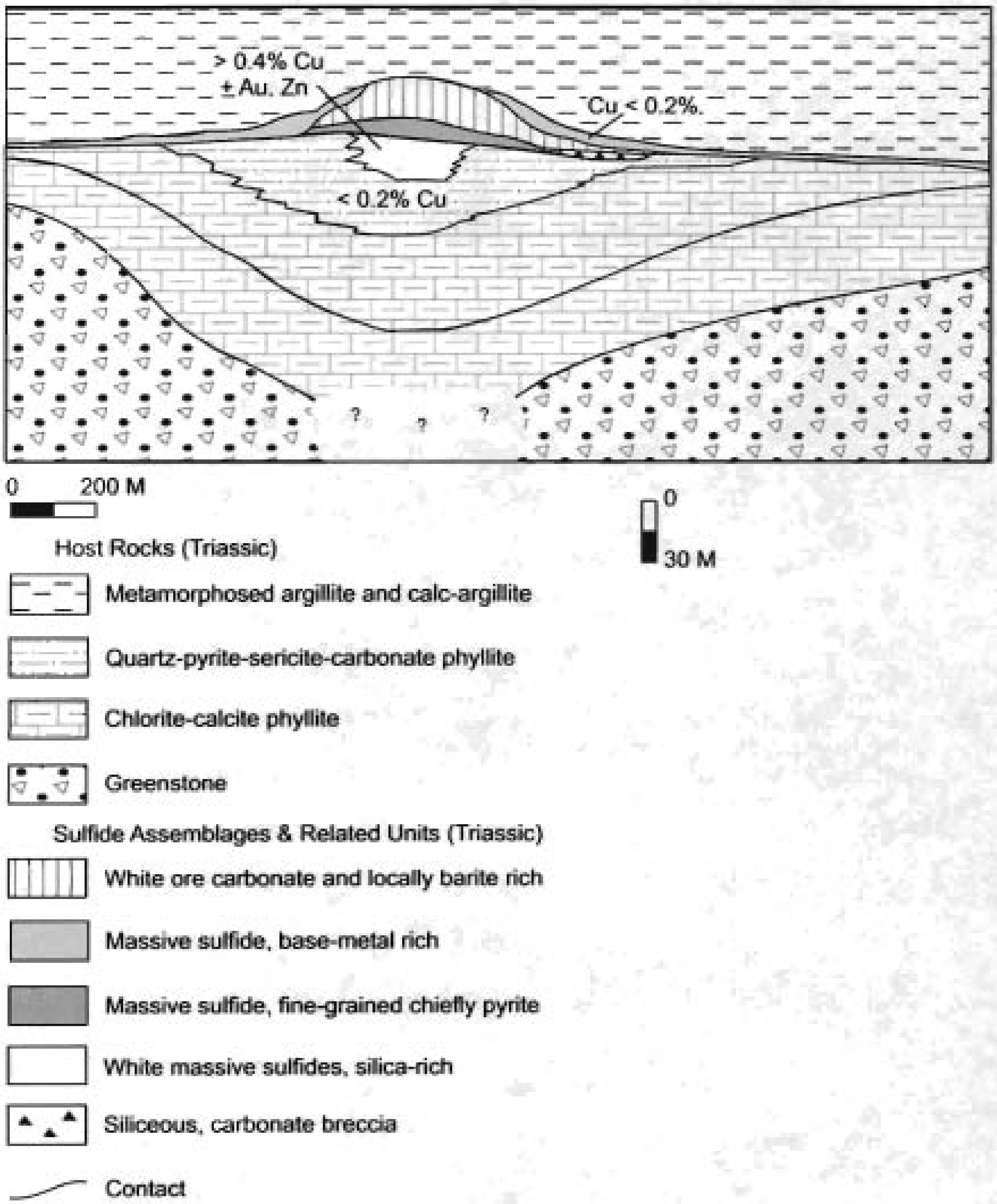


Figure 38. Greens Creek kuroko massive sulfide deposit, Alexander metallogenic belt, Southeastern Alaska. Schematic, predeformation, cross-section model based on drill core logging and underground and surface mapping. Modified from Newberry and others (1997).

Metallogenic Belts Formed in Middle Mesozoic Stikinia-Quesnellia Island Arc

Galore Creek Metallogenic Belt of Porphyry Cu-Au Deposits (Belt GL) Northern British Columbia

The Galore Creek metallogenic belt of porphyry Cu-Au deposits (fig 32; tables 3, 4) occurs in northern British Columbia and is hosted in alkaline granitoid plutons which are coeval and comagmatic with volcanic, volcaniclastic and subordinate sedimentary rocks of the Late Triassic Stuhini Group of the northern Stikinia terrane. The significant deposits are the Galore Creek, Gnat Lake, and Red Chris porphyry Cu, porphyry Cu-Au, and Cu-Au skarn deposits (table 4) (Nokleberg and others 1997a, b, 1998).

Galore Creek Alkalic Porphyry Cu-Au Deposit

The Galore Creek alkalic porphyry Cu-Au deposit consists of chalcopyrite, pyrite, bornite and magnetite which occur as disseminations, skarns, coarse replacements, and fracture fillings in syenitic porphyry and breccias and the Late Triassic Stuhini Group metasedimentary and metavolcanic rocks (Allen and others, 1976; EMR Canada, 1989; Dawson and others, 1991; Mining Review, 1992, J. Mortensen, written commun., 1993; Enns and others, 1995). The deposit contains estimated reserves of 125 million tonnes grading 1.06% Cu, 7.7 g/t Ag, and 0.4 g/t Au. Approximately 80% of deposit consists of altered skarn and replacements along contacts between syenite intrusives and Triassic volcanic and sedimentary rock. A U-Pb zircon isotopic age of 210 Ma is reported for the intramineral syenite porphyry. The porphyry is typical of undersaturated, feldspathoid-bearing subclass of alkalic porphyry deposits.

The Galore Creek deposit is hosted in volcanic rocks of the Stuhini Formation. The rocks are dominantly augite and plagioclase phyric basalt and andesite flows, fragmental rocks and less abundant feldspathoid-bearing flows. Prograde Cu skarns, which occurs in calcareous pyroclastic, volcaniclastic, and shoshonite volcanic rocks adjacent to contacts of pseudoleucite-phyric syenite dikes, constitutes about 80% of ore reserves in the Central Zone. Potassic alteration assemblages of orthoclase and biotite, which occur in or adjacent to potassic host rocks, are replaced by a calcic skarn assemblage of zoned andradite, diopside, Fe-rich epidote, and vesuvianite along with chalcopyrite, bornite, pyrite, and magnetite, and minor chalcocite, sphalerite, and galena. Retrograde assemblages consist of anhydrite, chlorite, sericite, calcite, gypsum, and fluorite (Dawson and Kirkham, 1996).

The Southwest Zone consists of disseminated chalcopyrite in a late-stage, diatreme breccia and adjacent orthoclase porphyry. The North Junction and other satellite deposits consist of disseminated chalcopyrite and bornite in volcanic rocks. Reserves calculated in 1992 are: Central Zone -233.9 million tonnes grading 0.67% Cu, 0.35 g/t Au, and 7 g/t Ag; Southwest Zone -42.4 million tonnes grading 0.55% Cu, 1.03 g/t Au, and 7 g/t Ag; and North Junction - 7.7 million tonnes grading 1.5% Cu.

Red Chris Porphyry Cu-Au Deposit

The Red Chris alkalic porphyry Cu-Au deposit consists of a stockwork and a set of sheeted-veins containing quartz, pyrite, chalcopyrite, and increasing bornite at depth. The deposit is hosted in an elongate porphyritic monzonite stock emplaced within the Late Triassic alkaline volcanic and volcaniclastic rocks of either the Stuhini, Group (EMR Canada, 1989; American Bullion Minerals Ltd., news release, Jan. 1995; Newell and Peatfield, 1995; Ash and others, 1997). The monzonite exhibits an isotopic age of 203+1.3 Ma (Friedman and Ash, 1997). An early K-Na alteration stage of orthoclase-albite-biotite with variable quartz- sericite, was succeeded by pervasive quartz-ankerite-sericite-pyrite alteration. Pyrite occurs as a halo to the steeply dipping deposit which is both controlled and offset by east-northeast trending subvertical faults. The deposit contains estimated resources of 320 million tonnes grading 0.38% Cu and 0.30 g/t Au (American Bullion Minerals, news release, Jan., 1995). A minimum K-Ar isotopic age of mineralization of 195 Ma (Early Jurassic) is obtained from a post-mineral dike (Newell and Peatfield, 1995). Subvolcanic complexes similar to the Red stock occur at the Rose and Groat Creek porphyry Cu-Au prospects which are located 10 km northwest, and 25 km southwest of Red Chris, respectively (Newell and Peatfield, 1995). Porphyry Cu-Au prospects at June and Stikine in the Gnat Lake area are hosted in quartz monzonite and granodiorite phases of the Hotailuh Batholith (Panteleyev, 1977).

Origin of and Tectonic Controls for Galore Creek Metallogenic Belt

The Galore Creek metallogenic belt of porphyry Cu-Au deposits is hosted in and adjacent to a Late Triassic (210 Ma) center of alkaline volcanism, contemporaneous with multi- phase intrusion and magmatic- hydrothermal activity, and late diatreme breccias, which together probably contributed to the high Cu and Au contents at Galore Creek relative to other alkaline porphyry systems as at Cat Face in British Columbia (Enns and others, 1995). The Galore Creek metallogenic belt is part of the subduction related Stikinia island arc (Monger and Nokleberg, 1996; Nokleberg and others, 2000). Isotopic ages indicate intrusion of host granitoid plutons and formation of associated mineral deposits from the Late Triassic to the Early Jurassic. This age represents the main and final part of subduction-related igneous building of the Stikinia island arc, just before accretion of the Stikinia terrane, along the with tectonically-related Quesnellia island arc and Cache Creek subduction-zone terranes, onto the North American Craton Margin (Monger and Nokleberg, 1996; Nokleberg and others, 2000).

Sustut Metallogenic Belt of Basaltic Cu Deposits (Belt SU) Northern British Columbia

The Sustut metallogenic belt of basaltic Cu deposits, which occurs in northern British Columbia, is hosted in fragmental volcanic rocks of intermediate composition and interlayered sedimentary rocks of the Late Triassic Takla Group in the northeastern part of the Stikinia island-arc terrane (fig. 32; tables 3, 4) (Nokleberg and others, 1997b, 1998). A more extensive, but less coherent belt could be defined to the south and west which would include minor volcanic redbed Cu occurrences in the overlying Hazelton Assemblage and the Nicola Assemblage in southern Quesnellia island-arc terrane. In each case, the deposits are located within emergent, subaerial parts of island-arc terranes. The significant deposit is at Sustut.

Sustut Basaltic Cu Deposit

The Sustut basaltic Cu deposit consists of a stratabound assemblage of hematite, pyrite, chalcocite, bornite, chalcopyrite and native copper which occurs as disseminations and as blebs and grains in the matrix of sandstone, conglomerate, tuff breccia and lahar of the Late Triassic Takla Group (EMR Canada, 1989; Dawson and others, 1991). The deposit is a large concordant body which is strongly zoned inward from an outer zone of pyrite, chalcopyrite, and bornite into a core of chalcocite, native copper and hematite. The zonation is interpreted as reflecting the migration of ore fluids along permeable aquifers. The host rocks are sandstone, conglomerate, lahar, and red/green or grey tuff breccia of subaerial origin. Estimated resources are 21 million tonnes grading 1.11% Cu (Kirkham, 1996b; Harper, 1977; Mining Review, summer 2000). The grade increases in finer grained units. Pyrite forms an incomplete envelope around Cu-bearing lenses, and hematite is ubiquitous. The deposit age is interpreted as Late Triassic. The Northstar deposit to the south of Sustut is a faulted block of lower-grade, chalcocite-bearing sedimentary rocks which are apparently interlayered within volcanic flows of the Takla Group (Sutherland Brown, 1968).

Origin of and Tectonic Controls for Sustut Metallogenic Belt

The origin of basaltic Cu deposits hosted in volcanic rocks is interpreted as analogous to that for diagenetic sedimentary Cu deposits in sedimentary sequences. However, the common presence of low-grade metamorphic minerals may also supports a metamorphic origin (Kirkham, 1996b). In the Sustut metallogenic belt, the deposits are interpreted as forming in the upper oxidized parts of volcanic piles during shallow burial metamorphism and diagenesis (Kirkham, 1996b) which was coeval with Late Triassic island-arc volcanism in the Stikinia and Quesnellia terranes.

Copper Mountain (North) Metallogenic Belt of Porphyry Cu-Au Deposits (Belt CMN) Northern British Columbia

The Copper Mountain (North) metallogenic belt of porphyry Cu-Mo-Au deposits (fig. 32; tables 3, 4) occurs in northern British Columbia and is hosted in granitoid plutonic rocks of the mainly in intermediate-composition granitoid plutons in the Copper Mountain suite in the Quesnellia island-arc terrane. Most plutons in the suite are small, equant stocks with diameters ranging up to a few kilometers. The significant deposits are the Lorraine and Mount Mulligan porphyry Cu-Au deposits (table 4) (Nokleberg and others 1997a, b, 1998).

Lorraine Porphyry Cu-Au Deposit

The Lorraine porphyry Cu-Au deposit consists of two fault-bounded zones of chalcopyrite, bornite and magnetite which occur as disseminations in the 30- by 5-km-wide Middle Jurassic Duckling Creek Syenite Complex which is part of the largest pluton in the Hogem Batholith of the alkaline Copper Mountain Suite (EMR Canada, 1989; Dawson and others, 1991; Woodsworth and others, 1991; Bishop and others, 1995; MINFILE, 2002). The sulfides are dominantly disseminated, but also occur in veins. In the Lower Zone, sulfides occur in mafic-rich lenses and are zoned from chalcopyrite + pyrite at the rim, through chalcopyrite with minor bornite to bornite with minor chalcopyrite at the core. Magnetite is common in veinlets and as an accessory mineral. The deposit contains an estimated resource of 9.1 million tonnes grading 0.70% Cu and 0.27 g/t Au (MINFILE, 2002). An Upper Zone is similar but is highly oxidized (Garnett, 1978). The Cu-Au deposit exhibits characteristics of both hydrothermal and magmatic origins, and is related to orthomagmatic-hydrothermal fluid flow contemporaneous with magmatism and development of migmatitic fabrics(Bishop and others, 1995). Cu minerals are associated with elevated intensity of biotite, chlorite, potassium feldspar and sericite alteration. A K-Ar isotopic age of 175 +/- 5 Ma (Middle Jurassic) for the syenite at Lorrine is interpreted as a reset age; a U-Pb zircon age is about 181 Ma (Bishop and others, 1995).

Mount Milligan Porphyry Cu-Au Deposit

The Mount Milligan Porphyry Cu-Au deposit consists of pyrite, chalcopyrite, bornite and magnetite which occur as disseminations and in quartz veinlets (Delong and others, 1991; McMillan, 1991; Nelson and others, 1991; Barrie, 1993; Sketchley and others, 1995). The deposit has estimated reserves of 298.4 million tonnes grading 0.22% Cu and 0.45 g/t Au. The deposit is hosted in augite porphyritic andesite of the Witch Lake (informal) formation of the Late Triassic to Early Jurassic Takla Group which is intruded by several small brecciated diorite and monzonite porphyry dikes and stocks. Cu-Au mineralization in the Main deposit accompanied the emplacement of the MBX stock and Rainbow dyke; the Southern Star deposit surrounds the stock of the same name. A U-Pb zircon isotopic age of 183 ± 1 Ma is obtained for the Southern Star monzonite. Cu and Au minerals are associated with moderate to intense potassic alteration around intrusive contacts. Potassic alteration, which is ubiquitous in mineralized stocks and surrounding volcanic rocks, is surrounded by propylitic alteration which decreases in intensity outward from intrusive. A well-developed mineral zoning consists of a biotite-rich core in the potassic zone which contains most of the Cu and Au. Numerous polymetallic veins are hosted by the propyliyic alteration zone immediately beyond the limits of the porphyry deposit.

Origin of and Tectonic Controls for Copper Mountain (North) Metallogenic Belt

The Copper Mountain (North) metallogenic belt is hosted mainly in intermediate-composition granitoid plutons in the Copper Mountain suite which are part of the subduction-related Quesnellia island arc (Nokleberg and others, 1994a, b; Monger and Nokleberg, 1996; Nokleberg and others, 2000). Emplacement of plutons was apparently along faults and intersections of faults. In both the Copper Mountain (North) and Copper Mountain (South) metallogenic belts, many of the porphyry Cu-Au deposits occur in alkaline plutons. Isotopic ages indicate intrusion of host granitoid plutons and formation of associated mineral deposits from about 175 to 185 Ma in the Middle Jurassic in the Copper Mountain (North) metallogenic belt. This age represents the end of subduction-related igneous building of Quesnellia island arc, just before accretion of the Quesnellia terrane, along the with tectonically-related Stikinia island arc and Cache Creek subduction-zone terranes, onto the North American Craton Margin (Monger and Nokleberg, 1996; Nokleberg and others, 2000).

Copper Mountain (South) Metallogenic Belt of Porphyry Cu-Au Deposits (Belt CMS) Southern British Columbia

The Copper Mountain (South) metallogenic belt of porphyry Cu-Au deposits (fig. 32; tables 3, 4) occurs in southern British Columbia and is hosted in the Copper Mountain alkalic plutonic suite in the Quesnellia island-arc terrane. The significant deposits are the Copper Mountain, Iron Mask area (Afton, Ajax), and Mt. Polley (Cariboo-Bell) porphyry Cu-Au deposits, and the Lodestone Mountain zoned mafic-ultramafic Fe-V deposits (table 4) (Nokleberg and others 1997a, b, 1998).

Copper Mountain (Ingerbelle) Porphyry Cu-Au Deposit

The Copper Mountain (Ingerbelle) alkalic porphyry Cu-Au deposit (fig. 39) consists of mainly of chalcopyrite and bornite which occur as disseminations and in stockworks in Early Jurassic alkaline intrusive rocks of the Copper Mountain Suite and similar age volcanic and volcaniclastic rocks of the Nicola Assemblage (Preto, 1972; McMillan, 1991; P. Holbeck, Cordilleran Roundup, written commun., 1995; MINFILE, 2002). This and similar deposits in the Copper Mountain area occur along a northwest trend for over 4 km. The main ore bodies are the Copper Mountain Pits 1-3, Ingerbelle East, Ingerbelle, Virginia and Alabama. Production up to 1994, was 108 million tonnes containing 770,000 tonnes Cu and 21.8 tonnes Au. Estimated reserves are 127 million tonnes grading 0.38% Cu, 0.16 g/t Au, and 0.63 g/t Ag (MINFILE, 2002). Estimated resources are 200 million tonnes grading 0.4% Cu equivalent. Significant values in Pt and Pd were reported from assays of chalcopyrite- and bornite-rich concentrates.

The Copper Mountain (Ingerbelle) deposit consists of a silica-deficient, chalcopyrite-pyrite-bornite stockwork hosted almost entirely by fragmental andesitic volcanic rocks, calcareous volcaniclastic rocks and minor carbonate strata (Fahrni and others, 1976). Intrusive rocks are equigranular diorite stocks, and more siliceous dikes, sills, and irregular plugs of the Lost Horse Intrusive Complex, a porphyritic unit which is often closely associated with bornite-chalcopyrite-pyrite-magnetite mineral deposits and occurrences. A K-Ar biotite isotopic age of 197 to 200 Ma is interpreted as an Early Jurassic age for the deposit. Alteration mineral assemblages at the Copper Mountain Pits 1 to 3, and the Alabama and Virginia ore bodies are early albite-diopside-epidote-calcite; and potassium feldspar-biotite-epidote-magnetite; and a later propylitic assemblage of chlorite-pyrite-epidote-scapolite-calcite (Preto, 1972; Stanley and others, 1995).

At the Ingerbelle deposit, skarn-like ore and gangue mineral zonation occurs along the contact of the Lost Horse stock where it intrudes agglomerate, tuff, tuff-breccia, and sedimentary rocks of the Nicola Assemblage (Sutherland Brown and others, 1971; Preto, 1972; Macauley, 1973; Fahrni and others, 1976; and Dawson and Kirkham, 1996). In these areas, early biotite hornfels was overprinted by prograde albite-epidote, chlorite, andradite, diopside, and sphene; then both the stock and prograde skarn were extensively replaced by retrograde albite, potassium feldspar, scapolite, calcite and hematite. Chalcopyrite-bornite ore, about 90% of which occurs in andesitic volcanic rocks, occurs along contacts, apophyses, and dikes of the Lost Horse stock.

Iron Mask (Afton, Ajax) Porphyry Cu-Au Deposit

The Iron Mask (Afton, Ajax) porphyry Cu-Au and other deposits in the Iron Mask district are hosted in the Iron Mask Batholith which consists of an Early Jurassic composite alkaline intrusion emplaced into the Nicola Group. The Ajax deposit occurs at the contact between two diorite phases of the Iron Mask pluton, a hybrid diorite and the younger Sugarloaf diorite (Ross and others, 1992, 1993; Ross and others, 1995). Pyrite, chalcopyrite, minor bornite, and molybdenite are accompanied by main-

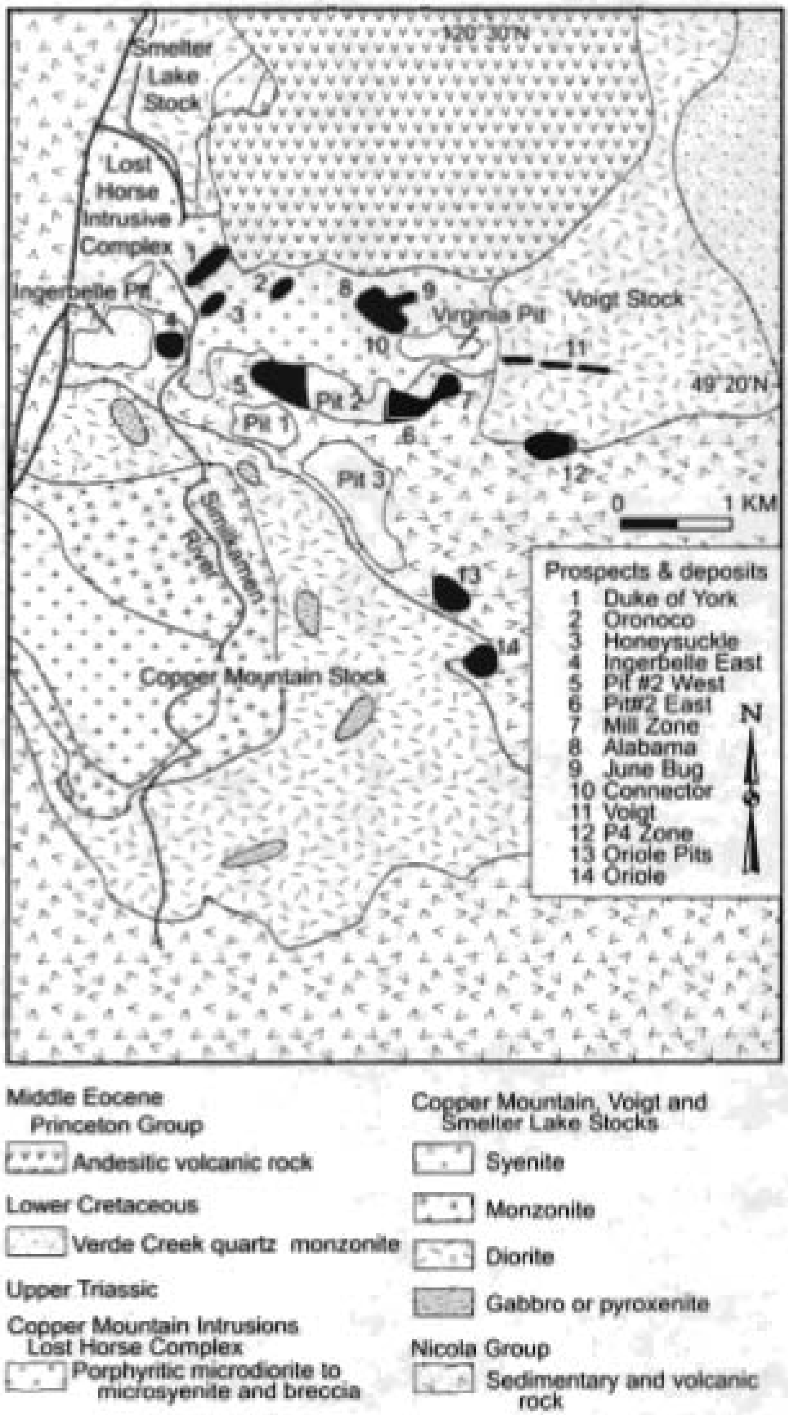


Figure 39. Copper Mountain (Ingerbelle) porphyry Cu-Au deposit, Copper Mountain South metallogenic belt, Canadian Cordillera. Schematic map view. Adapted from Preto and others (1972) and Stanley and others (1995).

stage albite and peripheral propylitic alteration. Potassic and scapolitic alteration crosscuts albite and propylitic alteration (Ross and others, 1992, 1993, 1995). The Afton deposit consists of a tabular-shaped body of chalcopyrite and bornite which is hosted in fractured diorite of the Cherry Creek pluton. A deeply penetrating supergene zone contains native copper and lesser chalcocite. Aggregate pre-production reserves and production for the Ajax East and West deposits and for the Afton deposit are 66 million tonnes grading 0.77% Cu and 0.56 g/t Au. The common occurrence of picrite intrusions along faults which cut the Nicola Group and their association with the porphyry deposits in the Iron Mask pluton indicate which regional, steeply-dipping faults controlled emplacement of the plutons in the batholith and also served as conduits for mineralizing fluids. An U-Pb zircon isotopic age of 207 Ma (Late Triassic) for the Cherry Creek pluton.

Deep drilling in 2001-2002 southwest of and below the Afton orebody by DRC Resources Corporation has proven a resource of 34.3 million tonnes of 1.55% Cu, 1.14 g/t Au, 3.42 g/t Ag and 0.125 g/t Pd in the Main Zone, and an additional 1.1 million tonnes of similar material in the Northeast Zone. The roughly tabular body is 850 m long, 750 m deep, and 70 m wide, and is open to length and depth. The deposit exhibitsboth hydrothermal and magmatic characteristics (DRC Resources Corp, news release April 2003).

Mt. Polley (Cariboo-Bell) Porphyry Cu-Au Deposit

The Mt. Polley (Cariboo-Bell) Porphyry Cu-Au deposit consists of magnetite, chalcopyrite and minor pyrite which occur in several intrusive phases and three distinct breccias in an Early Jurassic pseudoleucite-bearing alkaline complex which intrudes Upper Triassic Nicola alkaline volcanic and volcaniclastic rocks of the Quesnel trough (EMR Canada, 1989; McMillan, 1991; Mining Review, 1991; Gosh, 1992; Fraser and others, 1993; MINFILE, 2002). Some skarn and vein occurs in tuff and flows of the Nicola Assemblage. Supergene mineralization includes malachite, native copper, cuprite, chalcocite and covellite. The deposit contains proven reserves of 76.5 million tonnes grading 0.30% Cu, 0.47 g/t Au. Production through 1999 was 15.26 million tonnes with 341,000 g Ag, 6,858,448 g Au, and 31, 637,173 kg Cu (MINFILE, 2002). A U-Pb zircon isotopic age of 200 ± 1.5 Ma for diorite and a monzonite porphyry indicates an Early Jurassic age for intrusion of the host granitoid rocks.

Lodestone Mountain Zoned Mafic-Ultramafic Fe-Ti Deposit

The Lodestone Mountain zoned mafic-ultramafic Fe-Ti deposit consists of titaniferous magnetite and ilmenite which occur in pods and lenses and as disseminated grains in pyroxenite of the Tulameen zoned mafic-ultramafic (Alaskan type) complex (St. Louis and others, 1986; Nixon and others, 1997). The deposit contains estimated reserves of 81.65 million tonnes grading 17.56% Fe (EMR Canada, 1989). Minor Pt and Pd are reported. Reported Ti content of magnetite is 1%. An additional 249 million tons of possible and inferred ore is estimated. The deposit is interpreted as forming primarily by magmatic differentiation. The Late Triassic Tulameen layered mafic-ultramafic (Alaskan-type) complex is coeval, and in part cogenetic with adjacent gabbro plutons of the Lost Horse intrusive complex (Findlay, 1969). The complex intrudes basaltic andesite of the Nicola Group. Several lode and placer Pt-Pd deposits occur at Grasshopper Mountain in the Tulameen Complex (Findlay, 1969).

Origin of and Tectonic Controls for Copper Mountain (South) Metallogenic Belt

The Copper Mountain (South) metallogenic belt is hosted in the Copper Mountain plutonic suite. Syenite, monzonite, and monzodiorite are most common, but diorite, monzogranite, clinopyroxenite occur locally. The porphyry Cu-Au deposits are hosted in the felsic plutons, whereas the major Fe-Ti deposit at Lodestone Mountain is hosted in zoned mafic-ultramafic rocks. Many felsic plutons are lithologically and texturally complex, with multiple phases of intrusion and potassic metasomatism, characterized by abundant apatite and magnetite. Some plutons are nepheline-and leucite-normative; others are both quartz-saturated and quartz-undersaturated (Woodsworth and others, 1991). The deposits in the Copper Mountain (South) and (North) metallogenic belts are part of the subduction related Quesnellia island arc (Monger and Nokleberg, 1996; Nokleberg and others, 2000). In both the Copper Mountain (North) and Copper Mountain (South) metallogenic belts, many of the porphyry Cu-Au deposits occur in alkaline plutons. Isotopic ages indicate intrusion of host granitoid plutons and formation of associated mineral deposits occurred from about 207 to 197 Ma in the Late Triassic and Early Jurassic (Ross and others, 1995; Stanley and others, 1995). This age represents the end of subduction-related igneous building of Quesnellia island arc, just before accretion of the Quesnellia terrane, along the with tectonically-related Stikinia island arc and Cache Creek and Slide Mountain subduction-zone terranes, onto the North American Craton Margin (Monger and Nokleberg, 1996; Nokleberg and others, 2000).

Guichon Metallogenic Belt of Porphyry Cu-Mo-Au and Au Skarn Deposits (Belt GU) Southern British Columbia

The Guichon metallogenic belt of porphyry Cu-Mo-Au and Au skarn deposits (fig. 32; tables 3, 4) occurs in southern British Columbia and is associated with the Guichon Suite of numerous large calc-alkaline granitoid plutons hosted by the western Quesnellia island-arc terrane. The Guichon Suite has close spatial and temporal affinities with the Late Triassic and Early Jurassic island-arc volcanic rocks of the Nicola Assemblage of the Quesnellia island-arc terrane (Woodsworth and others, 1991). Parallel facies belts define a west-facing arc which progresses compositionally from calc-alkaline on the west to alkaline on the east for both volcanic and comagmatic granitoid plutonic rocks (Mortimer, 1987). The significant deposits in the belt are: (1) porphyry Cu-Mo deposits in the Highland Valley district (Bethlehem-JA, Valley Copper, Lornex, Highmont (Gnawed Mountain)); (2) porphyry Cu-Mo deposits at Axe (Summers Creek), Brenda (Peachland area), and Gibraltar (Pollyanna, Granite Mt); (3) porphyry Cu deposits at Primer (North Zone); (4) the Craigmont Cu-Fe skarn deposit; and (5) the Hedley Camp (Nickel Plate, Mascot) Au skarn deposit (table 4) (Nokleberg and others 1997a, b, 1998).

Highland Valley District (Bethlehem, Valley Copper, Lornex, Highmont) of Porphyry Cu-Mo Deposits

The Highland Valley district contains large porphyry Cu-Mo deposits which occur in the calc-alkaline, composite Guichon Creek Batholith in the southern Quesnellia terrane. Associated with the youngest, innermost, and most leucocratic phases of the batholith are late-stage dike swarms (McMillan, 1985Casselman and others, 1995). The batholith ranges from diorite and quartz diorite at the border, to younger granodiorite in the center. Although much variation occurs, individual deposits typically exhibit concentric zonation alteration which grades from central silicic alteration, to potassic, phyllic, and argillic alteration in an intermediate zone, and to peripheral propylitic alteration (McMillan and others, 1995). The principal deposits in the district at Bethlehem, Valley Copper, Lornex, and Highmont have combined production and reserves of about 2,000 million tonnes grading 0.45% Cu. The Highland Valley district is the largest porphyry Cu district in the Canadian Cordillera (McMillan, 1985).

Valley Copper, Brenda, Axe, and Primer Porphyry Cu-Mo Deposits

The Valley Copper porphyry Cu-Mo deposit (fig. 40) consists of fracture-controlled chalcopyrite (potassic alteration) and bornite (phyllic alteration) with minor digenite, covellite, pyrite, pyrrhotite, molybdenite, sphalerite and galena (McMillan, 1985, 1991; Highland Valley Copper Ltd., annual report, 1991; MINFILE, 2002). The linkages between sulfide minerals and alteration types are not clear because chalcopyrite also occurs in the phyllic zone and bornite occurs in the potassic zone. Combined estimated production and reserves are 716 million tonnes grading approximately 0.47% Cu, and 0.006% Mo. The deposit is hosted in granodiorite and quartz monzonite of the Bethsaida phase of the Guichon Creek Batholith. Minor amounts of Fe-Sb sulfide (gudmundite) and native gold are reported. An oxidized halo ranging in thickness from 0.3 to 100 meters consists of limonite, malachite, pyrolusite, digenite, native copper and tenorite. The average thickness of the oxidized zone is 33 meters.

The smaller Brenda, Axe, and Primer porphyry Cu-Mo deposits are hosted in calc-alkaline Jurassic stocks south of Highland Valley. The Gibraltar porphyry Cu-Mo deposit (Bysouth and others, 1995) is hosted in the calc-alkaline Granite Mountain granodiorite pluton which intruded the Cache Creek terrane during accretion with the tectonically-linked Stikinia Quesnellia island-arc terranes to the east and west, respectively. This accretion is interpreted as occurring during oroclinal warping of these terranes in the Early Jurassic (Drummond and others, 1976; Dawson and others, 1991).

Brenda Porphyry Cu-Mo Deposit

As another example, the Brenda porphyry Cu-Mo deposit consists of chalcopyrite and molybdenite with minor pyrite and magnetite which occur within veins and fractures (McMillan, 1991; Weeks and others, 1995; MINFILE, 2002). The deposit contains estimated combined production and reserves of 164.0 million tonnes grading 0.16% Cu, 0.04% Mo, 0.031 g/t Au, and 0.63g/t Ag. The deposit is hosted in granodiorite and quartz diorite of the Middle Jurassic Brenda Stock. Mineralization is interpreted as occurring during at least five stages of vein emplacement, each with unique attitudes and overall mineralogy developed in fractures. Grade is a function of fracture density and mineralogy of the veins. Potassic alteration (K-feldspar and biotite) accompanies sulfide mineralization. K-Ar hornblende ages are 176 Ma for the Brenda Stock and K-Ar biotite ages of 146 Ma is interpreted as the age of deposit.

Craigmont Cu-Fe Skarn Deposit

The Craigmont Cu-Fe skarn deposit occurs 30 km south of Highland Valley and consists of magnetite, hematite and chalcopyrite which occur as massive pods, lenses and disseminations within a calc-silicate skarn assemblage which replaces carbonate of the Nikola Assemblage (Dawson and others, 1991; MINFILE, 2002). Combined production and reserves are estimated at 34.9 million tonnes grading 1.21% Cu and 19.6% Fe. The host rocks are calcareous volcaniclastic and reefoid carbonate rocks of the western facies belt of the Nicola Assemblage, at their embayed contacts with the border phase of the Guichon Creek Batholith. Younger intrusive phases in the core of the batholith host the large Highland Valley porphyry Cu-Mo district (Dawson and others, 1991). Production between 1962 and 1982 was 33.4 million tonnes grading 1.21% Cu, 0.002 g/t Au and 0.007 g/t Ag. Reserves are estimated at 1.5 million tonnes grading 1.13% Cu. A 500,000 tonne stockpile of magnetite ore exists, from which approximately 45,000 tonnes per year are shipped to coalfields for use in heavy media separation. The deposit age is interpreted as Early Jurassic.

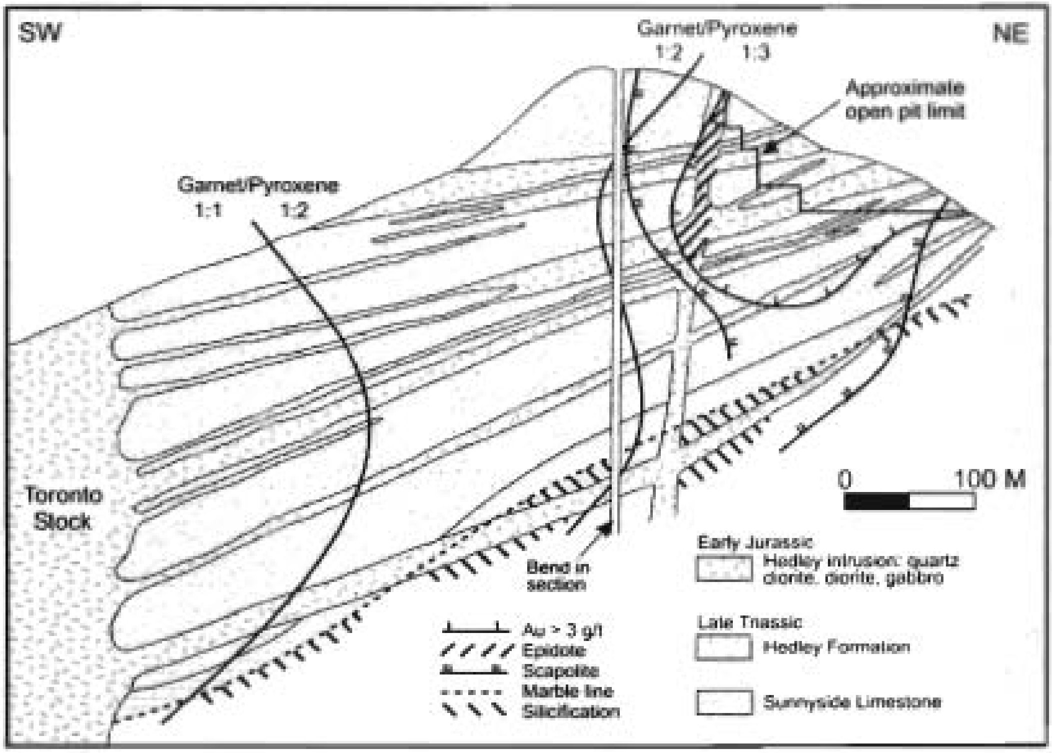


Figure 40. Valley Copper porphyry Cu-Mo deposit, Guichon metallogenic belt, Canadian Cordillera. Schematic cross section. Adapted from McMillan and others (1995).

Hedley Au Skarn Deposit

The Hedley Au-Ag skarn deposit consists of pyrrhotite, arsenopyrite, pyrite, chalcopyrite and sphalerite with trace galena, native Bi, native Au, electrum, tetrahedrite, native Cu, molybdenite and cobaltite (Ray and Webster, 1991; Ettlinger and others, 1992; Ray and others, 1993; Ray and Dawson, 1994) (fig. 41 for Nickel Plate part of deposit). The deposit is hosted in calc-silicate skarn associated with contact metamorphism of limestone of the eastern sedimentary facies of the Late Triassic Nicola Assemblage adjacent to the Early Jurassic Hedley diorite and gabbro intrusives. Production 1904 to 1991 was 8.43 million tonnes of ore from which was extracted 62.68 tonnes Au and 14.74 tonnes Ag from the Nickel Plate, Mascot, French, Goodhope and Canty parts of the deposit. Remaining reserves are 5.07 million tonnes grading 3.0 g/t Au, 2.5 g/t Ag, and 0.1% Cu. The ore bodies are semiconformable, tabular sulfide zones developed near the skarn-marble boundary, where alternating layers of garnet-rich and diopside-hedenbergite-rich prograde skarn follow bedding. Au together with anomalous amounts of Ag, Bi, Te, and Co are concentrated with arsenopyrite, pyrrhotite, and pyrite in the latest stage, a retrograde quartz-calcite-epidote-sulfide assemblage (Ettlinger and others, 1992). The deposit age is interpreted as Early Jurassic.

The intrusions associated with Au skarns in the Canadian Cordillera constitute a distinctive suite of calc-alkaline to alkaline plutons of synorogenic to late orogenic timing. At Hedley, intrusions are enriched in Fe, depleted in total alkalies and silica, and have low ferric/ferrous iron ratios, i.e. are reduced, relative to other types of skarn deposits (Ray and Webster, 1991; Dawson, 1996b).

Origin of and Tectonic Controls for Guichon Metallogenic Belt

The Guichon metallogenic belt of porphyry Cu-Mo deposits is hosted in and adjacent to Late Triassic to Early Jurassic plutonic rocks of the Quesnellia island arc (Monger and Nokleberg, 1996; Nokleberg and others, 2000). The calc-alkaline Guichon Creek batholith, which hosts the porphyry Cu-Mo deposits in the Highland Valley district, was emplaced at about 210 Ma, approximately contemporaneous with the intrusion of the composite alkaline Iron Mask and Copper Mountain plutons, 40 and 120 kilometers away to the northeast and southeast, respectively (McMillan and others, 1995). About 100 km to the south, the Alaskan-type, ultramafic-mafic Tulameen Complex was emplaced. The Quesnellia island-arc is interpreted as forming on the deformed continental margin strata of Yukon-Tanana terrane, as a rifted fragment of the North American Craton Margin (Gehrels and others, 1990; Monger and Nokleberg, 1996; Nokleberg and others, 1994c, 1997c, 2000).

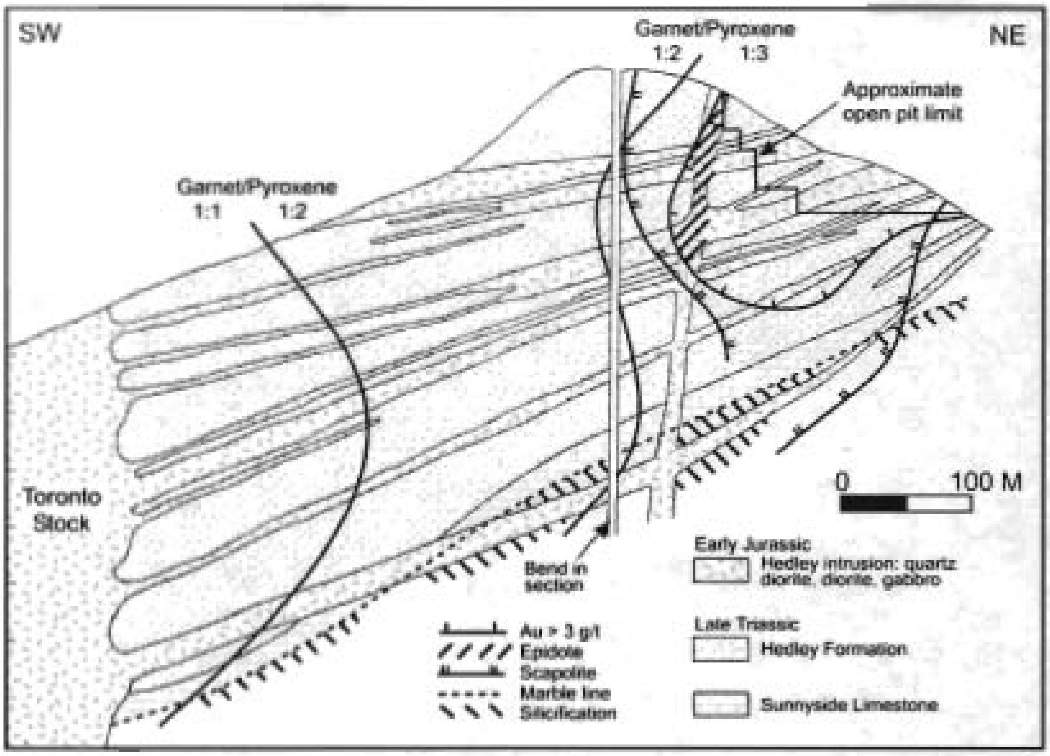


Figure 41. Nickel Plate Au skarn deposit, Hedley Camp, Guichon metallogenic belt, Canadian Cordillera. Schematic cross section. Adapted from Dawson (1996b).

Texas Creek Metallogenic Belt of Porphyry Cu-Mo-Au, Au-Ag Polymetallic Vein and Au Quartz Vein Deposits (Belt TC) Northern British Columbia

The Texas Creek composite metallogenic belt of porphyry Cu-Mo-Au, Au-Ag polymetallic vein, and Au quartz vein deposits (fig. 32; tables 3, 4) occurs in northern British Columbia and is hosted in Late Triassic to Middle Jurassic granitoid plutons which intrude coeval marine and subaerial mafic to felsic volcanic, volcaniclastic, and sedimentary rocks of the Stuhini and Hazelton Groups in the Stikinia island-arc terrane. The major porphyry Cu-Mo-Au deposits are at Schaft Creek (Liard Copper), Kerr (Main Zone), and Sulphurets (Gold Zone) (table 4) (Nokleberg and others 1997a, b, 1998). The major polymetallic vein deposits are at Brucejack Lake (West Zone, Shore Zone), Snip (Shan), Red Mountain, Silbak-Premier (Premier Gold), and Snowfields. Other significant deposits are the Polaris-Taku (Whitewater) and Muddy Lake (Golden Bear, Totem) Au quartz vein deposits, and the E & L gabbroic Ni-Cu deposit atSnippaker Creek.

Texas Creek District Porphyry Cu-Mo-Au Deposits

The Texas Creek district contains significant porphyry Cu-Mo and polymetallic vein deposits. The large Schaft Creek (Liard Copper) porphyry Cu-Mo deposit is hosted mainly in Triassic andesite which is intruded by diorite and granodiorite of the Middle Jurassic Hickman batholith. The deposit consists of a quartz-vein stockwork with potassic alteration in a low-grade core, an intermediate zone of bornite, chalcopyrite, and molybdenite associated with chlorite-sericite alteration which contains the bulk of the ore, and epidote in the periphery (EMR Canada, 1989; Spilsbury, 1995; MINFILE, 2002). Estimated reserves are 971.5 million tonnes grading 0.298% Cu, 0.033% MoS_2, 1.20 g/t Ag, and 0.14 g/t Au. The Hickman batholith has an isotopic age of 182 Ma.

The Kerr and Sulphurets porphyry Cu-Au deposits (Ditson and others, 1995; Fowler and Wells, 1995; Kirkham and Margolis, 1995) occur in intermediate volcanic rocks, volcaniclastic and sedimentary rocks of the Early Jurassic Unuk River formation of the Hazelton Assemblage. The Kerr deposit consists of an elongate shear zone, about 2 km long by 900 m wide. The deposit contains estimated reserves of 134.9 million tonnes grading 0.76% Cu and 0.34 g/t Au (Ditson and others, 1995). The Sulphurets deposit consists of a 1.5 km northeast-trending halo which surrounds the Kerr (Main Zone) deposit, and consists of a quartz-pyrite-sericite halo and associated stockwork of chalcopyrite and bornite surrounding the main copper deposit (Fowler and Wells, 1995). Estimated reserves are 18.2 million tonnes grading 0.82 g/t Au and 0.35% Cu.

The Snip (Au), Red Mountain (Au- Cu), Snowfields Au-Ag, and Brucejack Lake Au-Ag polymetallic vein deposits are hosted in clastic, volcaniclastic, and volcanic rocks of the Early Jurassic Hazelton Assemblage and adjacent plutons of the Texas Creek plutonic suite. The Snip deposit, the only mine in the group, consists of a shear-vein system with high Au values which crosscuts graywacke and siltstone adjacent to a contact with a porphyritic quartz monzonite stock. Estimated combined production and reserves are 1.9 million tonnes grading 29.5 g/t Au (Rhys and Godwin, 1992; Rhys and others, 1995). The Red Mountain deposit (Brown and Kahlert, 1995) consists of a semi-tabular stockwork of pyrite-pyrrhotite which contains high Au and Ag values (up to 20 g/t Au), disseminated sphalerite-pyrrhotite mineralization, and intense sericite alteration. The deposit occurs above a quartz-molybdenite stockwork at the top of a Early Jurassic monzodiorite and quartz monzodiorite stock and sill which intrude sedimentary and volcanic rocks of the Triassic Stuhini Group and the Early and Middle Jurassic Hazelton Group. Estimated resources at Red Mountain are 2.5 million tonnes of 12.8 g/t Au and 38.1 g/t Ag (Rhys and others, 1995).

The Silbak Premier Au-Ag-Pb-Zn epithermal vein deposit is hosted by volcanic and volcaniclastic rocks of the Hazelton Assemblage. The deposit consists of argentite and electrum which occur both in low-sulfide and base-metal sulfide ore. The veins are related to subvolcanic, quartz-K-feldspar porphyry dikes which form part of the Texas Creek plutonic suite. Between 1918 and 1987, about 56.1 tonnes of Au and 1,270 tonnes of Ag were produced. Estimated reserves are 6.1 million tonnes grading 2.33 g/t Au and 90.5 g/t Ag (Alldrick and others, 1987).

Polaris Au Quartz Vein Deposit

The Polaris Au quartz vein deposit consists of native gold associated with arsenopyrite and stibnite in quartz-ankerite veins (Marriott, 1992; Mihalynuk and Marriott, 1992). The deposit has produced approximately 231,000 oz Au from 760,000 tons of ore, with a recovered grade of 0.30 oz Au/t. The deposit contains estimated resources of 2.196 million tonnes grading 14.74 g/t Au. The deposit is underlain by late Paleozoic to Triassic Stuhini Group volcanic and sedimentary rocks. The volcanic rocks composed of andesite and basalt flows and pyroclastic rocks host gold in an assemblage of arsenopyrite, ankerite, sericite, pyrite, fuchsite, and stibnite. The structures hosting the deposit are splays of the Tulsequah River shear zone.

Muddy Lake Au Quartz Vein Deposit

The Muddy Lake (Golden Bear, Totem) Au quartz vein deposit consists of disseminations and fracture-fillings of extremely fine-grained pyrite which occur along fault contacts of tuffite and limestone (Melis and Clifford, 1987; Osatenko and Britton, 1987; Schroeter, 1987; Dawson and others, 1991; North American Metals Corp, news release, February 1995). The deposit contains estimated reserves of 720,000 tonnes grading 5.75 g/t Au. The deposit has been interpreted as a mesothermal Au-quartz veins hosted by silicified limestone, dolostone and tuff of the Permian Asitka Assemblage, and mineralization is probably related to an unexposed pluton of the Texas Creek suite. The deposit occurs in a north-trending, 20-km-long fault zone. Four deposits occur on the property at Bear, Fleece, Totem, and Kodiak. Recent studies interpret the deposit as a Carlin-type deposit (Poulsen, 1996; Lefebure and others, 1999), which contains both oxidized and primary ore.

Origin of and Tectonic Controls for Texas Creek Metallogenic Belt

The Texas Creek metallogenic belt occurs in a suite of dominantly calc-alkaline granitoid, but in part, gabbroic and alkalic, plutons which intruded mainly in the Early Jurassic as part of the Stikinia arc and the flanking Cache Creek subduction-zone terrane, prior to accretion to North America in the Middle Jurassic (Dawson and others, 1991; Kirkham and Margolis, 1995; Mihalynuk and others, 1994; Monger and Nokleberg, 1996; Nokleberg and others, 2000). The Stikinia island-arc terrane is interpreted as forming on the deformed continental margin strata of Yukon-Tanana terrane which is interpreted as a rifted fragment of the North American Craton Margin (Gehrels and others, 1990; Monger and Nokleberg, 1996; Nokleberg and others, 1994c, 1997c; 2000). Several metallogenic belts formed during granitic magmatism associated with formation of the Stikinia and Quesnellia island arcs. The metallogenic belts which formed in conjunction with the Stikinia island arc are the Copper Mountain (North), Galore Creek, Guichon, Klotassin, Texas Creek, and Toodoggone belts. The Copper Mountain (South) and Guichon metallogenic belts formed in conjunction with the Quesnellia island arc.

Early Jurassic Metallogenic Belts (208 to 193 Ma; Figure 42)

Overview

The major Early Jurassic metallogenic belts in Alaska and the Canadian Cordillera are summarized in table 3 and portrayed on figure 40. No major Early Jurassic metallogenic belts existed in the Russian Far East. The major belts in Alaska and the Canadian Cordillera are as follows. (1) Three belts are hosted in the Wrangellia island-arc superterrane These belts are the Talkeetna Mountains-Alaska Range belt (TM), which contains kuroko massive sulfide deposits, the Alaska Peninsula (AP) belt, which contains granitic magmatism deposits, and the Island Porphyry (IP) belt, which contains granitic-magmatism-related deposits,. These belts are interpreted as forming in the Talkeetna-Bonzana arc preserved in the Wrangellia superterrane. (2) In the Canadian Cordillera, continuing on from the Late Triassic, commencing in the Early Jurassic were the Coast Mountains (CM), Copper Mountain (North; CMN), Copper Mountain (South; CMS), Galore (GL), Guichon (GU), Klotassin (KL), and Texas Creek

(TC), and Toodoggone (TO) belts which contain granitic magmatism-related deposits and are interpreted as forming in the axial parts of the Stikinia-Quesnellia island arc. In the followiung descriptions of metallogenic belts, a few of the noteable signficant lode deposits (table 4) are described for each belt.

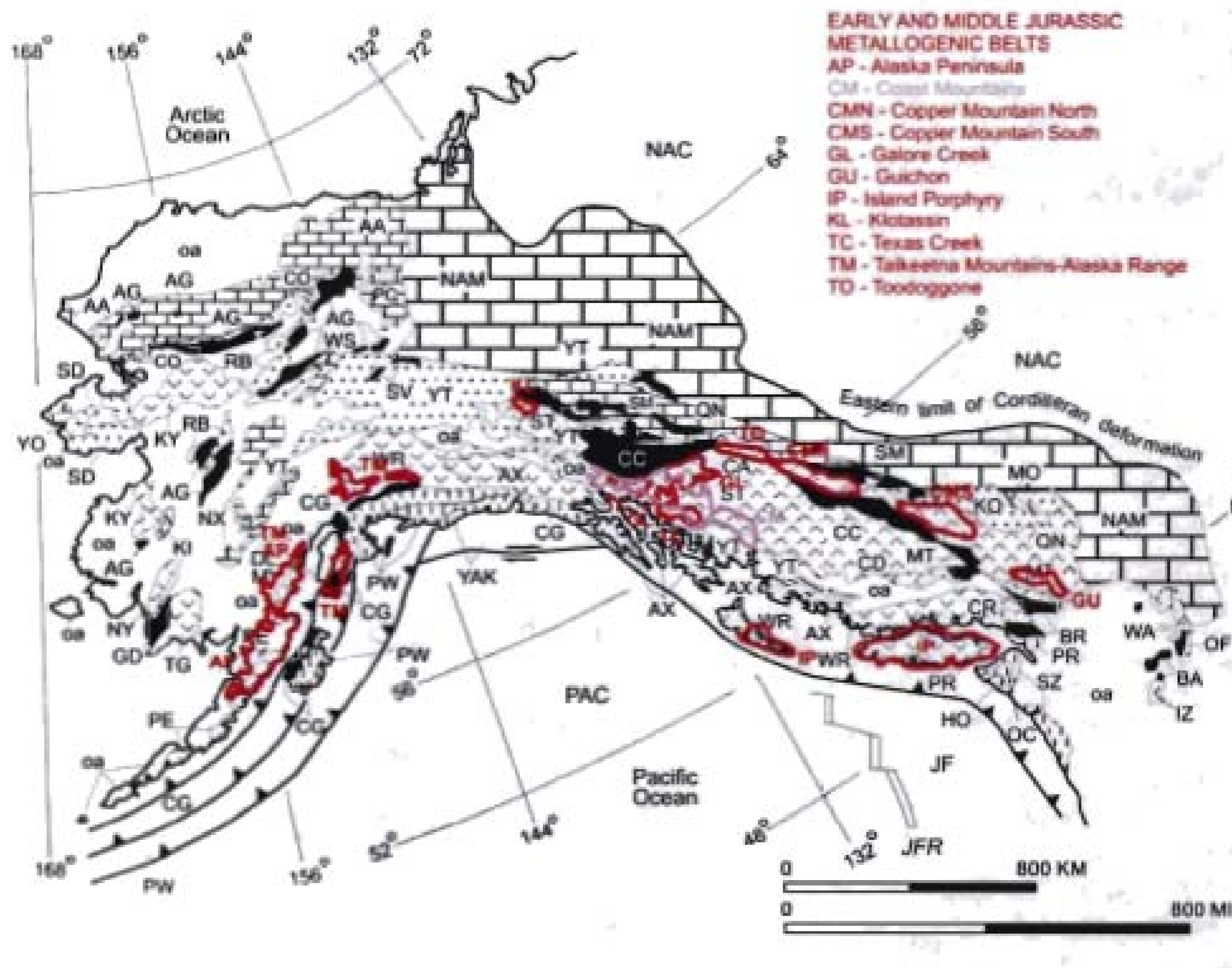


Figure 42. Generalized map of major Early and Middle Jurassic metallogenic belts and terranes for Alaska, Canadian Cordillera, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 3 for explanation.

Metallogenic-Tectonic Model for Early Jurassic (208 to 193 Ma; Figure 43)

During the Early Jurassic (Hettangian to Pleinsbachian - 208 to 193 Ma), the major metallogenic-tectonic events were (fig. 43; table 3): (1) continuation of continental-margin arcs and associated subduction near the North Asian Craton in the Russian Far East; (2) beginning of assembly of previously rifted cratonal, passive continental-margin, and island-arc terranes between which craton and the ancestral Pacific Ocean to form the Kolyma-Omolon superterrane; (3) continuation of the Talkeetna, Bonanza, and Stikinia-Quesnellia arcs and associated metallogenic belts, and formation of companion subduction zones; (4) continued sinistral-slip imbrication of the Stikinia-Quesnellia island arc, contained metallogenic belts, and associated subduction zones during oblique-sinistral convergence between the ancestral Pacific Ocean plate and the North American Craton Margin; and (5) with the beginning of accretion of the Stikinia-Quesnellia arc at about 185 Ma, the start of mountain building in the North American Cordillera. Sedimentation continued along the passive continental margins of North Asian and North American Cratons.

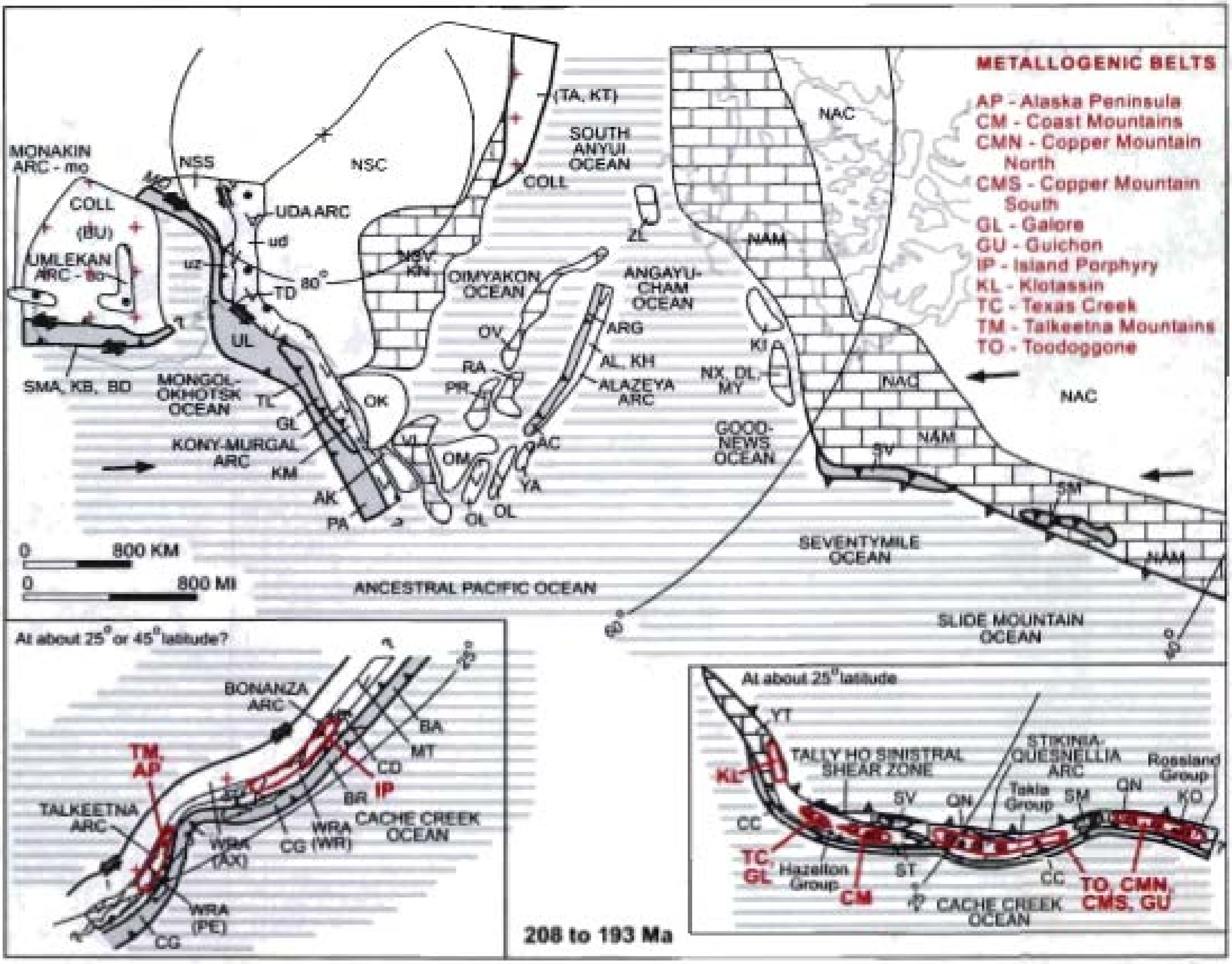


Figure 43. Early Jurassic (Hettangian through Pliensbachian - 208 to 193 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

Specific Events for Early Jurassic

(1) The Monakin continental-margin arc, consisting of the Monakin volcanic-plutonic belt (mo) and the Umlekan continental-margin arc, consisting of the Umlekan-Ogodzhin volcanic-plutonic belt (uo) and associated units, commenced activity. Associated with this arc was oblique (sinstral) subduction of part of the Ancestral Pacific Ocean plate to form the Samarka (SMA), Khabarovsk (KB), and Badzhal (BD) terranes.

(2) The continental-margin arc Uda arc (consisting of the Uda volcanic-plutonic belt (ud) and Uda-Zeya sedimentary basin (uz) continued to form. Associated with the arc was subduction and sinistral transpression of part of the Mongol-Okhotsk Ocean plate to form the Turkuringra-Dzhagdinski (TD), Ulban (UL), and Galam (GL) terranes. Subduction and sinistral transpression occurred along the Mongol-Okhotsk suture (*MO*).

(3) The extensive Kony-Murgal island arc (Kony-Murgal terrane (KM)) continued to form as an offshore extension of the Uda arc. Associated with the arc was subduction of part of the Ancestral Pacific Ocean plate to form the Talovskiy (TL) and Penzhina-Anadyr (PA) terranes. Inboard of the Kony-Murgal island arc (KM) were the Okhotsk (OK), Avekova (AK), and Omolon (OM) cratonal terranes which were previously rifted from the North Asian Craton (NSC), and the Viliga (VL) passive continental-margin terranes which was previously rifted from the North Asian Craton Margin (NSV). Behind the arc were fragments of prior Devonian to Pennsylvanian island-arc terranes, including the Beryozovka turbidite-basin (BE), and Oloy (OL), and Yarakvaam (YA) island-arc terranes.

(4) The Angayucham Ocean (Kobuck Sea of Plafker and Berg, 1994), along with the South Anyui Ocean, continued to receive sparse continental-derived detritus. Previously rifted terranes, including the Kilbuck-Idono cratonal (KI) and the combined Nixon Fork-Dillinger-Mystic passive continental-margin (NX, DL, MY) terranes were near the North American Craton Margin.

(5) The dextral-slip imbrication of the Stikinia-Quesnellia arc and associated subduction-zone terranes continued along the Tally Ho shear zone (Hansen and others, 1990; Hart, 1995) (inset, fig. 43). Part of the Tally Ho shear zone may occur be defined by a string of fault-bounded(?) ultramafic rocks which occur within the Yukon-Tanana terrane in northern Southeastern Alaska (Himmelberg and others, 1985). Alternatively, the present-day configuration of the Stikinia-Quesnellia island-arc and associated subduction zone terranes may have formed by oroclinal warping in response to a combination of oblique convergence and arc migration toward the companion subduction zone of the Cache Creek terrane (Mihalynuk and others, 1994) (not depicted in fig. 43). Oroclinal warping is interpreted as forming in response to: (1) oblique-sinstral convergence between the ancestral Pacific Ocean plate and the Stikinia-Quesnellia arc; and (2) arc migration toward the companion subduction zone (trench rollback), similar to tectonics of the present-day Banda arc in Southeast Asia (McCaffrey and Abers, 1991; Mihalynuk and others, 1994). Migration of the Stikinia-Quesnellia arc and associated terranes toward North America was accomplished by subduction and (or) obduction of the Seventymile Ocean plate along the continental margin.

(6) The Stikinia part of the arc consisted of the extensive suite of the subduction-related volcanic and plutonic arc rocks of the Hazelton Group which also formed in response to subduction of the Cache Creek Ocean plate (CC). In central part of the Stikinia-Quesnellia island arc, coeval subduction-related granitic plutonic rocks also intruded the previously-accreted passive continental-margin Yukon-Tanana terrane (YT), which may have been the stratigraphic basement for part of the Stikinia island arc (Mihalynuk and others, 1994).The plutonic rocks also intrude the structurally overlying Slide Mountain (SM) and Seventymile (SV) terranes. The subduction-related volcanic and plutonic arc rocks of the Quesnellia part of the arc, consisting of the Takla and Rossland Groups, and the coeval igneous belts formed in response to continued subduction of part of the Cache Creek Ocean plate (CC; Mihalynuk and others, 1994).

(7) In the axial parts of the Stikinia-Quesnellia island arc, continuing on from the Late Triassic, were the Coast (CM), Copper Mountain (North; CMN), Copper Mountain (South; CMS), Galore (GL), Guichon (GU), Klotassin (KL), and Texas Creek (TC), and Toodoggone (TO) belts which contain granitic magmatism-related deposits

(8) Also occurring was obduction of parts of the Seventymile and Slide Mountain Ocean plates onto the North American Craton Margin (NAM; Mihalynuk and others, 1994). Part of the obduction occurred by the Late Triassic and (or) Early Jurassic when granitic plutons of the Stikinia-Quesnellia island arc intruded across an intervening fault. During the final stage of obduction of the Slide Mountain terrane (SM) over the Kootenay metamorphosed continental-margin terrane (KO), these terranes started to obduct onto the North American Craton Margin (NAM). Migration of the Stikinia-Quesnellia arc and associated terranes toward the North American Craton Margin was accomplished by subduction of the Seventymile Ocean plate along the continental-margin and by obduction.

(9) Outboard and perhaps at a lower paleolatitude (either 25° or 45°), the Talkeetna and Bonanza arcs continued activity in the Wrangellia superterrane (WRA). This extensive arc formed along most of the length of the Wrangellia superterrane with coeval equivalents in the Cadwallader (CD) island arc and Methow (MT) turbidite-basin terranes. Forming in the arcs were the Talkeetna Mountains-Alaska Range metallogenic belt, which contains kuroko massive sulfide deposits, the Alaska Peninsula metallogenic belt (AP), which contains Cu- and Fe-skarn deposits, and the Island Porphyry metallogenic belt (IP), which contains granitic-magmatism-related deposits. Associated with the Talkeetna and Bonanza arcs was subduction of part of the Cache Creek Ocean plate to form the Chugach (CG), Bridge River (BR), and possibly Baker (BA) terranes.

Metallogenic Belts Formed in Middle Mesozoic Talkeetna-Bonzana Island Arc in Wrangellia Superterrane

Alaska Peninsula Metallogenic Belt of Granitic Magmatism Deposits (Belt AP) Alaska Peninsula

The Alaska Peninsula metallogenic belt of granitic magmatism deposits (fig. 42; tables 3, 4), mainly Cu-Au, Cu-Zn, and Fe skarn deposits, occurs on the northeastern Alaska Peninsula. The metallogenic belt is hosted in the central and northwestern part of the Peninsular sequence of the Talkeetna-Bonanza island in the Wrangellia superterrane where intruded by Jurassic granitoid plutons (Nokleberg and others, 1994c, 1997c). The significant deposits in the belt are the Crevice Creek, Glacier Fork, Kasna Creek Cu-Fe skarn deposits, and the Magnetite Island Fe skarn deposit (table 4) (Nokleberg and others 1997a, b, 1998).

Crevice Creek Cu-Au Skarn Deposit

The Crevice Creek Cu-Au skarn deposit (Martin and Katz, 1912; Richter and Herreid, 1965) consists of at least ten epidote-garnet skarn bodies which occur in limestone over a 2 km^2 area adjacent to the Jurassic(?) granodiorite stock of Pilot Knob. The skarn bodies vary from 3-800-m long and from a few centimeters to 60 m wide. Local magnetite-rich skarn occurs in isolated pods in nearby metavolcanic rocks, and local disseminated magnetite zones occur in epidote-garnet skarns. The garnet skarn bodies occur in limestone, chert, and argillite of the Late Triassic Kamishak Formation and in overlying metavolcanic rocks of the Late Triassic(?) to Early Jurassic Talkeetna Formation (Nokleberg and others, 1994d). The largest skarn body at Sargent Creek contains epidote, garnet, actinolite, quartz, pyrite, and chalcopyrite. Lenses up to 1 m wide and 10 m long average 7% Cu. Numerous airborne magnetic anomalies occur in the area surrounding the granodiorite stock. The Crevice Creek deposit produced 11 tonnes of ore from high-grade zones, with an average grade of 4.5 g/t Au, 514 g/t Ag, and 17.5% Cu.

Origin of and Tectonic Controls for Alaska Peninsula Metallogenic Belt

The Cu-Au and Cu-Zn skarn deposits of the Alaska Peninsula metallogenic belt occur in areas where Jurassic(?) quartz diorite and tonalite intrude calcareous sedimentary rock, and generally consist of epidote-garnet skarn in limestone or marble, containing disseminations and layers of chalcopyrite, sphalerite, and pyrrhotite. The Fe skarn deposits occur in dolomite or marble and generally consist of magnetite skarn containing lesser garnet, amphibole, and rare chalcopyrite. The Fe skarns occur in areas where Jurassic(?) quartz diorite and tonalite intrude calcareous sedimentary rocks. These skarn deposits occur in marine sedimentary rocks of the Late Triassic Kamishak Formation, in Early Triassic marble, and in volcanic and volcaniclastic rocks of the Late Triassic(?) to Early Jurassic Talkeetna Formation.

The Alaska Peninsula metallogenic belt occurs in, or adjacent to, the Late Triassic(?) and Early to Middle Jurassic, Talkeetna part of the Talkeetna-Bonanza island arc which extends for several hundred km along the strike length of the Alaska Peninsular part of the Wrangellia superterrane (Burns, 1985; Plafker and others, 1989; Nokleberg and others, 1994c, 1997c; DeBari and Coleman, 1989). Abundant field, chemical, and isotopic data indicate that the Talkeetna arc is mainly gabbro, diorite, and tonalite, and rarely granodiorite, has calc-alkaline composition and lower initial Sr ratios, and is interpreted as having formed in an island arc above a subduction zone (Reed and others, 1983; Burns, 1985; Plafker and others, 1985). The Jurassic(?) plutonic rocks, which host the Alaska Peninsula metallogenic belt, form the older part of the Alaska-Aleutian Range batholith, which along with the Late Triassic(?) and Early Jurassic Talkeetna Formation and Border Ranges ultramafic-mafic complex, collectively define the Talkeetna arc which is a key comlonent of the Peninsular sequence (Nokleberg and others, 1994a).

Talkeetna Mountains-Alaska Range Metallogenic Belt of Kuroko Massive Sulfide Deposits (Belt TM) Northern Part of Southern Alaska

The Talkeetna Mountains-Alaska Range metallogenic belt of kuroko massive sulfide deposits (fig. 42; tables 3, 4) occurs in the northern part of southern Alaska. The metallogenic belt is hosted in submarine tuff, andesite, and dacite of the Late Triassic(?) and Early Jurassic Talkeetna Formation, which is a major unit in the Peninsular sequence and Talkeetna-Bonanza islanc arc of the Wrangellia superterrane (Nokleberg and others, 1994c, 1997c). The one significant deposit is the Johnson River prospect (table 4) (Nokleberg and others 1997a, b, 1998).

Johnson River Massive Sulfide(?) Deposit

The Johnston River kuroko massive sulfide(?) deposit (R. L. Detterman, oral commun., 1984; Steefel, 1987; Madelyn Mollholyn, written commun., 1988; J. Proffett, written commun., 1991) consists of quartz-sulfide veins and massive sulfide lenses containing chalcopyrite, pyrite, sphalerite, galena, and gold which occur in discordant pipe-like bodies of silicified volcanic rock. Veins of chlorite, sericite, and anhydrite, and a cap of barite occur proximal to the four ore horizons. The deposit occurs in pyroclastic and volcaniclastic rocks of Portage Creek Agglomerate in the Talkeetna Formation; similar mineralized horizons have been found along strike to the northeast. Local stockworks, which cut the metavolcanic rock, suggest either mobilization or additional deposition. The deposit is interpreted as forming from deposition of sulfides directly over a capped submarine vent system during Jurassic volcanism. The deposit contains an estimated 997,540 tonnes grading 10.35 g/t Au, 7.84 g/t Ag, 8.3% Zn, 1.1% Pb, and 0.76% Cu (Bundtzen and others, 1994). In the same region, in the Oshetna River drainage of the Nelchina district, northeast of Anchorage, tuff in the Talkeetna Formation contains disseminated chalcopyrite and barite. Also in this region, Au-enriched massive sulfide deposits in the Eskay Creek district contain many similar morphological features to those described at Johnson River.

Origin of and Tectonic Controls for Talkeetna Mountains-Alaska Range Metallogenic Belt

The Late Triassic(?) and Early Jurassic Talkeetna Formation (fig. 42) which hosts the Talkeetna Mountains-Alaska Range metallogenic belt consists mainly of bedded andesitic volcaniclastic sandstone and tuff, ignimbrite, breccia, and agglomerate; andesite and lesser rhyolite and basalt flows; and shale (Plafker and others, 1989; Nokleberg and others, 1994a).The Talkeetna Formation is linked to Middle Jurassic plutonic rocks which form the older part of the Alaska-Aleutian Range batholith, which along with the Border Ranges ultramafic-mafic complex, define the Talkeetna arc (Nokleberg and others, 1994a). The Peninsular sequence forms a major part of the Talkeetna-Bonanza island arc, and is one of three major sequences in the Wrangellia superterrane. The Talkeetna arc is tectonically linked to a discontinuous series of Early Triassic to Jurassic(?)

blueschist units and the McHugh Complex which form a partly coeval subduction zone complex which occurs along the northern margin of the Chugach terrane (Nokleberg and others, 2000).

Island Porphyry Metallogenic Belt of Porphyry Cu-Mo, Cu Skarn, Fe Skarn and Cu Skarn Deposits (Belt IP) Vancouver Island

The Island Porphyry metallogenic belt of porphyry Cu-Mo; and Fe and Cu-Fe-Au skarn deposits (fig. 42; tables 3, 4) occurs on Vancouver Island and Queen Charlotte Islands in southern British Columbia and is hosted in the Island Plutonic Suite rocks that are part the Gambier overlap assemblage of the Wrangellia superterrane (Woodsworth and others, 1991; Anderson and Reichenbach, 1991). On Vancouver Island, the plutons are mainly Early to Middle Jurassic, whereas on Queen Charlotte Island, the plutons are mainly Middle to Late Jurassic. The significant deposits are the Island Copper (Rupert Inlet), Hushamu, Red Dog, porphyry Cu-Mo and porphyry Cu deposits, the Burnaby Iron (Jib), Jedway (Magnet, Jessie), Kennedy Lake (Brynnor), Tasu Sound (Wesfrob, Tasu, Garnet), Texada Iron, and Zeballos Iron (Ford) Fe skarn deposits, the Benson area (Empire, Coast Copper) Cu-Fe skarn deposits, and the Texada (Vananda, Marble Bay) Cu-Au skarn deposit (table 4) (Nokleberg and others 1997a, b, 1998).

Island Copper Porphyry Cu-Mo-Au Deposit

The Island Copper (Rupert Inlet) porphyry Cu-Mo-Au deposit (fig. 44) consists of pyrite, chalcopyrite and molybdenite which occur as fracture fillings and disseminations (EMR Canada, 1989; Perello and others, 1995; MINFILE, 2002). The main part of the deposit, which occurs in a carapace which surrounds a quartz-feldspar porphyry dike, is tabular shaped, ranges from 60 to 180 meters wide, 1700 meters long and 300 meters deep, and strikes 290° and dips 60°N, parallel to the dike. Between 1971 and 1994, the mine at the deposit produced 345 million tonnes with an average grade of 0.41% Cu, 0.017% Mo, 0.91 g/t Au, and 1.4 g/t Ag (MINFILE, 2002). The deposit contains additional estimated reserves of 257 million tonnes grading 0.52% Cu and 0.22 g/t Au. The deposit is hosted in andesite and basalt tuff in the Middle Jurassic Bonanza Group which are intruded by a quartz feldspar porphyry dike.

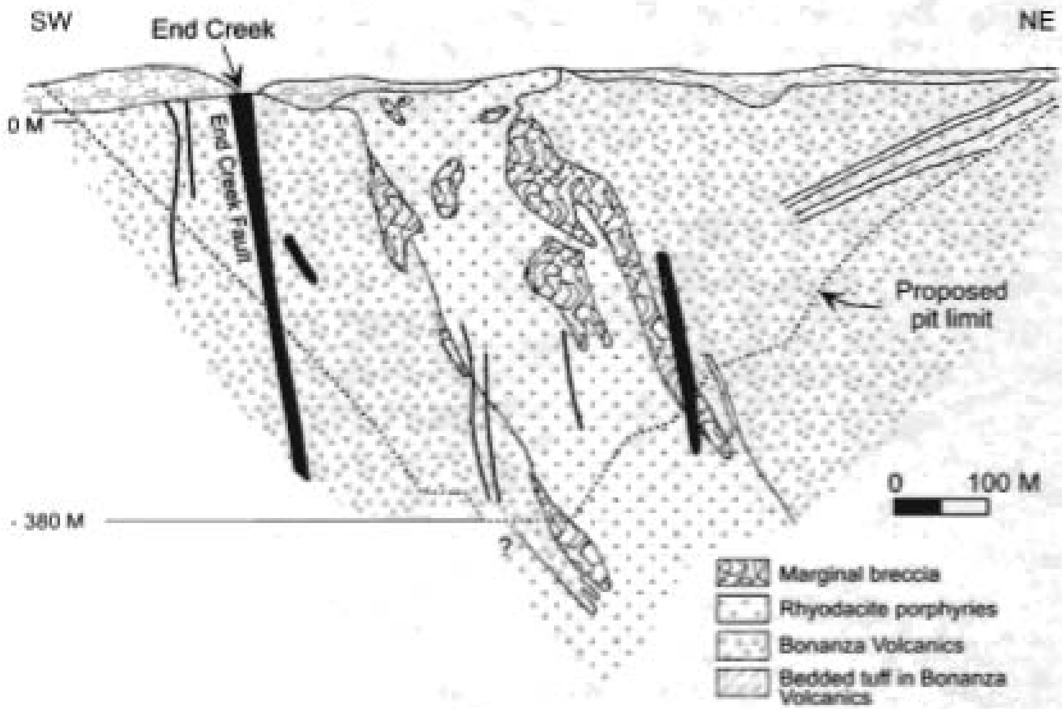


Figure 44. Island Copper porphyry Cu-Mo deposit, Island Copper metallogenic belt, Canadian Cordillera. Schematic cross section. Adapted from Perello and others (1995).

At Island Copper, early, intramineral and late stages of quartz-feldspar porphyry dike intrusions, which exhibit a U-Pb zircon isotopic age of 168.5 Ma (Ross and others, 1996), are mantled by breccias and concentrically enveloped by early-stage biotite-magnetite-chalcopyrite-molybdenite, main-stage quartz-chalcopyrite-molybdenite and magnetite-actinolite-plagioclase veining, and a late-stage, peripheral assemblage of chlorite-sericite-clay-epidote-chalcopyrite-pyrite (Leitch and others, 1995). The mineralized dikes are interpreted as coeval and cogenetic with the adjacent Rupert stock to the east (Ross and others, 1996). Late stage porphyry dikes and associated breccia contain an advanced argillic alteration assemblage of kaolinite, pyrophyllite, sericite and dumortierite, similar to advanced alteration assemblages of silica, clay, pyrophyllite, diaspore, zunyite, and alunite in volcanic rocks of the Bonanza Group at Mount McIntosh and Pemberton Hills. These units are interpreted by Panteleyev and Koyanagi (1994) as high levels of alteration related to a stock hosting porphyry Cu-Mo deposits as at Hushamu (Dasler and others, 1995).

Fe and Cu-Fe-Au Skarns in Island Porphyry Metallogenic Belt

Significant skarn Fe and skarn Cu deposits are hosted mainly by limestone of the Late Triassic Quatsino Formation on Vancouver and Texada Islands, the equivalent Kunga Formation on the Queen Charlotte Islands, and to a lesser degree, by volcanic rocks of the underlying Karmutsen Formation. Skarn deposits rich in iron and some deposits containing significant copper and precious metals, commonly occur along contacts of the above strata with granitoid plutons of the Jurassic Island Suite. Magnetite, chalcopyrite, bornite, pyrite, pyrrhotite and molybdenite are associated with the prograde skarn assemblage of grandite garnet, diopside, wollastonite and epidote. Significant concentrations of base and precious metals may be associated with the retrograde assemblage of actinolite, tremolite, epidote, quartz, chlorite and calcite (Dawson and Kirkham, 1996). The deposit size ranges up to 30 million tonnes grading 40-50% Fe. Important past iron producers were Tasu, Jedway, Burnaby Iron, Brynnor, and Texada Island. Significant copper skarns are Coast Copper and Marble Bay.

Texada Iron Fe Skarn Deposit

Texada Iron Fe skarn deposit consists of massive magnetite skarn mineralization which occurs as replacement bodies at the Prescott (fig. 45), Yellow Kid, and Paxton mines (Webster and Ray, 1990; Ray and Webster, 1997; MINFILE, 2002). The deposits produced an estimated 17.6 million tonnes grading 61% Fe. The deposits are hosted in limestone of the Late Triassic Quatsino Formation, at or near contacts with quartz monzonite of the Middle Jurassic Gillies Stock which has an U-Pb zircon isotopic age of 178 Ma. The deposits consist of massive magnetite and associated garnet, pyroxene, epidote, amphibole, minor calcite, and sporadic pyrite and pyrrhotite. Rare arsenopyrite and sphalerite also occur. Sampling of Fe-skarn magnetite from the Texada Iron Mines by Webster and Ray (1990) indicate grades of 3.14% Cu, 46.6 g/t Ag, and 2.8 g/t Au.

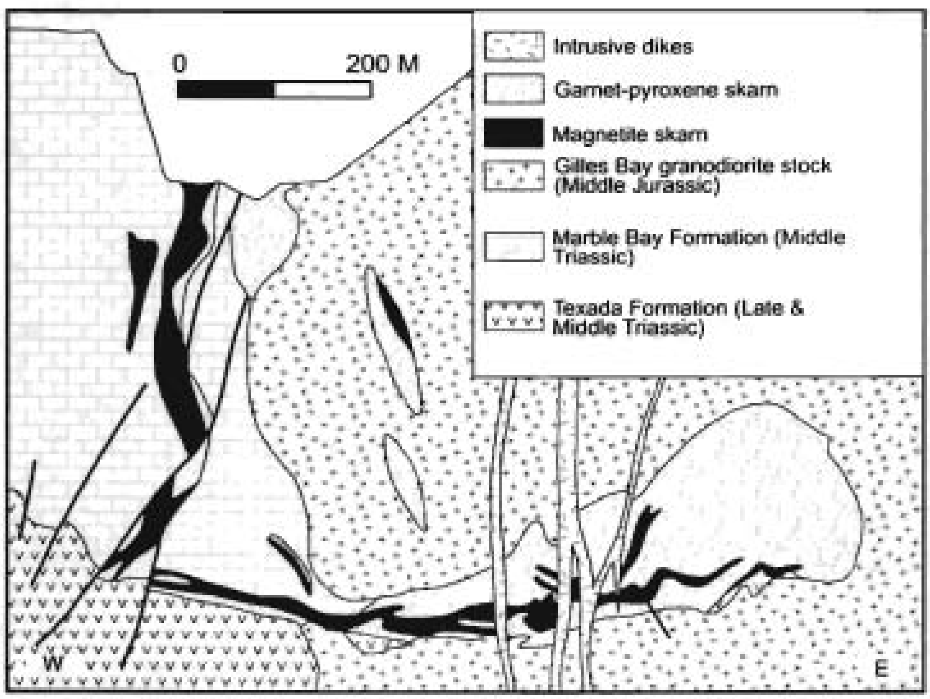


Figure 45. Prescott body, Texada Fe skarn deposit, Island Porphyry metallogenic belt, Canadian Cordillera. Schematic cross section. Adapted from Webster and Ray (1990).

Origin of and Tectonic Controls for Island Porphyry Metallogenic Belt

The Island Porphyry metallogenic belt is hosted in the Jurassic volcanic and plutonic rocks which form part of the Gambier overlap assemblage in southern British Columbia. This group is part of the Talkeetna-Bonanza arc in the Wrangellia superterrane (Nokleberg and others, 2000). In southern British Columbia, the host rocks on northern Vancouver Island consist of the Bonanza Group, and on Queen Charlotte Island, the host rocks consist of the correlative Yakoun Group. The Middle Jurassic volcanic and plutonic rocks, with isotopic ages of 165 to 170 Ma, which host the Island Copper metallogenic belt are the youngest part of the Bonanza arc which was initiated in the Early Jurassic (Monger and Nokleberg, 1996; Ross and others, 1996). The Middle to Late Jurassic plutons of the Burnaby Island suite and coeval volcanic rocks of the Yakoun Group are a younger and northern part of the arc.

The younger, Late Jurassic part of the Island Porphyry metallogenic belt is coeval with: (1) the Western-Southeastern Alaska metallogenic belt which is hosted in the Late Jurassic and Early Cretaceous Gravina belt of the Wrangellia superterrane in Southeastern Alaska; and (2) the Eastern Alaska Range metallogenic belt which is hosted in the Kahiltna and Nutzotin overlap assemblages in southern Alaska. Together, the granitoid plutonic and andesitic volcanic rocks of the Gravina-Nutzotin-Gambier overlap assemblage, and the Kahiltna overlap assemblage define the Gravina island arc which is interpreted as forming on the northern, or leading edge of the Wrangellia island-arc terrane during migration towards North America (Nokleberg and others, 1984, 1985, 2000; Nokleberg and Lange, 1985a; Plafker and others, 1989; Plafker and Berg, 1994; Nokleberg and others, 2000). The Gravina arc and associated granitic magmatism deposits are tectonically linked to the younger part of the McHugh Complex which forms the northern part of the Chugach subduction zone and accretionary wedge complex (Nokleberg and others, 2000).

Metallogenic Belts Formed in Middle Mesozoic in Stikinia-Quesnellia Island Arc

Klotassin Metallogenic Belt of Porphyry Cu-Au-Ag Deposits (Belt KL), Southern Yukon Territory

The Klotassin metallogenic belt of porphyry Cu-Au-Ag deposits (fig. 42; tables 3, 4) occurs in the southern Yukon Territory and is hosted in the Klotassin Batholith. This batholith consists of a calc-alkaline granitoid pluton which forms part of the more extensive Klotassin Plutonic Suite which intrudes the Stikinia island-arc terrane in southwestern Yukon Territory (Woodsworth and others, 1991). The significant deposits are metamorphosed and deformed porphyry Cu-Au-Ag deposits at Minto Copper and Williams Creek (table 4) (Nokleberg and others 1997a, b, 1998). Both deposits are hosted in a foliated Early Jurassic granodiorite pluton. Significant PGE prospects occur in mafic and ultramafic plutons at Pyroxene Mountain (Mortensen and others, 1994).

Minto Copper and Williams Creek Porphyry Cu-Au-Ag Deposits

The Minto Copper porphyry Cu-Au-Ag deposit consists of an assemblage of disseminated chalcopyrite, bornite, magnetite and pyrite with minor hessite and native gold which occur in zones of moderate to strong gneissic foliation in diorite of the Early Jurassic Klotassin Batholith (EMR Canada, 1989; Minto Explorations Ltd., news release, January 25, 1994). Estimated reserves are 6.55 million tonnes grading 1.87% Cu and 0.51 g/t Au. The deposit is interpreted as a metamorphosed porphyry Cu deposit. The deposit age is interpreted as Early Jurassic (Mortensen and others, 1994).

The Williams Creek porphyry Cu-Au-Ag deposit consists of chalcopyrite, bornite, pyrite and minor arsenopyrite and molybdenite which occur as interstitial grains parallel with the gneissic foliation in granodiorite of the Triassic Klotassin Batholith (EMR Canada, 1989; Western Holdings Ltd., annual report, 1992). Estimated reserves are 14.2 million tonnes grading 1.01% Cu and 0.51 g/t Au. Jurassic regional metamorphism destroyed much of the original features of the deposit. An oxidized zone, up to 200 meters deep, contains malachite and azurite which replaces copper sulfides. The deposit age is interpreted as Early Jurassic (Mortensen and others, 1994).

Origin of and Tectonic Controls for Klotassin Metallogenic Belt

The Minto Copper and Williams Creek porphyry Cu-Au-Ag deposits are similar, pre-accretionary porphyry Cu-Au-Ag deposits which are hosted in foliated, gneissic granodiorite and diorite of the Klotassin pluton (Pearson and Clark, 1979). The original textures of the deposits were mostly destroyed during Middle to Late Jurassic regional metamorphism and associated deformation. These events are interpreted as occurring during accretion of the Stikinia island arc and associated terranes onto the North American Craton Margin (Le Couteur and Tempelman-Kluit, 1976) after oroclinal warping of the Stikinia-Quesnellia island arc and tectonically-linked Cache Creek subduction-zone terrane (Mihalynuk and others, 1994; Monger and Nokleberg, 1996;

Nokleberg and others, 2000). Before accretion, the Stikinia island arc is interpreted as forming on the Yukon-Tanana terrane, a rifted and deformed fragment of the North American Craton Margin (Monger and Nokleberg, 1996; Nokleberg and others, 2000). Several metallogenic belts formed during granitic magmatism associated with formation of the Stikinia and Quesnellia island arcs. The metallogenic belts which formed in conjunction with the Stikinia island arc are the Copper Mountain (North), Galore Creek, Guichon, Klotassin, Texas Creek, and Toodoggone belts. The Copper Mountain (South) and Guichon metallogenic belts formed in conjunction with the Quesnellia island arc.

Toodoggone Metallogenic Belt of Au-Ag Epithermal Vein and Porphyry Cu-Au Deposits (Belt TO) Northern British Columbia

The Toodoggone metallogenic belt of Au-Ag epithermal vein and porphyry Cu-Au deposits (fig. 42; tables 3, 4) occurs in northern British Columbia and is hosted by: (1) the Toodoggone Formation, a Early Jurassic succession of subaerial, intermediate, calc-alkaline to alkaline, predominantly pyroclastic rocks (Diakow and others, 1991, 1993; Monger and others, 1991); (2) and the coeval and comagmatic calc-alkaline plutons of the Black Lake Suite (Woodsworth and others, 1991). The belt and host rocks occur in the eastern part of the Stikinia island-arc terrane along the southwestern flank of the Stikine Arch. The Toodoggone Formation forms part of the Early Jurassic, calc-alkaline part of the Stikinia terrane and were deposited on the alkaline-subalkaline, Late Triassic Takla Group. The Toodoggone Formation is correlated with the Hazelton Group to the south and west. The significant deposits are Au-Ag epithermal vein deposits in Toodoggone district, and the Kemess porphyry Cu-Au deposit (table 4) (Nokleberg and others 1997a, b, 1998).

Toodoggone District of Au-Ag Epithermal Vein Deposits

The Toodoggone district contains significant Au-Ag epithermal vein deposits, with production from four principal deposits; Cheni (Lawyers, Cliff Creek), Chappelle (Baker), Shas, and Al.

The Lawyers Au-Ag epithermal vein deposit (fig. 46) consists of native gold, silver and electrum, with amethystine quartz, calcite and barite occurring in veins, stockworks and breccia. The deposit is hosted in silicified, propylitized and argillized intermediate volcaniclastic rocks which are proximally associated with plutons of the Black Lake Suite and with regional faults. The current resource is estimated at 1.76 million tonnes grading 6.8 g/t Au and 242.7 g/t Ag (Schroeter, 1983; Vulimiri and others, 1986; Dawson and others, 1991). This and other deposits in the district display higher sulfide content and higher-temperature alteration assemblages in relation to decreasing distance from contacts with granitoid stocks and plutons.

The Chappelle (Baker) Au-Ag epithermal vein deposit consists of a Zn-Pb-Fe-sulfide-rich mineral assemblage hosted in calcareous sedimentary rocks of the Takla Group along the contact with the Black Lake stock (Barr, 1980). The Shasta Au-Ag epithermal vein deposit lacks sulfides and any evidence of underlying plutons, but exhibit advanced argillic alteration assemblages which indicate high-level deposition (MINFILE, 2002).

Kemess North and South Porphyry Cu-Au Deposit

The Kemess North, a developed prospect, and the Kemess South mine are porphyry Cu-Au deposits which consist of pyrite, chalcopyrite, magnetite, hematite, molybdenite and digenite which occur in stockwork veinlets and fractures and as disseminations (Diakow and others, 1991, 1993; Rebagliati and others, 1995, Diakow, 2001). The deposits are hosted in equigranular intrusions which cut mainly mafic volcanic rock of the the Late Triassic Takla Group. At the Kemess South mine, mineralization is related to a felsic to intermediate, mainly monzodiorite pluton of Early Jurassic age which is probably related to the Black Lake Suite and coeval with the Toodoggone Formation. At the Kemess North prospect, several large hydothermal alteration zones enclose six major zones of porphyry-style Cu-Au deposits, as well as several vein and skarn deposits. Oxidation of these deposits and subsequent development of a supergene blanket are interpreted as an Early Jurassic event which occurred in Early Jurassic volcaniclastic and epiclastic rock (Diakow, 2001). The Late Cretaceous sedimentary rock of the Sustut Group are interpreted as capping the supergene zone.

The Kemess South porphyry Cu-Au deposit is hosted by the relatively flat-lying Maple Leaf quartz monzodiorite sill. Higher Cu and Au grades correlate with zones of intense quartz-pyrite-chalcopyrite stockwork which contains intensely-developed K-feldspar vein selvages and magnetite stringers. A supergene zone, which formed contemporaneously with the Late Cretaceous Sustut Basin, forms about 20% of the deposit, and contains elevated Cu grades and contains chalcocite and native Cu. Production commenced at Kemess South in 1998, based on estimated reserves of 442 million tonnes of hypogene and supergene ore grading 0.23% Cu and 0.4 g/t Au (Rebagliati and others, 1995; El Condor Resources Ltd., news release, July 19, 1993).

The Kemess North porphyry Cu-Au deposit is hosted in potassic-altered, mafic volcanic rocks of the Takla Group. The deposit is centered on Early Jurassic porphyritic monzodiorite dikes. Higher grade Cu-Au mineral assemblages in volcanic host rocks are associated with hydrothermal biotite alteration, whereas potassium feldspar and propylitic alteration decrease zonally outwards from these centers, along with decreasing Cu and Au. Estimated reserves are116 million tonnes grading 0.19% Cu and 0.38 g/t Au (Rebagliati and others, 1995; Northern Miner, March 10, 2003).

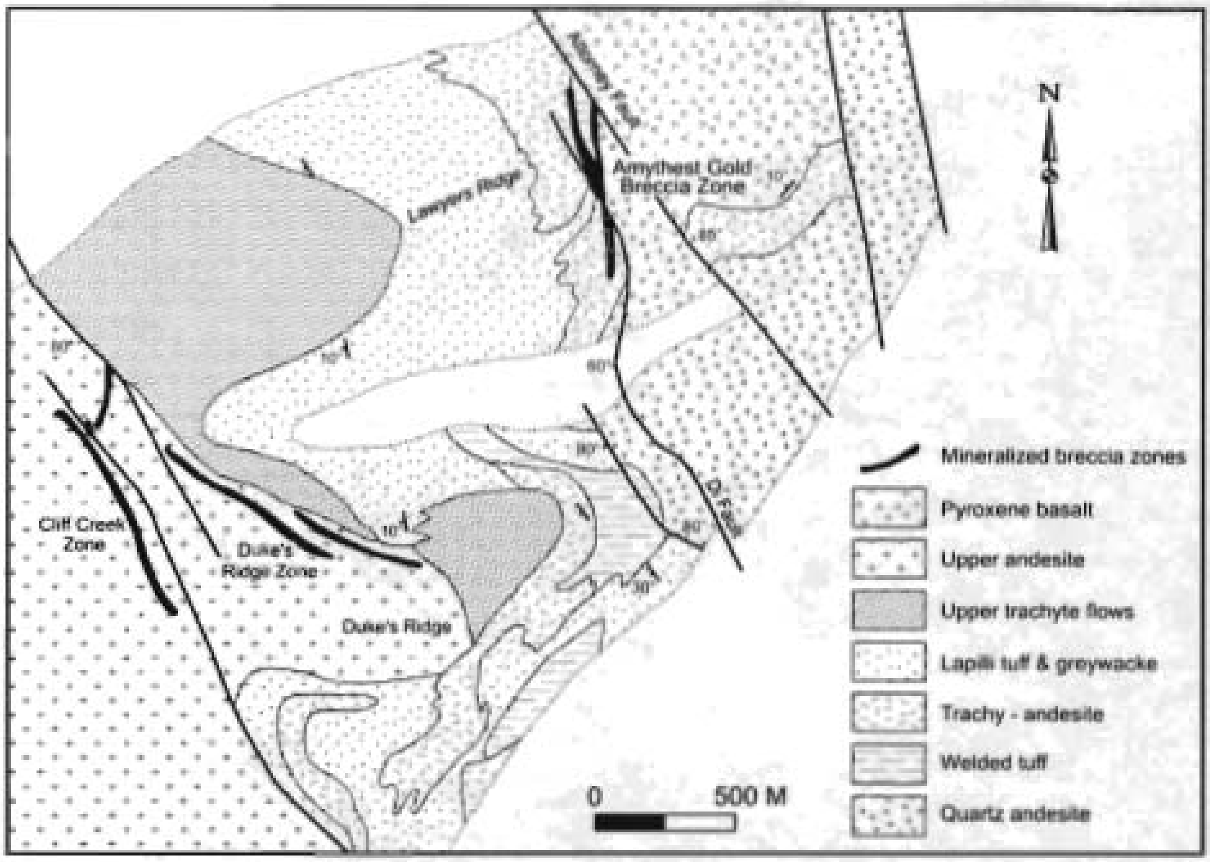


Figure 46. Lawyers Au-Ag epithermal vein deposit, Toodoggone metallogenic belt, Canadian Cordillera. Schematic geologic map showing various zones. Adapted from Vulimiri and others (1986).

Origin of and Tectonic Controls for Toodoggone Metallogenic Belt

The Toodoggone metallogenic belt is hosted in the Toodoggone Formation, a Early Jurassic succession of subaerial, intermediate, calc-alkaline to alkaline, predominantly pyroclastic rocks, and coeval and comagmatic calc-alkaline plutons of the Black Lake Suite which occur on the outer limb of the oroclinal warp of the Stikinia and Quesnellia island arc and associated terranes. The transition from alkaline to calc-alkaline magmatism is interpreted as forming during the final stages of the oroclinal warp in the Early Jurassic, before accretion of the Stikinia-Quesnellia arc and associated Cache Creek subduction-zone terrane in the Middle Jurassic (Mihalynuk and others, 1994; Monger and Nokleberg, 1996; Nokleberg and others, 2000). The volcanic rocks of the Hazelton Group and correlative units, such as the Toodoggone Formation, and associated granitoid plutonic rocks, represent emergence of the arc and a transition from marine to subaerial deposition in the Early Jurassic. The Toodoggone Formation consists exclusively of high-K, calc-alkaline volcanic rock which was deposited in high-energy subaerial flows, associated air-fall tuff, and lesser lava flows bertween about 200 to 190 Ma.

The Stikinia island-arc terrane is interpreted as forming on the deformed continental margin strata of Yukon-Tanana terrane which may be a rifted fragment of the North American Craton Margin (Gehrels and others, 1990; Monger and Nokleberg, 1996; Nokleberg and others, 1994c, 1997c, 2000). Several other metallogenic belts are herein interpreted as forming during granitic magmatism associated with formation of the Stikinia and Quesnellia island arcs, including the Copper Mountain (North), Galore Creek, Guichon, Klotassin, Texas Creek, and Toodoggone belts.

Coast Mountains Metallogenic Belt of Volcanogenic Cu-Zn-Au-Ag Massive Sulfide Deposits (Belt CM) Northern British Columbia

The Coast Mountains metallogenic belt of volcanogenic massive sulfide deposits (fig. 42; tables 3, 4) occurs in the western limb of the oroclinally-warped Stikinia island-arc terrane. To the west, the belt and terrane are border by, and in part, intruded by plutons along the eastern edge of the Coast Plutonic Complex. The metallogenic belt contains a variety of significant kuroko, Cyprus, and Besshi massive sulfide deposits (Nokleberg and others, 1997a, b). The significant deposits are the Tulsequah Chief and Eskay Creek kuroko Zn-Cu-Pb-Au-Ag massive sulfide deposits, the Granduc Besshi massive sulfide deposit, and the Alice Arm Silver and Anyox districts of Cyprus massive sulfide deposits (table 4) (Nokleberg and others 1997a, b, 1998).

The Coast metallogenic belt contains a variety of volcanogenic massive sulfide deposits of various ages. Following are the major rock sequences which host volcanogenic massive sulfide deposits in the Stikinia terrane: (1) the middle to upper Paleozoic Stikine assemblage which contains interbedded volcanic arc, carbonate and fine-grained clastic rocks; (2) the Late Triassic Stuhini Group and Takla Group, which unconformably overlie the Stikine assemblage, and contain volcanic arc rocks and interfingering clastic rocks which are intruded by coeval granitoids; and (3) the unconformably-overlying, Early Jurassic Hazelton and Spatzizi Groups, and the Takwahoni Formation which contain andesitic volcanic rocks and intercalated sedimentary rocks. The Stikinia island-arc terrane is interpreted as forming on the deformed continental margin strata of Yukon-Tanana terrane which may be a rifted fragment of the North American Craton Margin (Gehrels and others, 1990; Monger and Nokleberg, 1996; Nokleberg and others, 1994c, 1997c).

Tulsequah Chief Kuroko Massive Sulfide Deposit

The Tulsequah Chief kuroko Zn-Cu-Au-Ag-Pb volcanogenic massive sulfide deposit consists of massive to disseminated pyrite, sphalerite, chalcopyrite, and galena, with minor tennantite and tetrahedrite in conformable lenses which occur between a hanging wall of dacite tuff and a footwall sequence of basalt and andesite flows. The volcanic rocks constitute a bimodal sequence within the Devonian and Mississippian Mount Eaton series of the Stuhini Group. The occurrence of several stacked ore lenses, with repeated bimodal volcanic and sedimentary rocks indicate which several rifting events occurred in a local basin which was part of a mature island arc (Sebert and Barrett, 1996). Production from 1951 to 1957 was 574,000 tonnes. The deposit has reserves of 8.8 million tonnes of ore grading 6.42% Zn, 1.3% Cu, 1.21% Pb, 2.1 g/t Au and 106.4 g/t Ag. (Dawson and others, 1991; Redfern Resources Ltd., summary report,1995)

Granduc Besshi Massive Sulfide Deposit

The Granduc Besshi Cu (Ag-Au-Co) deposit consists of several overlapping, tabular sulfide lenses hosted in pelagic sedimentary rocks and turbidites which are underlain by basalt and andesite flows, within the Late Triassic Stuhini Group (Grove, 1986; Dawson and others, 1991; MINFILE, 2002). The host rocks are intruded by Jurassic to Tertiary granitoid plutons of the Coast Plutonic Complex. The deposit contains reserves of 32.5 million tonnes grading 1.93% Cu, 7 g/t Ag and 0.13 g/t Au. A Besshi-type exhalative origin is supported by laterally extensive, well-bedded ore lenses, dominantly sedimentary host rock, and ore minerals. The deposition is interpreted as occurring in a sedimentary basin adjacent to the Stuhini island arc.

Eskay Creek Kuroko Massive Sulfide Deposit

The Eskay Creek Ag-Au polymetallic kuroko massive sulfide deposit consists of sphalerite, tetrahedrite, boulangerite, and bournonite with minor pyrite and galena which occur as stratabound and stratiform massive, semi-massive and disseminated layers in carbonaceous and tuffaceous mudstone of the Lower Jurassic Mount Dilworth Formation of the Hazelton Assemblage (EMR Canada, 1989; Prime Equities Inc., 1991; MacDonald, 1992; Sherlock and others, 1999; MINFILE, 2002). Gold and silver occur as electrum grains (5 to 80 microns) within fractured sphalerite, commonly in contact with galena. The deposit has estimated reserves3.9 million tonnes grading 26 g/t Au and 986 g/t Ag. The 21B zone has reserves 1.04 million tonnes grading 63.8 g/t Au and 2567 g/t Ag, and the 109 zone, a coeval epithermal vein deposit, has reserves of 0.97 million tonnes grading 9.6 g/t Au and 127 g/t Ag.

Alice Arm Silver District of Massive Sulfide Deposits

The Alice Arm Silver district, which contains the Dolly Varden, North Star, and other kuroko Ag-Pb-Zn deposits, is hosted in Early Jurassic **calc-alkaline volc**anic rocks of the Hazelton Group. The deposits consists of pyrite, sphalerite, galena, tetrahedrite, pyrargyrite and some native silver in barite-Ag-rich sulfide lenses (Devlin and Godwin, 1986; EMR Canada, 1989; Mining Review, 1992). The various deposits are interpreted as structurally displaced parts of a once continuous massive sulfide zone. The combined production and reserves for the Alice Arm Silver district are 2.91 million tonnes grading 390 g/t Ag, 0.53% Pb, and 0.82% Zn.

Anyox Cyprus Massive Sulfide Deposit

The Anyox Cyprus Cu-Ag-Au district contains the Hidden Creek and Bonanza deposits, and five other occurrences. The deposits and occurrences consist of lenticular to sheet-like ore bodies of pyrite and pyrrhotite, lesser chalcopyrite, and minor sphalerite and magnetite (Grove, 1986; EMR Canada, 1989; Hoy, 1991; Smith, 1993). Combined production and reserves are 26.7 million tonnes grading 1.48% Cu, 9.6 g/t Ag, and 0.17 g/t Au. The deposits and occurrences are located near the contact between volcanic and sedimentary rocks in a roof pendant of tholeiitic mafic volcanic rocks and overlying turbidites which are intruded by the Coast Plutonic Complex. Host rock geochemistry indicates formation along an ocean ridge. The host strata are interpreted as Early and Middle Jurassic volcanic and sedimentary units of the Stikinia terrane (Macdonald and others, 1996).

Origin of and Tectonic Controls for Coast Mountains Metallogenic Belt

The Coast Mountains metallogenic belt contains a variety of volcanogenic massive sulfide deposits which occur in three age-range groups of volcanic and associated rocks in the Stikinia island-arc terrane. The following three age-range sequences of massive sulfide deposits and host rocks are identified. (1) The middle to upper Paleozoic Stikine assemblage contains interbedded volcanic arc, carbonate and fine-grained clastic rocks. The Tulsequah Chief kuroko massive sulfide deposit and associated occurrences formed in this age-range of the island arc. (2) The Late Triassic Stuhini Group and Takla Group, which unconformably overlie the Stikine assemblage, contains volcanic arc rocks and interfingering clastic rocks which are intruded by coeval granitoids. The Granduc Besshi massive sulfide deposit formed in this age-range of the island arc. And (3) the unconformably-overlying Early Jurassic Hazelton and Spatzizi Groups, and the Takwahoni Formation contain andesitic volcanic rocks and intercalated sedimentary rocks. The kuroko massive sulfide deposits in the Alice Arm Silver district, and the Cyprus massive sulfide deposits in the Anyox district formed in this age-range of an island arc. Each of the three age-range groups of volcanic and associated rocks are interpreted as parts of a long-lived volcanic arc which were deposited on Yukon-Tanana continental margin terrane, a rifted fragment of the North American Craton Margin (Gehrels and others, 1990; Monger and Nokleberg, 1996; Nokleberg and others, 1994c, 1997c). With more detailed study, each of the three age-range groups of volcanic rocks and associate massive sulfide deposits might be designated as separate metallogenic belts.

Middle Jurassic Metallogenic Belts (193 to 163 Ma) (Figure 47)

Overview

The major Middle Jurassic metallogenic belts in Alaska and the Canadian Cordillera are summarized in table 3 and portrayed on figure 47. No significant Middle Jurassic metallogenic belts exist in the Russian Far East. The major belts are as follows. (1) In Southern Alaska and the Canadian Cordillera, continuing on from the Early Jurassic, are the Talkeetna Mountains-Alaska Range belt, which contains kuroko massive sulfide deposits, the Alaska Peninsula (AP) belt, which contains Cu- and Fe-skarn deposits, and the Island Porphyry (IP) belt, which contains granitic-magmatism-related deposits. These belts are hosted in the Wrangellia island-arc superterrane and are interpreted as forming in the Talkeetna-Bonzana arc preserved in the superterrane. And (2) in the Canadian Cordillera, continuing on from the Early Jurassic were the Coast Mountains (CM), Copper Mountain (North; CMN), Copper Mountain (South; CMS), Galore (GL), Guichon (GU), Klotassin (KL), Texas Creek (TC), and Toodoggone (TO) belts which contain either granitic magmatism-related deposits or deposits related to felsic to mafic marine volcanism. These belts are interpreted as forming in the axial parts of the Stikinia-Quesnellia island arc.

Metallogenic-Tectonic Model for Middle Jurassic (193 to163 Ma; Figure 47)

During the Middle Jurassic (Toarcian through Callovian - 193 to 193 Ma), the major metallogenic-tectonic events were (fig. 47; table 3): (1) continuation of continental-margin arcs and associated subduction near the North Asian Craton in the Russian Far East; (2) beginning of assembly of previously rifted cratonal, passive continental-margin, and island-arc terranes between which craton and the ancestral Pacific Ocean to form the Kolyma-Omolon superterrane; (3) continuation of the Talkeetna, Bonanza, and Stikinia-Quesnellia arcs, associated metallogenic belts, and formation of companion subduction zones; (4) continued sinistral-slip imbrication of the Stikinia-Quesnellia island arc and associated subduction zones during oblique-sinistral convergence between the ancestral Pacific Ocean plate and the North American Craton Margin; and (5) with the beginning of accretion of the Stikinia-Quesnellia arc at about 185 Ma, the start of mountain building in the North American Cordillera. Sedimentation continued along the passive continental margins of North Asian and North American Cratons.

Specific Events for Middle Jurassic

(1) The Monakin continental-margin arc, consisting of the Monakin volcanic-plutonic belt (mo) and the Umlekan continental-margin arc, consisting of the Umlekan-Ogodzhin volcanic-plutonic belt (uo) and associated units, commenced activity. Associated with this arc was oblique (sinstral) subduction of part of the Ancestral Pacific Ocean plate to form the Samarka (SMA), Khabarovsk (KB), and Badzhal (BD) terranes.

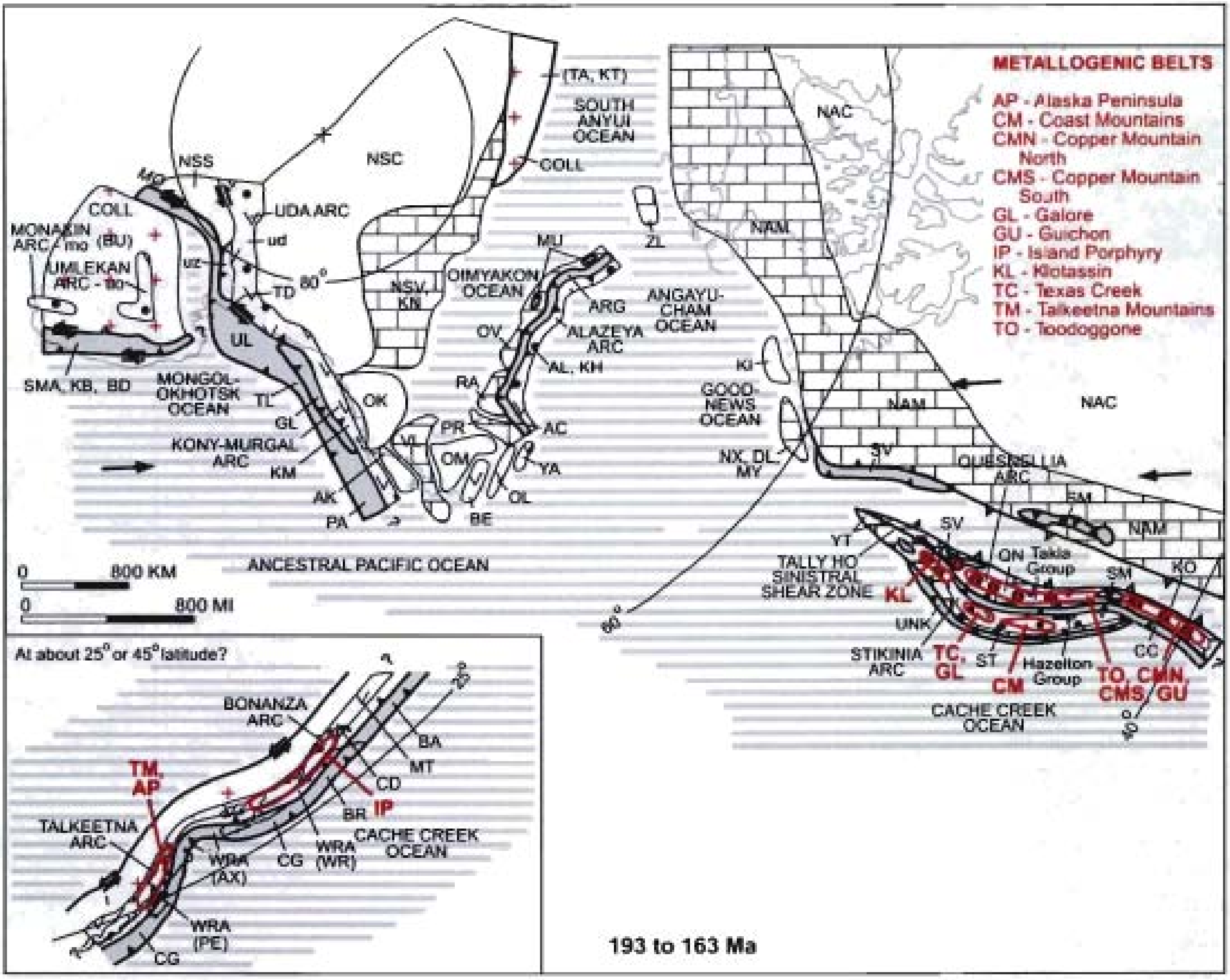


Figure 47. Middle Jurassic (Toarcian through Callovian - 193 to 163 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

(2) The continental-margin arc Uda arc (consisting of the Uda volcanic-plutonic belt (ud) and Uda-Zeya sedimentary basin (uz) continued to form. Associated with the arc was subduction and sinistral transpression of part of the Mongol-Okhotsk Ocean plate to form the Turkuringra-Dzhagdinski (TD), Ulban (UL), and Galam (GL) terranes. Subduction and sinistral transpression occurred along the Mongol-Okhotsk suture (*MO*).

(3) The extensive Kony-Murgal island arc (Kony-Murgal terrane (KM)) continued to form as an offshore extension of the Uda arc. Associated with the arc was subduction of part of the Ancestral Pacific Ocean plate to form the Talovskiy (TL) and Penzhina-Anadyr (PA) terranes. Inboard of the Kony-Murgal island arc (KM) were the Okhotsk (OK), Avekova (AK), and Omolon (OM) cratonal terranes which were previously rifted from the North Asian Craton (NSC), and the Viliga (VL) passive continental-margin terranes which was previously rifted from the North Asian Craton Margin (NSV). Behind the arc were fragments of prior Devonian to Pennsylvanian island-arc terranes, including the Beryozovka turbidite-basin (BE), and Oloy (OL), and Yarakvaam (YA) island-arc terranes.

(4) During the Bathonian, the Alazeya island arc, consisting of the Alazeya (AL) and Khetachan (KH) island-arc terranes, as a result of flip of the associated subduction zone, migrated towards the terranes forming the Kolyma-Omolon superterrane. The southern part of the Kolyma structural loop was formed during the convergence of the Alazeya arc toward the terranes forming the Kolyma-Omolon superterrane. The major terranes in the superterrane are the Alazeya (AL), Aluchin (AC), Argatas (ARG), Beryozovka (BE), Khetachan (KH), Munilkan (MU), Oloy (OL), Omolon (OM), Omulevka (OV), Prikolyma (PL), Rassokha (RA), Uyandina (UY), and Yarakvaam (YM) terranes. During this collision, fragments of the older part of the Angayucham Ocean plate were obducted onto the Omulevka terrane to form the Munilkan (MU) ophiolite terrane, and the Uyandina, Kybytygas, and Indigirka ophiolite terranes of Oxman and others (1995).

(5) The Angayucham Ocean (Kobuck Sea of Plafker and Berg, 1994), along with the South Anyui Ocean, continued to receive sparse continental-derived detritus. Previously rifted terranes, including the Kilbuck-Idono cratonal (KI) and the combined Nixon Fork-Dillinger-Mystic passive continental-margin (NX, DL, MY) terranes were near the North American Craton Margin.

(6) The dextral-slip imbrication of the Stikinia-Quesnellia arc and associated subduction-zone terranes was completed along the Tally Ho shear zone (Hansen and others, 1990; Hart, 1995). Or alternatively, the oroclinal warping of the Stikinia-Quesnellia island-arc and associated subduction zone terranes was completed (not depicted in fig. 47; Mihalynuk and others, 1994). For either interpretation, migration of the Stikinia-Quesnellia arc and associated terranes toward North America was accomplished by subduction and (or) obduction of the Seventymile Ocean plate along the continental margin.

(8) The subduction-related volcanic and plutonic arc rocks of the Quesnellia part of the arc, consisting of the Takla Group and the coeval igneous belts formed in response to continued subduction of part of the Cache Creek Ocean plate (CC; Mihalynuk and others, 1994). The Stikinia part of the arc consisted of the extensive suite of the subduction-related volcanic and plutonic arc rocks of the Hazelton Group which also formed in response to subduction of part of the Cache Creek Ocean plate. Remnants of this oceanic plate may be preserved in the terrane of ultramafic and related rocks which occurs discontinuously along the Denali strike-slip fault (DE, fig. 47) for several hundred kilometers (Nokleberg and others, 1994b).

(9) Forming in the Stikinia-Quesnellia arc and continuing on from the Early Jurassic were the Coast Mountains (CM), Copper Mountain (North; CMN), Copper Mountain (South; CMS), Galore (GL), Guichon (GU), Klotassin (KL), Texas Creek (TC), and Toodoggone (TO) belts which contain either granitic magmatism-related deposits or deposits related to felsic to mafic marine volcanism.

(10) Also completed was obduction of parts of the Seventymile and Slide Mountain Ocean plates onto the North American Craton Margin (NAM; Mihalynuk and others, 1994). Migration of the Stikinia-Quesnellia arc and associated terranes toward the North American Craton Margin was accomplished by subduction of the Seventymile Ocean plate along the continental-margin and by obduction.

(11) Outboard and perhaps at a lower paleolatitude (either 25° or 45°), the Talkeetna and Bonanza arcs continued activity in the Wrangellia superterrane (WRA). This extensive arc formed along most of the length of the Wrangellia superterrane with coeval equivalents in the Cadwallader (CD) island arc and Methow (MT) turbidite-basin terranes. Forming in the arc and continuing on from the Early Jurassic were the Talkeetna Mountains-Alaska Range metallogenic belt, which contains kuroko massive sulfide deposits, the Alaska Peninsula (AP) metallogenic belt, which contains Cu- and Fe-skarn deposits, and the Island Porphyry (IP) metallogenic belt, which contains granitic-magmatism-related deposits. Associated with the Talkeetna and Bonanza arcs was subduction of part of the Cache Creek Ocean plate to form the Chugach (CG), Bridge River (BR), and possibly Baker (BA) terranes.

Late Jurassic Metallogenic Belts (163 to 144 Ma; Figures 48, 49)

Overview

The major Late Jurassic metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 48 and 49. The major belts are as follows. (1) In the Russian Southeast, the Ariadny (AR) belt, which contains zoned mafic-ultramafic Ti deposits, is hosted in zoned mafic-ultramafic plutons intruding the Samarka subduction-zone terrane. The belt is interpreted as forming along a transform continental margin. (2) Also in the Russian Southeast is the North Bureya (NB) belt of granitic-magmatism-related deposits which is interpreted as forming in the Umlekan continental-margin arc. (3) In the central part of the Russian Far East is the Stanovoy (ST) belt which contains anatectic, granitic-magmatism-related deposits and is interpreted as forming during accretion of the Bureya superterrane to North Asian Craton. (4) In the Russian Northeast is the Chersky-Argatass Ranges (CAR) belt of kuroko massive sulfide deposits, and the Yasachnaya River (YS) belt of granitic-magmatism-related deposits. Both metallogenic belts are hosted in the Indigirka-Oloy volcanic-plutonic assemblage and are interpreted as forming in the Uyandina island arc. (5) In the Russian Northeast, the Oloy (OL) belt contains granitic-magmatism-related deposits and is hosted in the Oloy island arc. (6) In the same region, the Pekulney (PK) belt, which contains basaltic Cu deposits, is hosted in Late Jurassic oceanic crustal rocks which were subsequently tectonically incorporated into the Pekul'ney subduction-zone terrane; (7) In the same region, the Tamvatney-Mainits (TAM) belt, which contains podiform Cr deposits, is hosted in zoned mafic-ultramafic plutons, and the Mainits (MA) belt, which contains kuroko massive sulfide deposits, are both interpreted as forming in the Mainitskiy island arc. (8) Also in the same region, the Svyatoy-Nos (SVN) belt, which contains Au-Ag epithermal vein deposits, is hosted in the Svyatoy-Nos volcanic belt which is interpreted as forming in the co-named island arc. (9) In the Russian Northeast, Alaska, and the northern Canadian Cordillera, the Eastern Seward Peninsula and Marshall (ESM), Kobuk (KB), Kuyul (KUY), Southwestern Alaska (SWA), and Yukon-River (YR) belts, which contain podiform

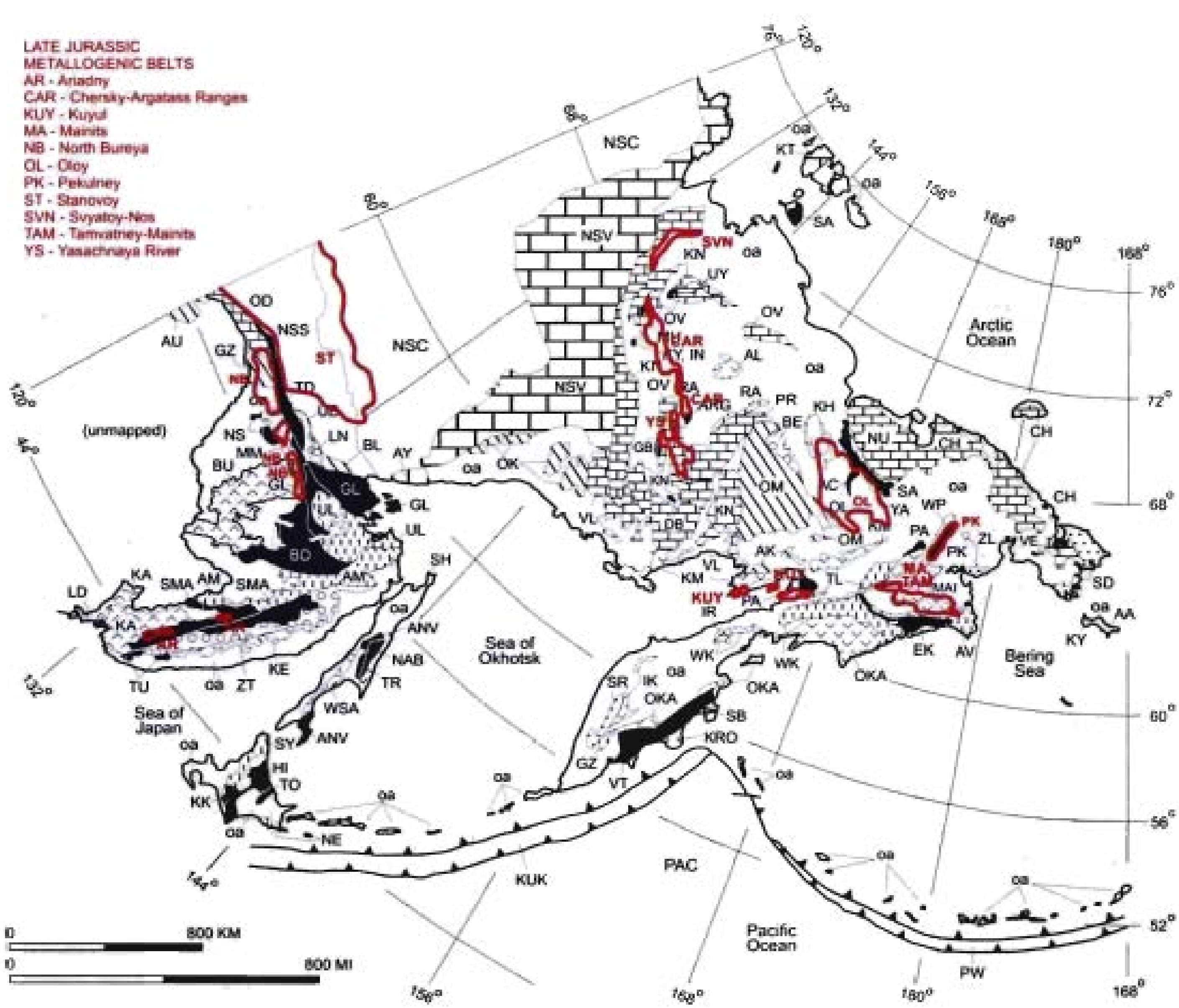


Figure 48. Generalized map of major Late Jurassic metallogenic belts and terranes for Russian Far East, northern Japan, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 2 for explanation.

Cr and related deposits, and also zoned mafic-ultramafic PGE deposits, are hosted in mafic-ultramafic plutons which intruded into the basal parts of various island arcs. These arcs include the Svyatoy-Nos, Kony-Murgal, Koyukuk, and Togiak arcs. (10) In Southern Alaska, the Eastern-Southern Alaska (ESA) belt, which contains granitic-magmatism-related deposits, is hosted in the Gravina-Nutzotin-Gambier belt which overlies the Wrangellia superterrane, and is interpreted as forming along the axial part of the Gravina arc. In Southeastern Alaska, the Klukwan-Duke (KL) belt, which contains oned mafic-ultramafic Ti-Cr-PGE deposits, is hosted in subduction-related, zoned mafic-ultramafic plutons which are associated with basal part of Gravina island arc on the Wrangellia superterrane. (11) In East-Central Alaska and central Canadian Cordillera, the Fortymile (FM) and Cassiar (CS) belts, which contain serpentinite-hosted asbestos deposits, are hosted in ultramafic rock of the Seventymile subduction zone and Slide Mountain accretionary wedge terrane. These belts are interpreted as forming during regional metamorphism which occurred during obduction and overthrusting of oceanic lithosphere of oceanic terranes onto the North American Craton Margin. (12) In the Canadian Cordillera, the Cariboo (CB) belt of Au quartz vein, the Francois Lake (FL) of porphyry Mo, and the Rossland (RL) belt of Au-Ag polymetallic vein deposits, are hosted in various island-arc and subduction-zone terranes. These metallogenic belts are both interpreted as forming during regional metamorphism and anatectic granitic plutonism associated with obduction of the Stikinia-Quesnellia arc and associated subduction zone complexes onto the North American Craton Margin. And (13) in the southern Canadian Cordillera, the continuity of the Island Porphyry (IP) belt of granitic-magmatism-related deposits is hosted in

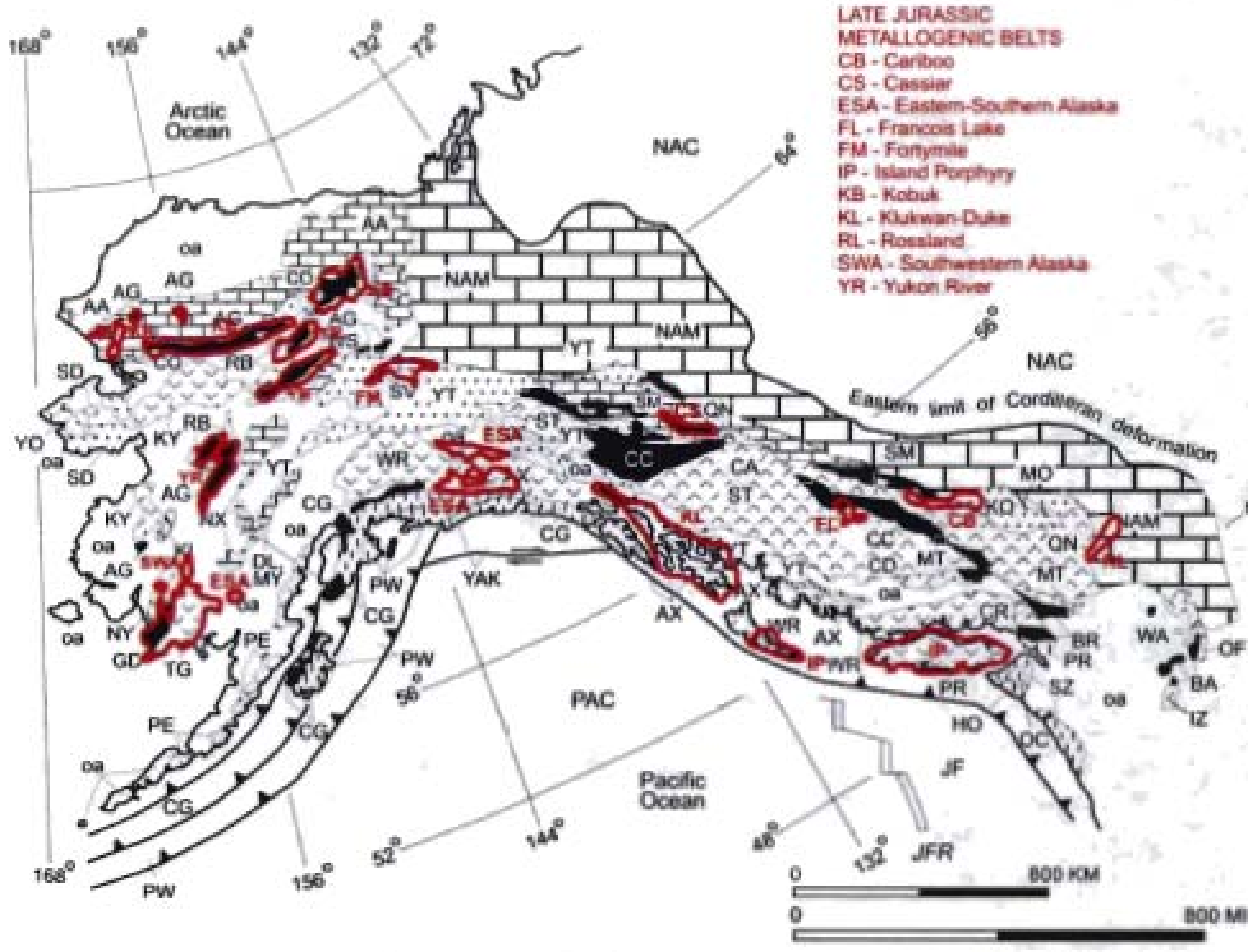


Figure 49. Generalized map of major Late Jurassic metallogenic belts and terranes for Alaska, Canadian Cordillera, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 3 for explanation.

the Wrangellia island-arc superterrane. This belt is interpreted as forming in the Gravina arc which overlies the superterrane. In the below descriptions of metallogenic belts, a few of the noteable or signficant lode deposits (table 4) are described for each belt.

Metallogenic-Tectonic Model for Late Jurassic (163 to 144 Ma; Figure 50)

During the Late Jurassic (Oxfordian through Kimmeridgian; 163 to 144 Ma), the major metallogenic-tectonic events were (fig. 50; table 3): (1) beginning of accretion of the Bureya superterrane against the North Asian Craton along the Mongol-Okhotsk suture and formation of associated metallogenic belts; (2) establishment of a series of continental-margin arcs, and formation of associated metallogenic belts companion subduction-zones around the Circum-North Pacific; (3) initiation of rift grabens which subsequently formed the Amerasia and Canada Basins and also resulted in inception of the Koyukuk arc; (4) obduction of the Stikinia-Quesnellia arc and associated terranes onto the North American Craton Margin; and (5) ending of the previous long-lived period (Late Proterozoic through Early Jurassic) of passive sedimentation on the North Asian and North American Cratons.

Specific Events for Late Jurassic

(1) Far to the south at about 60° paleolatitude, the Mainitskiy island arc (Mainitskiy terrane, MAI) commenced activity. Forming in the arc were the Tamvatney-Mainits (TAM) belt of podiform Cr deposits which is hosted in zoned mafic-ultramafic plutons, and the Mainits (MA) belt of kuroko massive sulfide deposits. Tectonically linked to the arc was the Alkatvaam accretionary-wedge terrane (AV) which formed from subduction of part of the adjacent oceanic plate. This arc and companion subduction zone migrated northward toward the Kony-Murgal island arc.

(2) The Monakin arc (Monakin volcanic-plutonic belt, mo) and the Umlekan arc (Umlekan-Ogodzhin volcanic-plutonic belt, uo and associated units) continued activity. Forming in the arc was the North Bureya (NB) metallogenic belt, which contains subduction-related granitic-magmatism deposits. Associated with formation of the arcs was oblique (sinstral) subduction of part of

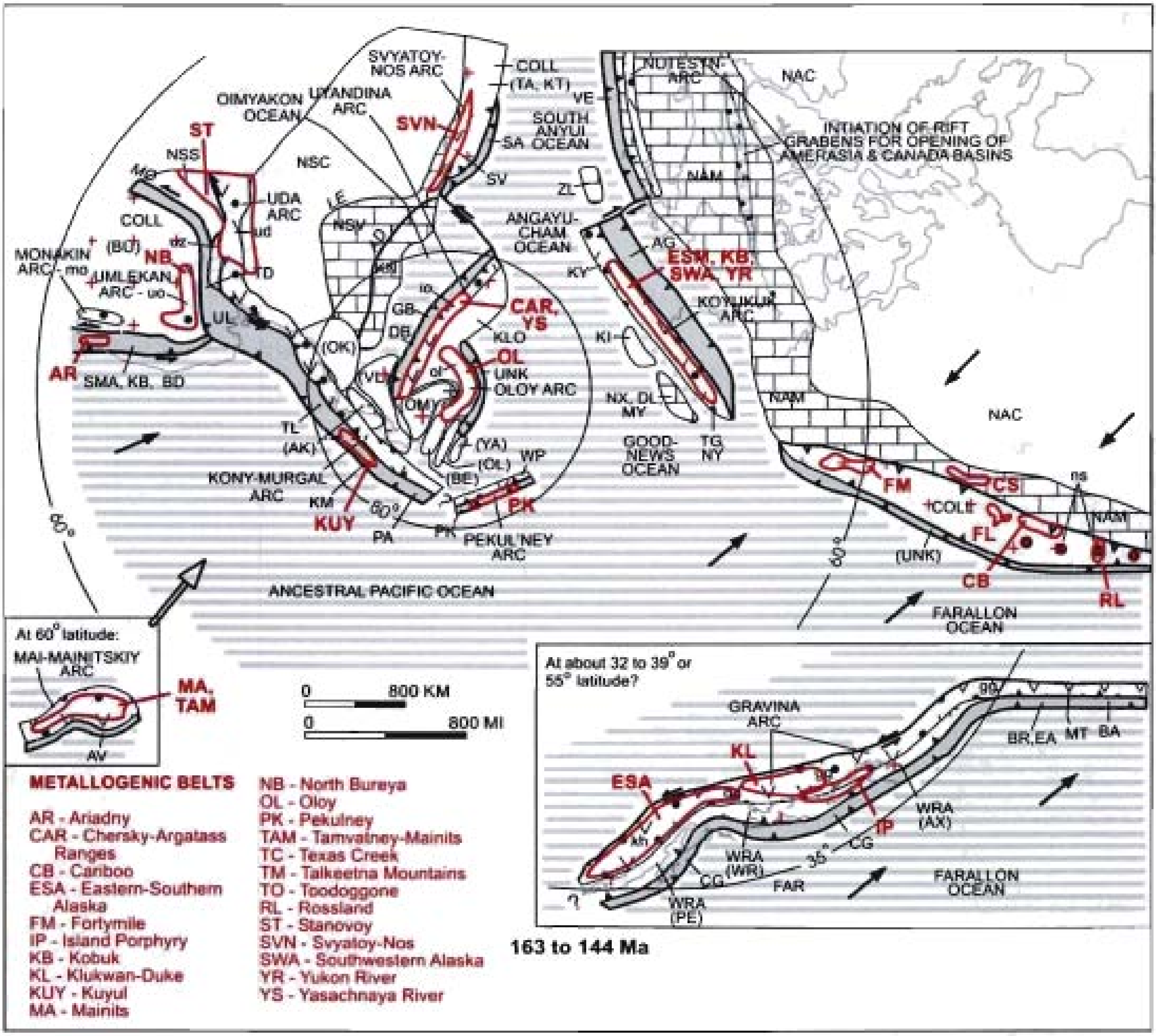


Figure 50. Late Jurassic (Oxfordian through Kimmeridigian - 163 to 144 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

the Ancestral Pacific Ocean plate to continue forming the Samarka (SMA), Khabarovsk (KB), and Badzhal (BD) terranes. Forming along the transform continental margin was the Ariadny (AR) belt of zoned mafic-ultramafic Ti deposits which is hosted in zoned mafic-ultramafic plutons intruding the Samarka subduction-zone terrane.

(3) In the same region, the Bureya (BU) superterrane accreted against the Ulban accretionary-wedge terrane (UL) along the Mongol-Okhotsk suture (*MO*) thereby closing the Mongol-Okhotsk Ocean. Forming during accretion was the Stanovoy (ST) metallogenic belt which contains anatectic, granitic-magmatism-related deposits.

(4) The Uda continental-margin arc (Uda volcanic-plutonic belt, ud, and Uda-Zeya sedimentary basin, uz) continued to form. Associated with the arc was subduction and sinistral transpression of part of the Mongol-Okhotsk Ocean plate to form the Turkuringra-Dzhagdinsk (TD), and Ulban (UL) terranes. Subduction was associated with sinistral transpression along the Mongol-Okhotsk suture (*MO*).

(5) The extensive Kony-Murgal continental-margin and island-arc terrane (KM) continued to form as an extension of the Uda continental-margin arc (ud). Associated with the arc was continued subduction of part of the ancestral Pacific Ocean plate to form the Talovskiy (TL) and Penzhina-Anadyr (PA) terranes. The Kony-Murgal island arc overlapped the Okhotsk (OK) and Avekova (AK) cratonal terranes which were previously rifted from the North Asian Craton (NSC), and the Viliga (VL) passive

continental-margin terranes which were previously rifted from the North Asian Craton Margin (NSV). As a transform extension of the Kony-Murgal terrane, the West Pekul'ney island-arc terrane (WP) was initiated. Associated with the arc was subduction of part of the ancestral Pacific Ocean plate to form the Pekul'ney terrane (PK).

(6) The Kolyma-Omolon superterrane (KLO) continued to migrate toward the North Asian Craton Margin (NSV). During migration, the Uyandina arc (consisting of Uyandina-Yasachnaya volcanic belt in the western part of the long Indigirka-Oloy sedimentary-volcanic-plutonic assemblage (io)) started to form along the leading edge of the superterrane. Forming in the Uyandina arc was the Chersky-Argatass Ranges (CAR) metallogenic belt, which contains kuroko massive sulfide deposits, and the Yasachnaya River (YS) metallogenic belt, which contains granitic-magmatism-related deposits. Tectonically linked to the Uyandina arc was subduction of the oceanic crustal rocks preserved in the Garbyn'ya (GA) and Debin (DB) ophiolite belt (and corresponding terranes, fig. 48) of Oxman and others (1995) which are herein interpreted as a remnants of the Oimyakon Ocean plate.

(7) On the opposite side of the Kolyma-Omolon superterrane (KLO), the Oloy island arc (ol) formed in response to subduction of part the South Anyui Ocean plate. Forming in the arc was the Oloy (OL) metallogenic belt which contains granitic-magmatism-related deposits. Along one part of the North Asian Craton Margin (NSV), the Svyotoy-Nos continental-margin arc formed along the margin of the Taymyr Peninsula collage (TA) in response to subduction of another part of the South Anyui Ocean plate to form the South Anyui subduction-zone terrane (SA). Forming in the arc was the Svyatoy-Nos (SVN) metallogenic belt which contains Au-Ag epithermal vein deposits and is hosted in the Svyatoy-Nos volcanic belt. The Angayucham Ocean continued to exist along with the South Anyui Ocean.

(8) Outboard of the Oloy arc was the minor Pekul'ney island arc. Incorporated into the tectonically-linked Pekul'ney subduction zone terrane was the basaltic Cu deposits of the Pekulney metallogenic belt that formed in a primitive island arc and neighboring sea-floor environment.

(9) Adjacent to the North American Craton Margin (NAM), two extensive arcs formed. The Nutesyn continental-margin arc formed in response to subduction of part of the South Anyui Ocean plate to form the Velmay subduction-zone terrane (VE). The Koyukuk (KY), Togiak (TG), and Nyac (NY) island-arc terranes formed in response to subduction of an (inner) Angayucham Ocean plate to extend the Angayucham (AG) subduction-zone terrane and opening of the Aerasia and Canada Basins. Outboard of the island arc were the outer Angayucham and the Goodnews Oceans. Forming in the basal parts of the Koyukuk (KY), Togiak (TG), and Nyac (NY) island arcs were the Eastern Seward Peninsula and Marshall (ESM), Klukwan-Duke (KL), Kobuk (KB), Kuyul (KUY), Southwestern Alaska (SWA), and Yukon-River (YR) metallogenic belts which contain podiform Cr and related deposits, and zoned mafic-ultramafic PGE deposits and are hosted in mafic-ultramafic plutons. The polarity of the island arc was continentward, toward the North American Craton Margin (NAM).

(10) The Kilbuck-Idono cratonal (KI) and the Nixon Fork-Dillinger-Mystic passive continental-margin terranes (NX, DL, MY) accreted onto the North American Craton Margin (NAM) at about the same time as obduction of the Stikinia-Quesnellia island arc described below.

(11) Rift grabens, depicted as rifting associated with sea-floor spreading, began to open the Amerasia and Canada Basins (Grantz and others, 1998). These grabens were an early stage of creation of new oceanic crust in the Early Cretaceous, as described below.

(12) A subduction zone (UNK) having a component of oblique sinistral-slip is inferred to have formed along, and parallel to the continental margin in order to accomplish migration of the Wrangellia superterrane toward the North American Craton Margin. Remnants of the subduction zone may be preserved in the terrane of ultramafic and related rocks which occurs discontinuously along the Denali strike-slip fault (DE, fig. 50) for several hundred kilometers (Nokleberg and others, 1994b). The mafic and ultramafic rocks may in part be derived from the Farallon Ocean plate (FAR) which separated the Wrangellia superterrane from the North American Craton Margin.

(13) Regional thrust faulting occurred with obduction of the Stikinia (ST), Quesnellia (QN), Cache Creek (CC), Slide Mountain (SM), Yukon-Tanana (YT), Seventymile (SM), and Kootenay (KO) terranes over the Cassiar (CA) terrane and the North American Craton Margin (NAM). This compressional event marked the beginning of a major orogenic event, including regional metamorphism, deformation, crustal thickening, anatectic magmatism, and uplift in the core of the Canadian Cordillera (Monger and Nokleberg, 1996). Forming during the regional metamorphism, or during younger hydrothermal alteration, were the serpentinite-hosted asbestos deposits of the Cassiar (CS) and Fortymile metallogenic belts (FM) that are hosted in ultramafic rock in the Slide Mountain (SM) and (or) Seventymile (SV) terranes. The Nelson plutonic suite (ns, fig. 50), which intrudes the Stikinia, Quesnellia, Kootenay, Cache Creek, and Slide Mountain terranes, and the coeval Francois Lake plutonic suite formed during this compressional event. The Nelson plutonic suite consists chiefly of granodiorite, quartz monzonite, and local monzonite plutons which yield isotopic ages mainly of 185 to 155 Ma and exhibit local crustal inheritance (Parrish and others, 1988; Woodsworth and others, 1992). Formed in the Nelson plutonic suite was the Rossland (RL) metallogenic belt of Au-Ag polymetallic vein deposits. Forming nearby in the Francois Lake plutonic suite was the Francois Lake (FL) metallogenic belt of porphyry Mo deposits. Forming in the nearby Kootenay terrane was the Cariboo (CB) belt of Au quartz vein deposits. By the Late Jurassic (about 155 Ma), detritus from this emergent orogenic welt in the eastern Canadian Cordillera was shed eastwards onto the North American Craton Margin (Cant, 1989).

(14) The extensive Gravina island arc was initiated along the length of the Wrangellia superterrane. Remnants of the arc are preserved in the Kahiltna (kh) and Gravina-Nutzotin-Gambier (gg) overlap assemblages which occur only on the Wrangellia

superterrane. Forming in the Gravina arc were the Eastern-Southern Alaska (ESA) metallogenic belt, which contains granitic-magmatism-related deposits, and the continuing Island Porphyry (IP) belt, which contains granitic-magmatism-related deposits. Tectonically linked to the arc was subduction of part of the Farallon Ocean plate (FAR) to form the Chugach (CG), Bridge River (BR), Easton (EA), and Baker (BA) terranes.

Metallogenic Belt Formed Along Late Mesozoic Along Continental-Margin Transform Fault

Ariadny Metallogenic Belt of Zoned Mafic-Ultramafic Ti Deposits (Belt AR) Southern Part of Russian Far East

The Ariadny metallogenic belt of zoned mafic-ultramafic Ti deposits (fig. 48; tables 3, 4) occurs in the southern part of the Russian Southeast only in the Samarka accretionary-wedge terrane. The principal Ti deposits are at Katenskoe, Ariadnoe, and Koksharovskoe (table 4) (Nokleberg and others 1997a, b, 1998), and consist mainly of disseminated to massive ilmenite which is hosted in layers in gabbro and pyroxenite. Titanium-magnetite and apatite are rare. The deposits also contains sparse PGE minerals, and sparse PGE minerals occur in stream-sediment samples. The bodies are several tens of m thick and several hundred m long. K-Ar isotopic studies yield ages of 160 to 170 Ma. The petrochemical features and mineral composition of the gabbro and pyroxenite intrusions hosting the zoned mafic-ultramafic Ti deposits are similar to those hosting the Kondyor PGE deposit (A.I. Khanchuk, written commun., 1992).

The zoned intrusions which host the Ariadny metallogenic belt consist of Late Jurassic ultramafic and gabbroic complexes with K-Ar isotopic ages of about 160 Ma age (Shcheka and Vrzhosek, 1985). The complexes are interpreted as syn-volcanic intrusives which intruded into the turbidite deposits of the Samarka accretionary-wedge terrane immediately before accretion of the terrane in the Early Cretaceous (A.I. Khanchuk, written commun., 1993; Nokleberg and others, 1994c, 1997c). Intrusion of the Samarka terrane may have occurred in the final stages of accretion during seaward migration of the subduction zone (Khanchuk and Ivanov, 1999). The Middle and Late Jurassic clastic matrix of the terrane consists of parautochthonous turbidite and olistostromal deposits rocks which contain fragments of mainly middle and late Paleozoic ophiolitic rocks and greenstone, Middle Triassic chert, Early Jurassic schist and shale, and Triassic to Jurassic clastic rocks. Olistostromes, particularly in the northern part of the terrane, consist of large fragments of Carboniferous to Early Permian limestone. A fragment of the terrane occurs near the town of Bikin, where meimechite and picrite flows occur in a Late Jurassic (?) matrix (Philippov; 1990). The Samarka accretionary-wedge terrane and correlative subduction zone units in Japan are tectonically linked to Jurassic granitoid rocks in Korea, and with a major Jurassic to Cretaceous volcanic-plutonic belt in southeastern China (Nokleberg and others, 1994c, 1997c). These subduction-related units are interpreted as offset from their tectonically-linked igneous arcs by left-lateral movement during the Cretaceous and Cenozoic (Nokleberg and others, 1994c, 1997c).

Metallogenic Belts Formed in Late Mesozoic Continental Margin and Island Arc Systems in Russian Far East

North Bureya Metallogenic Belt of Au-Ag Epithermal Vein and Granitoid-Related Au Deposits (Belt NB) Northwestern Part of Russian Southeast

The North Bureya metallogenic belt of Au-Ag epithermal vein and granitoid-related Au deposits (fig. 48; tables 3, 4) (Radkevich, 1984) occurs in the northwestern part of the Russian Southeast. The deposits are hosted in Early Cretaceous felsic and intermediate volcanic rocks which occur: (1) mainly in the Late Jurassic and Cretaceous Umlekan-Ogodzhin volcanic-plutonic belt; and (2) in the northern part of the Late Jurassic to Cenozoic Late Amur sedimentary assemblage. These units overlie the Malokhingansk and Turan terranes of the Bureya superterrane, and the Gonzha, North Sukhotinsk, Mamyn, and Tukuringra-Dzhagdi terranes. The volcanic rocks extend along the boundary of the Tukuringra-Dzhagdi terrane with the North Asia Stanovoy cratonal block. The major Au-Ag epithermal vein deposits are at Bamskoe, Burindinskoe, and Pokrovskoe (table 4) (Nokleberg and others 1997a, b, 1998). A granitoid-related Au deposit is at Pioneer. Only a few Au-Ag epithermal vein deposits are known. Several poorly-explored deposits are known in the area, but are unexplored because of extensive Cenozoic surficial deposits and swamps (Melnikov, 1974). Numerous placer Au mines occur within the North Bureya metallogenic belt. The gold in the placer mines is interpreted by Gurov (1978) as being mainly derived from Au-bearing quartz veins hosted in Late Jurassic to Early Cretaceous sedimentary and volcanic rocks. The North Bureya metallogenic belt is assessed to be promising for Au resources and needs further study.

Pokrovskoe Au-Ag Epithermal Vein Deposit

The Pokrovskoe Au-Ag epithermal vein deposit (Khomich and others, 1978; Mel'nikov, 1984; V.D. Mel'nikov, written commun., 1993; Khomich, 1990) occurs in Late Cretaceous andesite, dacite andesite, and related tuff. This volcanic sequence overlies a Jurassic coal-bearing sequence of sandstone, siltstone, and argillite. The ore bodies consist of gently-dipping quartz veins and zones of hydrothermal alteration. Main alteration types are propylitization (albite, sericite, calcite, chlorite, and pyrite), berezitization (quartz, sericite, and hydromica), and argillization (kaolinite, montmorillonite, hydromica, carbonates, quartz, and pyrite). The largest ore bodies are gently-dipping zones of altered rock, located near the lower contact of andesitic sequence with a granodiorite porphyry sill. Hydrothermally altered rocks consist of quartz (25-85%), carbonate (2-5%), hydromica (5-12%), adularia (up to 5%), kaolinite (5-7%), and sulfides (less than 1% and mostly pyrite). Gold is fine-grained (0.0005 to 0.032 mm), is associated with quartz, and is virtually not associated with sulfides. Silver grains (0.002 to 0.016 mm) were observed in Fe-hydroxide alteration. The deposit is medium size with reserves of 15 million tonnes grading 4.4 g/t Au and 15 g/t Ag. The deposit is interpreted as forming in the Late Cretaceous.

Pioneer Granitoid-Related Au Deposit

The Pioneer granitoid-related Au deposit (N.E. Malyamin and V.E. Bochkareva, written commun., 1990; V.N. Akatkin, written commun., 1991) occurs near the margin of an Early Cretaceous granodiorite intrusion, both within the intrusion, and in adjacent country rock of contact-metamorphosed Jurassic sandstone and siltstone. The ore bodies consist of quartz, quartz-feldspar, quartz-tourmaline, and quartz-carbonate veins and zones of altered quartz-potassium feldspar-sericite-albite rocks. The ore bodies vary from 1 to 50 m thick, and in plan branch with variable trends. The ore bodies are large, have low Au content, and have no visible boundaries. The extent of mineralization is determined by geochemical sampling. Both gold and Au-sulfide bodies are recognized. The gold ore type consists of quartz-adularia-carbonate veins, and the Au-sulfide type consists of quartz veins with pyrite, galena, stibnite, and Ag-sulfosalts. The deposit is small, with estimated reserves of 17.1 tonne Au, 20.1 tonne Ag, and average grades of grade 2.7 g/t Au, and 5.2 g/t Ag.

Origin of and Tectonic Controls for North Bureya Metallogenic Belt

The Umlekan-Ogodzhin volcanic-plutonic belt (Volsky, 1983; Kozlovsky, 1988) which hosts the North Bureya metallogenic belt consists chiefly of: (1) Early Cretaceous sandstone, conglomerate, and mudstone with sparse flora and freshwater fauna; (2) Early Cretaceous calc-alkalic andesite, dacite, and tuff which yield K-Ar isotopic ages of 112-135 Ma; and (3) Late Cretaceous alkalic basalt and rhyolite. The belt is intruded by coeval Early Cretaceous granite, granodiorite, diorite, and monzodiorite. Some granitoid plutons are probably Late Jurassic, or older because derived detritus occurs in the Early Cretaceous part of section of the Umlekan-Ogodzhin igneous belt. This belt was deposited on Gonzha terrane, and on Mamyn and Turan terranes of Bureya superterrane after collision of these terranes with the Tukuringra-Dzhagdinsk terrane (Nokleberg and others, 1994c, 1997c).

The Umlekan-Ogodzhin volcanic-plutonic belt belt constitutes part of the Umlekan continental-margin arc which is interpreted as forming from subduction of part of the ancestral Pacific Ocean plate which is now preserved as tectonically interwoven fragments of the Badzhal (BD), older Jurassic, part part of the Khabarovsk (KB), and Samarka (SMA) terranes. This tectonic pairing is based on: (1) occurrence of the accretionary-wedge terranes outboard (oceanward) of the Umlekan arc (fig. 48); (2) formation of mélange structures during the Jurassic and Early Cretaceous (Nokleberg and others, 1994a; Khanchuk and others, 1996); and (3) where not disrupted by extensive Cretaceous and early Cenozoic movement along the Central Sihote-Aline strike-slip fault, the mélange structures and bounding faults dip toward and beneath the igneous units of the arc. Subduction is generally interpreted as ending in the Early Cretaceous when extensive sinstral faulting occurred along the subduction zone (Khanchuk and others, 1996).

Chersky-Argatass Ranges Inferred Metallogenic Belt of Kuroko Massive Sulfide Deposits (Belt CAR) West-Central Part of Russian Northeast

An inferred metallogenic belt of kuroko massive sulfide deposits (fig. 48; tables 3, 4) occurs in the west-central part of the Russian Northeast. The metallogenic belt is hosted in Late Jurassic volcanic rocks in the Chersky and Argatass Ranges in the Indigirka-Oloy sedimentary-volcanic assemblage (unit io, fig .48) (Nokleberg and others, 1994c, 1997c). The belt extends northwest for nearly 700 km and occurs in four areas which are up to 35 to 30 km wide each (Danilov and others, 1990). The significant deposit is at Khotoidokh in the northwest part of the belt (table 4) (Nokleberg and others 1997a, b, 1998).

Khotoidokh Kuroko Massive Sulfide Deposit

The Khotoidoh Kuroko massive sulfide deposit (fig. 51) (G.G. Naumov, written commun., 1987; Danilov and others., 1990; Dylevsky and others, 1996) consists of a steeply-dipping stratiform body of massive sulfides in a lens which ranges up to 13 m wide and 450 m long. The lens is hosted in Late Jurassic sedimentary and volcanic rocks. The deposit is underlain by rhyolite and overlain by siltstone. The main ore minerals are pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, and barite. Also occurring are bornite, native Au, native Ag and matildite. The ores vary from massive to thin-banded. The ore is regionally metamorphosed, and wallrock metasomatic alteration includes propylitic, and late-stage silica and sericite alteration. The host rocks are the

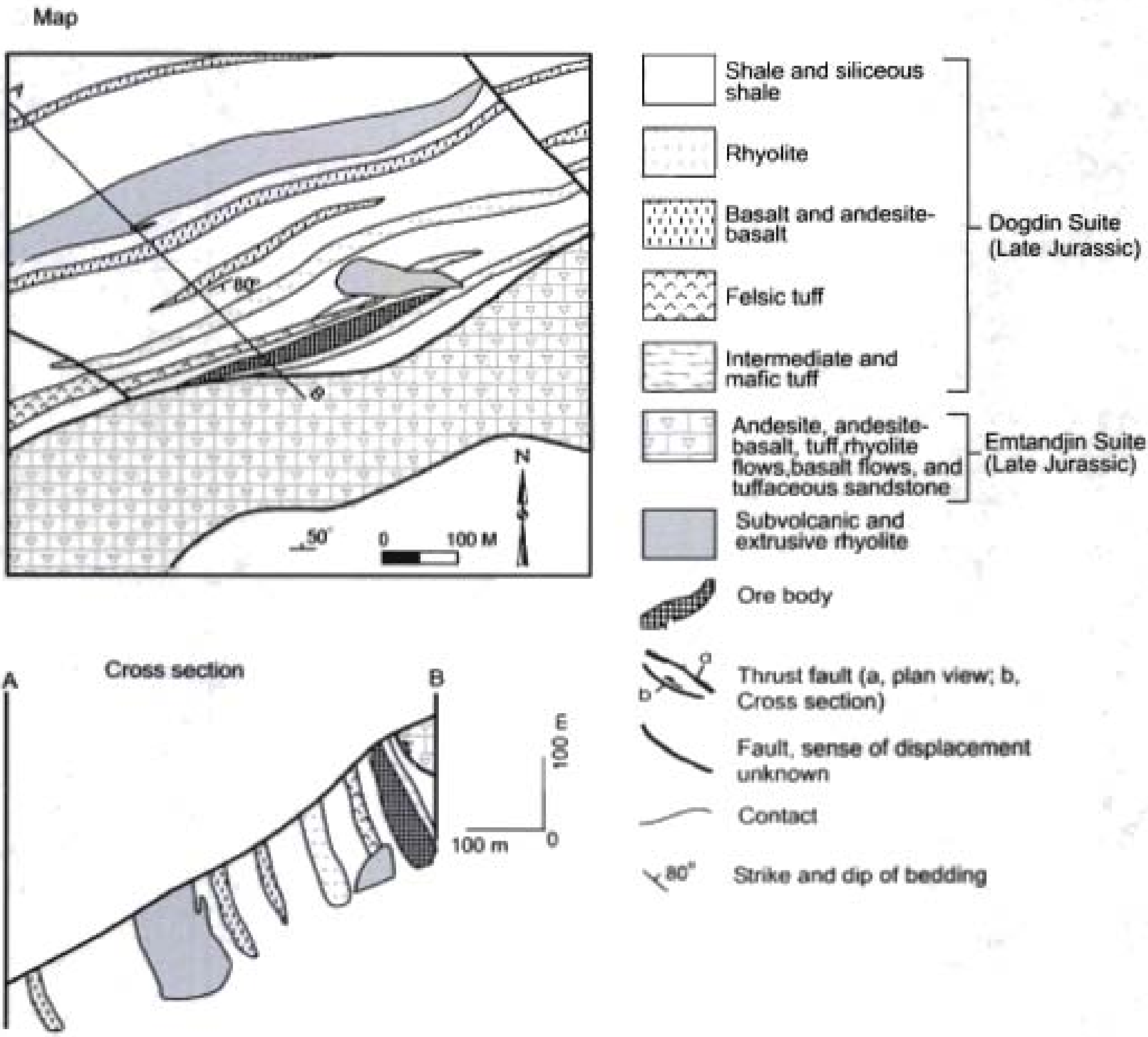


Figure 51. Khotoidokh kuroko Pb-Zn massive sulfide deposit. Schematic geologic map and cross section. Adapted from Dylevsky, Zuyev, Chersky-Argatass Ranges metallogenic belt, Russian Northeast. Schematic geologic map and cross section. Adapted from Dylevsky, Zuyev, and Shpikerman (1996).

Kimmeridgian Dogdin Formation which is about 450 m thick. This formation consists of marine, thin-bedded clastic sedimentary rocks which are interbedded with rhyolite lava and tuff and, to a smaller extent, with basalt and andesite-basalt. The volcanic rocks in the deposit are a bimodal rhyolite-basalt assemblage similar to which of island arcs. The environment of formation of the deposit is similar to which of the Miocene Kuroko massive sulfide deposits of the Green Tuff belt in Japan. The known reserves are 180,000 t Pb, 900,000 t Zn, 150,000 t Cu, and about 1,000 t Ag. The average grades are 5.15% Pb, 14.9% Zn, 0.7% Cu, 0.5-1.0 g/t Au and more than 100 g/t Ag.

Origin of and Tectonic Controls for Chersky-Argatass Ranges Metallogenic Belt

The Chersky-Argatass Ranges metallogenic belt is hosted in the Indigirka-Oloy sedimentary-volcanic assemblage which consists chiefly of shallow-marine and nonmarine late Middle Jurassic to Neocomian formations which overly various accreted terranes of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c). The Indigirka-Oloy is composed mainly of sandstone, siltstone, shale, conglomerate, and volcanic rocks of varying composition. The igneous rocks of the Indigirka-Oloy assemblage include coeval plutonic rocks and mainly shallow-marine, rarely nonmarine basalt, andesite, rhyolite, and tuff with interlayered sandstone, conglomerate, siltstone, and shale. The belt also contains small bodies of granite, granodiorite, and monzogranite. The igneous rocks of the Indigirka-Oloy sedimentary-volcanic assemblage are interpreted as part of the Jurassic Uyandina island arc which formed on margin of the Kolyma-Omolon superterrane during final stages of migration towards, but before accretion the northeastern North Asian Craton (Nokleberg and others, 2000).

Yassachnaya River Metallogenic Belt of Pb-Zn Skarn, Porphyry Cu, and Cu-Ag Vein Deposits (Belt YS) Western Part of Russian Northeast

The Yasachnaya River metallogenic belt of Pb-Zn skarn, porphyry Cu, and Cu-Ag vein deposits (fig. 48; tables 3, 4) occurs in the Yasachnaya River basin in the western part of the Russian Northeast. The belt extends in two branches to the northwest for nearly 500 km and ranges up to 100 km wide. The deposits are hosted in or near Late Jurassic granitic and subvolcanic intrusive bodies which are associated with the Uyandin-Yassachny volcanic-plutonic belt, part of the Indigirka-Oloy overlap assemblage (unit io, fig. 48) (Nokleberg and others, 1994c, 1997c). The significant Pb-Zn skarn deposits are at Terrassnoe and Kunarev (table 4) (Nokleberg and others 1997a, b, 1998). A porphyry Cu stockwork deposit at Datsytovoe is spatially associated with the Pb-Zn skarn deposit at Kunarev. These relations define a complex mineral deposit district where Pb-Zn skarn and porphyry Cu deposits are closely associated.

Terrassnoe Pb-Zn Skarn Deposit

The Terrassnoe Pb-Zn skarn deposit (Shpikerman, 1987; V.I. Shpikerman and others, written commun., 1988) occurs along a fault between Late Devonian (Frasnian) limestone and late Paleozoic pelitic and chert in the bottom of a Late Jurassic volcanic depression intruded by hypabyssal dikes which overly a buried late Mesozoic granitic intrusion. The skarn consists of hedenbergite, garnet (andradite-grossular), and ilvaite. The main ore minerals are sphalerite, galena, chalcopyrite, and magnetite. Silver occurs mainly with sulfide minerals and Ag-polymetallic minerals predominate. Ag mineralization was later than the skarn formation. The deposit contains a probable resource of 5.2 million tonnes with an average grade of about 1% Pb, 5% Zn, and 140 g/t Ag. The deposit extends for 700 m.

Kunarev Porphyry Cu and Pb-Zn-Cu-Ag Skarn Deposit

The Kunarev deposit (fig. 52) (Shpikerman, 1987; V.I. Shpikerman and N.E. Savva, written commun., 1988) is a composite deposit containing both porphyry Cu, Pb-Zn-Cu-Ag skarn, and polymetallic replacement deposits. In the middle of the host volcanic sequence is a Ag-Cu-Bi stockwork related to a porphyry trachyrhyolite dike and to a quartz diorite stock. Quartz-carbonate veinlets in the stockwork contain pyrite, chalcopyrite, sphalerite, galena, freibergite, and Ag-Pb-Bi sulfosalts. The host rhyolite and quartz diorite exhibit an intense pyrite alteration, and the quartz diorite is propylitically altered. This part of the deposit is known as the Datsytovoe porphyry Cu occurrence.

To the west and south is the Kunaryov Pb-Zn-Cu-Ag skarn deposit. The skarns occurs as sheet-like replacements in Middle and Late Jurassic calcareous conglomerate, and in fissure veins above and beneath the conglomerate. The skarns consists of hedenbergite and garnet, along with pyrrhotite, sphalerite, and chalcopyrite. The central part of the deposit consists of relatively younger quartz-carbonate veins and veinlets which contain sphalerite, galena, chalcopyrite, pyrite, cobaltite, matildite, and galena-bismuthite. Average grades are 0.7-1.1% Pb, 1.15-10.5% Zn, and 47-170 g/t Ag. Further to south, skarns in the conglomerate are replaced by epidote- and jasper-bearing metasomatic rocks. In addition are polymetallic replacements with a thickness from 10 to 25 m which occur in several places at the southern end of the deposit. The ore minerals are pyrite, sphalerite, chalcopyrite, and marcasite.

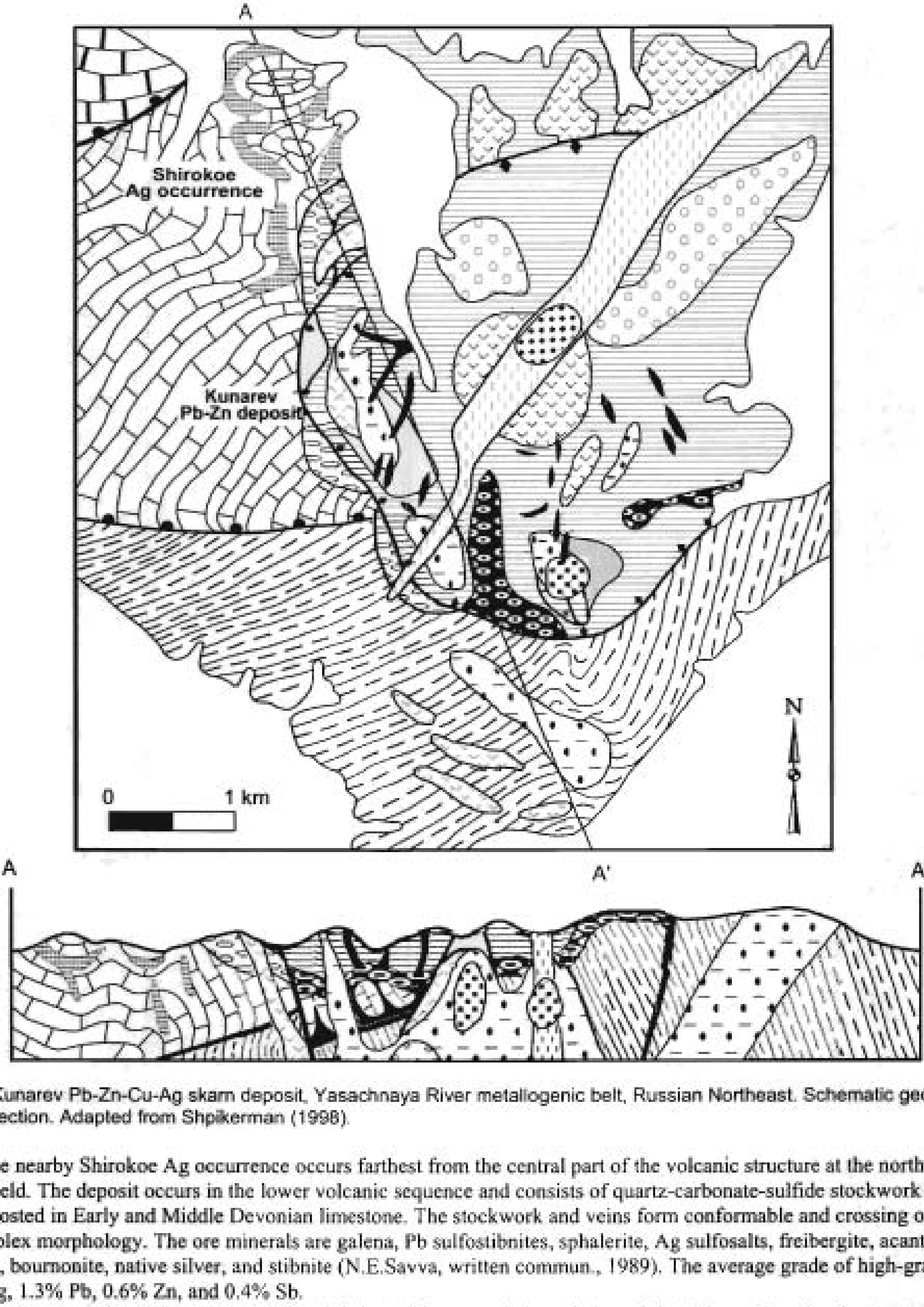
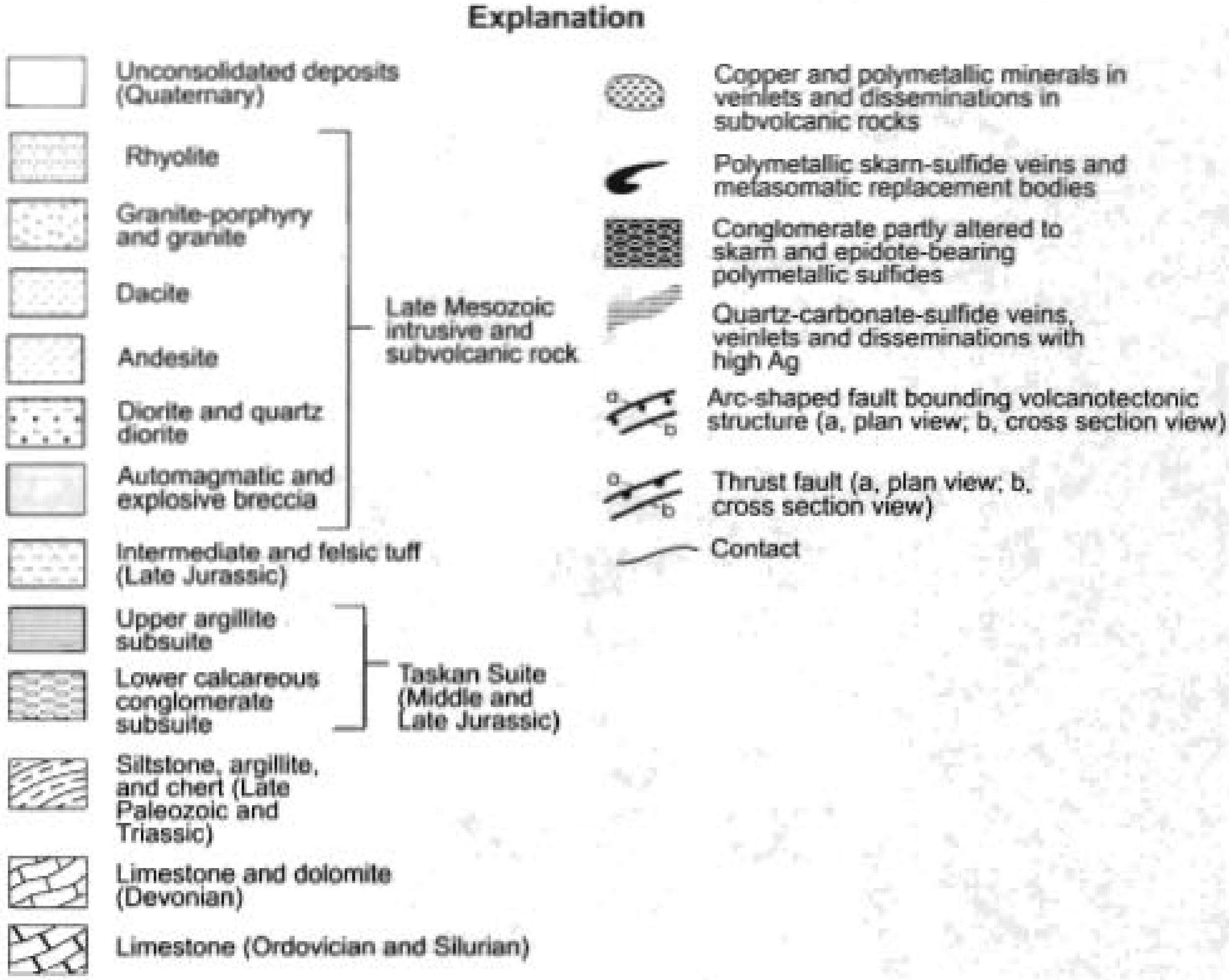


Figure 52. Kunarev Pb-Zn-Cu-Ag skarn deposit, Yasachnaya River metallogenic belt, Russian Northeast. Schematic geologic map and cross section. Adapted from Shpikerman (1998).

The nearby Shirokoe Ag occurrence occurs farthest from the central part of the volcanic structure at the northwestern end of the ore field. The deposit occurs in the lower volcanic sequence and consists of quartz-carbonate-sulfide stockwork and veins which are hosted in Early and Middle Devonian limestone. The stockwork and veins form conformable and crossing ore bodies with a complex morphology. The ore minerals are galena, Pb sulfostibnites, sphalerite, Ag sulfosalts, freibergite, acanthite, betechtinite, bournonite, native silver, and stibnite (N.E.Savva, written commun., 1989). The average grade of high-grade ore is 1,100 g/t Ag, 1.3% Pb, 0.6% Zn, and 0.4% Sb.

The Kunarev Pb-Zn-Cu-Ag skarn deposit is hosted in an eroded, oval-shaped, late Mesozoic volcanic structure. At the base of the volcanic sequence are faulted Paleozoic clastic and carbonate rocks. The main part of the volcanic sequence consists of gently-lying, Late Jurassic volcanic and sedimentary rocks. The lower part the volcanic sequence contains calcareous conglomerates, up to 150 m thick, overlain by argillite which is about 350 m thick. The upper part consists of a mixed tuff member, with a thickness of about 80 m. In the central part of the volcanic sequence is downdropped caldera with a diameter of about 4-5 km which extends into the folded Paleozoic basement. The caldera is filled with the upper volcanic sequence. Intrusive rocks include subvolcanic stocks composed of andesite, dacite, diorite, and granite-porphyries. Explosive breccias also occur. A



trachyrhyolite dike is the youngest intrusive and trends northeast. Rb-Sr isotopic ages for the subvolcanic rocks are 141.5±6.5 Ma (E.F. Dylevsky, written commun., 1988).

Origin of and Tectonic Controls for Yasachnaya River metallogenic belt

The Zn-Pb skarns and associated deposits of the Yasachnaya River metallogenic belt occur mainly in Paleozoic carbonate rocks of the Omulevka passive continental margin terrane of the Kolyma-Omolon superterrane where intruded by Late Jurassic granite, diorite, and rhyolite of the Uyandin-Yassachny volcanic-plutonic belt, part of the Indigirka-Oloy overlap assemblage (fig. 48). Petrochemical zonation of the Uyandina-Yassachny volcanic-plutonic belt suggests that the igneous rocks of this magmatic arc and associated metallogenic belt formed over a subduction zone which dipped towards the core of the Omulevka terrane. The Uyandin-Yassachny volcanic-plutonic belt and associated lode deposits of the Yasachnaya River metallogenic belt are interpreted as forming in the Late Jurassic Uyandina igneous arc which formed along the margin of the Kolyma-Omolon superterrane, immediately before accretion of the superterrane to the North Asian Craton (Nokleberg and others, 2000).

Oloy Metallogenic Belt of Porphyry Cu-Mo and Au-Ag Epithermal Vein Deposits (Belt OL) North-Central Part of Russian Northeast

The Oloy metallogenic belt of porphyry Cu-Mo and Au-Ag epithermal vein deposits (fig. 48; tables 3, 4) occurs mainly in the Oloy volcanic-plutonic island arc belt mainly in the drainages between the Oloy and Bolshoy Anyui rivers in the north-central part of the Russian Northeast. The belt extends for 400 km; the central part ranges up to 160 km wide. The numerous porphyry Cu-Mo-Au deposits and Au-Ag epithermal deposits in the belt are hosted in the Oloy volcanic belt which forms the northeastern part of the Indigirka-Oloy sedimentary and igneous assemblage (table 4) (Nokleberg and others, 1994c, 1997c). The significant porphyry Cu deposits are at Asket, Dalny, Innakh, and Peschanka (table 4) (Nokleberg and others 1997a, b, 1998). The significant Au-Ag epithermal deposits are at Vesennee and Klen. Associated Cu-Mo stockwork deposits occurs mainly in stocks and small bodies of the gabbro-monzonite-syenite series (Gorodinsky and others, 1978). In some areas, a zonation of felsic-magmatism-related deposits occurs in the Oloy metallogenic belt. Au-Ag epithermal veins generally occur peripheral to granitic intrusions which host porphyry Cu-Mo deposits whereas Au quartz-carbonate-sulfide polymetallic vein deposits occur in intermediate sites between the Au-Ag epithermal vein and porphyry Mo deposits.

Peschanka Porphyry Cu-Mo Deposit

The Peschanka porphyry Cu-Mo deposit (fig. 53) (Gorodinsky and others, 1978; Volchkov and others, 1982; Kaminskiy and Baranov, written commun., 1982; Migachev and others, 1984; V.V. Gulevich and others, written commun., 1993) occurs in the eastern portion of the Late Jurassic to Early Cretaceous Egdegkych multiphase pluton which is composed of monzodiorite and quartz monzodiorite which are intruded by planar bodies of quartz monzonite and granodiorite porphyry. The deposits consists of sulfide veinlets and disseminations, with pervasive Cu and Mo minerals which occur throughout the entire elongated quartz monzonite and granodiorite porphyry body and which extend into the wall rock. The main ore minerals are pyrite, chalcopyrite, bornite, tetrahedrite-tennantite, and molybdenite. Minor or rare minerals are magnetite, hematite, sphalerite, galena, chalcocite, native gold Au-tellurides, enargite, arsenopyrite, pyrrhotite, and marcasite. The gangue minerals are quartz, carbonate, and anhydrite. Four mineral associations occur: (1) molybdenite which is associated with the quartz-sericite subzone of phyllic alteration; (2) pyrite and chalcopyrite which are associated with quartz-sericite-chlorite alteration; (3) chalcopyrite, bornite, and tetrahedrite which are associated with quartz-sericite and biotite alteration; and (4) polysulfide minerals which occur with all alteration types. Mineralization was preceded by wide-spread pyritization in the peripheral propylitic zone. The deposit contains an estimated resource of 940 million tonnes with an average grade 0.51% Cu, 0.019% Mo, 0.42 g/t Au, and 1.4 g/t Ag.

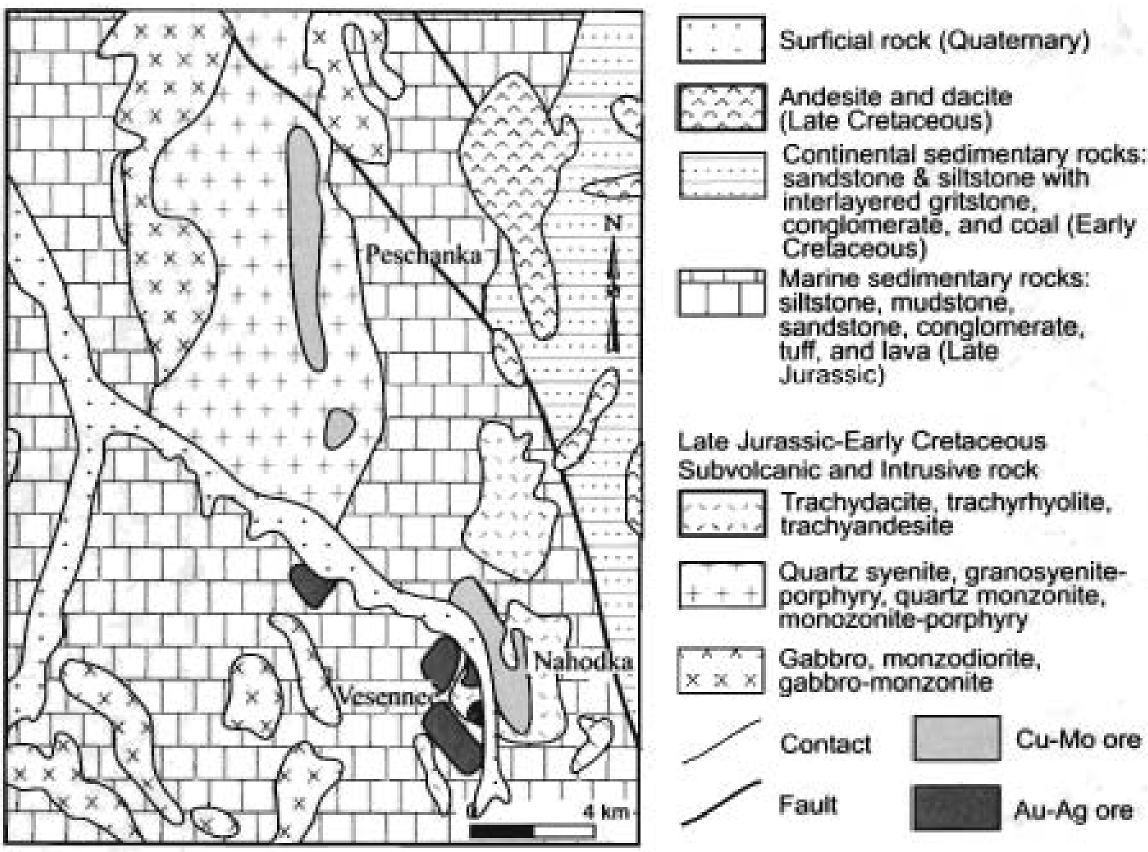


Figure 53. Peschanka porphyry Cu deposit, Oloy metallogenic belt, Russian Northeast. Schematic geologic map. Adapted from Migachev and others (1984) using materials of V.V. Gulevich and E.F. Dylevsky.

Vesennee Au-Ag Epithermal Vein Deposit

The Vesennee Au-Ag epithermal vein deposit (Gorodinsky and others, 1974; Shilo and others, 1975; Shapovalov, 1976; Sidorov, 1978; V.V. Gulevich and others, written commun., 1993) consists of carbonate-quartz veins, altered veinlets, and mineralized breccias which occur in structurally complex forms. The veins are controlled by northeast- and approximately east-west-trending fractures which cut northwest-trending zones of associated granitoid rocks. Individual ore bodies range from 150 to 500 m long. The ore minerals are sphalerite, galena, pyrite, chalcopyrite, tetrahedrite, tennantite, bournonite, and electrum, with minor Ag-sulfides and sulfosalts, stannite, and matildite. The main gangue minerals are quartz, calcite, and rhodochrosite with subordinate adularia, dolomite, celestite, and gypsum. Au:Ag ratio varies from 1:5 to 1:30. The deposit occurs mainly in propylitically-altered trachyandesite which is part of an Late Jurassic volcaniclastic sequence which is intruded by hypabyssal bodies and dikes of gabbro rocks, syenite, granodiorite porphyry, and andesite-dacite, all of Late Jurassic to Late Cretaceous age. The deposit is of medium size and grade ranges from 0.1 to 48 g/t Au and up to 300 g/t Ag.

Origin of and Tectonic Controls for Oloy metallogenic belt

The age of mineralization age for the Oloy metallogenic belt is interpreted as Late Jurassic (Gulevich, 1974). However, some K-Ar isotopic data indicate an Early Cretaceous age for some of the associated intrusions, and some deposits occur in Early Cretaceous wall rocks (Gorodinsky and others, 1978). Some, still younger porphyry and epithermal vein deposits may be related to remobilization during post-accretionary magmatism in the Late Cretaceous. The porphyry deposits in the Oloy metallogenic belt contain characteristic, widespread magnetite, Co, and PGE minerals which are interpreted as being derived from hosting oceanic terranes into which igneous rocks of the Oloy volcanic-plutonic belt intruded.

The Oloy metallogenic belt is hosted in the younger (Neocomian) part of Late Jurassic-Neocomian Oloy-Svyatoy Nos volcanic belt (Nokleberg and others, 1994c, 1997c). This igneous belt occurs along the northeastern margin of the Kolyma-Omolon superterrane and is part of the Indigirka-Oloy sedimentary-volcanic-plutonic assemblage. The volcanic belt occurs along the northeastern margin of the Kolyma-Omolon superterrane and consists of shallow-marine and nonmarine mafic, intermediate, and siliceous volcanic rocks and tuff, associated sedimentary rocks, and small plutons of granite, granodiorite, and monzogranite (Shul'gina and others, 1990; Natapov and Shul'gina, 1991). The volcanic belt also contains small bodies of granite, granodiorite, and monzogranite. The Oloy volcanic belt is interpreted as forming the upper part of the Oloy island arc during a short-lived period of Early Cretaceous subduction of part of the South Anyui terrane beneath the northeastern margin of the Kolyma-Omolon superterrane, after accretion of the Kolyma-Omolon superterrane to the North Asian Craton Margin (Nokleberg and others, 1994c, 1997c, 2000).

Pekulney Metallogenic Belt of Basaltic Cu Deposits (Belt PK) Eastern Part of Russian Northeast

The Pekulney metallogenic belt of basaltic Cu deposits occurs in a north-east-trending belt which extends along the Pekulney Range in the eastern part of the Russian Northeast (fig. 48; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt extends for about 170 km and ranges up to 20 km wide. The belt is hosted in the Late Jurassic and Early Cretaceous rocks of the Pekul'ney subduction-zone terrane (Nokleberg and others, 1994c, 1997c). The significant deposit is at Skalistaya.

Skalistaya Basaltic Cu Deposit

The Skalistaya deposit (Shkursky and Matveenko, 1973) consists of a network of prehnite-pumpellyite-silica-carbonate and epidote-carbonate veinlets which vary from 2 to 20 cm thick and which contain disseminated native copper. The veinlets occur in basalt and consist mostly of prehnite and low-Fe pumpellyite. The secondary minerals consist of laumontite, calcite, dolomite, chlorite, quartz, epidote, and adularia. Native copper intergrowths, ranging from 0.5 to 8 mm in diameter, occur in prehnite and pumpellyite masses and in wall rocks. Cu content of the ore is about 1 to 2%, and the native copper contains up to 100 g/t Ag. The ore bodies occur in amygdaloidal basalt and associated tuff in a Late Jurassic to Early Cretaceous volcaniclastic sequence which extends over an area of about 1.0 by 0.6 km. Similar occurrences of native copper are known along a zone which is up to 18 km long. The deposit is small with Cu grading about 1-2%.

Origin of and Tectonic Controls for Northwestern Pekulney Metallogenic Belt

The Pekul'ney subduction-zone terrane, which hosts the Pekulney metallogenic belt, is divided into western and eastern units (Nokleberg and others, 1994c, 1997c). The western unit consists of: (1) a basal serpentinite matrix melange which contains fragments of metamorphic rocks, including greenschist, glaucophane schist, and picritic basalt; (2) a metamorphic complex which is composed of amphibolite and schist which are derived from dunite, spinel peridotite, clinopyroxenite and which yields Pb-Pb isotopic ages of 1,600 to 1,800 Ma, and eclogite inclusions which yield isotopic ages of 2,400-1,900 Ma; and (3) the Late Jurassic and Early Cretaceous Pekulneyveem Formation which is composed of basalt, tuff, hyaloclastite, radiolarian chert, siltstone, and sandstone. The basalt flows range up to 60 to 80 m thick and are interbedded with tuff, and cherty shale, all with abundant hematite (Shkursky and Matveenko, 1973). The eastern Televeem unit consists of a thick flysch sequence of Early Cretaceous (Aptian to Albian) and Late Cretaceous (Cenomanian to Turonian) age. The basaltic Cu deposits occur in the Pekulneyveem Formation and are interpreted as forming in a primitive island arc and neighboring sea-floor environment with subsequent incorporation of the host rocks and deposits into a subduction zone, now preserved in the Pekul'ney subduction-zone terrane that was tectonically linked to the Pekul'ney island arc.

Tamvatney-Mainits Metallogenic Belt of Podiform Cr Deposits (Belt TAM) East-Central Part of the Russian Northeast

The Tamvatney-Mainits metallogenic belt of podiform Cr deposits (fig. 48; tables 3, 4) occurs in the Tamvatney ophiolite and other similar units in the east-central part of the Russian Northeast. The Tamvatney ophiolite is tectonically interlayered with other units in the Mainitskiy island-arc terrane (Nokleberg and others, 1994c, 1997c). The deposits consist of sparse localities of massive chrome spinel with accessory Os-Ru-Ir minerals in dunite, pyroxenite, and associated rocks (Dmitrenko and others, 1987, 1990). The significant deposits at Krasnaya and Chirynai occur in dunites and layered complexes of gabbro, dunite, and peridotite (table 4) (Nokleberg and others 1997a, b, 1998).

Krasnaya Podiform Cr Deposit

The Krasnaya podiform Cr deposit (fig. 54) (Dmitrenko and Mochalov, 1986; Dmitrenko and others, 1987) consists of two horizons with numerous chromite bodies occur within the Krassnaya Gora alpine-type ultramafic body. An upper horizon occurs at the contact of dunite and an overlying intergrown pyroxenite-dunite-harzburgite assemblage. Chromite occurs in dunite bands. Podiform and schlieren occurrences of nearly massive to massive chromite extend for 35-70 m with a thickness of up to several meters. Several large podiform chromite bodies at the base of dunite layers contain massive and concentrated chromite for 60-100 m along strike and are more than 1 m thick. Zones of disseminated chromite up 22 m thick also occur. PGE associated with chromite occur as solid solution in the sulfides with Os, Ir, and Ru in hexagonal sites, and Ir, Os, Pt, Ru, and Rh in cubic sites. Some secondary, rare, platinum, rhodium, and palladium arsenides and sulfoarsenides are also identified.

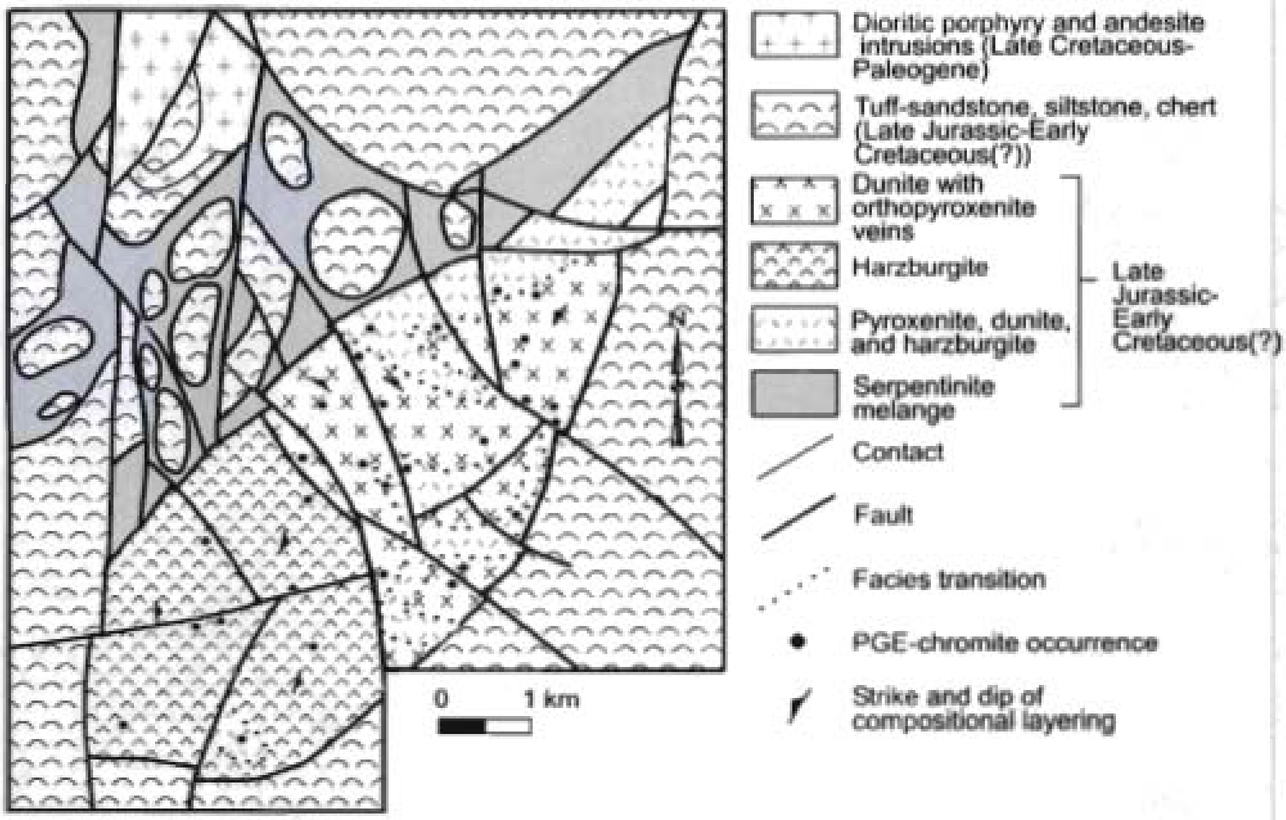


Figure 54. Krasnaya Gora podiform Cr deposit, Tamvatney-Mainits metallogenic belt, Russian Northeast. Schematic geologic map. Adapted from Dmitrenko and others (1987).

Origin of and Tectonic Controls for Tamvatney-Mainits Metallogenic Belt

The Tamvatney ophiolite which hosts the Tamvatney-Mainits metallogenic belt consists of a large, steeply-dipping tectonic block composed of an older assemblage of mainly serpentinite mélange with peridotite and lherzolite, and a younger assemblage of Late Jurassic to Early Cretaceous (Neocomian) basalt, andesite, and mafic volcaniclastic rocks (Dmitrenko and others, 1990). The serpentinite mélange has a complex structure and consists of ultramafic rocks,, gabbro, chert, Paleozoic and Early Mesozoic limestone, amphibolite, green and glaucophane schist, and eclogite. The younger assemblage consists of jasper, shale, basalt, plagiorhyolite, siltstone, and sandstone age (Tilman and others, 1982; Markov and others, 1982). Lower structural assemblage is an accretionary prism dominated by former oceanic lithosphere, whereas the upper assemblage is interpreted as the base of the Late Jurassic and Early Cretaceous Mainitskiy island arc (Palandzhyan and Dmitrenko, 1990). The podiform Cr deposits in the metallogenic belt (Krassnaya Gora and other deposits) are hosted in the older assemblage whereas the minor Cyprus massive sulfide deposits are hosted in the younger assemblage. The Mainitskiy terrane is tectonically linked to the Alkatvaam accretionary-wedge terrane (Nokleberg and others, 2000).

Mainits Metallogenic Belt of Kuroko Massive Sulfide Deposits (Belt MA) Eastern Part of Russian Northeast

The Mainits metallogenic belt of Kuroko massive sulfide deposits (fig. 48; tables 3, 4) occurs in the eastern part of the Russian Northeast. The east-west-trending belt is 170 km long, up to 40 km wide, and is hosted in the Late Jurassic and Early Cretaceous Mainitskiy island-arc terrane (Nokleberg and others, 1994c, 1997c). The significant deposit in the belt is at Ugryumoe (table 4) (Nokleberg and others 1997a, b, 1998).

Ugryumoe Massive Sulfide Deposit

The Ugryumoe deposit consists of massive sulfides which contain high concentrations of Cu, Zn, Pb, and Au which occur along a silicified zone up to 3 km long (Oparin and Sushentsov, 1988). The sulfide horizons consists of massive pyrite, and chalcopyrite, pyrite, and quartz. The sulfides occur in a Mesozoic sequence of interbedded basalt, plagiorhyolite, tuff, and siliceous tuffaceous siltstone. The deposit is interpreted as a possible kuroko massive sulfide deposit and occurs in the Hettangian and Sinemurian Lazov sequences. The sequences contain interbedded basalt, plagiorhyolite, tuffs, and tuffaceous siltstone. Intrusive rocks include granite, plagiogranite, and gabbro. Abundant geological data suggest significant potential for additional massive sulfide deposits in this belt.

Origin of and Tectonic Controls for Mainits metallogenic belt

The Mainitskiy island-arc terrane which hosts the Mainits metallogenic belt consists of older and a younger sequences (Nokleberg and others, 1994c, 1997c). The older sequence consists of: (1) a lower unit of serpentinite and serpentinite mélange which contain fragments of late Paleozoic and early Mesozoic ophiolites, and limestone with spilite and bedded jasper which contain Middle and Late Jurassic radiolarians; and (2) an upper unit of graywacke, siltstone, tuff, bedded chert which contain rare Berriasian and Valanginian *Buchia*. Local olistoliths are common and are composed of ophiolite, limestone, plagiogranite, andesite, and rhyolite which are all metamorphosed to pumpellyite facies. The younger sequence consists of a thick assemblage of Late Jurassic and Early Cretaceous island arc volcanic and sedimentary rocks composed of tholeiitic basalt, andesitic basalt, rhyolite, tuff, breccia, chert, siltstone, and sandstone. The younger sequence is interpreted as primitive island arc sequence and contains the Lazov sequence which hosts the massive sulfide deposits of the Mainits metallogenic belt. The Late Jurassic and Early Cretaceous part of the Mainitskiy terrane is interpreted as forming in a island arc which was tectonically linked to the Alkatvaam accretionary-wedge terrane (Nokleberg and others, 2000).

Svyatoy-Nos Metallogenic Belt of Au-Ag Epithermal Vein Deposits (Belt SVN) Northern Part of Russian Northeast

The Svyatoy-Nos metallogenic belt of Au-Ag epithermal vein deposits (fig. 48; tables 3, 4) occurs in the northern part of the Russian Northeast. The deposits are closely related to intermediate and felsic dikes with K-Ar isotopic ages of 149 Ma. which are part of Late Jurassic Svyatoy Nos volcanic belt (Bakharev and others, 1998). The epithermal Au-Ag deposits in the metallogenic belt, as at Polevaya, are associated with dikes and small bodies of Early Cretaceous subvolcanic rhyolite, monzonite, and quartz syenite-porphyry (Nokleberg and others 1997a, b, 1998). The Svyatoy-Nos metallogenic belt is partly overlain by Cenozoic sedimentary rocks of the Primorskaya lowland. The sole significant deposit is at Polevaya (table 4).

Polevaya Au-Ag Polymetallic Vein Deposit

The Polevaya Au-Ag polymetallic vein deposit (Nekrasov, 1962; Bakharev and others, 1988) consists of two thin, subparallel zones of intensely silicified and sericitized granodiorite and quartz diorite. The zones range from 1 to 2 m thick and up to 500 m long. The zones occur along and near the contact of an Early Cretaceous pluton which forms the core of a complex, Late Jurassic to Late Cretaceous volcanic-plutonic structure. The major minerals are chalcedony-like cryptocrystalline quartz, calcite, pyrite, galena, sphalerite, chalcopyrite, and gold. The sulfide content is about 2-3%. The deposit contains up to 10 g/t Au, 10 g/t Ag, 0.020-1% Pb, 0.050-1% Zn, 0.005-0.3% Cu, and 0.5% Sn.

Origin of and Tectonic Controls for Svyatoy-Nos Metallogenic Belt

The Svyatoy-Nos metallogenic belt is hosted in the younger (Neocomian) part of Late Jurassic and Early Cretaceous Oloy-Svyatoy Nos volcanic belt (Nokleberg and others, 1994c, 1997c). This igneous belt occurs along the northeastern margin of the Kolyma-Omolon superterrane and is part of the Indigirka-Oloy sedimentary-volcanic-plutonic assemblage. The belt contains mainly andesite, rhyolite, and tuff with interlayered shallow-marine sandstone, conglomerate, and siltstone (Parfenov, 1995a, b). The Oloy-Svyatoy Nos volcanic belt occurs adjacent to and southwest of the South Anyui terrane (fig. 48) and consists of mainly shallow-marine, rarely nonmarine basalt, andesite, rhyolite, and tuff with interlayered sandstone, conglomerate, siltstone, and shale. The volcanic belt also contains small bodies of granite, granodiorite, and monzogranite. The belt is interpreted as possibly related to a short-lived period of Late Jurassic Early Cretaceous subduction of the part of the South Anyui oceanic terrane beneath the northeastern margin of the Kolyma-Omolon superterrane, after accretion of the Kolyma-Omolon superterrane to the North Asian Craton Margin (Nokleberg and others, 1994c, 1997c, 2000).

Kuyul Metallogenic Belt of Podiform Cr, PGE and Associated Deposits (Belt KUY) East-Central Part of Russian Northeast

The Kuyul metallogenic belt of podiform Cr and associated PGE deposits (fig. 48; tables 3, 4) occurs in the southern part of the major nappe and thrust belt of the Koryak Highlands in the east-central part of the Russian Northeast. The belt extends for more than 900 km from the Taigonoss Peninsula to the northern spurs of the Pekulney Range. The metallogenic belt is hosted in the Kuyul ophiolite, part of the Gankuvayam and Elistratov units of the Kuyul subterrane (unit TLK) of the Talovskiy subduction zone-oceanic terrane (Nokleberg and others, 1994c, 1997c). The Kuyul ophiolite contains about 20 poorly-prospected Cr deposits in serpentinized peridotites which occur in about 50 mainly small, discontinuously-exposed ultramafic bodies. The significant deposits in the belt are at Talov and Tikhorechen (table 4) (Nokleberg and others 1997a, b, 1998). These deposits consist of chromite and accessory chromium spinel which occur with PGE minerals in dunite and associated ultramafic rocks. PGE minerals, in association with gold, is hosted in serpentinite and rodingite adjacent to peridotite and dunite. Local Cu-Zn-Co-Ag sulfide minerals occur in carbonate breccias (Gorelova, 1990).

Origin of and Tectonic Controls for Kuyul Metallogenic Belt

The Kuyul subterrane of the Talovskiy terrane consists chiefly of tectonic sheets composed of (Nokleberg and others, 1994c, 1997c): (1) serpentinite mélange with blocks of: (a) ultramafic rock, gabbro, plagiogranite, dike suites of oceanic and subduction zone origin, and amphibolite; (b) island arc volcanic and sedimentary deposits composed mainly of andesite, dacite, tuff; and glaucophane schist; and (c) forearc tuff and sedimentary rocks; (2) Kuyul ophiolite composed of harzburgite, gabbro, troctolite, wehrlite, plagiogranite, sheeted dikes, and pillow lava of Bathonian and Tithonian age (Chekov, 1982; Markov and others, 1982); (3) Kingiveem complex composed of oceanic volcanic, siliceous, and carbonate rocks of Permian, Middle and Late Triassic, and Middle Jurassic age; and (4) the Kuyul subduction-zone mélange composed of Late Jurassic and Early Cretaceous turbidite deposits which contain *Buchia* and Middle Jurassic radiolarian chert.

The Kulul ophiolite assemblage which hosts the Kuyul metallogenic belt is interpreted as forming either: (1) during spreading of a marginal-sea basin during the early stages of island arc formation; or (2) adjacent to a transform fault along the margin of an ocean basin (Palandzhyan and Dmitrenko, 1990). The Talovskiy subduction-zone terrane is tectonically linked to the mainly Late Jurassic and Early Cretaceous Koni-Murgal island-arc terrane (Nokleberg and others, 2000).

Metallogenic Belts Formed in Late Mesozoic Koyukuk and Togiak Island Arc Systems in Western and Southwestern Alaska

Eastern Seward Peninsula and Marshall Metallogenic Belt of Podiform Cr Deposits (Belt ESM) Northwestern Alaska

The Eastern Seward Peninsula and Marshall metallogenic belt of podiform Cr deposits occurs in the eastern Seward Peninsula and in the Marshall (Andreatsky River) area to the south in northwestern Alaska (fig. 49; tables 3, 4) (Nokleberg and others, 1997b, 1998). No significant lode deposits are known from the belt, but small, isolated occurrences of nickel sulfide minerals are found in ultramafic rocks in the region. These occurrences are interpreted as the sources of PGE minerals which have been recovered in placer mines in Sheep Creek and Dime Creek, and in the Ungalik River in the Koyuk district. The metallogenic belt is hosted in a complexly-deformed, fault-bounded unit of ophiolite and related rocks which occur discontinuously in five small areas (Foley and others, 1982). In the eastern Seward Peninsula area, the units consists of fault-bounded slivers of ultramafic rocks and serpentinite which occur along the tectonic boundary between the Koyukuk island-arc terrane to the east and the Seward metamorphosed continental margin terrane to the west (Nokleberg and others, 1997b, 1998, Sheet 3). In the Marshall (Andreatsky River) area, the unit consists of pillow basalt, chert, diorite, gabbro, serpentinite, and harzburgite. In both areas, the ophiolite and related rocks are interpreted as small, isolated klippen or faulted slivers of the upper part of the Angayucham oceanic and subduction-zone terrane. The thrust slices of ultramafic rocks in the highest structural level of the Angayucham terrane are interpeted lower part of an ophiolite which consitutes the base of the Koyukuk island arc (Loney and Himmelberg, 1989, Patton and Box, 1989). This interpretation suggests that the Eastern Seward Peninsula and Marshall metallogenic belt of podiform Cr deposits formed during subduction-related intrusion of mafic-ultramafic plutons into the basal part of the Late Jurassic Koyukuk island arc (Nokleberg and others, 1993; Goldfarb, 1997; Nokleberg and others, 2000).

Kobuk Metallogenic Belt of Podiform Cr Deposits (Belt KB) Northern Alaska

The Kobuk metallogenic belt of podiform Cr and associated PGE deposits, and one serpentine-hosted asbestos deposit (fig. 49; tables 3, 4), occurs for several hundred kilometers along the southern flank of the Brooks Range in northern Alaska. The metallogenic belt is hosted in the upper structural of the Angayucham oceanic and subduction-zone terrane (Jones and others, 1987; Nokleberg and others, 1994c, 1997c) which is interpreted as the basal part of the Koyukuk island arc (Patton and others, 1994). The major podiform Cr deposits are at Iyikrok Mountain, Avan, Misheguk Mountain, and Siniktanneyak Mountain (table 4) (Nokleberg and others 1997a, b, 1998). The serpentine-hosted asbestos deposit is at Asbestos Mountain.

Misheguk Mountain Podiform Cr Deposit

The Misheguk Mountain Podiform Cr deposit (Roeder and Mull, 1978; Degenhart and others, 1978; Zimmerman and Soustek, 1979; Foley and others, 1984, 1982, 1997) consists of disseminated fine- to medium-grained chromite in Jurassic or older, locally serpentinized dunite and peridotite tectonite. The dunite and harzburgite layers are intensely deformed into minor folds. Grab samples contain up to 27.5% Cr and 0.31 g/t PGE, and the deposit contains an estimated 110,000 to 320,000 tonnes chromite. Chromite-bearing zones have surface dimensions of 31 by 107 m. The deposit is interpreted as part of a dismembered ophiolite.

Avan Podiform Cr Deposit

The Avan podiform Cr deposit (Roeder and Mull, 1978; Degenhart and others, 1978; Zimmerman and Soustek, 1979; Mayfield and others, 1983; Foley and others, 1985, 1982) consists of disseminated fine- to medium-grained chromite in Jurassic or older dunite and harzburgite tectonite which is locally altered to serpentinite. Zones of chromite in dunite are up to a few meters wide and a few hundred meters long; the host dunite and harzburgite layers exhibit intense minor folds. Grab samples contain up to 43% Cr and 0.48 g/t PGE. The deposit contains an estimated 290,000 to 600,000 tonnes chromite.

The dunite and harzburgite tectonite host rocks at Avan and elsewhere are hosted by which occur as fault-bounded slabs in the Misheguk igneous sequence which also contains pillow basalt, gabbro, chert, and minor limestone (Roeder and Mull, 1978; Zimmerman and Soustek, 1979; Nelson and Nelson, 1982; Foley and others, 1982). The age of the ultramafic rocks hosting the podiform Cr deposits is probably Jurassic (Patton and others, 1994). This sequence is part of the Angayucham subduction zone terrane (Patton and others, 1994). The ultramafic rocks hosting the Asbestos Mountain deposit also occur as fault-bounded slabs in the upper part of the Angayucham terrane.

Origin of and Tectonic Controls for Kobuk Metallogenic Belt

The Kobuk metallogenic belt occurs in highly-deformed mafic and ultramafic rock that forms the upper structural level of the Angayucham subduction zone terrane along the southern margin of the Brooks Range (fig. 49; tables 3, 4). The belt occurs mainly in a major east-west-striking, south-dipping thrust sheet which extends for several hundred km, and in sparse isolated klippen. These Angayucham terrane occurs along south-dipping faults over the highly deformed metamorphosed, middle Paleozoic and older metasedimentary, metavolcanic, and lesser metagranitoid rocks of the Coldfoot metamorphosed continental margin terrane to the north, and in turn are overthrust by the mainly island-arc, Late Jurassic and Early Cretaceous Koyukuk island-arc terrane to the south (Moore and others, 1992; Patton and others, 1994). The thrust slices of ultramafic rocks in the highest structural level of the Angayucham terrane are interpeted lower part of an ophiolite which consitutes the base of the Koyukuk island arc (Loney and Himmelberg, 1989, Patton and Box, 1989; Patton and others, 1994). This interpretation suggests that the Kobuk metallogenic belt of podiform Cr and related deposits formed during subduction-related intrusion of mafic-ultramafic plutons into the basal part of the Late Jurassic Koyukuk island arc (Nokleberg and others, 1993; Goldfarb, 1997; Nokleberg and others, 2000).

Southwestern Alaska Metallogenic Belt of
Zoned Mafic-Ultramafic PGE Deposits (Belt SWA)
Southwestern Alaska

The Southwestern Alaska metallogenic belt of zoned mafic-ultramafic PGE deposits (fig. 49; tables 3, 4) are hosted in the Goodnews subduction zone and Togiak island-arc terranes (Nokleberg and others, 1994c, 1997c). The significant deposits in the belt are: (1) a concealed Fe-Ti (PGE) deposit at Kemuk; and (2) a zoned mafic-ultramafic PGE occurrence at Red Mountain (fig. 55) in ultramafic rocks at Goodnews Bay which is interpreted as the source of the extensive placer PGE deposits in the region (table 4) (Southworth and Foley, 1986; Foley and others, 1997; Nokleberg and others 1997a, b, 1998). The ultramafic plutons which host the deposits in both areas are a part of a belt of similar zoned mafic to ultramafic plutons which intrude both the Goodnews oceanic terrane and the adjacent Togiak island-arc terrane (Nokleberg and others, 1994c, 1997c).

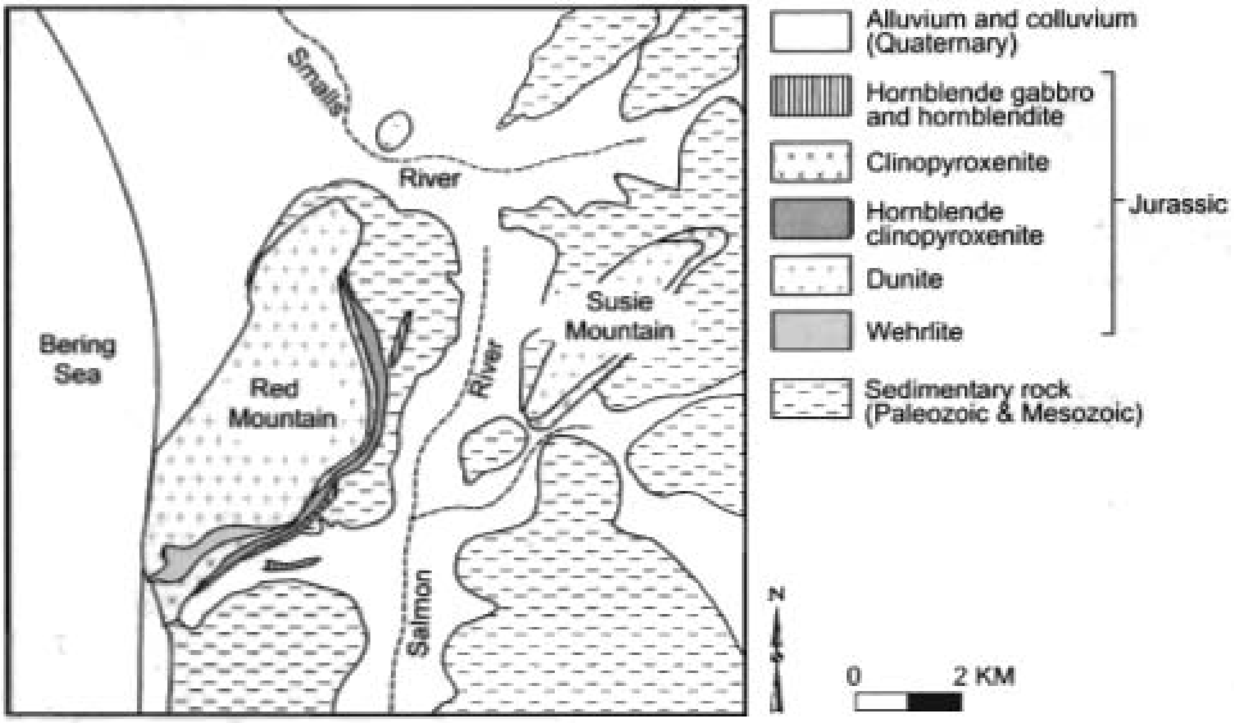


Figure 55. Red Mountain mafic-ultramafic PGE occurrence, Southwestern Alaska metallogenic belt, Southwestern Alaska. Occurrence is hosted in Goodnews Bay mafic-ultramafic complex. Schematic geologic map. Adapted from Southworth (1986) and Foley and others (1997).

Kemuk Mountain Fe-Ti (PGE) Deposit

The Kemuk Mountain Fe-Ti (PGE) deposit (Humble Oil and Refining Company, written commun., 1958; Eberlein and others, 1977; C.C. Hawley, written commun., 1980; Foley and others, 1997) consists of a buried titaniferous magnetite deposit in crudely zoned pyroxenite which is interpreted as part of a zoned Alaskan-type ultramafic pluton. A steeply-dipping, high-temperature, contact metamorphic zone occurs in adjacent Permian quartzite and limestone. An aeromagnetic survey indicates the concealed pluton is about 1,500 m thick, and underlies about 6 km^2 area. Based on Humble Oil and Refining Company drill data (written commun., 1988; Bundtzen and others, 1994), the deposit is estimated to contain 2,200 million tonnes grading 15 to 17 % Fe, and 2 to 3 % TiO_2.

Origin of and Tectonic Controls for
Southwestern Alaska Metallogenic Belt

The ultramafic plutons which host the Kemuk Mountain and Red Mountain deposits are a part of a belt of similar zoned mafic to ultramafic plutons which intrude both the Goodnews oceanic terrane and the adjacent Togiak island-arc terrane. These plutonic rocks are interpreted as the oldest known remnants of the Togiak island arc which consists chiefly of two major sequences (Box, 1985; Nokleberg and others, 1994c, 1997c): (1) a lower ophiolite sequence at the southwestern end of the terrane which consists of Late Triassic midocean-ridge pillow basalt, diabase, gabbro, and ultramafic rocks; and (2) a coherent upper sequence of Early Jurassic to Early Cretaceous marine volcaniclastic sandstone, conglomerate, shale, tuffaceous chert, minor argillaceous limestone, and marine to nonmarine andesite and basalt flows, and flow breccia, and tuff. The Togiak island arc is interpreted as forming in the Jurassic and Early Cretaceous and is tectonically linked to the Goodnews subduction-zone terrane (Box and Patton, 1989; Decker and others, 1994; Plafker and Berg, 1994; Nokleberg and others, 2000).

Yukon River Metallogenic Belt of Podiform Cr Deposits (Belt YR) West-Central Alaska

The Yukon River metallogenic belt of podiform Cr deposits (fig. 49; tables 3, 4) occurs along the southern flank of the Yukon-Koyukuk Basin in west-central Alaska (Foley and others, 1982, 1997). As in the Southern Brooks Range metallogenic belt of podiform Cr deposits to the north, the metallogenic belt is hosted in the upper structural level of the Angayucham oceanic and subduction-zone terrane which is interpreted as the basal part of the Koyukuk island arc (Nokleberg and others, 1994c, 1997c, 2000; Patton and others, 1994). The Yukon River metallogenic belt extends for several hundred kilometers. The principal deposits in the northeastern part of this belt are at Caribou Mountain, Lower Kanuti River, and Holonada, and the significant deposits in the southwestern part of this belt at Mount Hurst and Kaiyuh Hills are in the Tozitna and Innoko areas (table 4) (Nokleberg and others 1997a, b, 1998).

Kaiyuh Hills Podiform Cr Deposit

The Kaiyuh Hills podiform Cr deposit (Loney and Himmelberg, 1984; Foley and others, 1984, 1997) consists of banded and disseminated chromite from 1 cm to 1 m thick which occur in fresh and serpentinized Jurassic(?) dunite of the Kaiyuh Hills ultramafic belt. The dunite interlayered with harzburgite tectonite. The largest deposit covers an area of1 by 100 m, and consists of massive chromite containing an estimated 5,000 tonnes Cr_2O_3. Lesser occurrences consist of banded nodular pods of chromite. Metallurgical grade chromite containing 46% Cr_2O_3 is present. The deposit contains an estimated 15,000 to 34,000 tonnes Cr_2O_3 in one deposit. Surface samples from the largest deposit average 60% Cr_2O_3.

Origin of and Tectonic Controls for Yukon River Metallogenic Belt

Along the southern margin of the Brooks Range, the Angayucham oceanic terrane occurs mainly in a major east-west-striking, south-dipping thrust sheet which extends for several hundred km, and in sparse isolated klippen that forms the upper structural level of the Angayucham subduction zone terrane in West-Central alaska (fig. 49; tables 3, 4). These thrust sheets and klippen are thrust along north-dipping faults over the highly deformed metamorphosed, middle Paleozoic and older metasedimentary, metavolcanic, and lesser metagranitoid rocks of the Ruby metamorphosed continental margin terrane to the south. To north is the Late Jurassic and Early Cretaceous Koyukuk island-arc terrane (Moore and others, 1992; Patton and others, 1994). The thrust slices of ultramafic rocks in the highest structural level of the Angayucham terrane are interpeted lower part of an ophiolite which consitutes the base of the Koyukuk island arc (Loney and Himmelberg, 1989, Patton and Box, 1989; Pattern and others, 1994). This interpretation suggests that the Yukon River metallogenic belt of podiform Cr deposits formed during subduction-related intrusion of mafic-ultramafic plutons into the basal part of the Late Jurassic Koyukuk island arc (Nokleberg and others, 1993; Goldfarb, 1997; Nokleberg and others, 2000).

Metallogenic Belts Formed in Late Mesozoic Gravina Island Arc in Southern Alaska and Canadian Cordillera

Eastern-Southern Alaska Metallogenic Belt of Granitic Magmatism Deposits (Belt ESA) Eastern-Southern Alaska

The major Eastern-Southern Alaska metallogenic belt of granitic magmatism deposits (fig. 49; tables 3, 4) contains porphyry Cu, Mo, and Au, polymetallic vein, and Fe-Au skarn deposits (Nokleberg and others, 1995a). The metallogenic belt is hosted in the northern part of the Wrangellia island-arc superterrane, in and adjacent to the area underlain by the Late Jurassic to mid-Cretaceous Gravina-Nutzotin belt and coeval granitoid plutonic rocks (Nokleberg and others, 1994c, 1995a, 1997c). This igneous belt was designated as part of a volcanic-plutonic arc by Richter and others (1975), has been called the Nutzotin-Chichagof belt by Hudson (1983), the Chisana arc by Plafker and others (1989), and the Gravina arc by Stanley and others (1990). This igneous belt extends for a few hundred kilometers within and parallel to the northern margin of the Wrangellia island arc superterrane. The deposits of the Eastern-Southern Alaska metallogenic belt are associated with Early to mid-Cretaceous granitoid rocks, mainly granite and granodiorite (Miller, 1994). Most of the granitoid rocks are calc-alkaline and intermediate in composition. The significant deposits are the Nabesna (fig 56) and Rambler Fe-Au skarn deposits, the Pebble Copper porphyry Au-Cu deposit, the Bond Creek-Orange Hill, and London and Cape, porphyry Cu and Mo deposits, and the Midas Cu-Au skarn deposit (table 4) (Nokleberg and others 1997a, b, 1998).

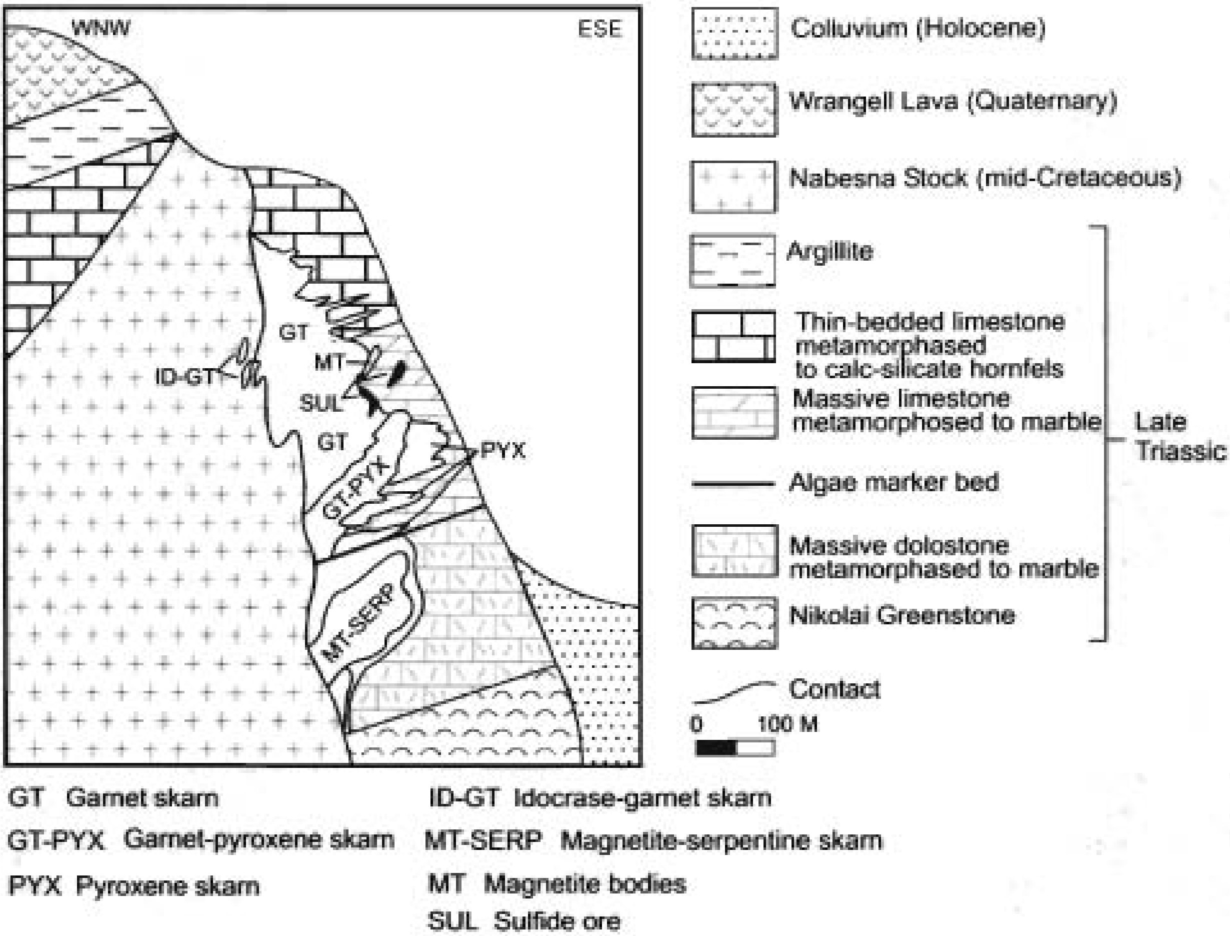


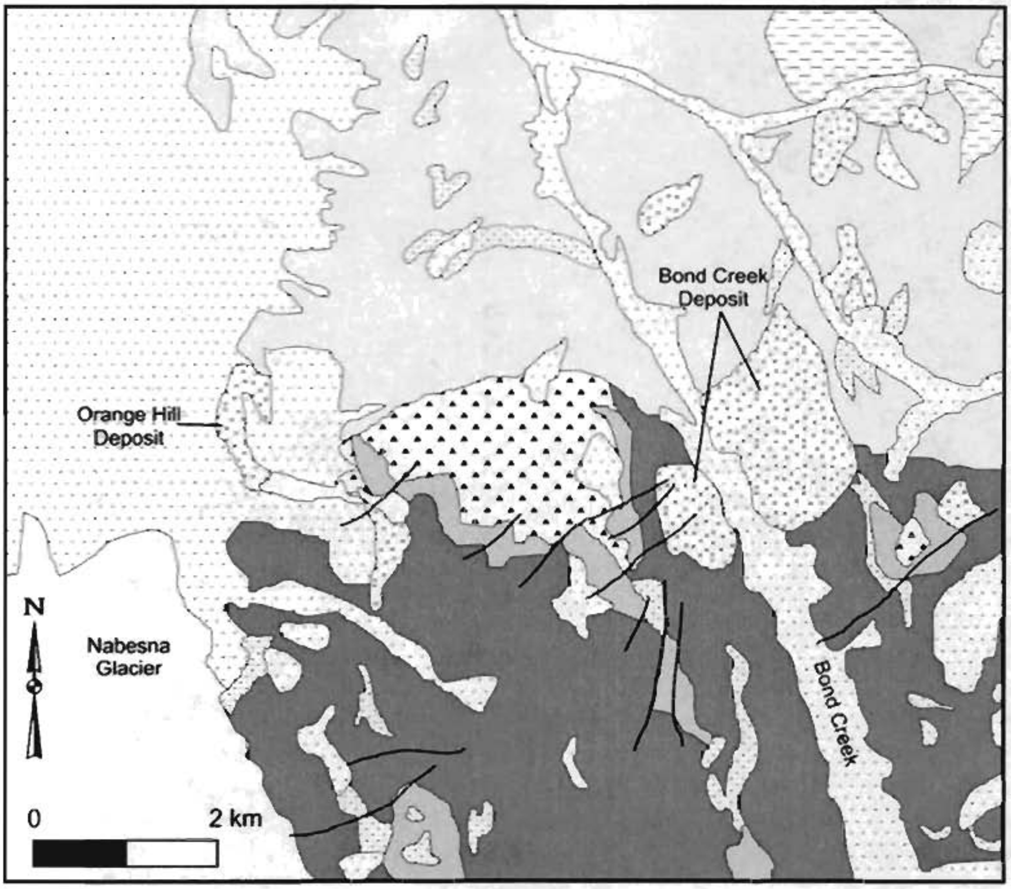
Figure 56. Nabesna Fe-Au skarn mine, Eastern-Southern Alaska metallogenic belt, Southern Alaska. Schematic cross section showing sulfide-magnetite-skarn relations. Magnetite-rich ore replaces dolomite. Gold-rich ores form small marble front replacements. The chief ore mineral is chalcopyrite in garnet-pyroxene skarn. Adapted from Wayland (1953), Weglarz (1991), and Newberry and others (1997).

Pebble Copper Porphyry Au-Cu Deposit

The Pebble Copper porphyry Au-Cu deposit occurs in the western part of southern Alaska (Phil St. George, written commun., 1991; Bouley and others, 1995; Young and others, 1997). The deposit consists of disseminated chalcopyrite, pyrite, and molybdenum, accompanied by minor to trace galena, sphalerite, and arsenopyrite, in a stockwork vein system. The deposit contains an inferred reserve of 430 million tonnes grading 0.35% Cu, 0.4 g/t Au, and 0.015% Mo. Recent data indicates 1.0 billion tonnes grading 0.61 % Cu equivalent, or 0.4% Cu and 0.30 g/t Au, 0.015% Mo (Northern Dynasty news release, September 25, 2003). The deposit is hosted in a mid-Cretaceous granodiorite porphyry and its adjacent hornfels aureole. The sulfide minerals formed during a late-stage intense hydrofracturing which followed potassic, silicic, and sericitic alteration events. Tourmaline breccias also exist locally. K-Ar ages for hydrothermal sericite and igneous K-feldspar are 90 and 97 Ma, respectively. The granodiorite hosting the deposit is part of a larger, composite 40 km volcanic-plutonic complex which also includes pyroxenite, alkali gabbro, and granite, and overlying dacite volcanic rocks. The volcanic and plutonic rocks are alkalic-calcic and quartz alkalic in composition. The granodiorite porphyry intrudes the Late Jurassic and Early Cretaceous Kahiltna overlap assemblage, and is overlain by Tertiary volcanic rocks.

Orange Hill and Bond Creek Porphyry Cu-Mo Deposits

The Orange Hill and Bond Creek porphyry Cu-Mo deposits (fig. 57) (Van Alstine and Black, 1946; Richter and others, 1975a, b; Nokleberg and others, 1995a) occur in the northern Wrangell Mountains. The deposits consist of pyrite, chalcopyrite, and minor molybdenite which occur in quartz veins which contain K-feldspar and sericite, and as disseminations in the Cretaceous Nabesna pluton. The pluton, which has K-Ar isotopic ages of 112-114 Ma, forms a complex intrusion of granodiorite and quartz diorite intruded by granite porphyry. The deposits exhibit abundant biotite-quartz, quartz-sericite, and chlorite-sericite-epidote



Ice (Holocene)

Undifferentiated surficial deposits (Quaternary)

Hornblende porphyry dikes and sills (Tertiary)

Potassic, phyllic, silicic, and argillic alteration zones with limonite staining

Granodiorite and quartz monzonite of Nabesna batholith (Cretaceous)

Ttondhjemite (Cretaceous)

Subaerial basalt of Nikolai Greenstone (Upper Triassic)

Fine-grained sedimentary rocks and limestone (Middle Permian to Middle Triassic)

Volcaniclastic rocks, tuffs, and flows (Pennsylvanian to Permian)

Fault   Contact

Figure 57. Bond Creek and Orange Hill porphyry Cu-Mo deposits, Eastern-Southern Alaska metallogenic belt, Eastern-Southern Alaska. Schematic geologic map. Adapted from Richter (1973) and Nokleberg and others (1995).

alteration, and late-stage anhydrite veins (R.J. Newberry, written commun., 1985). Widespread, late-stage chlorite-sericite-epidote alteration also occurs in the Nabesna pluton. The altered areas associated with the deposit have dimensions of about 1.0 by 3.0 km at Orange Hill, and 2.0 by 3.0 km at Bond Creek.

The Orange Hill deposit contains an inferred reserve of 320 million tonnes grading 0.35% Cu and 0.02% Mo, and the Bond Creek deposit contains an inferred reserve of 500 million tonnes grading 0.30% Cu and 0.02% Mo (Richter and others, 1975a, b). The Nabesna pluton intrudes Late Jurassic and Early Cretaceous flysch of the Gravina-Nutzotin belt. Associated skarn deposits contain disseminated andradite garnet, pyroxene, pyrite, chalcopyrite, bornite, and magnetite, and massive pyrrhotite, pyrite, chalcopyrite, and sphalerite. Also associated with the Nabesna pluton are the mined Nabesna Fe-Au and the Rambler Fe-Au skarn deposits (Weyland, 1943; Nokleberg and others, 1987; Newberry and others, 1997a).

Baultoff, Horsfeld, Carl Creek Porphyry Cu Deposits

The Baultoff, Horsfeld, and Carl Creek porphyry Cu deposits (Richter and others, 1975b) occur in three nearby areas in the northern Wrangell Mountains. The deposits consist of pyrite and chalcopyrite which occur both in veinlets and as disseminations in altered Cretaceous granitoid plutons composed of quartz diorite, quartz diorite porphyry, or granite porphyry. The altered areas associated with the deposits have dimensions up to 1,000 by 2,000 m. Alteration minerals are chlorite, sericite, albite, pyrite; local actinolite veins and disseminations also occur. The deposits contain an estimated resource of 240 million tonnes grading 0.2% Cu, <0.01% Mo, and trace Au (Richter and others, 1975b). The host granitoid rocks form part of the Cretaceous Klein Creek batholith which intrudes Late Jurassic and Early to mid-Cretaceous flysch of the Gravina-Nutzotin belt.

Origin of and Tectonic Controls for Eastern-Southern Alaska Metallogenic Belt

The Eastern-Southern Alaska metallogenic belt occurs in the central and northern part of the Wrangellia island-arc terrane, in and adjacent to the area underlain by the Late Jurassic and Early Cretaceous Gravina-Nutzotin belt, and by the partly coeval Kahiltna overlap assemblage (Nokleberg and others, 1995a) (fig. 49). In the Nutzotin Mountains between the Alaska Range and Wrangell Mountains, the Gravina-Nutzotin belt consists chiefly of argillite, graywacke, and conglomerate, and a lesser unit of andesite and basalt volcanic and volcaniclastic rocks in the Chisana Formation (Berg and others, 1972; Richter, 1976; Richter and others, 1976). Sedimentary rocks range in the from deep marine turbidites to shallow-water and nonmarine deposits. The coarse clastic rocks in the Nutzotin part of the Gravina-Nutzotin belt are interpreted as derived locally from the underlying Wrangellia superterrane and from unknown metamorphic source terranes. Metamorphism is lower greenschist facies (Dusel-Bacon and others, 1993).

The granitoid rocks of the Gravina arc are partly coeval with the andesitic and basaltic volcanic and volcaniclastic rocks of the Early Cretaceous Chisana Formation which occurs in the upper part of the Gravina-Nutzotin belt in the Nutzotin Mountains in eastern-southern Alaska. The igneous rocks of the Chisana Formation are Al_2O_3 rich, exhibit pronounced light-REE enrichment, are classified as tholeiitic-transitional to calc-alkalic, and are interpreted as subduction-related by Barker (1994). The Chisana Formation is interpreted as forming in the axial part of the Gravina arc with volcanic-rock-derived flysch of the Kahiltna overlap assemblage and Gravina-Nutzotin belt as forming along the arc flanks.

To the west, in the central and western Alaska Range and adjacent areas, the Kahiltna overlap assemblage, which is partly coeval with the Gravina-Nutzotin belt, consists chiefly of structurally-disrupted, deep marine, partly volcaniclastic, flyschoid graywacke and argillite, with minor amounts of chert, limestone, conglomerate, and andesite (Csejtey and others, 1986; Jones and others, 1982, 1987; Wallace and others, 1989; Nokleberg and others, 1994d). The assemblage is mostly Early Cretaceous in age, but includes rocks ranging in age from Late Jurassic to locally early Late Cretaceous (Cenomanian). Metamorphism is lower greenschist facies, but locally ranges from zeolite to amphibolite facies (Dusel-Bacon and others, 1993). The occurrence of locally abundant volcanic rock detritus in the flysch of the Kahiltna overlap assemblage indicates that the Gravina arc occurred sporadically across most of southern Alaska.

Together, the granitic and andesitic rocks of the Gravina-Nutzotin belt and the Kahiltna overlap assemblage define the Gravina island arc, which is interpreted as forming on the northern, or leading edge of the Wrangellia island-arc superterrane during migration towards North America (Nokleberg and others, 1984, 1985, 2000; Nokleberg and Lange, 1985a; Plafker and others, 1989; Plafker and Berg, 1994; Nokleberg and others, 2000). The Gravina arc and associated granitic magmatism deposits are tectonically linked to the younger part of the McHugh Complex which forms the northern part of the Chugach subduction zone and accretionary wedge complex (Nokleberg and others, 2000). These relations reveal the long and complex history of the Wrangellia island-arc superterrane (Nokleberg and others, 1984, 1985, 2000; Nokleberg and Lange, 1985a). The Eastern-Southern Alaska metallogenic belt is herein interpreted as partly coeval with: (1) the Western-Southeastern Alaska metallogenic belt, described below, which is also hosted in the Late Jurassic and Early Cretaceous Gravina overlap assemblage of the Wrangellia superterrane in Southeastern Alaska; and (2) the Island porphyry metallogenic belt, described above, which is hosted in the Gambier overlap assemblage in southern British Columbia.

Klukwan-Duke Metallogenic Belt of Mafic-Ultramafic Ti-Fe-Cr-PGE Deposits Southeastern Alaska (Belt KL)

The Klukwan-Duke metallogenic belt of zoned mafic-ultramafic Ti-Fe-Cr-PGE deposits (fig. 49; tables 3, 4) occurs along the length of Southeastern Alaska from Klukwan, near Haines, in the north, to Duke Island in the south (Taylor, 1967; Brew, 1993; Himmelberg and Loney, 1995; Foley and others, 1997). The deposits occur in a suite of zoned, *Alaskan-type* mafic-ultramafic plutons of mainly mid-Cretaceous age (100 to 110 Ma) which constitute a long, discontinuous suite of zoned plutons which intrude the flysch of the Late Jurassic and Early Cretaceous Gravina-Nutzotin-Gambier volcanic-plutonic-sedimentary belt. This belt, which forms a major overlap assemblage, occurs along the length of the Wrangellia island arc superterrane (Nokleberg and others, 1994c, 1997c). The significant deposits (table 4) are at Union Bay, Klukwan, and Haines, and lesser deposits are at Funter Bay, Duke Island, Snettisham, and Union Bay (Nokleberg and others 1997a, b, 1998).

Union Bay Zoned Mafic-Ultramafic Fe-Cr-PGE Deposit

The Union Bay zoned mafic-ultramafic Fe-Cr-PGE deposit (fig. 58) (Ruckmick and Noble, 1959; Berg, 1984; Brew and others, 1991; Himmelberg and Loney, 1995; Foley and others, 1997) consists of magnetite and chromite which are disseminated in dunite; chromite also occur as discontinuous stringers in dunite. The deposit is hosted in a mid-Cretaceous, concentrically zoned mafic-ultramafic complex which has a dunite core, named the Union Bay ultramafic pluton. The dunite occurs in a pipe and a lopolith in center of the ultramafic pluton. Peridotite also occurs with dunite; pyroxenite and hornblende pyroxenite on the periphery of the pluton. The pluton intrudes the Late Jurassic and Early Cretaceous flysch of Gravina-Nutzotin overlap assemblage. Magnetite and chromite form primary segregations, and PGE also occurs with chromite and magnetite in dunite. Hand- picked specimens of chromite average 0.093 g/t Pt, 0.200 g/t Pd, 0.062 g/t Rh and 0.215 g/t Ir. The deposit is large and contains an estimated 1,000 million tonnes grading 18 to 20% Fe. The deposit may also contain V.

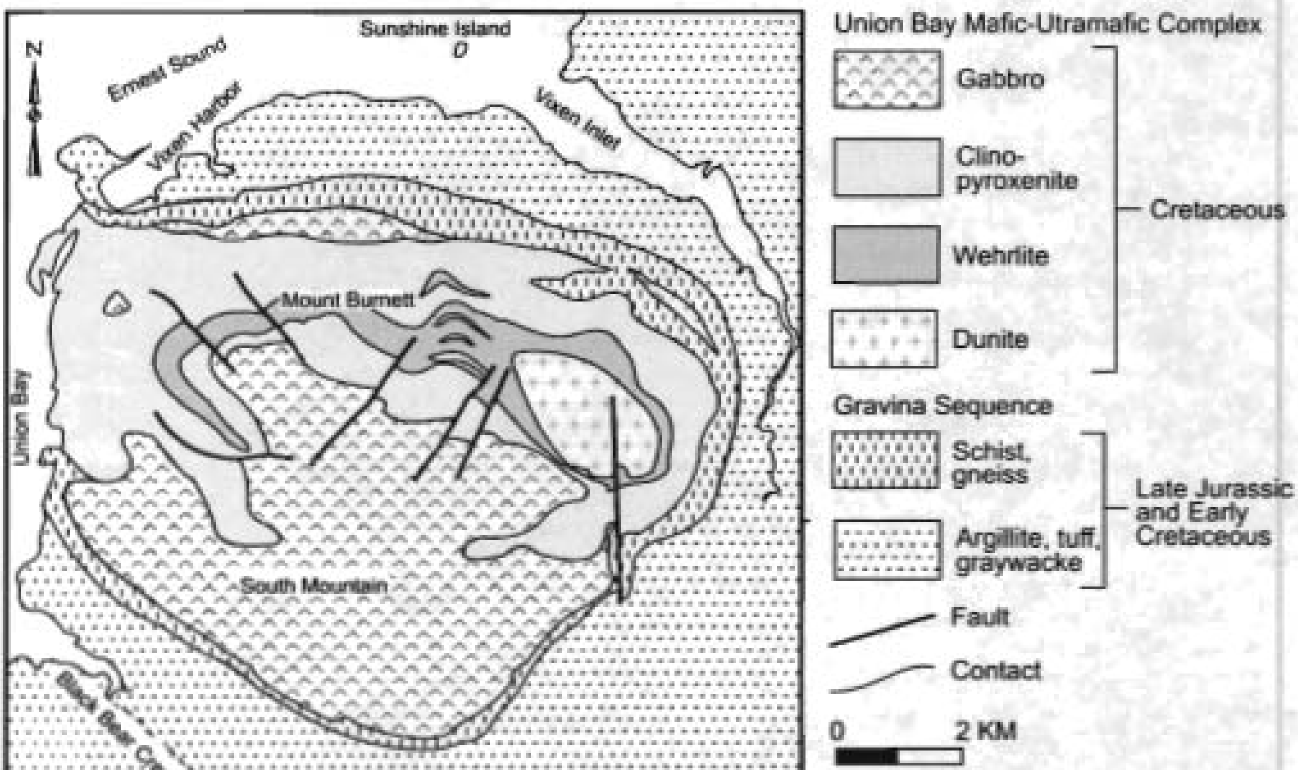


Figure 58. Union Bay zoned mafic-ultramafic Fe-Cr-PGE deposit, Klukwan-Duke metallogenic belt, Southeastern Alaska. Schematic geologic map. Adapted from Himmelberg and Loney (1995).

Klukwan Zoned Mafic-Ultramafic Fe-Ti Deposit

The Klukwan Zoned mafic-ultramafic Fe-Ti deposit (Wells and Thorne, 1953; Robertson, 1956; MacKevett and others, 1974; Berg, 1984; Still, 1984; Wells and others, 1986; Brew and others, 1991; Foley and others, 1997) consists of titaniferous magnetite accompanied by minor chalcopyrite, hematite, pyrite, pyrrhotite, spinel, and leucoxene which occur either as disseminations or in tabular zones in a pyroxenite body surrounded by diorite. Magnetite occurs interstitial to pyroxene and is idiomorphic against hornblende. The host pyroxenite and diorite are Cretaceous and intrude Triassic or older rock of the Wrangellia superterrane. Associated with the lode deposit is the nearby Klukwan magnetite placer deposit at Takshanuk Mountain which contains an estimated 453 million tonnes grading 10% titaniferous magnetite. The placer deposit occurs in an alluvial fan at the foot of the mountain slope below the Klukwan deposit.

Origin of and Tectonic Controls for Klukwan-Duke Metallogenic Belt

The zoned mafic-ultramafic Fe-Ti-PGE deposits of Klukwan-Duke metallogenic belt occur mainly in concentrically zoned, Alaskan-type, mafic and ultramafic plutons (fig. 49; tables 3, 4) (Foley and others, 1997). These plutons are part of the Gravina arc and intrude mainly Late Jurassic to Early Cretaceous flysch of the Gravina-Nutzotin-Gambier volcanic-plutonic-sedimentary belt, and adjacent units of the Wrangellia island arc superterrane (Plafker and Berg, 1994; Nokleberg and others, 1994c, 1997c; Himmelberg and Loney, 1995). In southeastern Alaska and the Canadian Cordillera, the Gravina-Nutzotin-Gambier belt consists chiefly of intercalated volcanic rocks and sedimentary rocks (Gravina, Dezadeash, and Gambier units) which range in age from Late Jurassic (Oxfordian) through Early Cretaceous (Albian) (Berg and others, 1972; Monger and Berg, 1987; McClelland and others, 1992). Coarse clastic rocks in the Gravina part of assemblage were largely derived from the stratigraphically underlying Wrangellia superterrane which lies mainly to west, but may also have been derived in part from the Stikinia and Yukon-Tanana terranes to the east.

The Gravina-Nutzotin-Gambier volcanic-plutonic-sedimentary belt (Berg and others, 1972; Monger and Berg, 1987; McClelland and others, 1992) forms a major Late Jurassic and Early Cretaceous overlap assemblage. The assemblage is generally interpreted as an island arc which was deposited on, and intruded into the Wrangellia island arc superterrane in Southeastern Alaska, British Columbia, and Eastern-Southern Alaska (Nokleberg and others, 1994c, 1997c). The zoned mafic and ultramafic plutons and associated zoned mafic-ultramafic Fe-Cr-PGE deposits of the Klukwan-Duke metallogenic belt are generally interpreted as the plutonic feeders to the island arc (Plafker and Berg, 1994; Nokleberg and others, 2000; Monger and Nokleberg, 1996). Cessation of the island arc is generally interpreted as coincident with accretion of the Wrangellia island superterrane to the North American continental margin in the mid-Cretaceous.

Metallogenic Belts Formed in Late Mesozoic Collision and Overthrusting in Eastern Alaska and Canadian Cordillera

Fortymile Metallogenic Belt of Serpentinite-Hosted Asbestos Deposits (Belt ECA) East-Central Alaska and Northwestern Canadian Cordillera

The Fortymile metallogenic belt of serpentinite-hosted asbestos deposits (fig. 49; tables 3, 4) occurs in the Yukon-Tanana Upland in east-central Alaska and in the northwestern part of the Canadian Cordillera (Foley, 1982). The metallogenic belt is hosted in the Seventymile oceanic and subduction-zone terrane which occurs in a discontinuous klippen thrust over the eastern part of Yukon-Tanana metamorphosed continental margin terrane in the Yukon-Tanana Upland (Jones and others, 1987; Foster and others, 1987; Nokleberg and others, 1994c, 1997c). The significant deposits are a large serpentinite-hosted asbestos deposit at Slate Creek, Alaska and at Clinton Creek, northwestern Canadian Cordillera (table 4) (Nokleberg and others 1997a, b, 1998).

Slate Creek Serpentinite-Hosted Asbestos Deposit

The Slate Creek serpentinite-hosted asbestos deposit (Foster and Keith, 1974; Robert K. Rogers, written commun., 1984) consists of antigorite with minor clinochrysotile, chrysotile, magnetite, brucite, and magnesite in serpentinized harzburgite. The chrysotile asbestos occurs in zones of fracturing near centers of thicker serpentinite, primarily as cross-fiber asbestos 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 harzburgite occurs as tabular tectonic lenses, generally from 60 to 150 m thick and up to 800 m long. The deposit contains an estimated 58 million tonnes grading 6.4% fiber.

Clinton Creek Serpentine-Hosted Asbestos Deposit

In the northwestern Yukon Territory, northwestern Canadian Cordillera, the Fortymile metallogenic belt contains a significant asbestos deposits at Clinton Creek (EMR Canada, 1989). The asbestos occurs mainly in fractures zones in fault-bounded lenses of serpentinite in sheared metasedimentary rocks of the tectonically-imbricated Slide Mountain and Yukon-Tanana (Nisling) terranes (Abbott, 1983). The chrysotile occurs as cross-fiber asbestos veinlets. The deposit has estimated reserves of 6.8 million tonnes grading 4.37% fibre. Approximately 0.94 million tonnes of fibre were produced from 15.9 million tonnes of ore mined between 1967 and 1978. A maximum Permian age of chrysotile formation is suggested by K-Ar and Rb-Sr isotopic ages which are interpreted as the age of metamorphism (Htoon, 1981).

Origin of and Tectonic Controls for Fortymile Metallogenic Belt

In east-central Alaska, the Seventymile subduction zone terrane, which contains the serpentinite-hosted asbestos deposits of the Fortymile metallogenic belt, occurs as discontinuous remnants of thrust sheets of ultramafic and associated rocks which are structurally thrust onto the subjacent Yukon-Tanana terrane. The Seventymile terrane contains serpentinized harzburgite and associated ultramafic rocks, gabbro, pillow basalt, chert, argillite, andesite, and graywacke of Permian to Triassic age (Foster and others, 1987; Nokleberg and others, 1994c, 1997c). The Seventymile terrane is interpreted as a dismembered ophiolite which formed during a Permian to Triassic period of sea-floor spreading (Foster and others, 1987; Nokleberg and others, 1989a, 1994c, 1997c). The Seventymile terrane is interpreted as a possible root to the Stikinia(?) island arc terrane in east-central Alaska (Nokleberg and others, 2000). In the northern Canadian Cordillera, the Slide Mountain accretionary wedge terrane is also interpreted as part of the root of the Jurassic Stikinia-Quesnellia island arc terranes.

The serpentinite-hosted asbestos deposits in the Fortymile metallogenic belt are the products of low-grade metamorphism and alteration of ultramafic rock in both the Seventymile and Slide Mountain terranes. The metamorphism and alteration are herein interpreted as occurring during either Jurassic thrusting of these terranes onto the North American Craton Margin, or more likely, during younger hydrothermal activity associated with extensive Late Cretaceous granitic magmatism.

Cassiar Metallogenic Belt of Serpentinite-Hosted Asbestos Deposits Northern British Columbia (Belt CS)

The Cassiar metallogenic belt of serpentinite-hosted asbestos (and local jade) deposits occurs in northern British Columbia in the east-central part of the Canadian Cordillera (fig. 49; tables 2, 3) (Nokleberg and others, 1997b, 1998). The metallogenic belt is hosted in the altered ultramafic rocks of the Slide Mountain subduction-zone terrane. The two significant deposits are at Cassiar and adjacent McDame.

Cassiar (McDame) Serpentine-Hosted Asbestos Deposit

The Cassiar (McDame) serpentine-hosted asbestos deposit (fig. 59) (Burgoyne, 1986; Leaming, 1978; Northern Miner, December 12, 1987) consists of a chrysotile asbestos stockwork hosted in serpentinized alpine ultramafic intrusive rocks which occur along the fault contact of the Slide Mountain terrane and structurally underlying shelf sedimentary rocks of the passive-continental margin Cassiar terrane (Nokleberg and others, 1997b, 1998). The deposit consists of two-fibre vein type chrysotile with magnetite which occurs in vein partings and in wall rocks, accompanied by some pyrite and jade. About 2.05 million tonnes of fibre were produced between 1953 and 1984 from 23.3 million tonnes of ore mined between 1953-1984. The deposit age is uncertain, but probably Cretaceous. The deposit is large and contains pre-production reserves of 55 million tonnes with high quality chrysotile.

Origin of and Tectonic Controls for Cassiar Metallogenic Belt

The chrysotile asbestos deposits of the Cassiar metallogenic belt occur in sheared and altered serpentine lenses and bodies which occur along the contacts between alpine ultramafic intrusions of the Slide Mountain terrane and the structurally underlying sedimentary rocks of the Cassiar passive continental-margin terrane (Nokleberg and others, 1997b, 1998, Sheet 3). Chrysotile veinlets, along with lizardite, antigorite, magnetite, pyrite and nephrite, formed as infiltrational replacements of serpentinite in and along shear zones (O'Hanley and Wicks, 1995). An incremental ^{40}Ar-^{39}Ar isotopic age of 94 Ma on phlogopite in the orebody footwall (Nelson and Bradford, 1993) is interpreted as a minimum age of serpentinization. Phlogopite formation apparently post-dates metamorphism related to emplacement of the Sylvester allochthon of the Slide Mountain terrane in the Middle to Late Jurassic (Harms, 1986; Monger and others, 1991).

The Slide Mountain terrane consists mainly of a fault-bounded oceanic assemblage of Devonian to Permian and locally Late Triassic marine volcanic and sedimentary rocks, and local mafic and ultramafic plutonic rocks (Nokleberg and others, 1994c). The terrane occurs for about 2,000 km along the length of the Canadian Cordillera (Nokleberg and others, 1997b, 1998, Sheet 1). The Slide Mountain terrane is interpreted as a sequence of oceanic crustal rocks which formed adjacent to, and were subducted under a late Paleozoic and early Mesozoic island arc now preserved as two fragments in the Quesnellia and Stikinia terranes (Nokleberg and others, 1994c; Monger and Nokleberg, 1996; Nokleberg and others, 2000). The Slide Mountain terrane occurs in large blocks to small, discontinuous remnants which are thrust over and (or) tectonically imbricated onto the Yukon-Tanana, Kootenay, and Cassiar continental-margin terranes, and onto the North American craton margin (Nokleberg and others, 1997b, 1998, Sheet 1). The Slide Mountain terrane is interpreted as being emplaced onto the North American craton and craton margin, along with the Stikinia, Quesnellia, and Cache Creek terranes during a major period of Jurassic accretion (Monger and

Nokleberg, 1996). The serpentinite-hosted asbestos deposits in the Cassiar metallogenic belt are the products of low-grade metamorphism and alteration of ultramafic rock in the Slide Mountain terranes. The metamorphism and alteration are herein interpreted as occurring during either Jurassic thrusting of these terranes onto the North American Craton Margin, or more likely, during younger hydrothermal activity associated with extensive Late Cretaceous granitic magmatism.

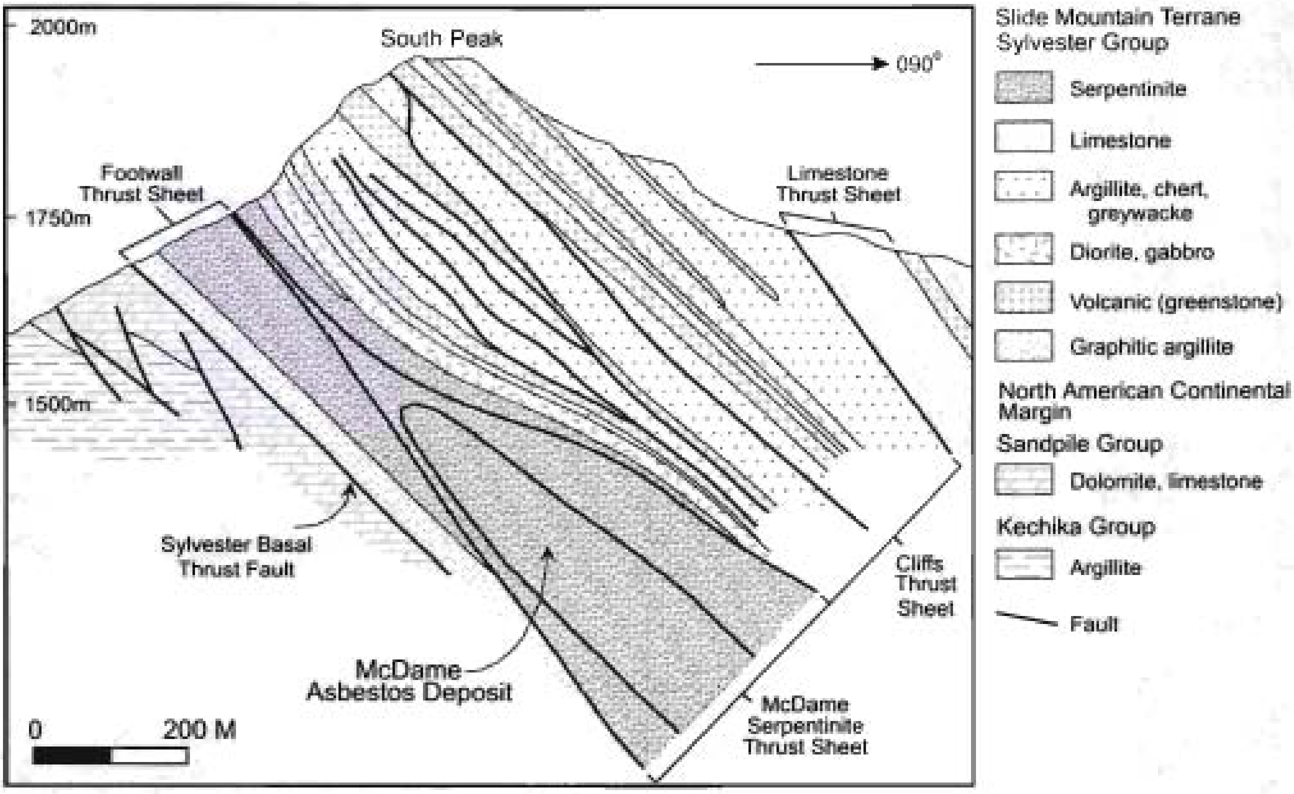


Figure 59. Cassiar (McDame) serpentine-hosted asbestos deposit, Cassiar metallogenic belt, northern British Columbia. Schematic cross section. Adapted from Burgoyne (1986).

Francois Lake Metallogenic Belt of Porphyry Mo Deposits (Belt FL) Central British Columbia

The Francois Lake metallogenic belt (fig. 49; tables 3, 4) (Nokleberg and others, 1997b, 1998) is defined by the distribution of porphyry Mo deposits in felsic plutons of the Francois Lake Suite (Carter, 1982) which intrude the Stikinia, Quesnellia and Cache Creek terranes along the eastern part of the Skeena Arch in central British Columbia. The Middle and Late Jurassic plutons of the Stag Lake (171-163 Ma) and Francois Lake (157-145 Ma) Suites (White and others, 1970; Whalen and others, 1998), with no identified coeval volcanic rocks, may correlate with the Nelson Plutonic Suite (170-155 Ma) in the southeastern part of the Canadian Cordillera. Both suites of intrusive rocks are herein interpreted as emplaced during major accretion and collision of the Stikinia-Quesnellia island arc and associated subduction zone complexes to the west with the North American Craton Margin.

Endako Porphyry Mo Deposit

The Endako quartz monzonite pluton of the Francois Lake Suite hosts the Endako porphyry Mo deposit, the largest Mo deposit in Canada with initial reserves of 280 million tonnes grading 0.08% Mo. The deposit is essentially a stockwork of quartz - molybdenite, pyrite and magnetite veins about 350 m wide, which extends for about 3.3 km along a west-northwesterly axis. The Endako pluton is flanked to the north and south by the younger Casey Alaskite and Francois Granite plutons, respectively. Potassic and phyllic assemblages envelope quartz-molybdenite and other vein assemblages, and the host rocks are pervasively kaolinized (Dawson and Kimura, 1972; Dawson and others, 1991; Bysouth and Wong, 1995). Similar, but smaller, Mo deposits occur at Nithi Mountain, Owl Lake and to the north and northwest of Endako deposit (Dawson, 1972).

Cariboo Metallogenic Belt of Au Quartz Vein Deposits (Belt CB) Southern British Columbia

The Cariboo metallogenic belt of Au quartz vein deposits (fig. 49; tables 3, 4) occurs in eastern-central British Columbia and is hosted by the Early Cambrian Downey Creek Formation of the Barkerville subterrane of Kootenay terrane. The belt consists of metamorphism-related, Au-quartz-sulfide lenses which are emplaced concordantly with limestone of the Baker Member of the Downey Creek Formation and cut by discordant quartz-sulfide-gold veins which occur mainly in the Rainbow Member of the Downey Creek Formation (Robert and Taylor, 1989). The significant deposits in the belt are in the Cariboo-Barkerville district and at Frasergold (table 4) (Nokleberg and others 1997a, b, 1998). The Cariboo-Barkerville district also contains major placer gold deposits (Nokleberg and others, 1997a).

Cariboo-Barkerville District (Cariboo Gold Quartz, Mosquito Creek, Island Mountain) of Au Quartz Vein Deposits

The Cariboo-Barkerville district contains three principal mines (Cariboo Gold Quartz, Mosquito Creek, and Island Mountain Mines) which consists of quartz-sulfide veins and pyritic replacement lenses (Robert and Taylor, 1989; Schroeter and Lane, 1991; MINFILE, 2002). The quartz-sulfide veins occur in phyllite and quartzite of the Rainbow Member, usually within 100 m of the contact with mafic volcanic rocks and limestone of the Baker Member of the Downey Creek Formation. Pyrite-gold lenses, which occur discontinuously in marble bands within the Baker Member, pre-date brittle deformation, are cut by quartz-sulfide-Au veins, and are interpreted as synmetamorphic (Robert and Taylor, 1989; Dawson and others, 1991). From 1933-1987, the three principal mines produced 38 tonnes of Au from 2.7 million tonnes of ore grading 13.94 g/t Au and 1.87 g/t Ag. Recent exploration of the Mountain and Bonanza Ledge deposits indicates a probable reserve of 3,109,800 tonnes grading 2.95 g/t Au (International Wayside Gold Mines 2003 Annual Report). The associated Wells-Barkerville placer Au district also produced 64.8 tonnes of Au between 1850 and 1990. The deposit age is interpreted as Middle Jurassic through Early Cretaceous.

Frasergold Au-Quartz Vein Deposit

The Frasergold Au quartz vein deposit consists of pyrrhotite, pyrite and coarse-grained gold, and minor galena, sphalerite, and chalcopyrite which occur in deformed quartz-carbonate veins and stockwork stratabound in at least three stratigraphic horizons in porphyroblastic phyllite (Eureka Resources Inc., annual report,1990; Mining Review, 1992; MINFILE, 2002). Estimated resources are 12.7 million tonnes grading 1.87 g/t Au. The prospect occurs 25 km south of Quesnel Lake in eastern British Columbia and consists of a 8-km-long zone of deformed, stratabound quartz-carbonate-pyrite-Au veins which are hosted in Late Triassic phyllite of the Quesnellia island-arc terrane near the suture with the adjacent Kootenay terrane (Dawson and others, 1991).

Origin of and Tectonic Controls for Cariboo Metallogenic Belt

The Cariboo metallogenic belt occurs near the margin of the Kootenay terrane near the suture (major fault) with the Quesnellia island-arc terrane (fig. 49, tables 3, 4). The deposits in the Cariboo-Barkerville district are interpreted as forming during chlorite- to sillimanite-grade regional metamorphism mainly in the Middle Jurassic to Early Cretaceous (Andrew and others, 1983). This event is related to the successive overthrusting of Kootenay terrane by Cassiar, Slide Mountain, and Quesnellia terranes during a major accretionary event (Struik, 1986). Similarly, the Frasergold Au quartz vein prospect is interpreted as forming early in the metamorphism of the area as metamorphic segregations related to the accretion of the Quesnellia island-arc terrane (Bloodgood, 1987).

The deposits in the Cariboo metallogenic belt are interpreted as forming during accretion of the Quesnellia and adjacent terranes to the North American Continental Margin because of: (1) the occurrence of the deposits near a major fault; (2) the metamorphic textures and structures of the deposits; and (3) an age of formation which approximates the interpreted age of accretion of the Quesnellia and adjacent terranes, which constitute the Intermontane Superterrane (Monger and others, 1972, 1992), to the North American Continental Margin. A Middle to Late Jurassic period of regional metamorphism and associated deformation is interpreted as the age of accretion of the Quesnellia and Stikinia island-arc terranes, and associated terranes, to the North American Craton Margin, after oroclinal warping of the Stikinia-Quesnellia island-arc terranes and tectonically-linked Cache Creek and Slide Mountain subduction-zone terranes (Monger and others, 1972, 1992; Mihalynuk and others; 1994; Monger and Nokleberg, 1996; Nokleberg and others, 2000). Before accretion, the Quesnellia island arc may have formed on the Kootenay terrane, a rifted and deformed fragment of the North American Craton Margin, and the coeval Stikinia island arc may have formed on the Yukon-Tanana terrane, another rifted and deformed fragment of the North American Craton Margin (Monger and Nokleberg, 1996; Nokleberg and others, 2000).

Rossland Metallogenic Belt of
Au-Ag Polymetallic Vein Deposits
Belt RL) Southern British Columbia

The Rossland metallogenic belt of Au-Ag polymetallic vein deposits (fig. 49; tables 3, 4) occurs in southern British Columbia is hosted in or near granitoid plutons of the Middle Jurassic Nelson Plutonic Suite. This granitic suite represents the oldest continental-margin arc in the Canadian Cordillera. The plutons and vein deposits intrude the Quesnellia, Kootenay, and Cassiar terranes, and the North American Craton Margin (Hoy and Dunne, 1992; Høy and Andrew, 1988). The significant deposits in the belt are at Rossland Camp (Le Roi, War Eagle), Sheep Creek (Kootenay Belle), and Ymir-Erie Creek (Yankee Girl; table 4) (Nokleberg and others 1997a, b, 1998).

Rossland Au-Ag Polymetallic Vein Camp

The Rossland Au-Ag polymetallic vein camp (fig. 60) occurs in three areas, the North belt, Main veins, and South belt. Most production (>80%) has been from the Le Roi, Center Star, Nickel Plate, War Eagle, and Josie mines which occur in the Main vein system (Dawson and others, 1991; Schroeter and Lane, 1991; Hoy and Dunne, 1992; MINFILE, 2002). The Main vein deposits consist of pyrrhotite and chalcopyrite in a gangue of quartz and calcite with an average ore grade of 1% Cu. The pyrrhotite-chalcopyrite veins are located along the margins of the intrusions, are disseminated and associated with K and Si skarn alteration at deep levels, grade to massive veins with minor gangue and alteration envelopes at higher levels, and in uppermost levels, brittle fracture-controlled veins with Pb-Zn-Ag and quartz-carbonate gangue predominate. The veins in the Main vein system form an en-echelon set which occurs between two large north-trending lamprophyre dikes. The veins dip steeply north and strike 070°. A structural control is inferred by growth faults which were active during deposition of Rossland Group. Total production from Rossland Camp between 1894 and 1941 was 7.62 million tonnes of ore grading 15.2 g/t Au, 19 g/t Ag, resulting in extraction of 84 tonnes of Au and 105 tonnes of Ag. The timing of vein emplacement with respect to the plutons in the district is not known precisely (Files, 1984; Hoy and others, 1998).

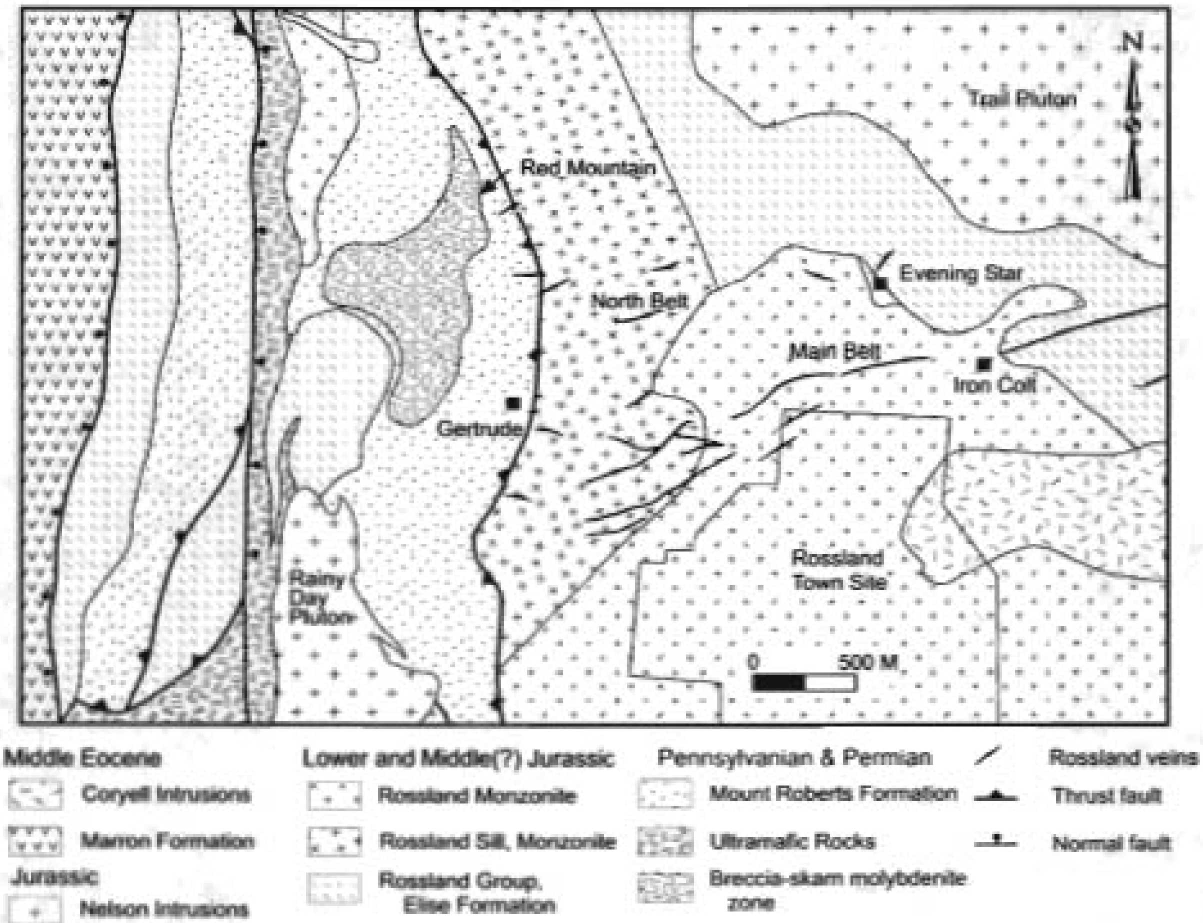


Figure 60. Rossland Au-Ag polymetallic vein and related deposits, Rossland metallogenic belt, Canadian Cordillera. Schematic geologic map. Adapted from Hoy and Andrew (1988).

Sheep Creek Au-Ag Polymetallic Vein District

The deposits in the Sheep Creek Au-Ag polymetallic vein district (Kootenay Belle and others) consist of an assemblage of pyrite, sphalerite, galena, and chalcopyrite which occurs in quartz veins within quartzite, argillite, and argillaceous quartzite of the Nevada and Nugget members of the Early Cambrian Quartzite Range Formation of the North American Craton Margin (Panteleyev, 1991; Schroeter and Lane, 1991). Estimated combined production and reserves are 1.8 million tonnes grading 15 g/t Au and 6 g/t Ag. The veins are controlled by northeast-trending faults which are particularly productive where they cross the axes of two north-trending anticlines. The deposits are interpreted as related to local dikes of the Middle Jurassic Nelson Plutonic Suite.

Ymir-Erie Creek Au-Ag Polymetallic Vein Deposit

The Ymir-Erie Creek (Yankee Girl) Au-Ag polymetallic vein deposits which consist of pyrite, galena, sphalerite and native gold, in a gangue of quartz, calcite and siderite which occur along northeast-trending shear zones in folded metasedimentary rocks of the Late Triassic Ymir and Early Jurassic Rossland groups (Schroeter and Lane, 1991). The veins occur near contacts of metasedimentary rocks intruded by granitoid dikes of the Middle Jurassic Nelson Plutonic Suite to which the deposits may be related (Hoy and Andrew, 1988; Hoy and others, 1998).

Origin of and Tectonic Controls for Rossland Metallogenic Belt

The Rossland metallogenic belt occurs in the southern Canadian Cordillera, and, on the basis of spatial, structural, and age data, is interpreted as forming during intrusion of dikes and plutons of the Middle and Late Jurassic Nelson Plutonic Suite (Parrish and others, 1988; Woodsworth and others, 1991). The Nelson plutonic suite consists chiefly of granodiorite, quartz monzonite, and local monzonite plutons which yield isotopic ages mainly of 155 to 170 Ma with local crustal inheritance. On the basis of structural and temporal relations, the Nelson Plutonic Suite is interpreted as forming immediately after a period of regional thrusting associated with accretion and obduction of the Stikinia, Quesnellia, Cache Creek, and Slide Mountain terranes, and obduction of the latter two terranes over the Yukon-Tanana, Kootenay, and Cassiar terranes, and over the North American Craton Margin (Monger and Nokleberg, 1996; Nokleberg and others, 2000). This major compressional orogenic event included regional metamorphism, deformation, crustal-thickening, anatectic magmatism, and uplift in the core of the Canadian Cordillera. By the Late Jurassic (about 155 Ma), detritus from this emergent orogenic welt in the eastern Canadian Cordillera was shed eastwards onto the North American Craton Margin (Cant, 1989).

Early Cretaceous Metallogenic Belts (144 to 120 Ma; Figures 61, 62)

Overview

The major Early Cretaceous metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 61 and 62. The major belts are as follows. (1) In the southern part of the Russian Far East is the Samarka metallogenic belt (SA) which contains W skarn and porphyry Cu-Mo deposits. This belt is interpreted as forming during anatectic granitic plutonism occurring during subduction of Kula oceanic ridge along the transform continental margin of the Russian Southeast. (2) In the same region are Algama (AL) belt which contains stratiform Zr deposits, and the Kondyor (KO) belt which contains zoned mafic-ultramafic Cr-PGE deposits. The latter belt is hosted in zoned mafic-ultramafic plutons intruding Stanovoy block of the North Asian Craton, and the former belt is interpreted as related alkali igneous rock associated with the zoned mafic-ultramafic plutons that intrude the Stanovoy block. These two belts are interpreted as forming during plutonic intrusion related to continental-margin transform faults. (3) In the central part of the Russian Far East are the Selemdzha-Kerbi (SK) and Stanovoy (ST) belts, which contain Au-quartz vein and anatectic granitic-magmatism-related deposits and are hosted in veins and plutons which intruded various terranes and the Stanovoy block of the North Asian Craton. The belts are interpreted as forming during collision of the Bureya and Khanka continental-margin arc superterranes with the North Asian Craton and closure of the Mongol-Okhotsk Ocean. (4) In the Russian Northeast are the Allakh-Yun (AY), Darpir (DP), Kular (KU), Shamanikha (SH), Tompon (TO), Verkhoyansk (VK), Yana-Kolyma (YA), and Yana-Polousnen (YP) belts which contain a large suite of Au quartz vein, and granitic-magmatism-related deposits. These belts are hosted in the Verkhoyansk granite belt which intrudes the Kolyma-Omolon superterrane and the North Asian Craton Margin and are interpreted as forming during regional metamorphism and anatectic granitic plutonism associated with accretion of Kolyma-Omolon superterrane onto the North Asian Craton Margin. (5) In the Russian Northeast, continuing on from the Late Jurassic, were: (a) the Oloy (OL) belt, which contains granitic-magmatism-related deposits and is hosted in the Oloy island arc; (b) the Tamvatney-Mainits (TAM) belt, which contains podiform Cr deposits and is hosted in zoned mafic-ultramafic plutons; and (c) the Mainits (MA) belt which contains kuroko massive sulfide deposits. In the Canadian Cordillera, also continuing on from the Late Jurassic, was the Cariboo (CB) belt of Au quartz vein deposits. (6) Also in the Russian Northeast was the Left Omolon (LO) belt, which contains porphyry Mo-Cu,

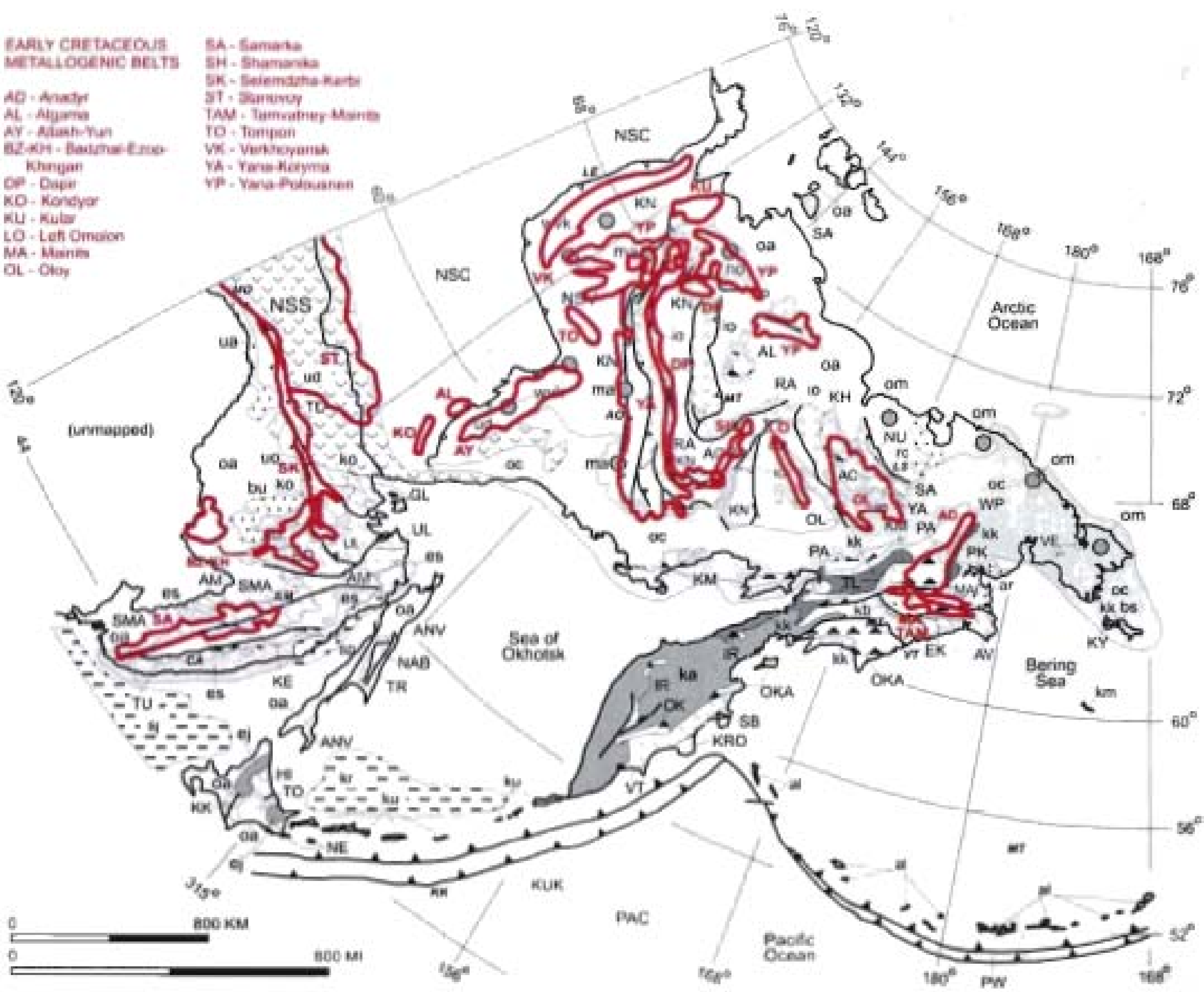
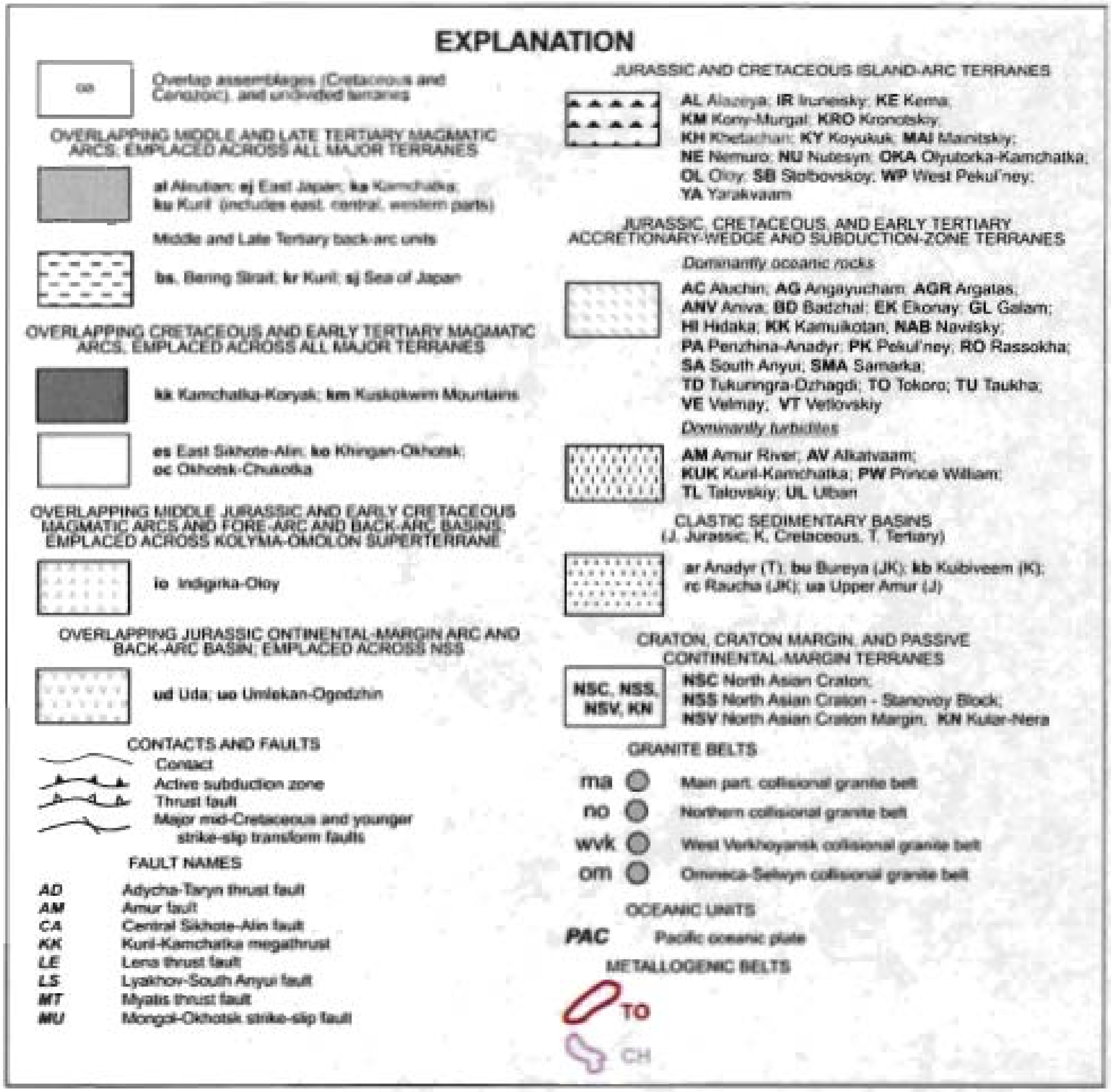


Figure 61. Generalized map of major Early Cretaceous metallogenic belts, overlap assemblages, and tectonically-linked subduction-zone or accretionary-wedge assemblages for Russian Far East, northern Japan, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998).

Mo-Cu skarn deposits and is hosted in the the Oloy arc island arc. (7) In Southeastern Alaska and the southern Canadian Cordillera are two metallogenic belts that formed during granitic plutonism that formed the Gravina island arc on the Wrangellia superterrane. These belts are the: (a) the Western-Southeastern Alaska (WSE) belt, which contains granitic-magmatism-related deposits; and (b) the Britannia belt that contains Kuroko massive sulfide deposits. In the below descriptions of metallogenic belts, a few of the noteable or signficant lode deposits (table 4) are described for each belt.

Metallogenic-Tectonic Model for Early Cretaceous (144 to 120 Ma; Figure 63)

During the Early Cretaceous (Neocomian - 144 to 120 Ma), the major metallogenic-tectonic events were (fig. 63; table 3): (1) completion of accretion of the Bureya superterrane against the North Asian Craton along the Mongol-Okhotsk suture and formation of associated metallogenic belts; (2) continuation of the continental margin and island arcs, and formation of associated metallogenic belts and companion subduction zone assemblages around the Circum-North Pacific; (3) accretion of the major Kolyma-Omolon superterrane and formation of associated metallogenic belts in the Russian Northeast; (4) initiation of subduction of the North American Continental Margin under the Angayucham subduction-zone terrane; (5) continuation of opening of the Amerasia, Canada, and Eurasia Basins in response to sea-floor spreading in the Arctic Ocean; (6) the beginning of accretion of the



Wrangellia superterrane in the Southern Canadian Cordillera; and (7) around the Circum-North Pacific, continued sinstral transpression between oceanic plates and continents.

Specific Events for Early Cretaceous

(1) Far to the south at about 32° paleolatitude, the Mainitskiy island arc (Mainitskiy terrane, MAI) commenced activity. Forming in the arc were the Tamvatney-Mainits (TAM) belt, which contains podiform Cr deposits, is hosted in zoned mafic-ultramafic plutons, and the Mainits (MA) belt, which contains kuroko massive sulfide deposits. Tectonically linked to the arc was the Alkatvaam accretionary-wedge terrane (AV) which formed from subduction of part of the adjacent oceanic plate. This arc and companion subduction zone migrated northward toward the Kony-Murgal island arc.

(2) The Umlekan arc (Umlekan-Ogodzhin volcanic-plutonic belt (uo) and associated units) continued activity. Associated with this belt was subduction of part of the Ancestral Pacific Ocean plate to form the Amur (AM) and Badzhal (BD) terranes.

(3) In the same region, the accretion of the Bureya (BU) superterrane against the Ulban accretionary-wedge terrane (UL) was completed along the Mongol-Okhotsk suture (*MO*), thereby closing the Mongol-Okhotsk Ocean. Forming during accretion was the Stanovoy (ST) metallogenic belt which contains anatectic, granitic-magmatism-related deposits, and the Selemdzha-Kerbi

(SK) metallogenic belt which contains Au-quartz vein deposits. In the same region is the Kondyor (KO) metallogenic belt which contains zoned mafic-ultramafic Cr-PGE deposits and is hosted in zoned mafic-ultramafic intrusions intruding Stanovoy block of

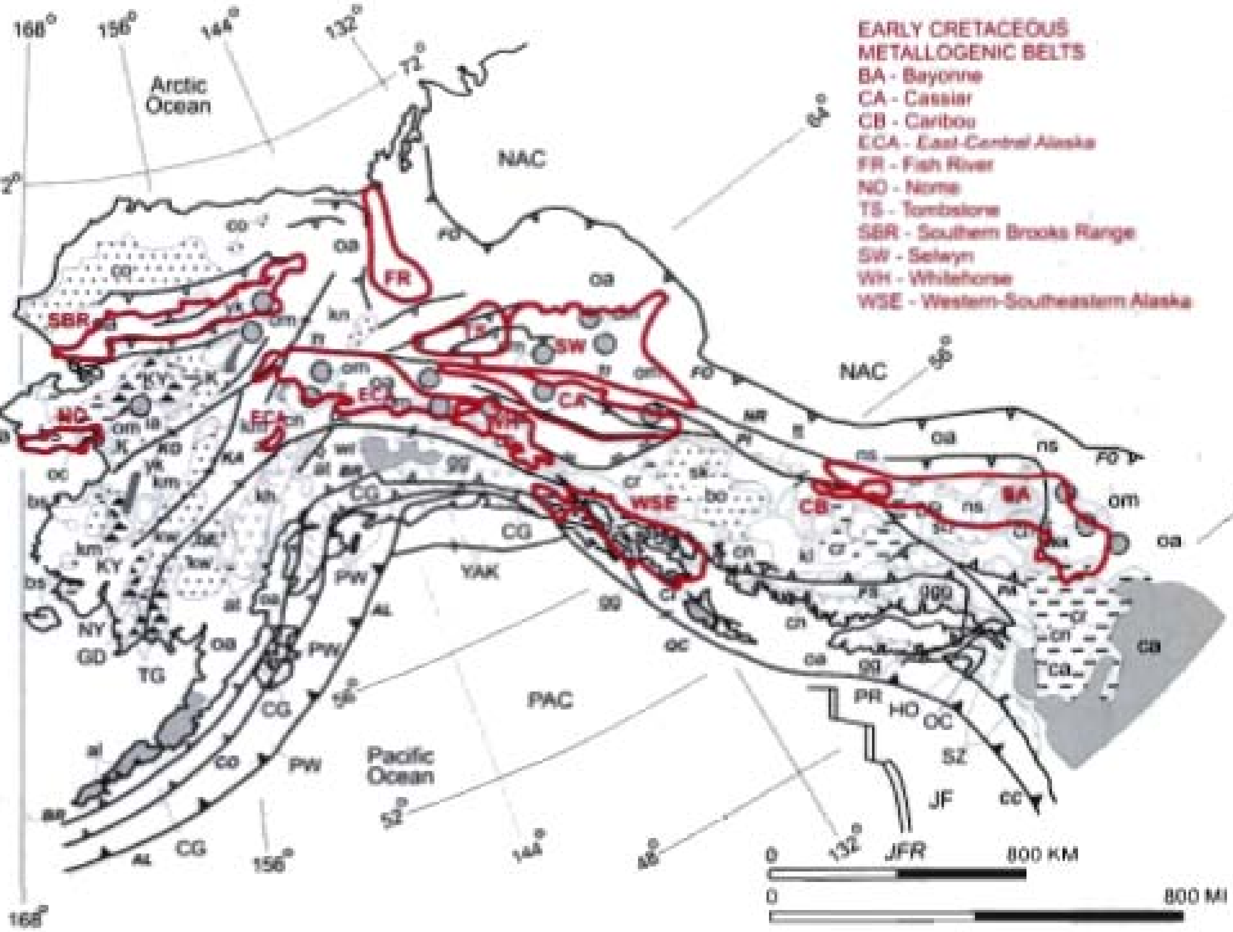


Figure 62. Generalized map of major Early Cretaceous metallogenic belts and overlap assemblages for Alaska, Canadian Cordillera, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998).

the North Asian Craton. Also in the same region is the Algama (AL) metallogenic belt which contains stratiform Zr deposits These two metallogenic belt are interpreted as forming during plutonic intrusion related to continental-margin transform faults when the margin of the North Asian Craton was being deformed during collision and accretion of outboard terranes.

(4) The continental-margin Uda arc (Uda volcanic-plutonic belt, ud, and Uda-Zeya sedimentary basin, uz) continued to form. Associated with the arc was subduction and sinistral transpression of the final remnant of the Mongol-Okhotsk Ocean plate, thereby forming the Ulban (UL) terrane. Sinistral transpression continued along the Mongol-Okhotsk suture (*MO*).

(5) The extensive Kony-Murgal continental-margin and island arc and Pekulney island arc continued to form. Associated with these arcs was subduction of part of the ancestral Pacific Ocean plate to form the Talovskiy (TL), Penzhina-Anadyr (PA), and Pekulney (PK) terranes.

(6) Behind the Kony-Murgal arc, the Kolyma-Omolon superterrane (KLO) was accreted between at about 140 to 100 Ma. During the early stage of accretion, the Main collisional granite belt (ma; 144 to 134 Ma) formed (Layer and others, 1995; Fujita and others, 1997). At about the final stage of accretion, the subduction-related Northern granite belt (no) formed at about 127 to 120 Ma (Fujita and others, 1997). In contrast to the Main granite belt, the coeval Northern granite belt is interpreted as forming in response to subduction related to closure of an inlet of the South Anyui Ocean. As a result, the northern bend of the Kolyma-Omolon structural loop formed (Sengor and Natal'in, 1996a). As a continuation of the structural loop, the extensional Transverse granite belt (tr) formed (Parfenov, 1995c). Associated with accretion of the Kolyma-Omolon superterrane (KLO) and intrusion of anatectic granites were formation of the Allakh-Yun (AY), Darpir (DP), Kular (KU), Shamanikha (SH), Tompon (TO), Verkhoyansk (VK), Yana-Kolyma (YA), and Yana-Polousnen (YP) metallogenic belts which contain a large suite of Au quartz vein and granitic-magmatism-related deposits.

(7) The Oloy island arc and the opposing Nutesyn and Koyukuk island arcs continued to be active on the opposite sides of the South Anyui and Angayucham Oceans. Forming in the Oloy arc were the Oloy (OL) and Left Omolon (LO) metallogenic

belts, which contains granitic-magmatism-related deposits. Parts of the Oloy, Nutesyn, and Koyukuk island arcs are preserved in the Nutesyn (NU), Koyukuk (KY), Togiak (TG), and Nyac (NY) terranes. Associated with these arcs was subduction of parts of the South Anyui and Angayucham Ocean plate, thereby forming the South Anyui (SA), Velmay (VE), and (inner) Angayucham (AG) terranes, and subduction of the outboard margin of the Arctic Alaska terrane. An extensive zone of blueschist facies metamorphism occurs in this region in both the Angayucham and Arctic Alaska terranes. After initial accretion of the Koyukuk arc with the Arctic

Alaska superterrane, beginning in the Late Jurassic at about 160 to 145 Ma (Moore and others, 1994a, b), subduction flipped to outboard of the new continental margin of this part of Alaska.

(8) At about 140 to 135 Ma, sea-floor spreading and associated rifting, which started with the formation of grabens in the Late Jurassic or earlier (Lawver and Scotese, 1990; Grantz and others, 1990, 1991, 1998) formed: (1) new oceanic crust and the large proto-Amerasia (ab) and proto-Canada (cb) basins; and (2) a collage of passive continental-margin terranes derived from the North American Craton Margin (Artis Plateau (AP), Chukchi Cap (CK), Chukchi Spur (CS), and Northwind Ridge (NR) terranes). Sea-floor spreading and opening of the Amerasia and Canada Basins is herein interpreted as causing: (1) closure of the inner Angayucham Ocean; (2) subduction of the North American continental margin (Chukotka terrane, CH, and the Arctic Alaska superterrane, AA); (3) beginning of closure of the South Anyui Ocean; (4) intense deformation and metamorphism of the southern margin of the eastern Chukotka terrane (CH) and southern Arctic Alaska superterrane (AA) to form the Seward (SD), Coldfoot (CO), and Ruby (RB) terranes; (5) formation of an extensive blueschist facies belt in both the subducted continental margin (Arctic Alaska superterrane (AA), and Seward (SD), Coldfoot (CO), and Ruby (RB) terranes) and in the overthrust Angayucham terrane (AG); and (6) deposition of synorogenic Early to mid-Cretaceous flysch in the Koyukuk basin in what became western

Alaska. For additional information the opening of the Canada Basin, whether by rifting and rotation, or by strike-slip translation, or by a combination of the two processes, please refer to the analyses by Grantz and others (1990, 1998) or Lane (1994, 1997).

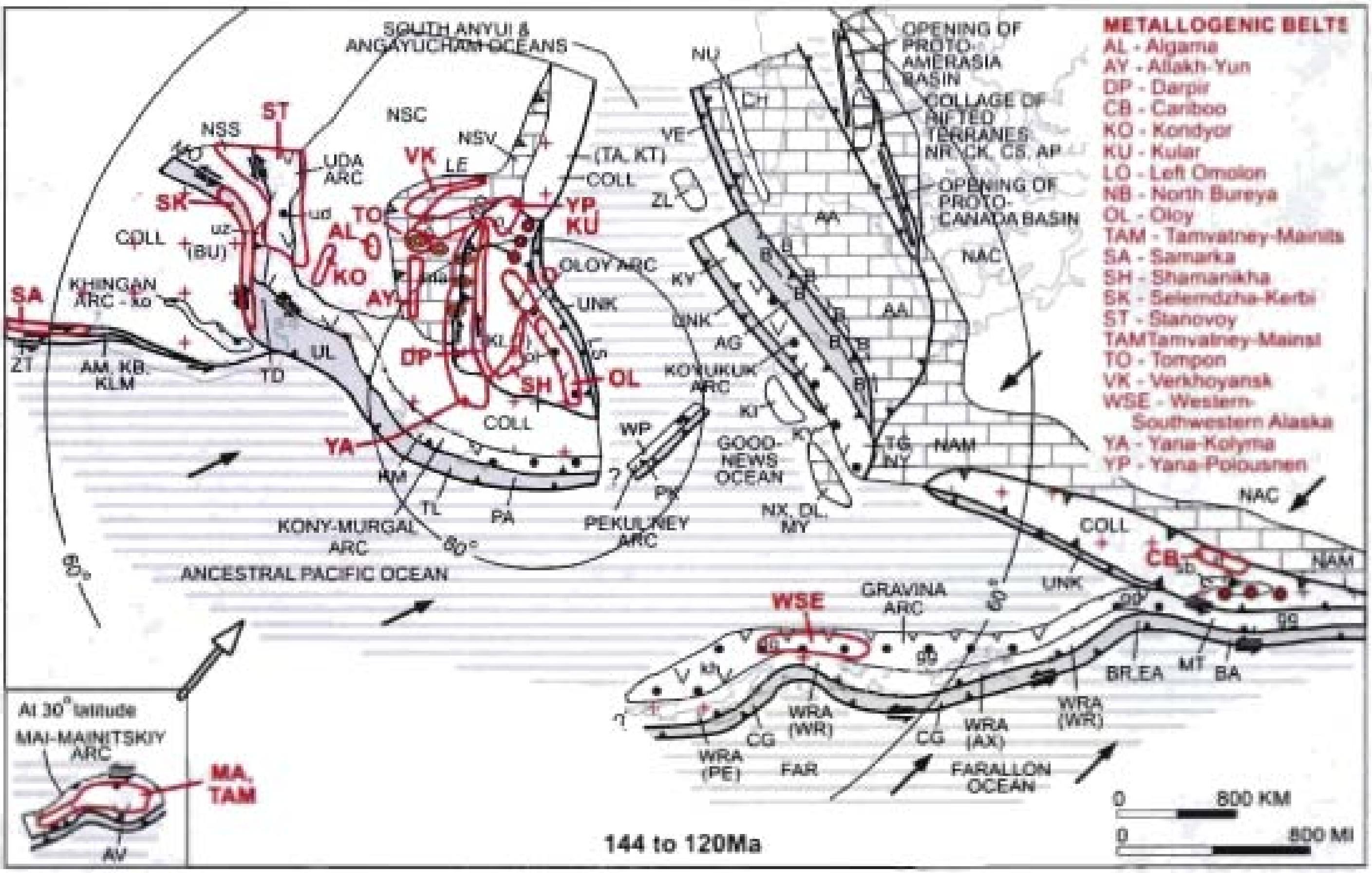


Figure 63. Early Cretaceous (Neocomian - 144 to 120 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

(9) Underthrusting in a subduction zone along the North American Craton Margin (NAM) resulted in consumption of the Farallon Ocean plate (FAR). Small tectonic lenses of terranes of alpine ultramafic and related rocks, which occur along the ancestral Denali fault (fig. 63) (Nokleberg and others, 1985, 1994a), may be remnants of the subduction-zone assemblages which may have been mostly thrust under the margin of what is now North America.

(10) The Gravina arc continued to form. Associated with the Gravina arc was subduction of part of the Farallon Ocean plate to form the Chugach (CG), Bridge River (BR), Easton (EA), and Baker (BA) terranes. The arc is preserved in the Kahiltna (kh) and Gravina-Nutzotin-Gambier (gg) assemblages which occur only on the Wrangellia superterrane. Forming in the Gravina arc was the Western-Southeastern Alaska (WSE) metallogenic belt which contains granitic-magmatism-related deposits.

(11) The Wrangellia superterrane (WRA) started to accrete at about 60° paleolatitude. The continentward part of the Wrangellia superterrane impinging onto a collage of terranes previously accreted to the North American Craton Margin (NAM). During accretion, the arc was extended to the south during the formation of two major overlap assemblages, the coeval Tahtsa-Three Sisters magmatic assemblage (tt) and the Spences Bridge volcanic-plutonic belt (sb).

Metallogenic Belts Formed Along Late Mesozoic Continental-Margin Transform Faults in Russian Southeast

Samarka Metallogenic Belt of W Skarn, and Porphyry Cu-Mo Deposits (Belt SA) West-Central Part of Russian Southeast

The Samarka metallogenic belt of W and Sn skarn and porphyry Cu-Mo deposits (fig. 61; tables 3, 4) occurs in aluminous, mainly S-type granitoid rocks of Early to mid-Cretaceous age which intrude the Samarka accretionary-wedge terrane in the west-central part of the Russian Southeast. The belt contains major W skarn deposits at Benevskoe and Vostok-2, small porphyry Cu-Mo deposits at Khvoshchovoe, Kafen, and Malakhitovoe, and a porphyry Mo deposit at Skalistoe (table 4) (Nokleberg and others 1997a, b, 1998). The deposits are hosted in Early to mid-Cretaceous granodiorite porphyry, granite, and gabbro-diorite. The southern-most part of the Samarka metallogenic belt occurs in a displaced fragment of the Samarka terrane which is displaced along a left-lateral, north-east-trending strike-slip fault (fig. 61). The small W skarn deposit at Benevskoe occurs in this displaced fragment. Also possibly part of the same Samarka metallogenic belt is a younger, Paleocene porphyry Cu-Mo deposit at Skalistoe (fig. 61). This deposit consists of veinlet molybdenum ore and wolframite which occur in a subvolcanic granite porphyry. Alternatively, the Skalistoe deposit may be part of post-accretionary Luzhkinsky metallogenic belt described below.

Vostok-2 W Skarn Deposit

The major productive Vostok-2 deposit (fig. 64) (Stepanov, 1977; Rostovsky and others, 1987) consists of vein and sheet skarn which formed in several stages. An older stage consists dominantly of pyroxene, plagioclase, amphibole, and garnet. A subsequent stage consists of greisen alteration of skarn and granitoid rocks with formation of quartz, feldspar, and muscovite, along with minor chlorite and biotite which contains scheelite and apatite, and minor arsenopyrite, pyrrhotite, and chalcopyrite. A late stage consists of scheelite and quartz with followed by crystallization of low temperature scheelite and arsenopyrite. The deposit occurs along the flat to steeply-dipping contacts of granitoid plutons which intrude olistostromes of large, Carboniferous-Permian limestone and calcareous-shale. Successive skarn and greisen alternation of limestone preceded the deposition of scheelite and other minerals, including gold and apatite, locally up to a few tens of percent. Plagiogranite with an approximate K-Ar age of 110 ma is interpreted as forming with the deposit. The deposit is large with average grades of 0.65% W_2O_3 and 1.64% Cu. The deposit has been mined since the 1980's.

The olistostromes which host the Samarka belt of Sn and W skarn deposits are derived from the caps of guyots which are enclosed in a matrix host of highly-deformed Jurassic sedimentary rocks in the accretionary wedge complex of the Samarka terrane. The skarns are hosted in limestone layers and occur along the contacts of calcareous and alumosilicate clastic rock.

Benevskoe W Skarn Deposit

The small Benevskoe W skarn deposit (V.D. Shlemchenko and others, written commun., 1983) occurs along the margin of an Early Cretaceous biotite, peraluminous granite which intrudes olistoliths of Permian sedimentary shales and interbedded with limestone. The skarn occurs in altered limestone. Various mineral assemblages are magnetite, garnet, pyroxene-garnet, garnet-epidote, and garnet-orthoclase. Late-stage quartz-feldspar and quartz-amphibole overgrowths which replace the skarns and locally contain disseminated scheelite. Late-stage quartz-sericite and zeolite alterations also occur. The major ore minerals are scheelite with minor magnetite, arsenopyrite, pyrite, and rare cassiterite. Gangue minerals are quartz, feldspar, amphibole, epidote, biotite, and tourmaline. Easily-concentrated apatite also exists. The deposit is small with average grades of 0.44 to 3.15% W_2O_3. As to the north, small porphyry Cu-Mo occurrences also occur in this part of the metallogenic belt.

Origin of and Tectonic Controls for Samarka Metallogenic Belt

The W skarn deposits of the Samarka metallogenic belt occur near mainly Early Cretaceous, S-type granitoid rocks which intrude the Samarka accretionary-wedge terrane. The host granitoid rocks and associated deposits are herein interpreted as forming in underthrusting of the Kula oceanic ridge and resultant genesis of bimodal igneous activity along the transform continental margin of the Russian Southeast (A.I. Khanchuk, written commun., 1997; Khanchuk and others, 1998). K-Ar isotopic studies indicate intrusive ages of 110 to 115 Ma for the granitoid rocks hosting the deposits (Rostovsky, 1987; Stepanov, 1977).

Algama Metallogenic Belt of Stratiform Zr Deposits (Belt AL) Northern Part of Russian Southeast

The Algama metallogenic belt of stratiform Zr deposits (fig. 61; tables 2, 3) occurs to the north of the Kondyor massif at Algama in the southeastern part of the Stanovoy block of the North Asian Craton (unit NSS; Nokleberg and others, 1997b, 1998). in the western part of the Khabarovsk province of the Russian Southeast. The deposits are hosted in Vendian carbonate rock. The belt contains many small occurrences and a significant deposit at Algaminskoe which has been drilled and explored by underground workings (Nekrasov and Korzhinsky, 1991). The Algaminskoe deposit consists of hydrozircon and baddeleyite which occurs with a colloform texture. The ore occurs in long lenses, conformable to a layer of cavernous dolomite marble which ranges up to about 40 m thick, and in zones which crosscut metamorphosed Vendian metasedimentary rocks. The baddeleyite deposits are interpreted as forming during hypogene and supergene alteration which was associated with karst formation. The U-Pb zircon isotopic age of baddeleyite is approximately 100 Ma (J.N. Aleinikoff, written commun., 1992). The origin of the stratiform Zr deposits is interpreted as related to alkalic igneous rocks, possibly including carbonatite, which were associated with the late stage intrusion of the zoned mafic-ultramafic rocks, possibly part of the same belt of Late Jurassic to mid-Cretaceous intrusives at Kondyor. With this interpretation, the Algama belt formed during intrusion of alkali igneous rock associated with mafic-ultramafic plutons that intruded along major continental-margin transform faults during subduction of terranes along Mongol-Okhotsk fault system.

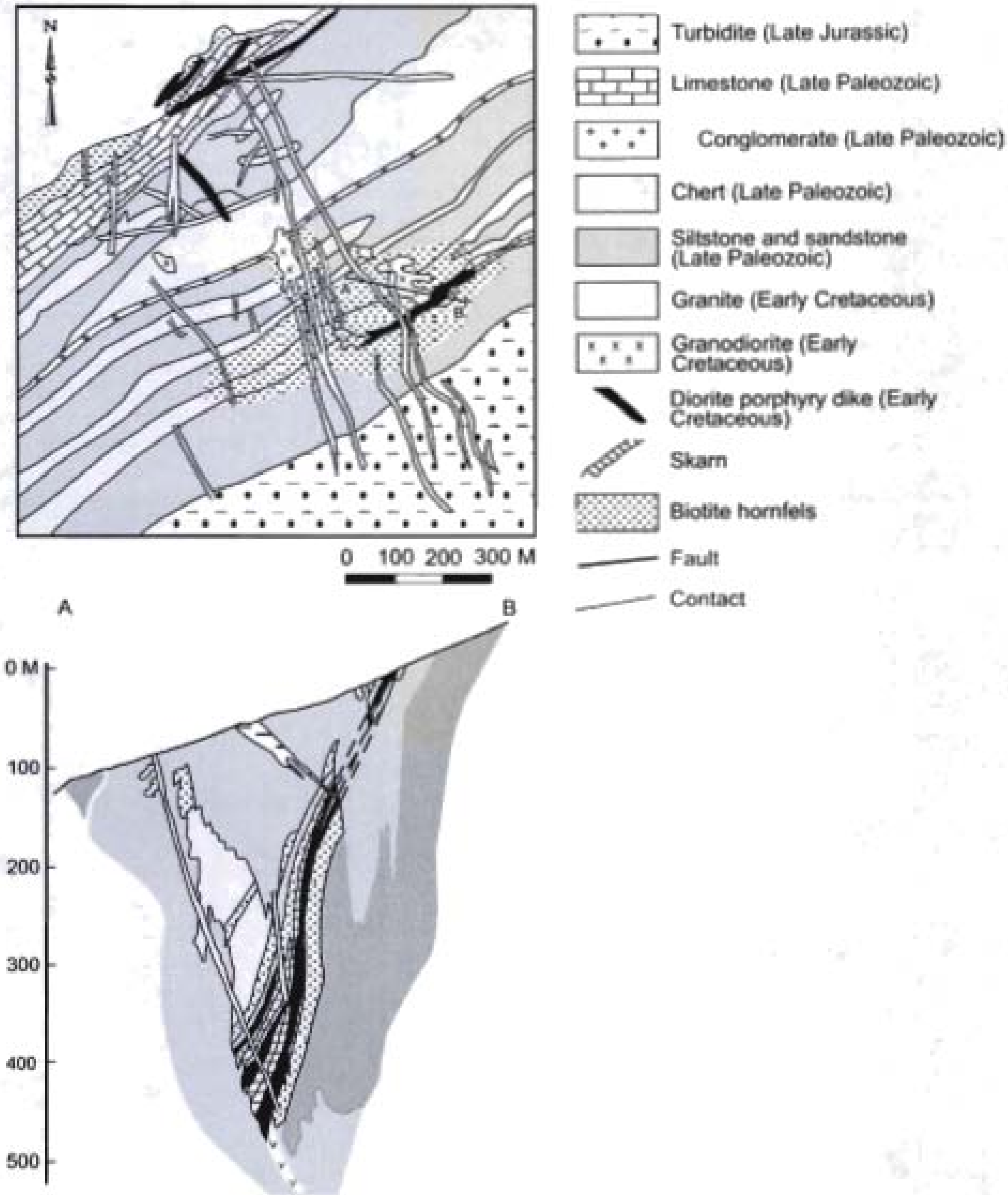


Figure 64. Vostok-2 W skarn deposit, Luzhkinsky metallogenic belt, Russian Southeast. Schematic geologic map and cross section. Adapted from Stepanov (1977).

Kondyor Metallogenic Belt of Zoned Mafic-Ultramafic Cr-PGE Deposits (Belt KO) Northern Part of Russian Southeast

The Kondyor metallogenic belt of zoned mafic-ultramafic PGE-Cr deposits (fig 61; tables 3, 4) occurs in several zoned intrusions (Kondyor, Chad, Ingagli, Sy-Bakn, Usmun-Dara, Arbarastakh) which in a linear direction across Khabarovsk territory for about 850 km (Zalishchak and others, 1993). The deposits are interpreted as occurring along a northwest-trending, deep-seated, buried fault which cuts the southeastern part of the Stanovoy block of the North Asian Craton (unit NSS). This area is in the northern part of the Khabarovsk province of the Russian Southeast. The belt contains a single large zoned mafic-ultramafic Cr-PGE deposit at Kondyor and Chad (table 4) (Nokleberg and others 1997a, b, 1998). In a generalized plan view, the zoned complexes consist of circular-shaped plutonic bodies of dunite which are successively rimmed by pyroxenite, peridotite, gabbro, ojolite, and nepheline syenite (Marakushev and others, 1990).

Kondyor Zoned Mafic-Ultramafic Cr-PGE Deposit

The productive Kondyor (fig. 65) (Marakushev and others, 1990) and Chad PGE-Cr deposits contain two types of lode deposits: (1) semi-massive to massive lenses of chromite which range from 2 to 50 m thick; and (2) oval-shaped, roughly equa-dimensional metasomatic deposits which range from 200 to 300 m thick. The first type consists of PGE minerals which occur as intergrowths with chromite and olivine; and as small inclusions. Isoferroplatinum is the major PGE mineral. The second type consists of PGE minerals which form intergrowths with magnetite, pyroxene, and rarely with metasomatic phlogopite, chrome diopside, and magnetite. This deposit is cut by veins and dikes of alkalic igneous rocks including nepheline syenite, lujavrite, ijolite, and urtite. In addition to isoferroplatinum and tetraferroplatinum, this type of deposit commonly contain up to 5 to 8% sulfide and arsenide minerals. At Kondyor approximately 13.5 tonnes PGE were produced from 1984-1993 (Bundtzen and Sidorov, 1998). Annual production has averaged about 2.5 to 3.0 tonnes PGE since 1993. In 1999, approximately 2.9 tonnes PGE were produced (Bakulin and others, 1999). Beginning in 1999, PGE production was started at the Chad zoned complex (Bakulin and others, 1999; N.I. Lysyuk and N.P. Romanovsky, written commun., 2000). By-product gold, which is also recovered from the Kondyor deposit, contains up to 10 percent Pd and 40 percent Cu (Zalishchak and others, 1993; V. Molchanov and V. Sapin, written commun., 1993) All production is from placer deposits, not lode deposits. The Kondyor placer deposits have produced 3.1 and 2.2 kg platinum nuggest which rank as some of the world's largest native platinum specimens. In 1998 and 1999, about 75 kg PGE were recovered from chromite lodes during pilot tests studies The Kondyor deposit is one of the most important sources of platinum in the Russian Federation.

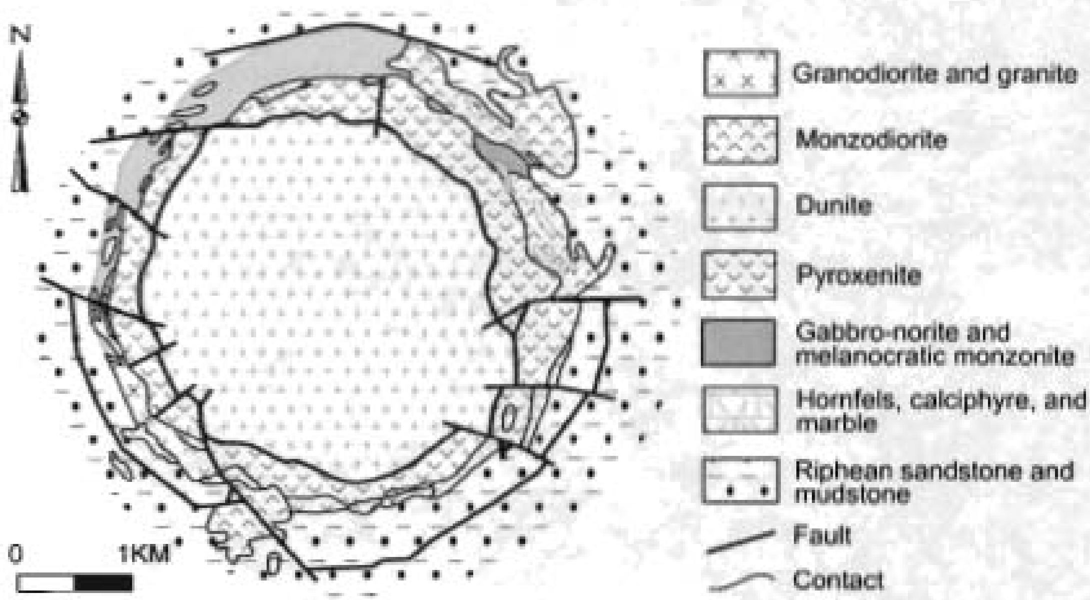


Figure 65. Kondyor zoned mafic-ultramafic PGE-Cr deposit, Kondyor metallogenic belt, Russian Southeast. Adapted from Nekrasov and others (1994).

Origin of and Tectonic Controls for Kondyor Metallogenic Belt

Controversy exists about the age and tectonic environment for the mafic and ultramafic rocks which host the Kondyor and similar deposits. The host rocks were originally interpreted as an integral part to the Late Proterozoic and older cratonal rocks of the Stanovoy block of the North Asian Craton. However, A.I. Khanchuk (written commun., 1994) interprets the mafic and ultramafic rocks as Jurassic, because the intrusions are similar in composition to other Jurassic massifs of the Ariadny igneous belt. However, this belt is herein interpreted as forming in the mid-Cretaceous along with the Algama metallogenic belt, described above. Unpublished K-Ar isotopic ages for the zoned mafic-ultramafic intrusions in the Kondyor metallogenic belt range from 60 to 110 to 160 Ma (A.M. Lennikov, written commun., 1993). An Ar-Ar isotopic age of 127 Ma (Early Cretaceous) was recently obtained for the alkalic mafic and ultramafic igneous rocks at Ingagli (Dalrymple and others, 1995) which may be part of the same igneous belt which hosts the Kondyor metallogenic belt. The interplate intrusions of the Kondyor metallogenic belt are herein interpreted as having been emplaced along a deep-seated, continental-margin transform fault during the Early Cretaceous, when the margin of the North Asian Craton was being deformed during collision and accretion of outboard terranes.

Metallogenic Belts Formed During Late Mesozoic Closure of Mongol-Okhotsk Ocean in Russian Southeast

Selemdzha-Kerbi Metallogenic Belt of Au Quartz Vein Deposits and Granitoid-Related Au Deposits (Belt SK) Northwestern Part of Russian Southeast

The Selemdzha-Kerbi metallogenic belt of Au quartz vein, granitoid-related Au deposits, and the Talaminskoe clastic-sediment-hosted Sb-Au deposit (fig. 61; tables 3, 4) occurs in the northwestern part of the Russian Southeast. The belt is hosted in the Tukuringra-Dzhagdi subduction-zone terrane and in the Nilan subterrane of the Galam accretionary-wedge terrane (Nokleberg and others, 1994c, 1997c).

The Au quartz vein deposits, as at Afanas'evskoe, Kharga, Ingagli, Malomyr, Sagurskoe, Tokur, and Zazubrinskoe, occur throughout the metallogenic belt, but are mainly in three large and remote areas, the Verkhne-Selemdzha, Sophiisky, and Kerbi mining districts which comprise an area of over 1,000 km^2 (Eirish, 1991; (Nokleberg and others 1997a, b, 1998). The deposits are interpreted as forming during regional metamorphism. In this area, Au was probably derived from black shale which commonly contains disseminated Au in very small quartz veinlets and rarely in small veins (Moiseenko, 1977). In the Kerbi mining district, an exhalative origin for primary gold is interpreted because gold is concentrated near eruptive centers composed mainly of Paleozoic marine basalt. Placer gold mines, common in all three mining districts, have been active for many decades. The Au quartz vein mines at Tokur, the significant deposit in the belt, and at Petrovsko-Eleninsky occur near dike swarms where gold is interpreted as

presumably forming just before dike intrusion. The belt also contains the Poiskovoe granitoid-related Au deposit and the Talaminskoe Sb-Au vein deposit (table 4).

Tokur Au Quartz Vein Deposit

The Tokur Au quartz vein deposit (Radkevich E.A., Moiseenko V.G., Molchanov P.Ya., Melnikov V.D., and Fat'yanov I.I., 1969; Eirish, 1972; Mel'nikov V.D. and Fat'yanov I.I., 1970; Layer, Ivanov, and Bundtzen, 1994) consists of Au-bearing veins. The ore minerals comprise 3% of the veins and consist of pyrite, arsenopyrite, gold, sphalerite, galena, chalcopyrite, pyrrhotite, tetrahedrite, tennantite, and scheelite. Sphalerite and arsenopyrite increase with depth. The gangue minerals are quartz, adularia, sericite, chlorite, and calcite. Gold fineness ranges from 650 to 800. Vein zones normally range from 25 to 90 m thick and carbonaceous material occurs along vein margins. The veins commonly occur conformable to bedding of host rocks and are locally discordant. The veins range up to 800 m in length and vary from 0.2 to 0.7 m thick. The maximum depth of deposit is 500 m. The host rocks are argillite, sandstone, and quartzite, part of a structurally-deformed middle Paleozoic sequence of sandstone and schist. The deposit is medium size; 27.1 tonnes of Au were mined between 1933 and 1940. Ar-Ar isotopic study of vein adularia indicate an age of 114 Ma or Early Cretaceous which is interpreted as the age of mineralization (P.H. Layer, Ivanov, and Bundtzen, 1994). Diorite dikes and stocks cut the veins. The dikes are interpreted as forming during the late stage of accretion with Au having been derived from the host black shale which is also the source for placer gold.

Origin of and Tectonic Controls for Selemdzha-Kerbi Metallogenic Belt

The Selemdzha-Kerbi metallogenic belt is interpreted as forming during Late Jurassic and Early Cretaceous collision of the Bureya and Khanka continental-margin arc superterranes with the North Asian Craton and closure of the Mongol-Okhotsk Ocean (Nokleberg and others, 2000). During this collision, the middle to late Paleozoic passive continental-margin clastic rocks of the craton to the north were thrust onto the Bureya superterrane to the south. The Paleozoic clastic rocks and the lesser oceanic tholeiite, chert, limestone, and black shale of the Tukuringra-Dzhagdi and Galam subduction zone -accretionary-wedge terranes occur in large nappes. During collision and regional thrusting, these rock units underwent greenschist facies regional metamorphism with late-stage formation of Au quartz vein deposits formed. Local higher-grade metamorphism occurred in metamorphic domes.

Stanovoy Metallogenic Belt of Granitoid-Related Au Deposits (Belt ST) Northern Part of the Russian Southeast

The Stanovoy belt of granitoid-related Au deposits (fig. 61; tables 3, 4) occurs in northern part of the Russian Southeast in the Stanovoy block of the North Asian Craton (unit NSS) in the northwestern part of the Russian Southeast. The granitoid-hosted Au deposits generally consist of quartz and quartz-carbonate veins which are spatially associated with Jurassic to Early Cretaceous granite and granodiorite which are generally interpreted as forming in a collisional setting (Parfenov, 1995a, b; Nokleberg and others, 2001). The single, large granitoid-related Au deposit in the belt is at Kirovskoe, a small Au quartz vein deposit is at Zolotaya Gora, and Au-Ag epithermal vein deposits are at Bamskoe and Burindinskoe (table 4) (Nokleberg and others 1997a, b, 1998). Also occurring in the area are numerous placer Au mines, as at Dzhalinda, Yannan, and Ingagli Rivers, which constitute some of the largest placer Au mines in the west-central part of the Russian Far East.

Kirovskoe Granitoid-Related Au Deposit

The Kirovskoe granitoid-related Au deposit (Gurov, 1969; G.P. Kovtonyuk, written commun., 1990) consists northwest-striking Au-quartz-sulfide veins hosted in an Early Cretaceous granodiorite stock. The veins occur mainly along the contacts of diabase porphyry dikes which cut the granodiorite. The contacts of veins are generally sharp, although host rocks are hydrothermally altered. The veins are 0.5 to 1.0 m thick, and the surrounding altered rock range from 5.0 to 9.0 m thick. The altered rocks consist mainly of quartz (40 to 95%), and albite, sericite, and hydromica. The main sulfide minerals are pyrrhotite, arsenopyrite, and chalcopyrite along with common galena, sphalerite, bismuthite, and tennantite-tetrahedrite. Fineness of gold ranges from 844 to 977. The deposit is small, was mined until 1961, and about 10 tonnes Au were produced.

Zolotaya Gora Au Quartz Vein Deposit

The Zolotaya Gora Au quartz vein deposit (Mel'nikov, 1984) consists of quartz veins and zones of hydrothermally altered metamorphic rocks which occur conformably to host rock layering. Alteration is predominantly sericite-quartz and chlorite-amphibole-quartz. The main mineral assemblage is sulfides-biotite-quartz, sulfide-sericite-quartz and biotite-quartz-amphibole-chlorite. Less common are amphibole-quartz-feldspar mineral assemblages. Four successive stages of mineralization are identified: (1) magnetite-chalcopyrite-pyrrhotite-quartz; (2) Au-carbonate-sulfide; (3) zeolite; and (4) supergene. Gold occurs both in early and late quartz, and in hydrothermally-altered rocks. Gold generally forms films and fine plates in fractures, and is concentrated in selvages of quartz and quartz-pyrite veins. Gold fineness is high (985). The deposit is small, has an average grade of grade 52 g/t Au, and was intermittently mined from 1917 to 1948, and about 2.5 tonnes Au were produced. The deposit is hosted in gneissic granite, granulite, calcareous shale, and quartzite of the Stanovoi block of the North Asian Craton.

Burindinskoe Au-Ag Epithermal Vein Deposit

The Burindinskoe Au-Ag epithermal vein deposit (V.A. Taranenko, written commun., 1991; G.P. Kovtonyuk, written commun., 1993) occurs in steeply-dipping quartz and quartz-carbonate gold-bearing veins. The veins range up to 200 m length, with an average thickness of about 10 m, and are hosted in an Early Cretaceous volcanic sequence overlying the Gonzhinsky terrane of the Burea-Khanka superterrane. The deposit is small with an average grade of 9.5 g/t Au, 42.6 g/t Ag. Ore reserves are about 827,400 tonnes with inferred 6,230 kg Au and 38,200 kg silver.

Origin of and Tectonic Controls for Stanovoy Metallogenic Belt

The largest number of granitoid-related Au deposits and related large placer deposits occur in the southern part of the metallogenic belt, near a major fault between Precambrian gneisses of the Stanovoy block to the north with the Paleozoic rocks of the Tukuringra-Dzhagdi subduction-zone terrane to the south (fig. 61). The latter is metamorphosed to greenschist facies. The Paleozoic rocks contain beds of Au-bearing, pyritized graphitic shale (V.I. Sukhov and others, written commun., 1979). Because of these relations, the placer Au mines and the associated granitoid-related Au deposits, mainly Au-bearing veins and veinlets in collisional granitic intrusions and adjacent metamorphic rocks (Gurov, 1978), are herein interpreted as forming during the Late Jurassic and Early Cretaceous(?) accretion of the Bureya superterrane to the south with the North Asian Craton to the north, and closure of the Mongol-Okhotsk ocean (Nokleberg and others, 2000).

Metallogenic Belts Formed During Late Mesozoic Accretion of Kolyma-Omolon Superterrane in Russian Northeast

Kular Metallogenic Belt of Au Quartz Vein, Granitoid-Related Au, and Sn Quartz Vein Deposits (Belt KV) Northern Part of Eastern Siberia

The Kular metallogenic belt of Au quartz vein, granitoid-related Au, and Sn-W quartz vein deposits (fig. 61; tables 3, 4) occurs in the northern part of eastern Siberia. The belt may extend under extensive Cenozoic deposits of the Primorskaya Lowland. The deposits of the Kular belt occur in or near Early Cretaceous collisional (anatectic) granitoid rocks of the Verkhoyansk collisional granite belt (unit vk) which intrude Late Permian and Triassic sandstone and shale of the Verkhoyansk complex within the Kular-Nera terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c). Most of the deposits occur adjacent to, or in granite and adamellite of the informally-named Kular batholith (Ivensen and others, 1975). The significant deposits in the belt are the Burguat and Dzhuotuk Au quartz vein deposits, the Novoe and Solur granitoid-related Au deposits, and the Tirekhtyak district (Nagornoe, Podgornoe, Poputnoe) with Sn quartz vein deposits (table 4) (Nokleberg and others 1997a, b, 1998).

The major Au quartz vein deposits, as at Burguat and Dzhuotuk, typically consist of lenticular veins of quartz and carbonate-quartz with gold and scarce (1-2%) sulfide minerals including pyrite, galena, sphalerite, and chalcopyrite. Minor granitoid-related Au deposits, as at Solur and Novoe, typically consist of quartz and white mica-quartz veins. The veins and mineralized shear zones occur in Late Permian clastic rocks adjacent to an Early Cretaceous granitic intrusion. Also in this area are associated placer Au deposits in the Kular district. Small, non-economic occurrences of Sn and W occur in Sn quartz vein deposits, as at Nagornoe and Poputnoe in the Tirekhtyak district, and are also associated with Early Cretaceous granitoid plutons.

The lode deposits of the Kular metallogenic belt are related mainly to the Early Cretaceous collisional (anatectic) granitoid rocks of the Verkhoyansk collisional granite belt (fig. 61) (Nokleberg and others, 1994c, 1997c). The Verkhoyansk belt, of Late Jurassic and Early Cretaceous age consists chiefly of two major belts, the Main granite belt of Late Jurassic to early Neocomian age, and the Northern granite belt of Neocomian age. The Northern granite belt, which hosts the Kular metallogenic belt, extends for about 600 km along northwestern margin of the Kolyma-Omolon superterrane. The Northern belt consists of inclined sheet-like plutons, up to 200 km long, which are generally conformable with major folds. Major lithologies are tonalite, granodiorite, and, less commonly, two mica leucogranite. These granitoid rocks are interpreted as forming immediately after the Late Jurassic accretion of the Kolyma-Omolon superterrane to the North Asian Craton (Nokleberg and others, 2000).

Allakh-Yun Metallogenic Belt of Au Quartz Vein Deposits, and Associated W-Sn Quartz Vein Deposits (Belt AY) Southern Part of Russian Northeast

The Allakh-Yun metallogenic belt Au of quartz vein deposits, W and Sn quartz vein deposits (fig. 61; tables 3, 4) occurs in the southern part of the Russian Northeast. The deposits are hosted in late Paleozoic to early Mesozoic carbonate and clastic rocks of the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV; Nokleberg and others, 1994c, 1997c; Goryachev, 1998, 2003). The sedimentary rocks are regionally metamorphosed to greenschist facies, locally to staurolite grade along major fault zones (Simanovich, 1978). Regional metamorphism is interpreted as occurring prior to the development of Au quartz vein deposits. Sparse intermediate-composition granitic dikes and major granodiorite plutons, with K-Ar ages of 140-110 Ma, occur in the region (Nenashev, 1979). The Au-quartz vein deposits occur along a linear trend along the western boundary of the belt of granitoid plutons and dikes. The significant deposits in the belt are the Bular, Duet, Malyutka, Nezhdaninka, Novinka, Onello (Lider), Svetly, Voskhod, Yur, and Zaderzhnoe Au quartz vein deposits, the Dies and Muromets Cu-Mo skarn deposits, the Burgali porphyry-Mo (W) deposit, the Levo-Dybin granitoid-related Au deposit, and the It-Yuryak W vein and Sn (W)-quartz vein deposit (table 4) (Nokleberg and others 1997a, b, 1998).

The Au quartz vein deposits consist of three types. (1) Concordant deposits, as at Bular, Yur, and Duet, are interpreted as metamorphic and have K-Ar isotopic ages of 170 to 140 Ma (Nenashev, 1979; Goryachev, 1998, 2003). (2) Crosscutting, postmetamorphic Au-quartz veins and mineralized shear zones, as at Voskhod, Novinka, Zaderzhnoe, and Nezhdanin, are closely related to the early stage granitic dikes and are interpreted as igneous (Ivensen, Levin, 1975; Gamyanin and others, 1985; Goryachev, 1998, 2003). And (3) quartz granitioid-related Au deposits, as at Levo-Dybin, and W-Sn quartz vein deposits, as at Yt-Yuryak, are associated with and interpreted as related to late-stage granitoid rocks. The deposit sizes range from small to large. Related placer Au deposits are widespread in the southern portion of the metallogenic belt.

Nezhdanin Au Quartz Vein Deposit

The major Nezhdanin Au quartz vein (shear zone Au) deposit (fig. 66) (V.I. Korostolev, written commun., 1963; Silichev and Skobelev, 1970; Grinberg and others, 1970; Gamyanin and others, 1985; G.N. Gamyanin and others, written commun., 1990, Goryachev, 1995, 1998, 2003) consists of disseminated gold in: (1) steeply-dipping shear zones up to 40 m thick and 5.4 km long; (2) related tension-gash quartz veins up to 200 m long and 1.2 m thick; and (3) quartz lenses within the shear zones. Vein minerals include quartz, carbonate, arsenopyrite, galena, sphalerite, scheelite, sericite, albite, chalcopyrite, tetrahedrite, lead and copper sulfosalts, stibnite, and gold. Wallrock alteration includes silicification, sulfidization, and sericitization. Quartz-silver-polymetallic ore bodies both cross-cut and post-date the feathered quartz-vein mineralization. The ore bodies are located along a deep fault which cuts the core of a doubly-plunging anticline in Late Carboniferous to Early Permian sandstone and shale. The deposit extends more than 1,000 m vertically. Workings include boreholes and seven levels of adits. The deposit is major with proven reserves of 475 tonnes Au, and an estimated additional resource of more than 500 tonnes Au. The average minimum grade is 5 g/t Au with up to 6,748 g/t Au, and up to 8,300 g/t Ag in veins.

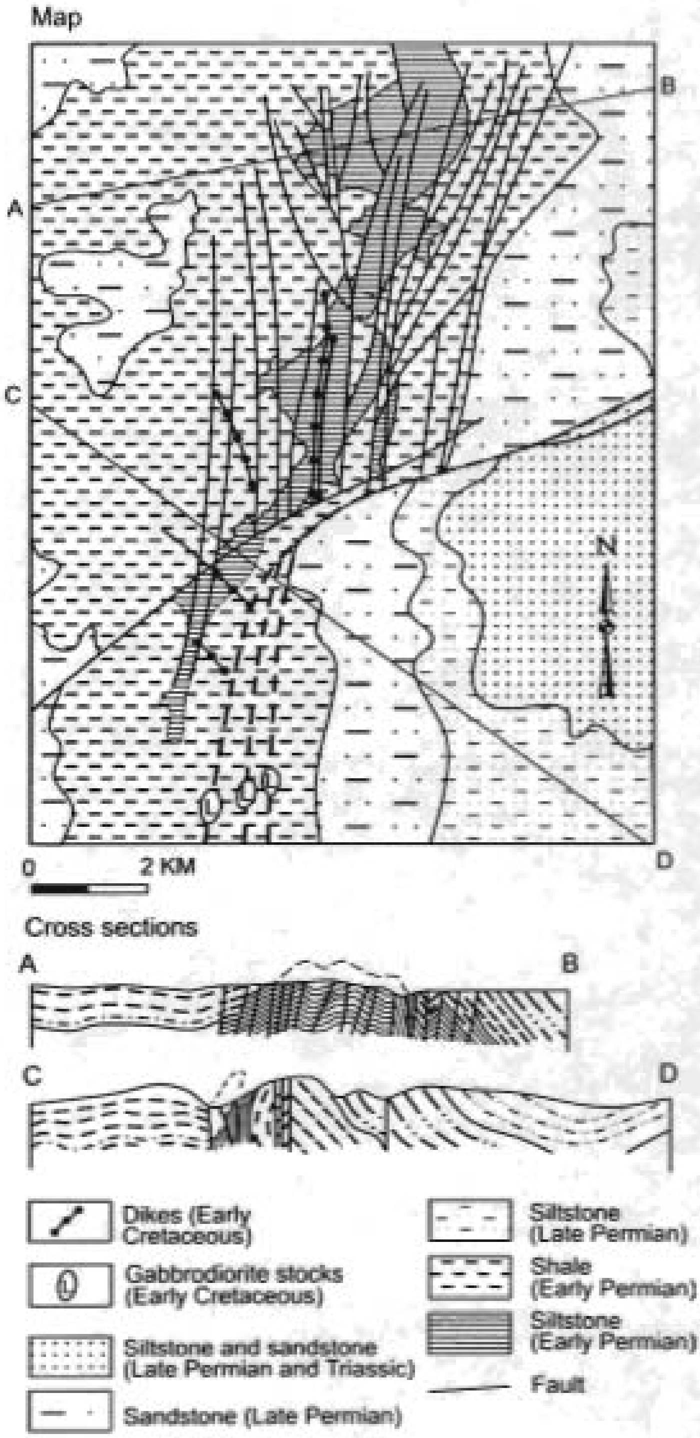


Figure 66. Nezhdaninka Au-Ag-quartz vein deposit, South Verkhoyansk metallogenic belt, Russia, East-Central Yakutia (Verkhoyansk area). Schematic geologic map and cross sections. Adapted from Shour (1985).

Yur Au Quartz Vein Deposit

The small Yur Au quartz vein deposit (Strona, 1960; N.D. Kobtseva, written commun., 1988) consists of four interbedded quartz veins which occur in a zone of meridional faults in middle Carboniferous sandstone-shale. The veins range from 0.3-0.4 m thick and are 100-500 m long. The main ore minerals are gold, arsenopyrite, galena, pyrite, and sphalerite. The ore minerals comprise up to 2% of veins. The gangue minerals are quartz, ankerite, and albite. Wallrock alteration is insignificant, but includes sericite, silica, and arsenopyrite alteration. The deposit is small with an average grade of 3.5-5.7 g/t Au.

Levo-Dybin Granitioid-Related Au Deposit

The Levo-Dybin granitioid-related Au deposit (A.V. Kokin, written commun., 1978; Zubkov, 1984; Goryachev, 1998, 2003) consists of abundant quartz stringers, from 0.2 to 0.3 m thick, which form peculiar sheet stockworks in contact metamorphosed, Late Permian sandstone beds, which range from 5 to 20 m thick. The stringers consists of quartz (90-95%), muscovite, potassium feldspar, scheelite, molybdenite, arsenopyrite, niccolite, löllingite, pyrrhotite, bismuth, gold, bismuthine, bismuth tellurides and sulfotellurides, and maldonite. The deposit occurs for 800-1,000 m along the strike of the bedding; and also occurs above an Early Cretaceous granitoid body and in adjacent country rocks. The deposit contains up to 3% As, 7-13 g/t Au, up to 2.5% WO_3, up to 1% Bi, and up to 0.6% Te.

Origin of and Tectonic Controls for Allakh-Yun Metallogenic Belt

The vein deposits of the Allakh-Yun metallogenic belt are interpreted as forming during two major tectonic events (Goryachev, 1998, 2003). The relatively older, metamorphic-related Au quartz vein deposits are interpreted as forming during the early stages of thrusting and associated metamorphism of the southern part of the North Asian Craton Margin (unit NSV, Verkhoyansk fold belt) during accretion of the Okhotsk terrane and Kolyma-Omolon superterrane onto the North Asian Craton Margin. Accretion of the Okhotsk terrane may have been accentuated by the coeval accretion of the outboard Kony-Murgal island-arc terrane. The relatively younger, crosscutting, Au-quartz vein deposits, and granitioid-related Au and W-Sn quartz vein deposits of the Allakh-Yun metallogenic belt are interpreted as forming during intrusion of the Early Cretaceous anatectic granitoid rocks of the Verkhoyansk collisional granite belt (unit vk; Nokleberg and others, 1994c, 1997c). This Late Jurassic and Early Cretaceous granite belt consists of two main belts, the Main granite belt of Late Jurassic to early Neocomian age, and the Northern granite belt of Neocomian age. The Main granite belt, which hosts the Allakh-Yun metallogenic belt, extends for about 110 km along southwest border of the Kolyma-Omolon superterrane and stitches the superterrane to North Asian Craton margin. The granites occur as inclined, sheet-like plutons, up to 200 km long, which are generally conformable with major folds. Ar-Ar ages of granitoid rocks range from 134 to 144 Ma (Parfneov, 1995). These granitoid rocks are interpreted as forming immediately after the Late Jurassic accretion of the Kolyma-Omolon superterrane to the North Asian Craton Margin (Nokleberg and others, 1994c, 1997c, 2000).

Yana-Polousnen Metallogenic Belt of Granitoid-Related Au, Sn Quartz Vein, W Vein, Sn Greisen, Co-, Au-, and Sn-Skarn, Sn-Silicate Sulfide Vein and Related Deposits (Belt YP) Central Part of Russian Northeast

The Yana-Polousnen metallogenic belt of granitoid-related Au, Sn quartz vein, W vein, Sn greisen, Co-, Au-, and Sn-skarn, Sn-silicate sulfide vein and related deposits (fig. 61; tables 3, 4) occurs in an enormous, discontinuous wide zone, about 1000 km and up to 200 km wide in the northwestern part of the Russian Northeast (Shpikerman and Goryachev, 1995, 1996, 2003). The belt trends from the lower part of the Alazeya River in the southwest to the headwaters of the Yana River in the northeast. The belt is locally extensively overlain by unconsolidated Cenozoic sedimentary deposits. The granitoid-related deposits occur in or near granitoid rocks which intrude: (1) the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV); (2) carbonate, clastic, and igneous rocks of the Omulevka, Munilkan, and Kular-Nera terranes of the Kolyma-Omolon superterrane; and (3) the overlapping Polousnen flysch of the Indigirka-Oloy sedimentary-volcanic assemblage (unit io; Nokleberg and others, 1994c, 1997c).

Several types of lode deposits occur in the Yana-Polousnen metallogenic belt (table 4) (Nokleberg and others 1997a, b, 1998). (1) Medium to major Sn and W quartz vein, and Sn greisen mines and deposits, some of which are now mostly exhausted, occur at Argin, Kester, Balyktaah, Ploskoe, Odinokoe, Polyarnoe, and Takalkan. These deposits generally occur in the apical portions of granitoid plutons and are associated with placer Sn and W placer deposits. (2) Co, Au, and Sn skarn deposits, as at Kandidatskoe and Arbatskoe, and granitoid related Au quartz vein deposits, as at Chistoye and Tuguchak-2, generally occur along the contacts of granitoid plutons. (3) Sn-silicate-sulfide and Sn polymetallic vein deposits, usually associated with Ag, occur at Alys-Khaya, Anomalinoe, Bugdogar, Burgachan, Ege-Khaya, Khoton-Khaya, Ilin-Tas, Sigilyakh, and Ulakhan-Egelyakh. These deposits generally occur adjacent to intrusions along contacts, often adjacent to mafic and intermediate dikes, and are associated with the late stage mineralization and associated granitic magmatism. And (4) Sb, Pb, and Zn polymetallic vein deposits, as at

Altinskoe, Aragochan, Dalnee, Dokhsun, and Verkhne-Naanchan, are associated with granitoid plutons. Isotopic studies indicate the deposits and associated granitoid rocks formed from about 130-110 Ma (Nenashev, 1979; Goryachev, 1998, 2003; Parfenov, 1995; Parfenov and others, 1999).

Polyarnoe Sn greisen and Vein Deposit

The Polyarnoe Sn greisen and vein deposit (Nekrasov, 1962; O.G. Epov and G.S. Sonin, written commun., 1964; Flerov, 1974) consists of quartz and quartz-topaz veins which dip gently to moderately (5-40°) near and within a stock of apogranite at the top of the major Cretaceous Omchikandin leucogranite batholith. The veins range from 0.1 to 3.5 m thick, are up to 300 m long, and extend up to 260 m down-dip. The main minerals are quartz, topaz, fluorite, muscovite, zinnwaldite, wolframite, cassiterite, arsenopyrite, molybdenite, tourmaline, sphalerite, galena, pyrite, chalcopyrite, stibnite, bismuth, bismuthine, and bismuth sulfosalts. No size or grade data are available. The deposit is associated with quartz-topaz greisen.

Kandidatskoe Au Skarn Deposit

The Kandidatskoe Au skarn deposit (Nekrasov, 1962; Bakharev and others, 1988) consists of zones of garnet-pyroxene, pyroxene-wollastonite, pyroxene, and epidote-pyroxene skarn which range up to 100 to 150 m long and up to 50 m thick. The skarn zones occur in a block of Devonian carbonate and Permian clastic rocks located between granodiorite of the Early Cretaceous Ulakhan-Tass pluton and monzonite of the mid-Cretaceous Kandidatsky stock. The main (No. 1) ore body occurs as a steeply-plunging, funnel-shaped pipe of massive and disseminated ore with an outcrop area of 150 m long and up to 20 m wide. The main minerals are arsenopyrite, löllingite, pyrrhotite, molybdenite, glaucodot, cobaltite, gold, bismuth, bismuthine, maldonite, hedleyite, and A and B joseite. The gold is fine-grained (98% less than 0.08 mm) and has a fineness of 650-1,000. At the adit level (50 m), the thickness of the ore body is half of which at surface. The deposit contains up to 55 g/t Au, 3% Co, 20% As, 0.5% Bi, 3% Zn, 0.5%Ni, 0.1% Te.

Chistoe Granitoid-Related Au Deposit

The Chistoe granitoid-related Au deposit (Bakharev and others, 1988) consists of a set of quartz veins which range from 10 to 50 m long and from 0.1 to 0.5 m thick. The veins occur in two steep-lying northeast-striking shear zones which range up to 500 m long and are hosted in contact metamorphosed Late Jurassic sandstone and in Early Cretaceous granodiorite stocks. The main minerals are muscovite, quartz, tourmaline, arsenopyrite, cobaltite, calcite, wolframite, native bismuth, native gold (fineness 500-1000), bismuthine, joseite (A, B, M, L types), and maldonite. The veins are associated with greisen zones which range up to 1 to 2 m wide. The deposit contains up to 20 g/t Au, 0.9% W, 0.5% Bi, and 1% As.

Ilin-Tas Sn Silicate-Sulfide Vein Deposit

The Ilin-Tas Sn silicate-sulfide vein deposit (Shur and Flerov, 1979; T.N. Spomior and others, written commun., 1985) consists of complex veins and less common shear zones and stringers which occur in contact metamorphosed Late Triassic sandstone and siltstone adjacent to the Bezymyanny granitoid pluton. Granodiorite of the early magmatic phase has an Rb-Sr isotopic age of 170 Ma with an initial Sr isotopic age of 0.7035, and fine-grained granite of the second phase has a Rb-Sr isotopic age of 143 Ma with an initial Sr ratio of 0.0761 (Nenashev and others, 1985). The ore bodies dip steeply, range from 0.01 to 6 m thick, and are about 100 m long. The veins are most dense at a distance of 500-1,000 m from the intrusive contact. The major minerals are quartz, tourmaline, cassiterite, stannite, wolframite (ferberite), pyrrhotite, pyrite, arsenopyrite, and chalcopyrite. Also occurring are Bi and Te minerals. The deposit is major with an average grade of 0.7-2.5% Sn; 0.3-1.0% WO_3; up to 10 g/t Au.

Origin of and Tectonic Controls for Yana-Polousnen Metallogenic Belt

The lode deposits of the Yana-Polousnen metallogenic belt are related mainly to the Early Cretaceous collisional (anatectic) granitoid rocks of the Northern part of the Verkhoyansk granite belt (unit vk) (Nokleberg and others, 1994c, 1997c; Goryachev, 1995, 1998, 2003). The Northern part of this granite belt, which extends for about 600 km along northwestern margin of the Kolyma-Omolon superterrane, consists of inclined sheet-like plutons, up to 200 km long, which are generally conformable with major folds. Major lithologies are granodiorite, granite, and, less commonly, leucogranite. These granitoid rocks are interpreted as forming immediately after the final, Early Cretaceous stage of accretion of the Kolyma-Omolon superterrane to the North Asian Craton (Nokleberg and others, 2000).

Darpir Metallogenic Belt of Sn and Associated Felsic-Magmatism Deposits (Belt DP) Western Part of Russian Northeast

The Darpir metallogenic belt of Sn and associated felsic-magmatism-related deposits (fig. 61; tables 3, 4) occurs in the western part of the Russian Northeast. The belt is hosted in a zone of Early Cretaceous granitic intrusions which trends northwest along the southwest boundary of the Omulevka passive continental margin terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c). The belt extends for more than 1,000 km (fig. 61). The metallogenic belt and zone of granitic intrusions is transverse, or nearly orthogonal to the trend of the younger Okhotsk-Chukotka volcanic-plutonic belt to the southeast. A diverse group of granitic-intrusive-related mineral deposit types occur in the Darpir metallogenic belt (table 4). The significant deposits in the belt are the Bolshoy Kanyon Sn skarn deposit (fig. 67), the Bastion Sn greisen deposit, the Titovskoe Sn (B) magnesian skarn deposit, the Chibagalakh Sn-B skarn deposit, the Darpir and Lazo Sn silicate-sulfide deposit, the Verkhne-Seimchan Co-arsenide polymetallic vein deposit, and the Chepak granitoid-related Au deposit (Nokleberg and others 1997a, b, 1998). The belt also contains a few Pb-Zn skarn deposits.

The significant felsic-magma-associated deposit of the Darpir metallogenic belt occur in diverse geologic settings. The Sn skarn deposits at Titovskoe and Bolshoy Kanyon occur in Paleozoic carbonate rocks near Early Cretaceous granitoid plutons. The Sn greisen deposit at Bastion occurs in leucocratic granite. Sn polymetallic vein and Sn silicate-sulfide deposits, such as the Darpir and Lazo deposits, commonly occur in or near Early Cretaceous granite plutons which intrude contact-metamorphosed, Early and Middle Jurassic siltstone. Bi-, Co-, and As-vein deposits, as at Verkhny Seimchan, and granitoid-related Au deposits, as the Chepak deposit, occur in a similar setting.

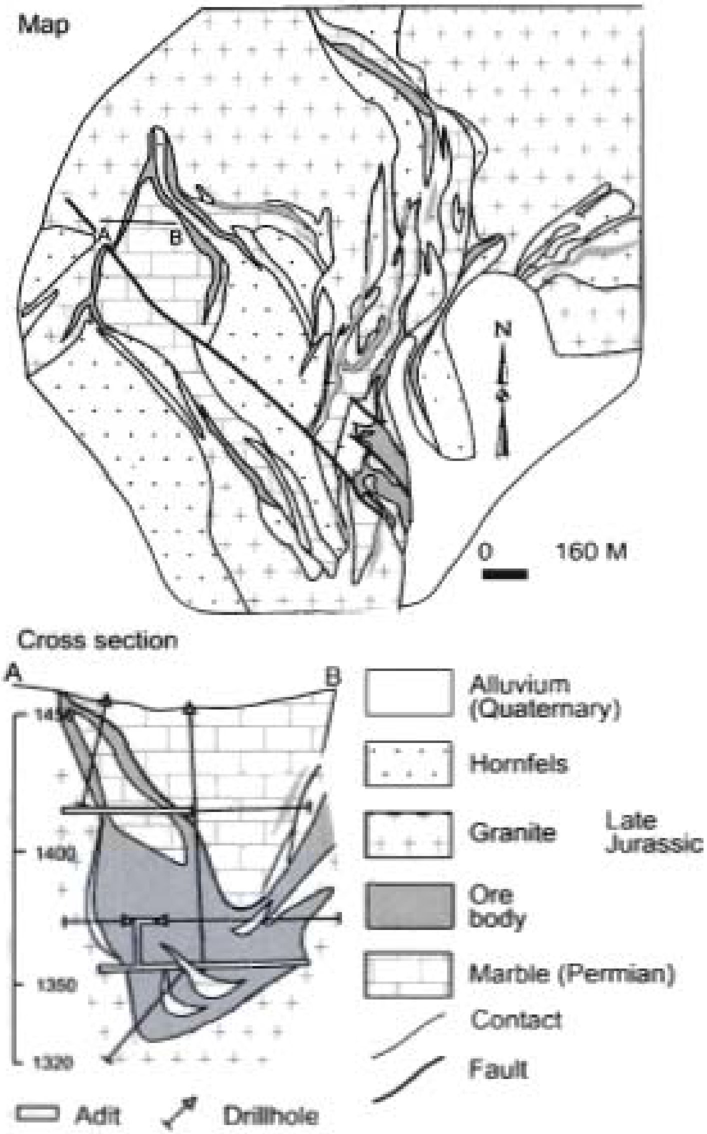


Figure 67. Bolshoy Kanyon Sn skarn deposit, Darpir metallogenic belt, Russian Northeast. Schematic geologic map and cross section. Adapted from Politov (1983).

Titovskoe Sn (B) Magnesium Skarn Deposit

The Titovskoe Sn (B) magnesium skarn deposit (Dorofeev, 1979) consists of forty ore bodies which occur along the contact between the quartz monzonite phase of an Early Cretaceous granitoid intrusion and Silurian and Devonian dolomite and limestone. The ore bodies range from 5 cm to 20 m thick and from 50 to 1,000 m long. The main ore mineral is ludwigite, which comprises up to 70-80% in some ore bodies. The ore minerals also include ascharite, kotoite, datolite, harkerite, monticellite, fluoborite, clinohumite, calcite, periclase, forsterite, diopside, vesuvianite, brucite, garnet, axinite, tourmaline, biotite, phlogopite, serpentine, spinel, hornblende, pyroxene, feldspar, quartz, and magnetite. Sn occurs as an isomorphous admixture in ludwigite. Ludwigite is often replaced by sulfide minerals (pyrrhotite, sphalerite, pyrite, arsenopyrite, and chalcopyrite). Kotoite veins occur along the margins of ludwigite bodies. The contact between the intrusion and carbonate is highly irregular. Most of the skarns occur where the contact forms embayments (pockets) into the intrusion. The deposit covers a 3 by 6 km area, and is of medium to major size. The average grades are 9.5% B_2O_3; 0.3% Sn.

Chepak Granitoid-Related Au Deposit

The Chepak granitoid-related Au deposit (P.I. Skornyakov, written commun., 1951; V.I. Shpikerman and N.A. Goryachev, written commun., 1995) consists of steeply dipping, quartz-sulfide veinlets, replacement veins, and associated alteration zones which are both concordant with, and cut intensely contact-metamorphosed Late Triassic sandstone and shale which overlie a buried granitoid pluton. The Au ore bodies occur in zones of northeast-trending veins. The host rocks are intruded by dikes of diorite porphyry, lamprophyre, and dolerite; and by small intrusive bodies of Late Jurassic-Early Cretaceous granite porphyry, granodiorite porphyry, and dacite. Disseminated veinlets are also occur in the magmatic rocks and in hornfels. The wall rocks are silicified, chloritized, and sericitized. The veins are composed mainly of quartz (30-60%), sericite, feldspar, chlorite, carbonate, apatite, arsenopyrite, löellingite, scheelite, pyrrhotite, and pyrite. Less common or rare are chalcopyrite, bismuth, bismuthinite, marcasite, wolframite, magnetite, ilmenite, rutile, sphene, tourmaline, epidote, and fluorite. Arsenopyrite and löellingite make up to 20 to 40% of the veins. Most gold is finely dispersed in arsenopyrite, löellingite, and pyrrhotite. The deposit is medium size. The Au content ranges from 5 to 50 g/t Au, with values as high as 200 g/t Au. Proven reserves are 30 tonnes Au with an average grade of 7 to 8 g/t Au.

Origin of and Tectonic Controls for Darpir Metallogenic Belt

The Early Cretaceous granitic intrusions which host the Darpir metallogenic belt are part of the Main part of the Verkhoyansk collisional granite belt (fig. 61) which intrudes Paleozoic and early Mesozoic bedrock of the Kolyma-Omolon superterrane and the adjacent North Asian Craton Margin (Nokleberg and others, 1994c, 1997c). The Main part of the collisional granite belt is of Late Jurassic to early Neocomian age. The Main part of the granite belt occurs along southwest border of the Kolyma-Omolon superterrane and stitches the superterrane to North Asian Craton Margin (Verkhoyansk fold belt, unit NSV). The Main part of the granite belt occurs as inclined, sheet-like plutons, up to 200 km long, which are generally conformable with major folds. Younger differentiates are biotite, two-mica, and amphibole-biotite granitoid rocks. Ar-Ar ages of granitoid rocks range from 134 to 144 Ma. The Main part of the Verkhoyansk collisional (anatectic) granitic belt and associated Darpir metallogenic belt are interpreted as forming during a period of anatectic granitic magmatism which occurred immediately after the Late Jurassic accretion of the Kolyma-Omolon superterrane to the North Asian Craton Margin (Nokleberg and others, 1994c, 1997c).

Tompon Metallogenic Belt of Cu, W, Sn Skarn, and Sn Quartz Vein Deposits (Belt TO) West-Central Part of Eastern Siberia

The small Tompon metallogenic belt of Cu, W, and Sn skarn deposits (fig. 61; tables 3, 4) occurs in the west-central part of eastern Siberia. The belt extends for about 150 km in the North Asian Craton margin (Verkhoyansk fold belt, unit NSV; Nokleberg and others, 1994c, 1997c). The deposits are hosted in altered Triassic limestone which is interlayered with sandstone and shale. The major deposits in the belt are the Khunkhada Sn-W skarn, Agylki W skarn, and Erikag Sn quartz vein deposits (table 4) (Nokleberg and others 1997a, b, 1998). The deposits generally occur above the apical portions of unexposed granitoid intrusions. W in the skarn deposits occurs as scheelite which is associated with chalcopyrite. The deposits contain anomalous Bi. The deposits are of small to medium size and are not economic. Older K-Ar isotopic studies yield an Early Cretaceous age of 125-130 Ma for the associated granitoid rocks. Newer Ar-Ar isotopic ages of granitoid rocks range from 134 to 144 Ma (Layer and others, 1995).

The lode deposits of the Tompon metallogenic belt are associated with intrusion of the Main part (Late Jurassic to early Neocomian) of the Verkhoyansk collisional granite belt (unit vk; Nokleberg and others, 1994c, 1997c). The Main collisional granite belt extends for about 110 km along southwest border of the Kolyma-Omolon superterrane and stitches the superterrane to North Asian Craton margin. The granites in the belt occur as inclined, sheet-like plutons, up to 200 km long, which are generally conformable with major folds. These granitoid rocks are interpreted as forming immediately after the Late Jurassic accretion of the Kolyma-Omolon superterrane to the North Asian Craton Margin (Nokleberg and others, 1994c, 1997c).

Shamanikha Metallogenic Belt of Au Quartz Vein and Cu-Ag Quartz Vein Deposits (Belt SH) Central Part of the Russian Northeast

The Shamanikha metallogenic belt of Au quartz and Cu-Ag quartz vein deposits (fig. 61; tables 3, 4) occurs in the Shamanikha River basin in the west-central part of the Russian Northeast. The belt is hosted in a zone of metamorphic rocks in Paleozoic and older rocks in the western part of the Shamanikha subterrane of the passive continental margin Prikolyma terrane of the Kolyma-Omolon superterrane (fig. 61). The zone of metamorphic rocks and vein deposits is adjacent to the Late Jurassic volcanic and plutonic rocks of the Indigirka-Oloy overlap assemblage (unit io; Nokleberg and others, 1994c, 1997c). The major deposits in the belt are the Glukhariny and Kopach Au quartz vein deposits, and the Opyt Cu-Ag quartz vein deposit (table 4) (Nokleberg and others 1997a, b, 1998). The metallogenic belt extends north-south for about 350 km and varies in width from 5 to 50 km.

Au Quartz Vein Deposits

The Au quartz vein deposits generally occur as thin quartz veins in late Proterozoic sedimentary rocks metamorphosed to greenschist facies. The significant Au quartz vein deposits are at Glukhariny and Kopach. The Glukhariny occurrence (E. Ya. Lutskin, written commun., 1964; V.A. Semenov, written commun., 1974) consists of gold in quartz veins in Late Proterozoic quartz-chlorite-epidote schist, quartzite, and metarhyolite; and in quartz-cemented breccias in these rocks. The wall rocks are metamorphosed to upper greenschist facies. The ore minerals are native gold, galena, chalcopyrite, arsenopyrite, and hematite. The deposit occurs in three east-west trending zones which range up to 1,200-4,000 m long and vary from 400 to 900 m wide. The deposit is small. Grab samples contain up to 25 g/t Au and up to 50 g/t Ag.

Cu-Ag quartz Vein Deposits

The Cu-Ag quartz vein deposits occur in Late Proterozoic Cu-bearing sandstone metamorphosed to greenschist facies. The significant deposit at Opyt (E. Ya. Lyaski, written commun., 1937; V.A. Erzin, written commun., 1946; A.N. Ruchkin and S.L. Tsykarev, written commun., 1984) occurs as veins and zones of massive, disseminated, and brecciated veinlets. The ore minerals are pyrite, chalcopyrite, bornite, galena, sphalerite, cuprite, native copper, chalcocite, arsenopyrite, and electrum. The gangue minerals are quartz, calcite, dolomite, graphite, and chlorite. The veins are hosted in Late Proterozoic, Cu-bearing, graphite-sericite-chlorite-quartz schist, and also in Late Jurassic siltstone and sandstone. The deposit is located at the intersection of a Late Jurassic depression and a block of old metamorphic rocks near a barely eroded granite body. The main ore body is about 2 km long; the entire deposit trends northwest-southeast for about 3 km. The deposit contains a probable resource of 14 million tonnes of reserves grading 1.5% Cu, 1.2% Pb, 0.5% Zn, 180 g/t Ag, and up to 1 g/t Au. The Cu-Ag quartz vein deposits of the Shamanikha metallogenic belt occur adjacent to the Late Jurassic Uyandin-Yassachny volcanic-plutonic belt which forms the southwestern part of the Indigirka-Oloy sedimentary and igneous assemblage (unit io, fig. 61). The Cu-Ag quartz vein deposits exhibit a more diverse mineral composition compared to the Au quartz vein deposits in the same belt.

Origin of and Tectonic Controls for Shamanikha Metallogenic Belt

Because the metamorphic vein deposits of the Shamanikha metallogenic belt occur partly in Late Jurassic sedimentary rock, the veins are interpreted in forming in the latest Jurassic or Early Cretaceous (Nokleberg and others, 2000; this study). The metamorphism, associated deformation, and formation of the Au and Cu-Ag quartz vein deposits are interpreted as occurring during one of two major tectonic events (Nokleberg and others, 2000): (1) the latest Jurassic and Early Cretaceous accretion of the Kolyma-Omolon superterrane, including accretion of the Prikolyma passive continental margin terrane, to the North Asian Craton margin (unit NSV, fig. 61); or (2) the Early to mid-Cretaceous accretion of the Chukotka superterrane against the South Anyui and Velmay subduction-zone terranes, and the Nutesyn island-arc terrane which were in turn were colliding with the Kolyma-Omolon superterrane to the southwest. Herein, the first interpretation is favored.

Verkhoyansk Metallogenic Belt of Au Quartz Vein, Au-Sn Polymetallic Vein Deposits (Belt VK) Western Part of Russian Northeast

The Verkhoyansk metallogenic belt of Au quartz vein and Au polymetallic vein, and Sn vein deposits (fig. 61; tables 3, 4) occurs in the western part of the Russian Northeast (Goryachev, 1998, 2003). The deposits are hosted in the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV) (Nokleberg and others, 1994c, 1997c). The belt extends for about 1000 km from the Tompo River basin to the Arctic Ocean in a narrow band which occurs in the axial portion of the Verkhoyansk meganticlinorium. The major Au quartz vein deposits are at Anna-Emeskhin, Enichan-Tolono, Galochka, Nikolaevskoe, Otkrytoe, Syncha-I & II, and Syugyunyakh-Kende, and the major Au-Sn polymetallic vein deposits are at Balbuk, Bochiyskoe, Chochimbal, Dyabkhanya, and Imtandzha (table 4) (Nokleberg and others 1997a, b, 1998). A Pb polymetallic vein deposit is at Balbuk.

The Au quartz vein deposits are interpreted as synmetamorphic and formed relatively earlier than the nearly coeval Au-polymetallic vein deposits (Goryachev, 1998, 2003). The Au quartz vein deposits are controlled by diagonal and longitudinal faults and anticlinal domes (Amuzinsky, 1975) and occur both as sheeted ore bodies and sometimes as stockworks.

An example of an Au polymetallic vein deposit is at Chochimbal. An example of a Sn polymetallic vein deposits is at Imtandzha. The polymetallic vein deposits occur in the southern half of the metallogenic belt and are closely associated with Cretaceous granitoid rocks. The Au-Sn polymetallic vein deposits are relatively older than associated granitoid rocks (Ivensen and others, 1975; Goryachev, 1998, 2003).

Nikolaevskoe and Otkrytoe Au Quartz Vein Deposits

The Au quartz vein deposits at Nikolaevskoe and Otkrytoe (Abel and Slezko, 1988) consist of conformable and cross-cutting quartz veins with gold, galena, arsenopyrite, pyrite, tetrahedrite, sulfosalts, carbonates, and albite which are hosted in Early Permian sandstone beds. The veins occur in anticlinal hinges, are up to 1 km long, and range from 0.2 to 1 m thick, sometimes up to 10 m thick. Sulfides comprise up to 5% of the veins. The Au quartz vein deposits are not economic, but the source for the placer Au mines of the Verkhoyansk district.

Chochimbal Au Polymetallic Vein Deposit

The Au polymetallic vein deposit at Chochimbal (Goryachev, 1994, 2003) consists of interbedded shallow-dipping, steeply-dipping, cross-cutting carbonate-quartz-sulfide veins which are hosted in mid-Carboniferous clastic rocks. The ore bodies vary from 0.1 to 2.8 m thick and from 400 to 500 m long. The major minerals are quartz, siderite, sulfides, pyrite, arsenopyrite, Fe-sphalerite, and galena. Less common minerals are chalcopyrite, pyrrhotite, tetrahedrite, bournonite, native gold, and boulangerite.

Imtandzha Sn polymetallic Vein Deposit

The Imtandzha Sn polymetallic vein deposit occurs in a zone of an intense fissures along the axis of an anticline which is about 500 m wide and 2 km long. Coeval granodiorite porphyry dikes which both cut a and are cut by the polymetallic vein deposits (Goryachev, 1998, 2003). Early-stage polymetallic veins are mostly conformable whereas late stage, cross-cutting veins are less common. The early-stage veins range from 0.01 to 0.85 m thick. The major minerals are galena, sphalerite, and siderite; minor minerals are quartz, tetrahedrite, pyrite, arsenopyrite, and boulangerite. The late stage veins contain quartz, chlorite, pyrite, arsenopyrite, galena, cassiterite, tourmaline, and stannite and range from 0.1 to 0.6 m thick.

Origin of and Tectonic Controls for Verkhoyansk Metallogenic Belt

The Verkhoyansk metallogenic belt is hosted in rocks late Paleozoic to early Mesozoic clastic sedimentary rocks which are weakly metamorphosed, lower greenschist facies with development of metamorphic chlorite and rare biotite. Permian and Triassic diabase dikes are wide-spread along with isolated Cretaceous granitoid plutons and variable-composition dikes. The Au quartz vein deposits of the Verkhoyansk metallogenic belt are interpreted as forming during regional deformation and metamorphism associated with accretion of the Kolyma-Omolon superterrane to the Verkhoyansk fold belt of the North Asian Craton Margin (Goryachev, 1998, 2003). The slightly younger Au and Sn polymetallic vein deposits of the Verkhoyansk metallogenic belt are interpreted forming during the Main part of the Early Cretaceous Verkhoyansk collisional granitic belt (vk) (Nokleberg and others, 1994c, 1997c). The belt is interpreted as forming immediately after the Late Jurassic accretion of the Kolyma-Omolon superterrane to the North Asian Craton Margin (Nokleberg and others, 1994c, 1997c).

Yana-Kolyma Metallogenic Belt of Au Quartz Vein, Sn Vein and Greisen, W Vein, Granitoid-Related Au, and Clastic-Sediment-Hosted Hg Deposits (Belt YA) Central Part of Russian Northeast

The Yana-Kolyma metallogenic belt of mainly Au quartz vein, lesser Sn vein, Sn greisen, granitoid related Au, W vein deposits, and clastic-sediment-hosted Hg deposits (fig. 61; tables 3, 4) occurs in the central part of the Russian Northeast (Goryachev, 1998, 2003). The Yana-Kolyma belt is hosted in the upper Paleozoic through middle Mesozoic rocks of the Kular-Nera accretionary-wedge terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c). Major, wide shear zones, distinct folds, and numerous granitic intrusions characterize the host rocks of the metallogenic belt. These structures and intrusions are interpreted as forming during collision of continental blocks in the Late Jurassic to Early Cretaceous. The collisional zone contains a major belt of Early Cretaceous granitoid plutons which are mainly high alumina and S-type with lesser I-type plutons (Shkodzinsky and others, 1992). The latter are associated with numerous andesite and granitic porphyry dike suites.

The numerous Au quartz vein lode and related placer Au deposits in the Yana-Kolyma metallogenic belt are sites of extensive Russian Northeast Au production (Shilo, 1960; Firsov, 1957, 1985; Goryachev, 1998, 2003). The total production has been more than 2,570 tonnes of placer Au, and about 100 tonnes of lode Au. The most important lode Au deposits in the metallogenic belt are: (1) the Natalka deposit, in production since 1945, which has produced about 75 tonnes of Au; (2) the Igumen deposit, with a production of 11 tonnes Au; (3) the Rodionov, Vetrenskoye, and Utin deposits with combined production about 8 tonnes Au; and (4) other deposits at Srednikan, and Shturm. Mining has ceased at all lode deposits except at Natalka and Svetloye. However, the majority of the deposits are not thoroughly prospected. The significant deposits in the belt are (tables 3, 4): (1) Au quartz vein deposits at Aleshkino, Bazovskoe, Badran, Burkhala, Chai-Yurya, Chelbanya, Daika Novaya, Darpir, Degdekan, Dirin-Yuryak, Djelgala-Tyellakh, Dorozhnoe, Ekspeditsionnoe, Goletsov (Golets), Igumen, Imtachan, Kamenistoe, Khangalass, Khaptagai-Khaya, Kholodnoe, Kontrandya, Laryukov, Lazo, Maldyak, Mitrei, Natalka, Nadezhda, Pavlik, Pil, Rodionov, Sana, Srednekan, Stakhanov, Shturm, Sokh, Svetloe, Taboga, Talalak, Tokichan, Tumannoe, Tunguss, Tuora-Tas, Uchui, Utinka (fig. 68), Verkhne-Khakchan, Vetrenskoe, Yugler, Yukhondja, Zatessnoe, and Zhdannoe; (2) granitoid-related Au deposits at Delyuvialnoe and Ergelyakh; (3) Sn and Sn-W greisen deposits at Alyaskitovoe, Baryllyelakh, Bekkem, and Kere-Yuryak; (4) Sn quartz vein deposits at Butugychag, Burgavli, Burkat, Medvezhje, and Svetloe, (5) a Sb-Au vein deposit at Krokhalin; (6) a W vein and greisen deposit at Bokhapcha; and (7) a clastic sediment-hosted Hg or hot-spring Hg deposit at Kuzmichan (Nokleberg and others 1997a, b, 1998).

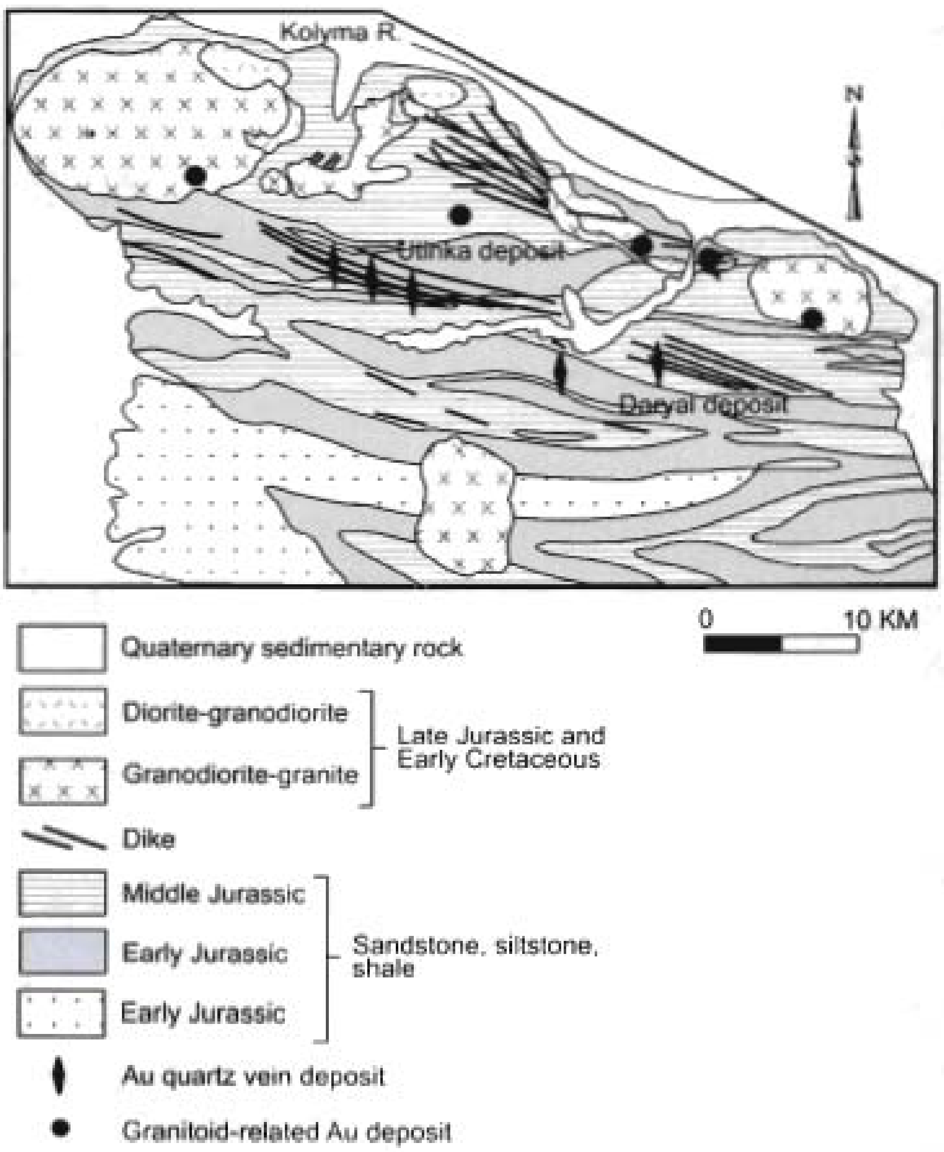


Figure 68. Utinka Au-quartz vein deposit, Yana-Kolyma metallogenic belt, Russian Northeast. Schematic geologic map showing geologic setting of the Utinka lode deposit. Adapted from Goryachev (1998).

Host Granitoid rocks and Associated Lode Deposits

Hosting and associated with the lode deposits of the Yana-Kolyma metallogenic belt are various collisional plutons composed of diorite-granodiorite, granodiorite-granite, and granite-leucogranite (Goryachev, Goncharov, 1995, Goryachev, 1998, 2003). The granitoid plutons are interpreted as forming at various depths. The Late Jurassic and Early Cretaceous granite-leucogranite plutons form large, homogeneous, batholith-like intrusions with surface areas as large as 7,000 km^2. The granitoid rocks occur in an axial portion of the Yana-Kolyma collision zone and consist of biotite and two-mica granites with accessory sillimanite, andalusite, cordierite and garnet. High Rb contents are characteristic, the granites are typical S-type collisional granites which have initial Sr ratios ranging up 0.7045 to 0.7111 (Goryachev and Goncharov, 1995; Goryachev, 1998, 2003). Small Sn occurrences are associated with these granites.

The Late Jurassic and Early Cretaceous diorite-granodiorite intrusions form numerous dikes and small stocks which are occur as separate suites in central portions of these zones. Diorite-porphyries, granodiorite-porphyries, and granite-porphyries are most prevalent as dikes; stocks are composed of two and three rock types, from diorite to biotite-amphibole granodiorite or granite. These igneous rocks are calc-alkaline, with some predominance of Na over K, and locally contain accessory garnet (up to 20.5% pyrope), and initial Sr ratios of 0.7045 to 0.7087 (Goryachev and Goncharov, 1995; Goryachev, 1988, 2003). These granites are typical I-type granites of the ilmenite-series. Au-quartz vein deposits are usually associated with these intrusions.

The Early Cretaceous granodiorite-granite intrusions occur in small plutons (with surface areas of up to 300 km^2) in the same area occupied by the diorite-granodiorite intrusions. The granodiorite-granite plutons are composed of granodiorite and mostly biotite granite rocks, are characterized by relatively high CaO, low alkali content, with some predominance of K over Na, and with initial Sr rations of 0.7057 to 0.7087. Accessory minerals are ilmenite, garnet, zircon and sulfide minerals (Gamyanin and others, 1991). Associated with these plutons are Au lode and W vein deposits.

Also part of the Yana-Kolyma metallogenic belt are suite of Sn quartz vein and greisen, W vein, Sb-Au and clastic-sediment-hosted Hg occurrences (fig. 61). Notable examples are Sn quartz vein and greisen deposits at Alaskitovoye and Burgavli, the Krokhalin Sb-Au vein occurrence, and the clastic-sediment-hosted Hg at Kuzmichan. Most of the Sn deposits are small, except for Alaskitovoye.

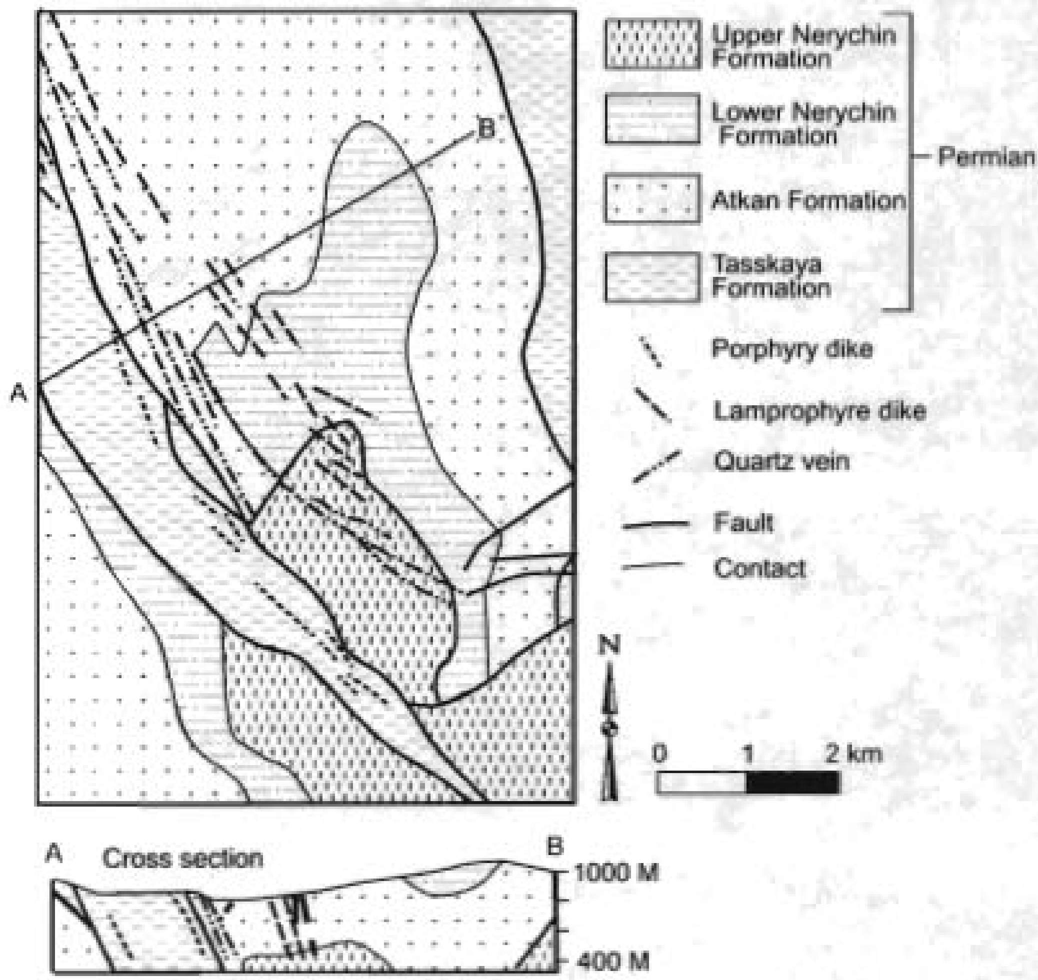


Figure 69. Natalka Au quartz vein deposit, Yana-Kolyma metallogenic belt, Russian Northeast. Schematic geologic map and cross section. Adapted from Eremin (1995).

Natalka Au Quartz Vein Deposit

The Natalka Au quartz vein deposit (fig. 68) (Firsov, 1957a; Shilo, 1960; Voroshin and others, 1989; Goncharov, 1995; Eremin and others, 1994) consists of zones of subparallel and reticulate quartz veinlets which can be grouped into two or three systems which converge locally along strike into podiform and platy veins. The ore minerals cement schistose, brecciated, cataclastic, and graphite-altered Late Permian tuffaceous sedimentary rocks. The deposit occurs along the Tenka strike-slip fault. The ore deposit is deformed with synclines and anticlines which occur near the fault zone. The deposit is intruded locally by abundant pre-ore and post-ore dikes of felsic to intermediate composition. The zone of mineralized veinlets is approximately 300 m wide; individual ore bodies occur in zones ranging from 50 to 300 m long and from 1 to 15 m thick. The gangue in the veinlets are composed mainly of quartz (90-95%), albite, anorthoclase, carbonate, chlorite, and sericite; with lesser kaolinite, barite, apatite, and graphite. The ore minerals are dominated by fine-grained disseminated arsenopyrite intergrown with pyrite in wall rocks. Subordinate and rare minerals include galena, sphalerite, chalcopyrite, pyrrhotite, bournonite, boulangerite, tetrahedrite-tennantite, scheelite, rutile, ilmenite, and stibnite. Fine-grained and microscopic, low-grade Au is commonly associated with arsenopyrite and galena in the veins and veinlets. A considerable proportion of the gold is intergrown in arsenopyrite in the wall rock adjacent to the veins. The Natalka deposit is large with total reserves of 450 t Au. From 1945 to 1994, the Natalka mine has produced 75 tonnes Au and 22 tonnes Ag. The annual production is 8 t Au and 4 t Ag. The lower grade ores average 4 g/t. More recent production data are not available.

Svetloe and Kholodnoe Au Quartz Vein Deposits

The Svetloe Au quartz vein deposit (fig. 70) (P.I. Skornyakov, written commun., 1953; Fedotov, 1960b, 1967, Goryachev, 1998, 2003) consists of subparallel quartz veins 600-1500 m long average 0.2-0.5 m thick, and 20-80 m apart. The veins occur as conformable bodies or in acute fractures in the limbs of an asymmetric anticline and dip 70° to 85°. The ore bodies trend mainly northwest, but range from east-west to north-south. Hosting the Au quartz veins is Late Triassic and Early Jurassic sandstone and shale which are intruded by a transverse set of dikes of felsic and intermediate composition. The ore minerals are mainly arsenopyrite, pyrite, and galena containing gold (858 fine). Subordinate ore minerals are sphalerite, chalcopyrite, scheelite, pyrrhotite, and native gold. The deposit is small and has proven reserves 3.6 t Au with grade ranging from 1.0 to 100 g/t Au. The nearby Kholodnoe deposit, which occurs to the south, is made up of three sets of quartz veins and mineralized fracture zones which trend northwest. Some veins occur within the dikes. Gold occurs as very small inclusions or irregular masses.

Zhdannoe Au Quartz Vein Deposit

The Zhdannoe Au quartz vein deposit (Gavrikov and Zharova, 1963; Rozhkov and others, 1971; Yu. A. Vladimirtseva, written commun., 1987; V.A. Amuzinskyi, G.S. Anisimova, and Ya.Yu. Zhdanov, written commun., 1992) consists of a set of 13 interbedded veins which range from 0.1 to 3 m thick and to 500 m long. Some ore bodies occur in cross-cutting fissures. Ore minerals are arsenopyrite, pyrite, galena, sphalerite, native gold (fineness 848), and very scarce boulangerite and chalcopyrite. Pre-mineral content of quartz veins is 1 to 3%. Veins accompanied by minor wallrock alteration to bersite. The deposit is judged to be exhausted and was small with an average grade of 22 to 95 g/t Au. The deposit occurs in the hinge of a brachyanticline at its periclinal closure and is hosted Late Triassic (Carnian) silty shale and sandstone.

Utin Au Quartz Vein Deposit

The Utin Au quartz vein deposit (I.R. Yakushev, written commun., 1950; P.I. Skornyakov, written commun., 1953; Goryachev, 1995, 1998, 2003) occurs in a Late Jurassic suite of ore-bearing dikes which extend for about 35 km. The dikes cuts a Middle Jurassic sedimentary sequence at an acute angle to bedding. The host sedimentary rocks are isoclinally folded into west-northwest trending structures. The main ore body extends 12 km and occurs in a steeply dipping dike, 0.4 to 1.3 m thick, which consists of hydrothermally altered andesite porphyry. The dike is intensely crushed and deformed. The Au quartz veins form complicated, often diagonally cross-cutting systems within the dike. Some quartz veins also cut the dikes obliquely, and extend into the surrounding sedimentary rocks. Arsenopyrite, pyrite, and pyrrhotite comprise up to several per cent of the veins. Also occurring are gold, galena, sphalerite, chalcopyrite, jamesonite, Bi-boulangerite, tetrahedrite, scheelite, marcasite, and stibnite. The gold distribution is quite irregular; individual ore shoots extend from 5 to 30 m in strike and are up to several hundreds of meters in width. The small deposit was discovered in 1929 and produced 12 tonnes Au with grade ranging from 0.1 to 3,923 g/t Au. The grade of ore shoots ranges from 5 to 3,923 g/t Au.

Alyaskitovoe Sn-W Greisen Deposit

The Alyaskitovoe Sn-W greisen deposit Shur, 1985; Yu. A. Vladimirtseva and V.M. Vladimirtsev, written commun., 1987) consists of veins and greisen which occur inside and adjacent to a stock of two-mica granite which intrudes Late Triassic sandstone and shale. The veins are greisen are variable in thickness and length and occur in fissures which strike north-northeast and dip northwest at 75-85°. The veins have complex morphology with en-echelon lenses which alternate with thin stringers. The Main ore minerals are wolframite, cassiterite, and arsenopyrite. The gangue minerals are mainly quartz, muscovite, tourmaline, and apatite. A complex combination of sulfosalts of lead, silver, and bismuth occur in the veins. The wallrocks exhibit quartz-muscovite, muscovite-apatite, and tourmaline greisen alteration. The deposit is small and has average grades of 0.45 to 1.33% WO_3 and up to 0.38% Sn.

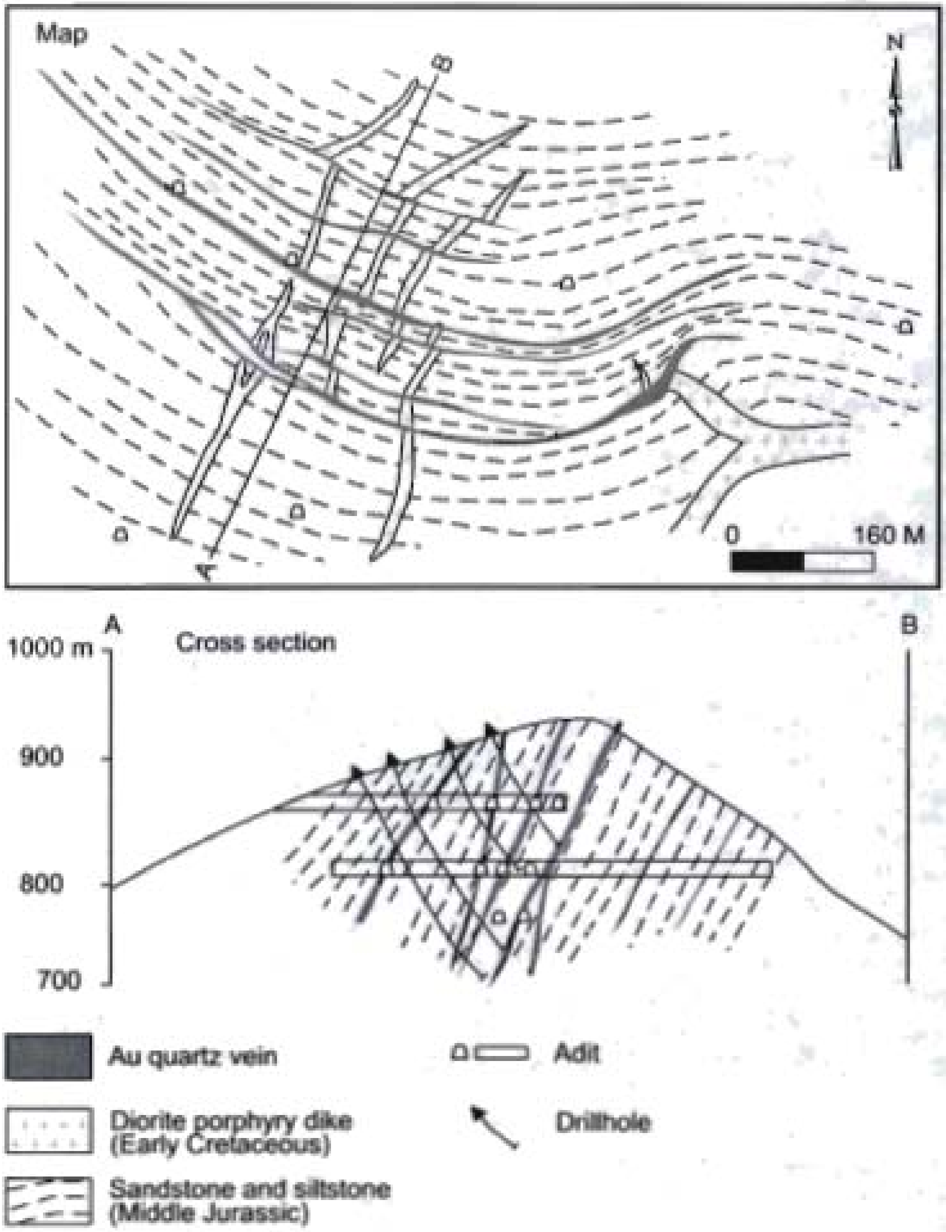


Figure 70. Svetloe Au quartz vein deposit, Yana-Kolyma metallogenic belt, Russian Northeast. Schematic geologic map and cross section. Adapted from Goryachev (1998).

Origin and Tectonic Controls for Yana-Kolyma Metallogenic belt

The Au quartz vein and associated deposits of the Yana-Kolyma metallogenic belt occur as linear bands and clusters which are controlled by two major sets of strike-slip fault zones which trend northwest for over 500-600 km (Goryachev, 1995, 1998, 2003). Secondary controlling structures are less extensive, diagonal and transverse fault zones which are bounded by northwest-trending strike-slip fault. The larger Au quartz vein deposits generally occur in the northwest-trending zones. The main types of the Au deposits occur in: (1) mineralized shear zones (linear stockworks) with low-grade ores which are not as widespread as the other types of ore, but contain approximately half of the Au reserves in the region; (2) quartz veins which commonly contain high-grade ores and coarse gold which are most favorable for milling, but contain smaller reserves; (3) Au-bearing, quartz stockworks in altered dikes, with low-grade ores, but they contain high-grade ore shoots, and medium reserves; and (4) granitoid-related Au quartz veins and greisens with low-grade Au and arsenic enriched ores

The host rocks for the Au quartz vein deposits of the Yana-Kolyma metallogenic belt are Permian to Jurassic black shale and tuffaceous sedimentary rocks which form part of the Kular-Nera accretionary-wedge terrane. The shales locally contain anomalous syngenetic carbonaceous matter. Au mineralization is associated with burial and low-grade greenschist facies metamorphism which consists of both contact and regional, penetrative metamorphism, and hydrothermal activity (Gelman, 1976). The Au quartz vein deposits of the Yana-Kolyma metallogenic belt are similar to other deposits of this type throughout the world.

The main features of this deposit type are: (1) predominance of quartz; (2) minor amounts of subordinate sulfide minerals, mainly arsenopyrite and pyrite, but a telluride minerals are absent; (3) less than 3-5% sericite, albite, carbonate minerals, and chlorite; and (4) in many places, a considerable down-dip extension of ore with little or no vertical zonation.

Most of the Au quartz vein deposits are associated with the low-grade greenschist facies regional metamorphism. They formed during collision event after small dikes and stocks diorite-granodiorite intrusive suites, and before intrusion of the granitoid plutons granodiorite-granite suites, and were subsequently thermally metamorphosed. Consequently, the Yana-Kolyma Au quartz vein deposits are interpreted as being genetically or paragenetically related to the coeval, I-type, diorite dikes and small granitoid plutons. The Au is interpreted as forming of two stage: (1) from the hydrothermal fluid generated during metamorphism of sediment-hosted Au which in turn was derived from an older period of multi-stage redeposition of Au from auriferous zones of pyrrhotite and pyrite in SEDEX deposits; and (2) from hydrothermal fluid generated during intrusion of the I-type granitoids. The granitoid-related Au quartz vein deposits are strongly genetically connected to the Late Jurassic and Early Cretaceous granodiorite-granite and granite-leucogranite plutons (Goryachev, 1998, 2003).

The Yana-Kolyma metallogenic belt is hosted in rocks upper Paleozoic through middle Mesozoic age of the Yana-Kolyma fold belt in the Kular-Nera accretionary wedge terrane of the Kolyma-Omolon superterrane (Nokleberg and others, 1994c, 1997c; Goryachev, 1998, 2003). These units are weakly metamorphosed to lower greenschist facies with development of metamorphic chlorite and biotite. The Au quartz vein, granitoid-related Au, and associated deposits of the Yana-Kolyma are interpreted as forming during syn-collisional regional deformation, metamorphism, and granitoid magmatism related with accretion of the Kolyma-Omolon superterrane to the North Asian Craton Margin (unit NSV, Verkhoyansk fold belt; Nokleberg and others, 2000). The Sn vein, Sn greisen, W vein deposits, and clastic-sediment-hosted Hg deposits of the Yana-Kolyma metallogenic belt are interpreted as forming during intrusion of the Early Cretaceous late-collisional (anatectic) granitoid rocks (granodiorite-granite and granite-leucogranite associations) of the Main part of the Verkhoyansk collisional granite belt (unit vk; Nokleberg and others, 1994c, 1997c). Alternatively, Babkin (1975) and Berger (1993) interpret that the clastic-sediment-hosted Hg deposits of the Yana-Kolyma metallogenic belt formed during a younger event in the Paleocene.

Metallogenic Belts Formed During Late Mesozoic Island Arcs in Russian Northeast and Southeastern Alaska, and Southern Canadian Cordillera

Left Omolon Belt of Porphyry Mo-Cu and Mo-Cu Skarn Deposits (Belt LO) East-Central Part of Russian Northeast

The Left Omolon metallogenic belt of igneous-arc-related deposits is associated with a chain of Early Cretaceous granodiorite stocks and small bodies which trend northwest for nearly 300 km along the left side of the Omolon River Basin (fig. 61; tables 3, 4) (Nokleberg and others, 1997b, 1998). The major deposit types in the belt are porphyry Mo-Cu and related Mo-Cu skarn deposits. The significant deposits are at Bebekan and Medgora. The porphyry Mo-Cu deposits are associated with Au-Ag and Pb-Zn vein deposits.

Bebekan Porphyry Mo-Cu Deposit

The Bebekan porphyry Mo-Cu deposit (Alekseenko, Korobeinikov, and Sidorov, 1990) consists of a stockwork of sulfide-quartz veinlets with disseminated molybdenite, chalcopyrite, pyrite, sphalerite, pyrrhotite, arsenopyrite, bornite, and covellite. The deposit occurs in an Early Cretaceous stock of porphyritic granodiorite. The ore body is confined to silicified and sericitized rocks marked by biotite, quartz, and orthoclase. The ore body is about 1.5 km by 400-500 m in size and coincides with the intrusion. A pyrite aureole extends about 1 km from the intrusion and coincides with a zone of propylitic alteration of the host Late Jurassic volcanic-sedimentary sequence. The deposit is of small to medium size and on the average contains about 0.5% Mo and 0.7% Cu with minor Pb, Zn, W, Au, and Ag.

Medgora Mo-Cu skarn Deposit

The Medgora Mo-Cu skarn deposit (Gorodinsky, Gulevich, and Titov, 1978) consists of disseminated veinlets in skarn which is associated with the Early Cretaceous Medgora granite and granodiorite pluton. The metallic minerals are pyrite, chalcopyrite, molybdenite, pyrrhotite, magnetite, hematite, and sphalerite. The skarns are composed of garnet, pyroxene, actinolite, scapolite, calcite, quartz, chlorite, epidote, and green mica. Individual ore zones extend from 30 to 160 m. The deposit is of medium size with grades of 0.1 to 0.64% Mo, 0.94 to 2.94% Cu, and 0.4 g/t Au. The Cu content of the ore varies from hundredths of a percent to over 2%.

Origin of and Tectonic Controls for Left Omolon Metallogenic Belt

The Left Omolon metallogenic belt occurs along the northeast marginal of the Omolon cratonal terrane. Two possible tectonic settings are interpreted for the Early Cretaceous granitic intrusions hosting this metallogenic belt: (1) The Early Cretaceous granitic intrusions may be a transverse, nearly orthogonal branch of the Cretaceous Okhotsk-Chukotka volcanic-plutonic belt; or (2) the Early Cretaceous granitic intrusives, as interpreted herein, are part of the Oloy-Svyatoy Nos volcanic belt that constitute part of the Early Cretaceous Oloy continental-margin magmatic arc which occurs to the northeast of the Omolon cratonal terrane (fig. 61) (Nokleberg and others, 1994c, 1997b, c, 1998; 2000).

Western-Southeastern Alaska Metallogenic Belt of Granitic-Magmatism-Related Deposits (Belt WSE) Southeastern Alaska

The Western-Southeastern Alaska metallogenic belt of granitic-magmatism-related deposits (fig. 62; tables 3, 4) occurs in Southeastern Alaska, and is hosted in Early to mid-Cretaceous granitoid plutons of the Muir-Chichagof plutonic belt which intrude the Wrangellia superterrane (Nokleberg and others, 1995a). The significant deposits are in the Jumbo Cu-Au skarn district, and the Bokan Mountain felsic plutonic U-REE deposit (table 4) (Nokleberg and others 1997a, b, 1998).

Jumbo Cu-Au Skarn Deposit

The Jumbo Cu-Au skarn district includes significant deposit at Jumbo, several small deposits at Magnetite Cliff, Copper Mountain, and Corbin, and lesser deposits at Late Magnetite, Gonnason, Houghton, Green Monster, and Hetta. All of the deposits occur within a few kilometers of the Jumbo deposit. The Jumbo district contains an estimated 280,000 tonnes of ore grading 45% Fe and 0.73% Cu, and has produced 4.6 million kg Cu, 220,000 g Au, and 2.73 million g Ag from 111,503 tonnes of ore (Kennedy, 1953; Herreid and others, 1978; Newberry and others, 1997). The deposits are hosted in, or lie adjacent to early Paleozoic marble and pelitic metasedimentary rocks of the Wales Group of the Alexander sequence where intruded by mid-Cretaceous hornblende-biotite granodiorite which exhibit concordant hornblende and biotite K-Ar isotopic ages of 103 Ma. The Jumbo deposit consists of chalcopyrite, magnetite, sphalerite, and molybdenite in skarn which occurs at the contact between marble and a granodiorite stock. Gangue is mainly diopside and garnet. The deposit has been explored by more than 3.2 km of underground workings and is the largest in the district. The Magnetite Cliff deposit consists of a 25-m-thick shell of magnetite which mantles granodiorite in contact with garnet-diopside skarn. The skarn contains 2% to 3% chalcopyrite, estimated resources of 335,600 tonnes grading 46% Fe and 0.77% Cu. The Copper Mountain deposit consists of scattered chalcopyrite and copper carbonate in diopside endoskarn which contains veins and masses of epidote, garnet, magnetite, and scapolite near granodiorite. This deposit has produced 101,800 kg Cu, 321,300 g Ag, and 4,510 g Au, and has about 410 m of tunnels and shafts.

Bokan Mountain Felsic plutonic U-REE deposit

The Bokan Mountain felsic plutonic U-REE deposit (fig. 71) consists of disseminated U, Th, REE, and niobate minerals, including uranothorite, uranoan thorianite, uraninite, xenotime, allanite, monazite, pyrite, galena, zircon, and fluorite which occur in an irregular, steeply-dipping pipe of Jurassic peralkaline granite (Warner and Barker, 1989; Brew and others, 1991; Berg, 1984; Foley and others, 1997; Thompson, 1997). The deposit produced about 109,000 tonnes grading about 1% U_3O_8; Th was not recovered. Most of ore was produced from a crudely cigar-shaped upper part of the pluton. The central zone which contains the deposit grades outward into normal granite. Associated pegmatite and vein REE, Nb, Th, and U deposits occur in the outer parts of granite or adjacent country rock, which consists of metamorphosed early Paleozoic granitic and sedimentary rocks of Alexander sequence.

Origin of and Tectonic Controls for Western-Southeastern Alaska Metallogenic Belt

The Western-Southeastern Alaska metallogenic belt is hosted in the Jurassic(?) and Early to mid-Cretaceous granitoid plutons of the Muir-Chichagof plutonic belt which are interpreted by Plafker and others (1989b) as part of the granitoid roots of the Late Jurassic to Early and mid-Cretaceous Gravina arc. The U-REE deposits in the belt, as at Bokan Mountain, may have formed in extensional setting (Goldfarb, 1997), possibly in a back-arc environment. The Western-Southeastern Alaska metallogenic belt is interpreted as a northern extension of the Island metallogenic belt to the south, and as the southeastern extension of the Eastern-Southern Alaska metallogenic belt. All three metallogenic belts are hosted in the Late Jurassic through mid-Cretaceous Gravina island arc which was built on the Wrangellia superterrane. The Gravina island arc is interpreted as forming on the northern, or leading edge of the Wrangellia island-arc terrane during migration towards North America (Nokleberg and others, 1984, 1985, 2000; Nokleberg and Lange, 1985a; Plafker and others, 1989; Plafker and Berg, 1994). The Gravina arc and associated granitic magmatism deposits are tectonically linked to the younger part of the McHugh Complex which forms the northern part of the Chugach subduction zone and accretionary wedge complex (Nokleberg and others, 2000).

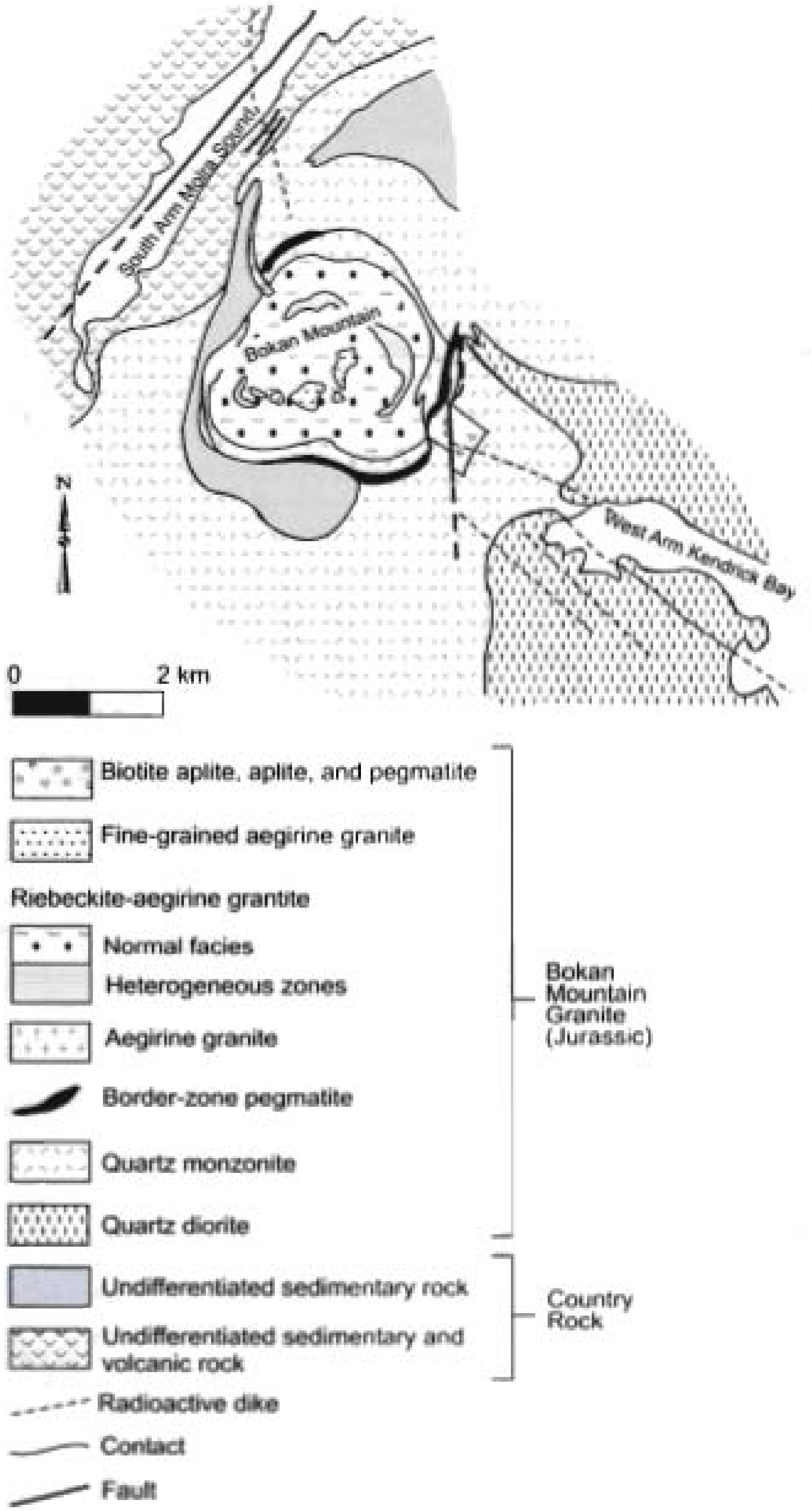


Figure 71. Bokan Mountain felsic plutonic U-REE deposit, Western-Southeastern Alaska metallogenic belt, Southeastern Alaska. Schematic geologic map. Adapted from Warner and Barker (1989) and Foley and others (1997).

Britannia Metallogenic Belt of Kuroko Cu-Zn Massive Sulfide Deposits, Southern British Columbia (Belt BR)

The Britannia metallogenic belt of kuroko Cu-Zn massive sulfide deposits is hosted in the Late Jurassic to Early Cretaceous Gravina-Nutzotin-Gambier volcanic-plutonic-sedimentary belt which forms an overlap assemblage on the inward margin of Wrangellia superterrane (fig. 63; tables 3, 4) (Nokleberg and others, 1997b, 1998, 2000). The significant deposit is at Britannia. The metallogenic belt also includes the Maggie, Northair, and Nifty deposits.

Britannia Kuroko Volcanogenic Cu-Zn Massive Sulfide Deposit

The Britannia deposit consists of a series of kuroko Cu-Zn (Ag-Au) ore bodies hosted a roof pendant of dacite tuff and breccia. The massive sulfide bodies consists of massive pyrite, chalcopyrite, sphalerite with minor galena, tennantite, tetrahedrite, barite and fluorite which occur in numerous discrete, concentrically zoned siliceous ore bodies (EMR Canada, 1989; Dawson and others, 1991; MINFILE, 2002). A U-Pb zircon age for a feldspar porphyry dike which cuts the deposit indicates a Middle Jurassic or older age for the deposit (Ray and Webster, 1994). The host rocks are metamorphosed dacite to andesite pyroclastic rocks. The massive sulfides consist mainly of stringers which occur in the upper of two major mafic to felsic metavolcanic layers which are separated by, and overlain by metasedimentary rock. From 1905 to 1974, the mine at the deposit produced 47,884,558 tonnes of ore from which 15.3 tonnes Au, 180.8 tonnes Ag, 517 tonnes Cu, 15.6 tonnes Pb and 125.3 tonnes Zn were recovered. The nearby Northair deposits near Whistler are interpreted as volcanogenic massive sulfide deposits remobilized during emplacement of adjacent plutons (Miller and Sinclair, 1985). The Early Cretaceous metavolcanic host rocks form pendants and screens within granodiorite of the Coast Plutonic Complex. The deposit and host rocks are thinned and partially remobilized by the northwest-trending Britannia shear zone (Payne and others, 1980).

Origin of and Tectonic Controls for Britannia Metallogenic Belt.

The Britannia metallogenic belt is hosted in the Middle and Late Jurassic and Early Cretaceous sedimentary and calc-alkaline volcanic rock of the Gambier Group which is intruded by partly coeval plutons which range in age from 130 to 94 Ma (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1966). The arc-related calc-alkaline volcanic and sedimentary rocks of the Gambier Group overlie Jurassic and older plutonic, volcanic and sedimentary rocks of the Coast Plutonic Complex and Harrison terrane on the east, and Middle to Late Jurassic plutons of Wrangellia Superterrane on the west. The Gambier Group and coeval plutonic rocks are part of the extensive Gravina-Nutzotin-Gambier volcanic-plutonic-sedimentary belt which forms a major middle Mesozoic sequence of volcanic, sedimentary, and plutonic rocks deposited on and intruded into the Wrangellia superterrane. The belt is interpreted as an elongate island arc which extended for several thousand km along the inner margin of the Wrangellia superterrane (sheet 3; Nokleberg and others, 1994c, 1997c). This Middle Jurassic to Early Cretaceous island arc, which was built on the Wrangellia superterrane, is interpreted as forming immediately before accretion of a of the superterrane to the accretionary margin of the North American Cordillera in the mid-Cretaceous (Monger and others, 1994; Monger and Nokleberg, 1996; Nokleberg and others, 2000). The volcanic exhalative activity deposited Kuroko-type massive sulfides in several centers in the Gambier Group. Mineral deposits and their host rocks were sheared and attenuated along faults active during and after the accretion of the Wrangellia superterrane.

Late Early Cretaceous Metallogenic Belts (120 to 100 Ma; Figures 61, 62)

Overview

The major Late Early Cretaceous metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 61 and 62. Six major belts are identified. (1) In the Russian Southeast, the Badzhal-Ezop-Khingan (BZ-KH) belt of granitic-magmatism-related deposits, which is hosted in the Khingan-Okhotsk volcanic-plutonic belt, is interpreted as forming in the Khingan continental-margin arc. (2) In the Russian Southeast, continuing on frm the Early Creteacoues was the Samarka (SA) belt of granitic-magmatism-related deposits. (3) In the Russian Northeast, continuing on from the Early Cretaceous, was the Kular (KU) metallogenic belt which contains Au quartz vein, and granitic-magmatism-related deposits. (4) Also in the Russian Northeast, was the Anadyr River (AD) metallogenic belt of Au quartz vein deposits, which is hosted in the Mainitskiy, West Pekulney, and (or) Penzhina-Anadyr terranes. The belt is interpreted as forming during regional metamorphism and generation of hydrothermal fluids associated with accretion and collision of Mainitskiy island arc onto North Asian Craton margin. (5) In Northern Alaska, the Nome (NO) and Southern Brooks Range (SBR) belts, which contain Au quartz vein deposits, are hosted in metamorphosed continental-margin terranes and are interpreted as forming during regional metamorphism associated with extension which occurred after overthrusting of Angayucham subduction zone terrane. (6) In the northern Canadian Cordillera, the Fish River (FR) metallogenic belt, which contains stratabound sedimentary P and Fe deposits and is hosted in the North American Craton Margin, is interpreted as forming during Late Mesozoic, dextral movement along the Kaltag-Porcupine fault system. (7) In the Canadian Cordillera, continuing on from the Early Cretaceous was the Western-Southeastern Alaska (WSE) belt, which contains granitic-magmatism-related deposits which are hosted in the Gravina-Nutzotin-Gambier belt which overlies the Wrangellia superterrane. And (8) also in the Canadian Cordillera, the Bayonne (BA), Cassiar (CA), Selwyn (SW), Tombstone (TS), and Whitehorse (WH) belts, which contain granitic-magmatism-related deposits, are also hosted in or near anatectic granitic plutons of the Omineca-Selwyn plutonic belt which is interpreted as forming during final accretion of Wrangellia superterrane to North American continental margin. In the below descriptions of metallogenic belts, a few of the noteable or signficant lode deposits (table 4) are described for each belt.

Metallogenic-Tectonic Model for Late Early Cretaceous (120 to 100 Ma; Figure 72)

During the late Early Cretaceous (Aptian through Albian - 120 to 100 Ma), the major metallogenic-tectonic events were (table 3): (1) inception of the short-lived Khinghan continental margin arc, and formation of associated metallogenic belts and companion subduction zone in the Russian Southeast; (2) accretion of the Mainitskiy island arc and associated Alkatvaam (AV) accretionary-wedge terranes to the active continental margin; (3) completion of accretion of the major Kolyma-Omolon superterrane in the Russian Northeast and formation of associated metallogenic belts; (4) obduction of Angayucham subduction-zone terrane onto the Arctic Alaska terrane and formation of metallogenic belts during extension which succeeded obduction; (5) continued opening of the Amerasia, Canada, and Eurasia Basins; and (6) continuation of the Gravina arc and formation of associated metallogenic belts during continuing accretion of the Wrangellia superterrane, and inception of collision-related metallogenic belts.

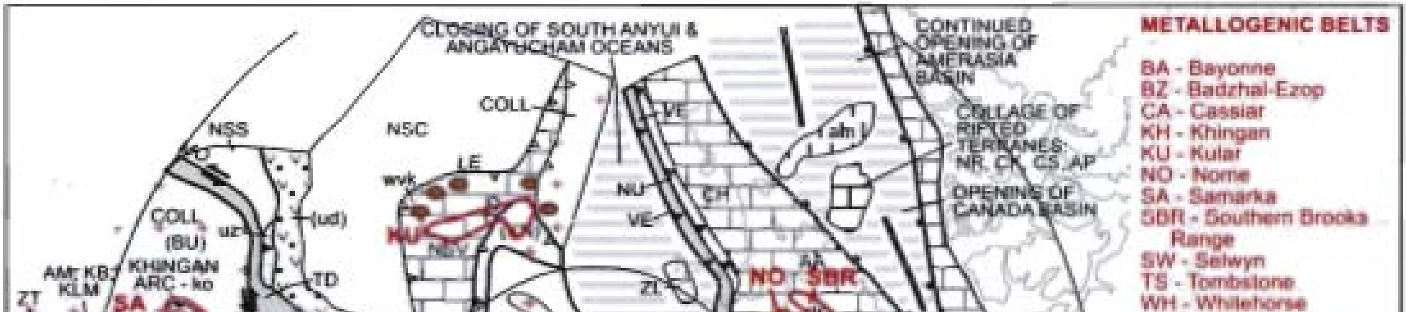


Figure 72. Late Early Cretaceous (Aptian through Albian - 120 to 100 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

(1) At about 50° paleolatitude, the Mainitskiy island arc (Mainitskiy terrane, MAI) continued activity. Associated with this arc was subduction of part of the adjacent oceanic plate to form the Alkatvaam accretionary-wedge terrane (AV). This arc and companion subduction zone continued to migrate northwards towards the North Asian Craton Margin and outboard terranes and was accreted to the active continental margin at the end of the Early Cretaceous (about 100 Ma). During this accretion, the Au quartz vein and associated deposits of the Anadyr River (AD) metallogenic belt formed. The accretion is interpreted as occuring by the beginning of the Albian with deposition of the overlying Kuibiveem sedimentary assemblage (kb), which is interpreted as a forearc unit to the Okhotsk-Chukotka continental margin arc (oc). Subduction stepped outboard during accretion.

(2) At the end of the Neocomian, oblique subduction was replaced by sinistral-slip faulting parallel to the continental margin. This faulting resulted in structural interleaving of the previously active subduction-zone terranes. This structural interleaving is interpreted as similar to the present-day region of Southern California and resulted in formation of the fault-bounded basin of marine turbidites now preserved in the Zhuravlesk-Tumnin turbidite-basin terrane (ZT) (Golozubov and Khanchuk, 1996).

(3) The Khingan continental margin arc (ko) started to form. Forming in the arc was the Badzhal-Ezop-Khingan (BZ-KH) belt of granitic-magmatism-related deposits. Tectonically linked to the arc was oblique subduction of part of the Ancestral Pacific Ocean plate to form the Amur River (AM), Khabarovsk (KB), and Kiselevka-Manoma (KLM) subduction-zone and accretionary-wedge terranes. Also in the same region, the Samarka (SA) belt of granitic-magmatism-related deposits, which is hosted in the Samarka island-arc terrane (SA), is interpreted as forming during anatectic granitic plutonism associated with thrusting of Kula-Farallon oceanic ridge under margin of southern Russian Far East.

(4) The continental margin Uda arc and associated subduction zones ceased activity with accretion of the Bureya superterrane and closure of the Mongol-Okhotsk Ocean along the Mongol-Okhotsk suture (*MO*).

(5) The extensive Kony-Murgal continental-margin and island arc and Pekulney island arc continued to form. Associated with these arcs was subduction of part of the ancestral Pacific Ocean plate to form the Talovskiy (TL), Penzhina-Anadyr (PA), and Pekulney (PK) terranes.

(6) The final stages of accretion of the Kolyma-Omolon superterrane is interpreted as causing a second phase of deformation in the Verkhoyansk fold and thrust-belt and formation of the West Verkhoyansk collisional granite belt (wk; 90 to 120 Ma) along the Lena fault (*LE*). Forming in the associated Verkhoyansk granite belt and continuing on from the Early Cretaceous was the Kular (KU) metallogenic belt which contains Au quartz vein and granitic-magmatism-related deposits.

(7) The Nutesyn and Koyukuk island arcs continued activity on the opposite sides of the South Anyui and Angayucham Oceans. Parts of these arcs are preserved in the Nutesyn (NU), Koyukuk (KY), Togiak (TG), and Nyac (NY) terranes. Associated with these arcs was subduction of parts of the South Anyui and Angayucham Ocean plate thereby forming the Velmay (VE); and (outer) Angayucham (AG) terranes, and subduction of the outboard margin of the Arctic Alaska terrane. An extensive zone of blueschist facies metamorphism occurs in this region in both the Angayucham and Arctic Alaska terranes. Forming during extension which succeeded obduction were Nome (NO) and Southern Brooks Range (SBR) metallogenic belts which contain Au quartz vein deposits, and are hosted in metamorphosed continental-margin terranes. These belts are interpreted herein as forming during regional metamorphism associated with extension.

(8) In the Arctic, sea-floor spreading and associated rifting continued with formation of large sedimentary basins, creation of a collage of passive continental-margin terranes derived from the North American Craton Margin (NAM; Lawver and Scotese, 1990; Grantz and others, 1990, 1991, 1998). Continuing was closure of the Angayucham Ocean, subduction along the North American continental margin, intense thrusting in the passive continental margin terranes, and deposition of Early to mid-Cretaceous flysch.

(9) On the edge of the Wrangellia superterrane (WRA), the Gravina arc continued to form. Associated with the Gravina arc was subduction of part of the Farallon Ocean plate to form the Chugach (CG), Bridge River (BR), Easton (EA), and Baker (BA) terranes. Part of the arc was preserved in the Kahiltna (kh) and Gravina-Nutzotin-Gambier (gg) assemblages which occur only on the Wrangellia superterrane. The Gravina arc extended into the southern Canadian Cordillera with the formation of the Spences Bridge volcanic-plutonic belt (sb). Forming in the Gravina arc, and continuing on from the Early Cretaceous was the Western-Southeastern Alaska (WSE) belt which contains granitic-magmatism-related deposits.

(10) The central and northern parts of the Wrangellia superterrane (WRA) accreted to the Northern Canadian Cordillera and southern Alaska. Along the accreting edge of the superterrane, the intervening oceanic plate and the Kahiltna overlap assemblage were thrust during the active continental margin of the Southern Alaska and the northern Canadian Cordillera (Stanley and others, 1990). The small tectonic lenses of terranes of alpine ultramafic and related rocks along the ancestral Denali fault (unit UM; Nokleberg and others, 1985, 1994a) may be remnants of this oceanic lithosphere.

(11) Coeval with accretion of the Wrangellia superterrane was intrusion of the Omineca-Selwyn anatectic granite belt (om) which occurs along the length of Canadian Cordillera and Alaska. Forming in or near the granite belt were the Bayonne (BA), Cassiar (CA), Selwyn (SW), Tombstone (TS), and Whitehorse (WH) metallogenic belts which contain granitic-magmatism-related deposits.

Metallogenic Belt Formed in Late Mesozoic Continental-Margin Arc, Russian Southeast Badzhal-Ezop-Khingan Metallogenic Belt of

Sn Greisen, Skarn, and Sn Quartz Vein Deposits (BZ-KH) Western Part of Russian Southeast

The Badzhal-Ezop-Khingan metallogenic belt of Sn greisen and Sn quartz vein deposits (fig. 61; tables 3, 4) occurs in the western part of the Russian Southeast. The belt consists of the Badzhal-Ezop and Khingan parts and is hosted in granitoid rocks of the Early and mid-Cretaceous Khingan-Okhotsk volcanic-plutonic belt (fig. 61; Nokleberg and others, 1994c, 1997c). The significant deposits in the belt are the Festivalnoe, Ippatinskoe, Loshadinayadgriva, and Solnechnoe Sn quartz vein deposits, the Olgakanskoe and Pravourmiskoe Sn greisen deposits, the Kapral porphyry Mo deposit, and the Ezop Sn polymetallic vein deposit (table 4) (Nokleberg and others 1997a, b, 1998).

The Badzhal-Ezop part, which occurs in the northern part of the metallogenic belt, consists of Sn greisen, Sn skarn, and Sn quartz vein deposits. Sn minerals are predominant; Pb, Zn, Ag, Bi, Cu, and W minerals are less prevalent. The distribution of the Sn deposits is zoned. Quartz-cassiterite deposits (mainly greisen with rare Sn skarn and Sn quartz vein deposits, as at Verkhne-Ippatinskoe, Shirotnoe, Ezop, and Pravourmiiskoe) occur along the contacts of large, crustal-origin granite and leucogranite intrusions. These occur mainly in the western part of the metallogenic belt adjacent to the craton. K-Ar isotopic studies indicate the Sn deposits and associated Sn granites formed between 75 to 100 Ma. The Badzhal-Ezop metallogenic belt contains Sn quartz vein deposits at Ezop, Festivalnoe, Ippatinskoe, Loshadinayadgrive, and Solnechnoe. Sn greisen and polymetallic vein deposits, as at Ezop, Olgakanskoe, and Pravourmiiskoe generally occur in veins.

Disseminated manto replacement deposits, as at Shirotnoe, also occur in the Badzhal-Ezop part of the belt. In this and similar deposits, a major and relatively older assemblage of ore minerals consists of quartz, cassiterite, topaz, fluorite, muscovite, tourmaline, arsenopyrite, molybdenite, and wolframite. A relatively younger and minor assemblage of ore minerals consists of sphalerite, galena, chalcopyrite, bismuthite, pyrrhotite, stannite, fluorite, and rare scheelite. This younger assemblage is more dominant to the east, away from source granitic intrusions, thereby illustrating a lateral zoning. This zoned change of mineral composition of ore from east to west is clearly observed in the Badzhal and Ezop mining districts. In addition to Sn, the greisen deposits often contain molybdenite and wolframite; locally each mineral is dominant.

The Khinghan part, which occurs in the southern part of the metallogenic belt, contains Sn deposits are mainly associated with potassic granitic intrusions with a K-Ar isotopic ages of 80 to 90 Ma (Ognyanov, 1986), and a Rb-Sr whole-rock isochron age of 78 Ma (Gonevchuk and others, 1998). Common in the belt are both Sn greisen deposits, with topaz-muscovite-quartz greisen which formed adjacent to plutons (as at Khingan, Nizhnee, Obeshchayushchee, and Verkhnebidzhanskoe deposits), and volcanic wood tin deposits (as at Dzhalinda) which formed in the upper part of felsic vents or calderas. The major Sn quartz vein deposits is at Verkhnebidzhanskoe.

Solnechnoe Sn Quartz Vein Deposit

The Solnechnoe Sn quartz vein deposit (fig. 73) (Ognyanov, 1986, Ishihara and others, 1997) consists of highly altered quartz-tourmaline veins with numerous apophyses is related to a long north-south, left-lateral, strike-slip fault. The deposit varies from 0.5 to 15 m thick, 800 m long, and extends to the depth more than 500 m below the surface. Five vertically-zoned mineral assemblages are distinguished, from bottom to top: (1) quartz-tourmaline; (2) quartz-arsenopyrite-cassiterite with wolframite, bismuthinite, and scheelite; (3) quartz-sulfide (pyrrhotite, chalcopyrite, and marcasite); (4) quartz-galena-sphalerite; and (5) quartz-carbonate. The deposit is closely related to a K-rich granite phase of a gabbro-diorite-granodiorite complex with K-Ar isotopic ages of 75 to 86 Ma. The deposit is medium with an average grade of 0.56% Sn, 0.05% W, and 0.1% Cu. The deposit has been mined since 1960's(?) and is mostly exhausted.

Pravourmiskoe Sn Greisen Deposit

The Pravourmiskoe Sn greisen deposit (fig. 74) (Ognyanov, 1986) consists of disseminations and in veins which occur in a linear area over 1500 m long, 5 to 25 m thick, and extends several hundred m down dip. An earlier ore assemblage consists of quartz-topaz-cassiterite with fluorite, and a later assemblage consists of quartz-arsenopyrite-chalcopyrite, and quartz-tourmaline with cassiterite and stibnite. In addition to Sn, W, and Cu; Bi, Pb, and Sb also occur. The gangue is composed of quartz-siderophyllite (zwitters) with quartz-topaz greisen. The deposit is large with an average grade of 0.1-5 % Sn, 0.05% WO_3, and 0.5% Cu. The deposit occurs along an east-west-trending thrust fault with small offset. The deposit is hosted in and genetically related to Late Cretaceous felsic volcanic rocks which overlie the large, shallow, granite and leucogranite complex of the Verkhneurmiisky batholith with K-Ar isotopic ages of 75 to 85 Ma. The granite has a long-ranging Rb-Sr age of 95 to 83 Ma with an initial Sr ratio of 0.703 to 0.708 (Lebedev and others, 1994).

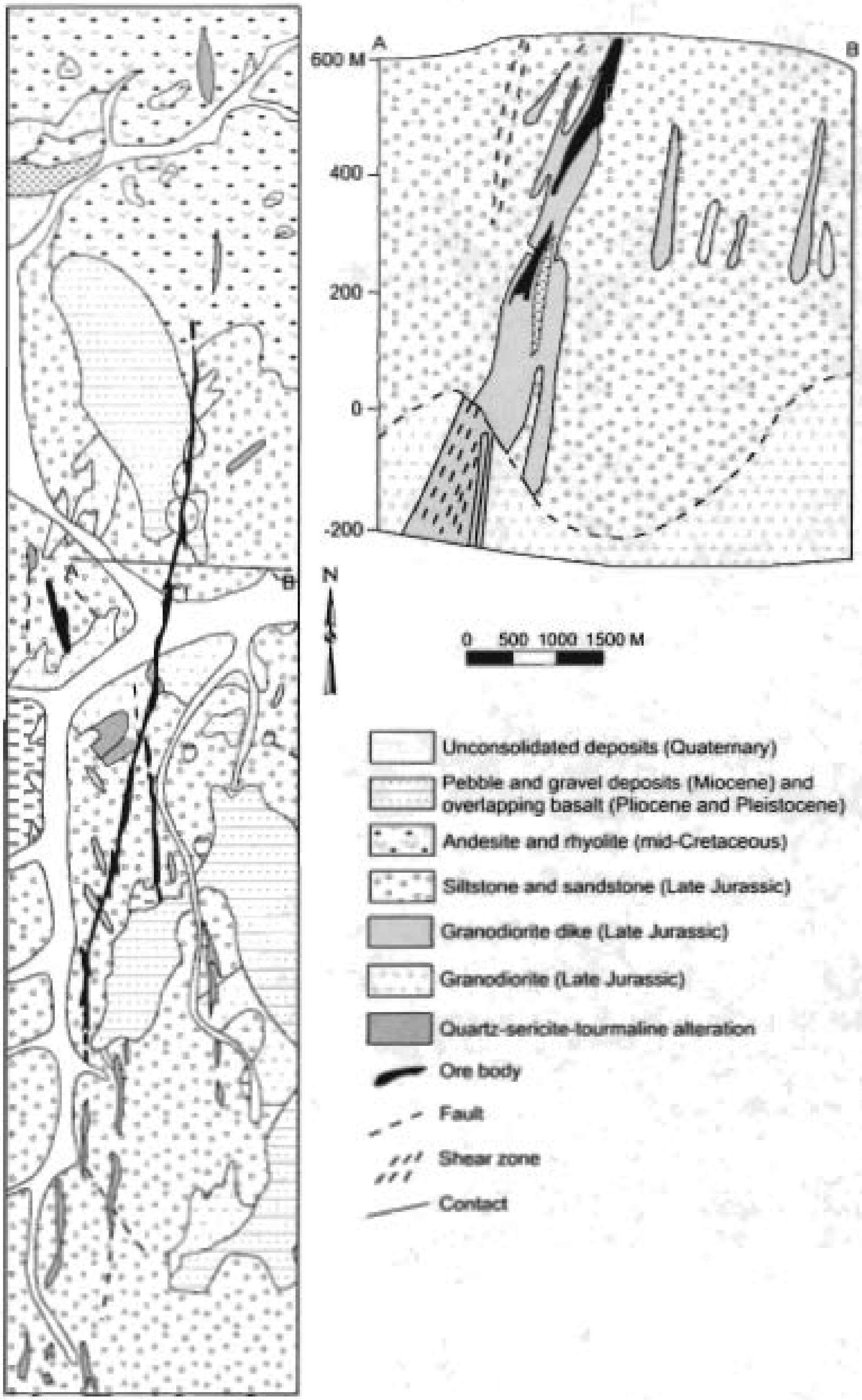


Figure 73. Solnechnoe Sn quartz vein deposit, Badzhal-Ezop-Khingan metallogenic belt, Russian Southeast. Schematic geologic map and cross section. Adapted from Vedernikov and Peltsman (1980).

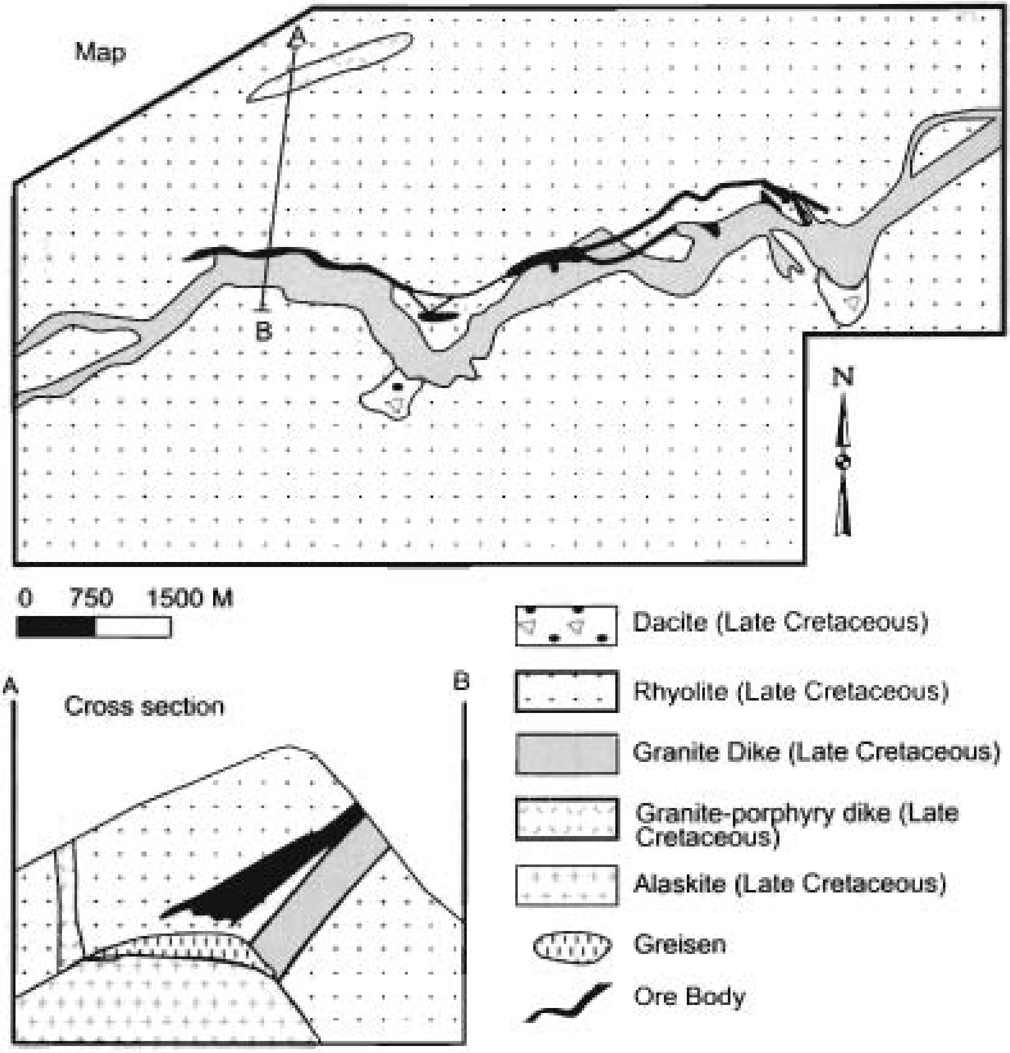


Figure 74. Pravourmiskoe Sn greisen deposit, Badzhal-Ezop-Khingan metallogenic belt, Russian Southeast. Adapted from Semenyak and others (1988).

Khingan Sn Greisen Deposit

The large and well known Khingan Sn greisen deposit (fig. 75) (Ognyanov, 1986) is of hypabyssal origin and occurs in a pipe-shaped ore bodies of hydrothermal explosion breccia which cut a sequence of felsic volcanic rocks. The deposit contains over 15 ore zones from 10 to 50 m across and 100 to 400-500 m which are concentrated down-dip in a symmetrical breccia zone about 250-300 m across. The zone has been traced to depths of over 1200 m. At the upper levels of the deposit, the breccia is replaced by chlorite, and at the depths of 700-800 m, the breccia is replaced by quartz-muscovite (sericite)-topaz greisen. Most of the ore zone is quartz-fluorite-cassiterite. Arsenopyrite, marcasite, loellingite, chalcopyrite, and Bi-minerals are subordinate. The deposit is interpreted as probably genetically related to subalkaline potassium granite with a K-Ar age of 80-90 Ma and a Rb-Sr whole-rock isochron age of 78 Ma with an initial Sr isotopic ratio of 0.7123 (Gonevchuk and others, 1991). The deposit has been mined since the 1970's.The deposit is of large and averages 0.6-0.7% Sn.

Verkhnebidzhanskoe Sn Quartz Vein Deposit

The Verkhnebidzhanskoe Sn quartz vein deposit (Ognyanov, 1986) is hosted in Late Proterozoic dolomite adjacent to a rhyolite porphyry stock. The deposit occurs at a tectonic contact of the dolomite with Late Proterozoic schist. The deposit consists of metasomatic quartz-sulfide lenses which range from 50 to 80 m along strike, and extend up to 70 m downdip with a maximum thickness of 10 to 12 m. The deposit extends for about 1,300 m. The dominate late-stage ore minerals are mainly sulfosalts (boulangerite, jamesonite) The subordinate, earlier-stage ore-minerals are quartz, cassiterite, and arsenopyrite. Alteration minerals include talc, calcite, siderite, and dolomite. Both the sedimentary and volcanic rocks are extremely rich in Sn (up to 10 clarkes). A Late Cretaceous rhyolite porphyry stock, which contains geochemically anomalous Sn (about 0.005%), is interpreted as the source for the vein Sn which formed during hydrothermal alteration. The deposit is small and contains an average of 0.3-2.0% Sn.

Origin of and Tectonic Controls for Badzhal-Ezop-Khingan Metallogenic Belt

The Sn deposits of the Badzhal (northern) part of the Badzhal-Ezop-Khingan metallogenic belt are hosted in, or near the Early and mid-Cretaceous Khingan-Okhotsk volcanic-plutonic belt (unit ko, fig. 61) (Nokleberg and others, 1994c, 1997c). The deposits occur mainly around the outcrops of large intrusions of crustal-derived granite and leucogranite or crustal- to mantle-derived granitoid rocks which intrude mainly along older, elongate, east-west-striking faults which were subduction zones in the Middle Jurassic to Early Cretaceous. The Cretaceous Khingan-Okhotsk volcanic-plutonic belt is divided into two main sequences: (1) Barremian to Cenomanian andesite and minor basalt, with coeval gabbro, diorite, and granodiorite. Andesite exhibits calc-alkalic composition, whereas basalt exhibits tholeiitic composition. And (2) Late Cretaceous (mainly pre-Senonian) suite of K-rich felsic volcanic rocks, tuff, ignimbrite, and coeval subvolcanic intrusive and granitoid rocks. These Cretaceous granitoid rocks include granite, leucogranite, and composite gabbro-diorite-granodiorite plutons (Ognyanov, 1986). The plutonic units are coeval and comagmatic with volcanic rocks; both suites exhibits high potassium contents. The Khingan-Okhotsk belt overlies the Turan and Malokhingask terranes of the Bureya continental-margin arc superterrane, and Badzhal and Ulban accretionary-wedge terranes (Nokleberg and others, 1994c, 1997c). The belt defines the Khingan continental margin arc in the Russian Southeast (fig. 61) (Nokleberg and others, 2000).

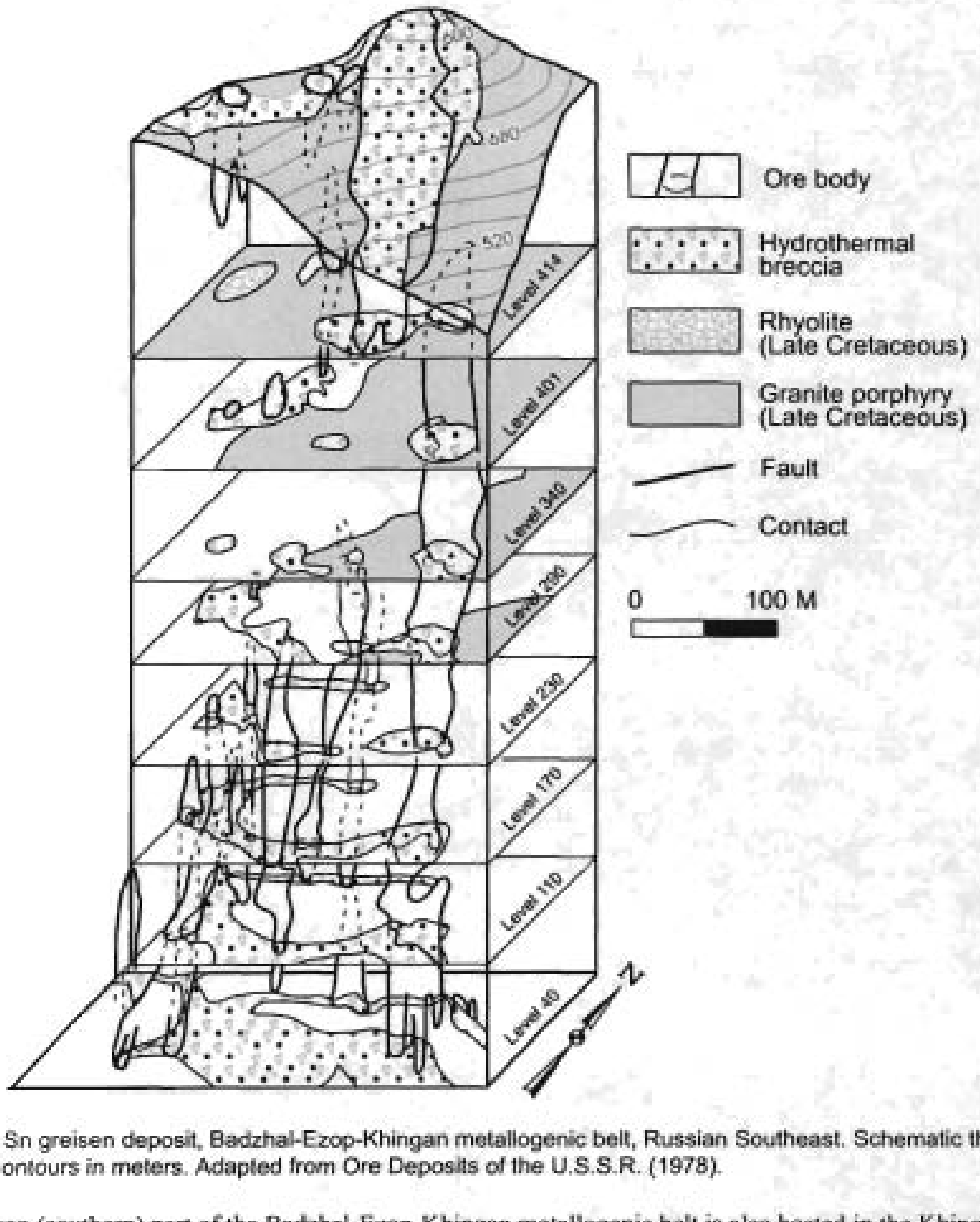


Figure 75. Khingan Sn greisen deposit, Badzhal-Ezop-Khingan metallogenic belt, Russian Southeast. Schematic three-dimensional figure. Levels and contours in meters. Adapted from Ore Deposits of the U.S.S.R. (1978).

The Khingan (southern) part of the Badzhal-Ezop-Khingan metallogenic belt is also hosted in the Khingan-Okhotsk volcanic-plutonic belt (isotopic age of 134 to 88 Ma). In the area underying the Khingan part of the metallogenic belt, these igneous rocks occur in a post-accretionary Cretaceous volcanic-tectonic depression in the eastern part of Bureya continental-margin arc superterrane. The volcanic-tectonic depression is filled with mid- Cretaceous, intermediate-composition volcanic rocks and overlying Late Cretaceous tuff and rhyolite lava. The volcanic rocks range from 1.5 to 3.0 km thick. The volcanic rocks rest on a basement Proterozoic metamorphic rocks of the Bureya superterrane. The intrusive rocks of the Khingan-Okhotsk belt in this area are dominantly granite and are comagmatic with the volcanic rocks. The granitoid rocks of the Khingan-Okhotsk belt are interpreted as subduction-related, calc-alkalic igneous rocks, which include both S- and I-type granites.

The Khingan continental-margin arc (ko) is herein interpreted as forming from oblique subduction of the ancestral Pacific Ocean plate. Fragments of this plate are interpreted as occurring in tectonically interwoven fragments of the Amur River (AM), Khabarovsk (KB; younger Early Cretaceous part), and Kiselevka-Manoma accretionary-wedge terranes (Natal'in, 1991, 1993; Nokleberg and others, 1994a; Sengör and Natal'in, 1996a, b). This tectonic pairing is based on: (1) occurrence of accretionary-wedge terranes outboard (oceanward) of, and parallel to the various parts of the Khinghan arc; (2) formation of mélange structures during the Early and mid-Cretaceous (Natal'in, 1991; Nokleberg and others, 1994a; Vrublevsky and others, 1988; Nechaev and others, 1996); and (3) where not disrupted by extensive Cretaceous movement along the Central Sihote-Aline strike-slip fault, dipping of mélange structures and bounding faults toward and beneath the igneous units of the arc (Natal'in, 1993). Formation of the Khingan arc and associated subduction is generally interpreted as ending in the late mid-Cretaceous when oblique subduction changed into sinistral-slip faulting along the outboard margin of the arc (Nokleberg and others, 2000).

Metallogenic Belts Formed in Late Mesozoic Collision and Accretion of Island Arcs, and Transform Continetnal-Margin Faulting, Russian Northwest, Western and Northern Alaska, and Northern Canadian Cordillera

Anadyr River Metallogenic Belt of Au Quartz Vein and Associated Deposits (Belt AD) Eastern Part of Russian Northeast

The Anadyr metallogenic belt of sparse Au quartz vein deposits occurs in the eastern part of the Russian Northeast in the Anadyr region (fig. 61, tables 3, 4) (Nokleberg and others, 1997b, 1998). The significant deposits are at Vaegi and Nutekin. Significant associated placer Au districts occur at Kenkeren, Otrozhny, and Pekulney (Nokleberg and others, 1997b, 1998). The knowledge of associated lode deposits is poor, although placer Au deposits were discovered in the Zolotoy Range in 1902. The placer Au districts overlie island arc and oceanic crust terranes which occur in intricate fold, thrust, and nappe structures.

The lode sources for the placer Au deposits are interpreted as: (1) various Au quartz and sulfide-quartz vein which containing feldspar, carbonate minerals, epidote, chlorite, and other minerals; and (2) various mineralized zones in Paleozoic and Mesozoic clastic rocks, chert, volcanogenic rocks which are intruded by Late Cretaceous calc-alkaline magmatism. Some Au occurrences are associated with PGE deposits which occur in silica-carbonate metasomatic rocks in serpentinite melange. Two small Au quartz vein occurrences are at Vaegi and Nutekin. Both are hosted in the Mainitskiy island-arc terrane (Nokleberg and others, 1997b, 1998).

The lode Au deposits of the Anadyr metallogenic belt are tentatively interpreted as forming mostly during late Early Cretaceous accretion and associated metamorphism and deformation of the Mainitskiy arc that includes the Mainitskiy and West Pekulney island-arc terranes and the Penzhina-Anadyr accretionary wedge or subduction-zone terranes (Nokleberg and others, 1994c, 1997c; 2000).

Vaegi Au Quartz Vein Occurrence

The small Vaegi Au quartz vein occurrence (M.N. Zakharov and V.P. Vasilenko, written commun., 1977) consists of thin quartz and carbonate-quartz veins and veinlets which contain disseminated gold, hematite, pyrite, and chalcopyrite with spare arsenopyrite. The deposit is hosted in Paleozoic and supposed Proterozoic intermediate metavolcanic rocks. Gold-cinnabar intergrowths occur in nearby heavy mineral placers which have been mined. The deposit occurs in a nappe of early Paleozoic and possibly older metavolcanic rocks which display both greenschist facies metamorphism and extensive host rock replacement by sulfide minerals and quartz, and which may have potential for vein and disseminated Au deposits (Ivanov and others, 1989).

Nutekin Au Quartz Vein Occurrence

The small Nutekin Au quartz vein occurrence (V.P. Vasilenko, written commun., 1977) consists of steeply-dipping quartz and quartz-carbonate veins which grade into zones of silicified and sulfidized veinlets along strike. The deposits trend northwest and are up to 500 m long. The Au-bearing veins occur in early Mesozoic, and less frequently Early Cretaceous, clastic sedimentary rocks. The highest Au contents are in veins within Paleogene dolerite dikes. The Au is associated with rare disseminated pyrite and arsenopyrite, and is marked by high Hg content. The deposit occurs in the axial portion of a horst-anticlinorium structure.

Nome Metallogenic Belt of Au Quartz Vein Deposits (Belt NO) Seward Peninsula

The Nome metallogenic belt of Au-bearing quartz vein deposits (fig. 62; tables 3, 4) forms a 200 km long, east-west-trending belt along the southern part of the Seward Peninsula. The metallogenic belt occurs along the southern margin of the Seward metamorphosed continental margin terrane (Nokleberg and others, 1994c, 1997c). The most favorable mineralized areas are associated with upper greenschist facies metamorphic rocks. Two major concentrations of deposits occur at (table 4) (Nokleberg and others 1997a, b, 1998): (1) Bluff and Big Hurrah in the Solomon District; and (2) Rock Creek, Mount Distin, and Sophia Gulch in the Nome District. In both areas, the deposits consist mainly of mesothermal, sulfide-poor, Au-quartz deposits in individual high grade veins or in zones of multiple, more-or-less en-echelon, sheeted veins which generally contain lower Au grades. The quartz veins, which typically contain minor carbonate, albite, and oligoclase, cut shallow-dipping metamorphic foliation. The best studied deposits in the Nome district are at Rock Creek and Mount Distin, both immediately north of Nome (Gamble and others, 1985; Apodaca, 1992). These newly evaluated lodes may be examples for the rich placer Au deposits mined in the Nome District.

In the Nome district, Bundtzen and others (1994) recognize three major mineral deposit types: (1) early-stage chalcopyrite-sphalerite-gold-quartz-carbonate veins, which appear as boudins which are rolled around early fold axes (Banger deposit); (2) Au-quartz polysulfide veins which crosscut schistosity at low angles (Rodine, McDuffy, and Twin Mountain deposits); and (3) brittle, Au-polysulfide-quartz-albite-carbonate veins which crosscut schistosity at high angles (Rock Creek, Sliscovish, Sophies Gulch deposits). The Au deposits are thought to have formed during various stages of dewatering of a metamorphic pile during Barrovian-type, greenschists facies regional metamorphism and associated plutonism, as interpreted for the Rock Creek deposit (Apodaca, 1992), and for the Mt. Distin and Bluff and deposits (Ford, 1990). However, recent Ar-Ar isotopic studies indicate the vein mica from quartz veins at the Bluff deposit formed at about 109 Ma, about 30 m.y. after metamorphic mica in the area reached closure temperature (Ford and Snee, 1996).

Rock Creek Au Quartz Vein Deposit

The Rock Creek Au quartz vein deposit (Ted Eggelston and R.V. Bailey, written commun., 1990-1991; Apodaca, 1992) consists of arsenopyrite, scheelite, galena, stibnite, and pyrite which occur in a northeast-trending, sheeted, quartz vein system. At the surface, the deposit extends for 1,200 meters along strike, averages 70 meters width, and extends up to 150 meters in depth. The host rocks are phyllite and schist of the Paleozoic Nome Group. Fluid inclusion studies indicate ore deposition occurred in the mesothermal range (240°C-320°C). The ore minerals occur along selvages of quartz vein-host rock contacts. Vein mica yields an Ar-Ar isotopic age of 109 to 104 Ma (T.K. Bundtzen and P.W. Layer, written commun., 1995). The deposit is interpreted as forming by hydrofracturing and dewatering during the waning stage of a mid-Cretaceous metamorphic event. The deposit contains an estimated 10.2 million tonnes grading 2.4 g/t Au and about 0.43% W (Swainbank and Szumigala, 2000). At Mount Distin, several similar, en-echelon Au quartz veins occur along an east-west-trending thrust fault for at least 3 km.

Big Hurrah Au Quartz Vein Deposit

The Big Hurrah deposit (Collier and others, 1908; Cathcart, 1922; Asher, 1969; Mullen, 1984; Gamble and others, 1985; Read, 1985; Read and Meinert, 1986) consists of four major quartz veins, and zones of ribbon quartz. The major veins and ribbon zones range from 1 to 5 m thick and are a few hundred meters long. The veins contain sparse gold, pyrite, and arsenopyrite, and minor scheelite, chalcopyrite, and sphalerite, in a gangue of quartz, carbonate, and feldspar. These veins are intermixed with older, concordant, non-Au-bearing, metamorphic quartz veins. The Au-bearing veins range from discordant tension veins to discontinuous quartz lodes which occur in shear zones crossing foliation. The Au-bearing veins range from 0.5 to 5 m wide and extend to a depth of at least 90 m. Most of the veins are less than 1 m wide. The veins and ribbon quartz zones are hosted in quartz-rich,, graphitic, quartz-mica schist or quartzite of the Paleozoic Nome Group. The veins are interpreted as forming during shearing and uplift associated with metamorphic dehydration in the mid-Cretaceous. Mining occurred at the deposit from 1903-1909, and from 1953-1954. The deposit has produced about 839 kg Au, averaging about 34.3 g/t Au (Reed and Meinhart, 1986). Recent assays range from 25 to 65 g/t Au.

Origin of and Tectonic Controls for Nome Metallogenic Belt

The Big Hurrah and Bluff deposits in the Solomon district and the deposits in the Nome district exhibit several similarities, including low-sulfide mineral concentration, fault localization, and confinement to low-grade, greenschist facies metamorphic rocks. In all the deposits, a post-metamorphic fluid origin is suggested for the deposits by (Gamble and others, 1985): (1) the discordance of the veins to metamorphic foliations; (2) oxygen isotope and fluid inclusion data; and (3) the lack of coeval intrusions in the belt. These relations indicate that the Au deposits formed from fluids which equilibrated with the sedimentary and (or) volcanic protoliths of the Nome Group under greenschist facies regional metamorphism. Subsequently, the fluids moved upward during a later, post-kinematic event to deposit the vein minerals. As in the southern Brooks Range, regional metamorphism of the Seward metamorphosed continental margin terrane occurred during two stages. A relatively older blueschist facies event in the Jurassic was followed by: (1) thrusting of oceanic units of the Angayucham terrane onto the passive continental-margin arctic Alaska superterrane; and (2) subsequent, Early to mid-Cretaceous extensional, retrograde, greenschist metamorphism (Armstong and others, 1986; Moore and others, 1994; Miller and Hudson, 1991; Till and Dumoulin, 1994).

The Nome metallogenic belt is interpreted as forming in the waning stages of extension, which is defined by Early to mid-Cretaceous greenschist facies metamorphism and companion penetrative deformation (Miller and Hudson, 1991; Moore and others, 1992; Nokleberg and others, 1994c, 1997c; Goldfarb, 1997). In a few areas, the Nome Group exhibits an older, relict blueschist facies metamorphism which is interpreted as forming in a Jurassic or older period of convergent deformation and metamorphism (Armstrong and others, 1986; Moore and others, 1994; Till and Dumoulin, 1994). The convergent deformation and blueschist facies metamorphism is interpreted as forming during Late Jurassic and Early Cretaceous subduction of the Seward terrane under the oceanic Angayucham terrane, resulting in formation of the Koyukuk island-arc terrane to the south (present-day coordinates) (Moore and others, 1994; Patton and others, 1994; Plafker and Berg, 1994; Nokleberg and others, 2000). Incremental Ar isotopic studies suggest quartz vein formation at about 109 to 104 Ma (Ford and Snee, 1996), and which quartz vein formation was temporally related to a thermal pulse. This thermal pulse is also interpreted as causing high-grade metamorphism and anatectic plutons to the north in the Kigluaik Mountains, and to the east in the Bendeleben and Darby Mountains (Ford and Snee, 1996). The Au quartz vein deposits of the Nome metallogenic belt are interpreted as coeval with the Au quartz vein deposits in the Southern Brooks Range metallogenic belt to the northeast.

Southern Brooks Range Metallogenic Belt of Au Quartz Vein Deposits (Belt SBR) Northern Alaska

The Southern Brooks Range metallogenic belt of Au-bearing quartz vein deposits (fig. 62; tables 3, 4), which includes the Chandalar district, lies in the southern Brooks Range. The metallogenic belt is hosted in both the Hammond terrane (Arctic Alaska superterrane) and the Coldfoot terrane to the south (Nokleberg and others, 1994c, 1997c). The significant deposits are at Little Squaw and Mikado in the Chandalar district (table 4) (Nokleberg and others 1997a, b, 1998). Recent work on Au-bearing quartz vein deposits in the Wiseman area is summarized by Eden (2000).

Mikado Au Quartz Vein Deposit

The Mikado Au quartz vein deposit (Chipp, 1970; DeYoung, 1978; Dillon, 1982; Ashworth, 1983; J.T. Dillon, oral commun., 1986; Rose and others, 1988) consists of several quartz veins up to 3 m thick in a zone about 4.0 km long and 1.6 km wide. The veins contain scattered, minor arsenopyrite, galena, sphalerite, stibnite, and pyrite and sparse gold. The veins occur along steeply dipping normal faults in Devonian or older quartz-muscovite schist, phyllite, and quartzite. The Little Squaw Mining Company drove more than 1,000 m of underground workings from 1980 to 1983. Minor production and several episodes of exploration activity have occurred, notably during the 1920's and 1960's. The Mikado deposit contained an estimated 12,000 tonnes averaging 75 g/t Au, and produced about 542 kg Au from ore averaging about 30 g/t Au (Bundtzen and others, 1994). The Mikado deposit and surrounding district contains an estimated remaining 45,000 tonnes grading 30 g/t Au.

Origin of and Tectonic Controls for Southern Brooks Range Metallogenic Belt

The Au quartz vein deposits occur along steeply dipping normal faults in greenschist facies metasedimentary rocks that are part of a structurally complex, polymetamorphosed, and poly-deformed assemblage of Devonian or older carbonate rocks, including the Skajit Limestone, calc-schist, quartz-mica schist, and quartzite, which are intruded by Proterozoic and Late Devonian gneissic granitoid rocks. These early Paleozoic metasedimentary rocks and Devonian metagranitoid rocks form a major part of the Hammond passive continental margin terrane of the Arctic Alaska superterrane (Jones and others, 1987; Moore and others, 1992).

Field relations indicate the deposits, that were deposited from hydrothermal fluids, were deposited during normal faulting. The normal faulting may be associated with a period of regional extension which was associated with the waning stages of greenschist facies regional metamorphism and companion penetrative deformation in the Early to mid-Cretaceous (Moore and others, 1992; Nokleberg and others, 1994c, 1997c). This period of regional metamorphism is interpreted as the last major metamorphic event in the Hammond and Coldfoot terranes. In a few areas, the Coldfoot and Hammond terranes exhibit relict blueschist facies minerals which are interpreted as forming in a Jurassic or older period of convergent deformation and metamorphism (Moore and others, 1994). The convergent deformation and blueschist facies metamorphism probably occurred during Late Jurassic and Early Cretaceous subduction of the Coldfoot and Hammond terranes under the Angayucham subduction zone terrane, and Koyukuk island-arc terrane to the south (Moore and others, 1994; Patton and others, 1994; Plafker and Berg, 1994; Nokleberg and others, 2000). As in the Nome region, the regional blueschist facies metamorphism was followed by: (1) thrusting on oceanic units of the Angayucham terrane onto the Coldfoot and Hammond terranes, and other parts of the passive continental-margin arctic Alaska superterrane; and (2) extensional, Early to mid-Cretaceous retrograde, greenschist metamorphism and formation of Au quartz vein deposits (Armstong and others, 1986; Moore and others, 1994; Till and Dumoulin, 1994). The Au quartz vein deposits of the Southern Brooks Range metallogenic belt only occur in a small portion of the greenschist facies metasedimentary rocks of the southern Brooks Range. However, the more extensive placer Au deposits along the Brooks Range may be derived from undiscovered, or now totally eroded Au quartz vein deposits. The Au quartz vein deposits in the Southern Brooks Range metallogenic belt are interpreted as coeval with the Nome metallogenic belt to the southwest.

Fish River Metallogenic Belt of Sedimentary P and Fe Deposits (Belt FR) Northern Yukon Territory

The Fish River metallogenic belt of sedimentary P and Fe deposits occurs in the northern Yukon Territory (fig. 62; tables 3, 4) (Nokleberg and others, 1997b, 1998)and is hosted in the Early Cretaceous Blow River Formation. The significant deposits are at Big Fish River and Alto. The Fish River metallogenic belt is herein tentatively interpreted as forming during Late Mesozoic, dextral movement along the Kaltag-Porcupine fault system.

The Fish River (Big Fish, Boundary, Rapid) stratabound Fe-P deposit consists of siderite and phosphatic ironstone which occur in shale in an Early Cretaceous (Albian) clastic wedge (Yukon Minfile, 1988; Butrenchuk, 1996). The ironstone consists of phosphate-siderite pellets and granules in a matrix of detrital quartz and mudstone. Rare phosphate minerals occur in epigenetic fracture veins and to a lesser degree in vugs, bedding plane partings, and fault breccia. The deposit is the well-known type locality of lazulite, the official Yukon gemstone. Estimated resources are over 1 billion tonnes grading 40% Fe.

The Alto oolitic magnetite iron formation is hosted in black shale of the Jurassic and Cretaceous Kingak Formation (Norris, 1976; Yukon Minfile, 1987). The deposit consists of olitic magnetite which occurs in a 45-m-thick bed, which occurs for a strike length of 350 m, and is part of a recessive-weathering black shale which is about 50 m above the base of the Kingak Formation. Estimated resources are 50 million tonnes grading 55% Fe (Norris, 1976).

The Early Cretaceous Blow River Formation is part of a thick, clastic wedge deposited in the Blow Trough which is interpreted as forming during late Mesozoic, dextral movement along the Kaltag-Porcupine fault system (Norris and Yorath, 1981). The sideritic ironstone and phosphorites are interpreted to be distal, reworked deep water pellet packstone deposits within a thick silt and conglomerate unit with a westerly clastic source (Yeo, 1992). The Blow River Formation contains an estimated P_2O_5 resource of approximately 7 billion tonnes, in addition to a larger resource of low-grade iron ore Young (1977b).

Metallogenic Belts Formed in Late Mesozoic Collision and Accretion of Wrangellia Superterrane, and Generation of Omineca-Selwyn Plutonic Belt, Canadian Cordillera

Selwyn Metallogenic Belt of W-Cu Skarn, Zn-Pb-Ag Skarn, and Zn-Pb-Ag Manto Deposits, Eastern and Northeastern Yukon Territory (Belt SW)

The Selwyn metallogenic belt W-Cu skarn, Zn-Pb-Ag skarn, and Zn-Pb-Ag manto deposits (fig. 62; tables 3, 4) occurs in the eastern and northeastern Yukon Territory and consists primarily of an arcuate belt of W-Cu (Zn-Mo) skarns, and Zn-Pb-Ag (Cu-W) skarns and manto deposits which are hosted in or near the related granitoid stocks of the mid-Cretaceous Selwyn Plutonic Suite (Anderson, 1983b). This suite is part of the Omineca-Selwyn plutonic belt which extends from southeastern Yukon Territory and southwestern Northwest Territories, northwestward into the Mayo district. The major W skarn deposits are at Bailey (Pat), Canada Tungsten (Cantung), Lened (Rudi, Godfrey), MacTung (MacMillan Tungsten), and the major Pb-Zn skarn and manto deposits are at Sa Dena Hes (Mt. Hundere), McMillan (Quartz Lake), and Prairie Creek (Cadillac; table 4) (Nokleberg and others 1997a, b, 1998). Other potentially economic skarn tungsten deposits in the belt include, from southeast to northwest, Bailey with an estimated resource of 405,454 tonnes grading 1.0% WO_3, Baker-Lened with an estimated resource of 750,000 tonnes grading 1.2% WO_3, and Clea (Dawson, 1996c).

Canada Tungsten (Cantung) W Skarn Deposit

The Canada Tungsten (Cantung) W skarn deposit (fig. 76) consists of pyrrhotite, scheelite and chalcopyrite with minor sphalerite in diopside skarn bodies which replace two members of Early Cambrian limestone (Sinclair, 1986; EMR Canada, 1989; Yukon Minfile, 1990; Dawson and others, 1991). The host rocks are the Cambrian to Devonian part of the North American Continental Margin. The skarns are related to intrusion of a Late Cretaceous quartz monzonite (K-Ar age of 94.6 Ma) of the Selwyn Plutonic Suite. Prograde garnet-pyroxene skarn is overprinted by a hydrous, retrograde, pyrrhotite-andradite-amphibole-biotite-scheelite skarn. The deposits include the Pit orebody which produced 1.51 million tonnes of ore yielding 40,087 tonnes of WO_3 between 1962 and 1986, and the E-Zone orebody with reserves of 4.2 million tonnes grading 1.6% WO_3 and 0.23% Cu, with associated Bi (Dawson, 1996c; Matheison and Clark, 1984). The large, high-grade E-zone scheelite orebody contains estimated combined reserves and resources of 7 million tonnes grading 1.5% WO_3 and 0.2% Cu. Production, that ceased in 1986, resumed in

2001 on mineable reserves of 630,00 tonnes of 1.82% WO3.(North American Tungsten Corporation news release, January 21, 2001).

Macmillan Pass (Mactung) Skarn W Deposit

The Macmillan Pass (Mactung) skarn W deposit consists of scheelite, pyrrhotite and minor chalcopyrite in several pyroxene-garnet skarns which replace Cambrian to Ordovician limestone and limestone breccia (Sinclair, 1986; EMR Canada, 1989; Dawson and others, 1991; Mining Review, 1992). The host rocks are part of a folded Cambrian and Devonian outer-shelf sequence of carbonate and pelitic rocks of the North American Continental Margin. The host rocks are flanked by and inferred to be underlain by the Late Cretaceous quartz monzonite Mactung stock (with a K-Ar isotopic age of 89 Ma) of the Selwyn Plutonic Suite. Hydrothermal alteration has produced three distinct concentric skarn zones: a peripheral zone of garnet-pyroxene skarn; an intermediate zone of pyroxene skarn; and a central zone of pyroxene-pyrrhotite skarn. Estimated combined reserves and resources are 32 million tonnes grading 0.92 WO_3 (Atkinson and Baker, 1986; Dawson and others, 1991).

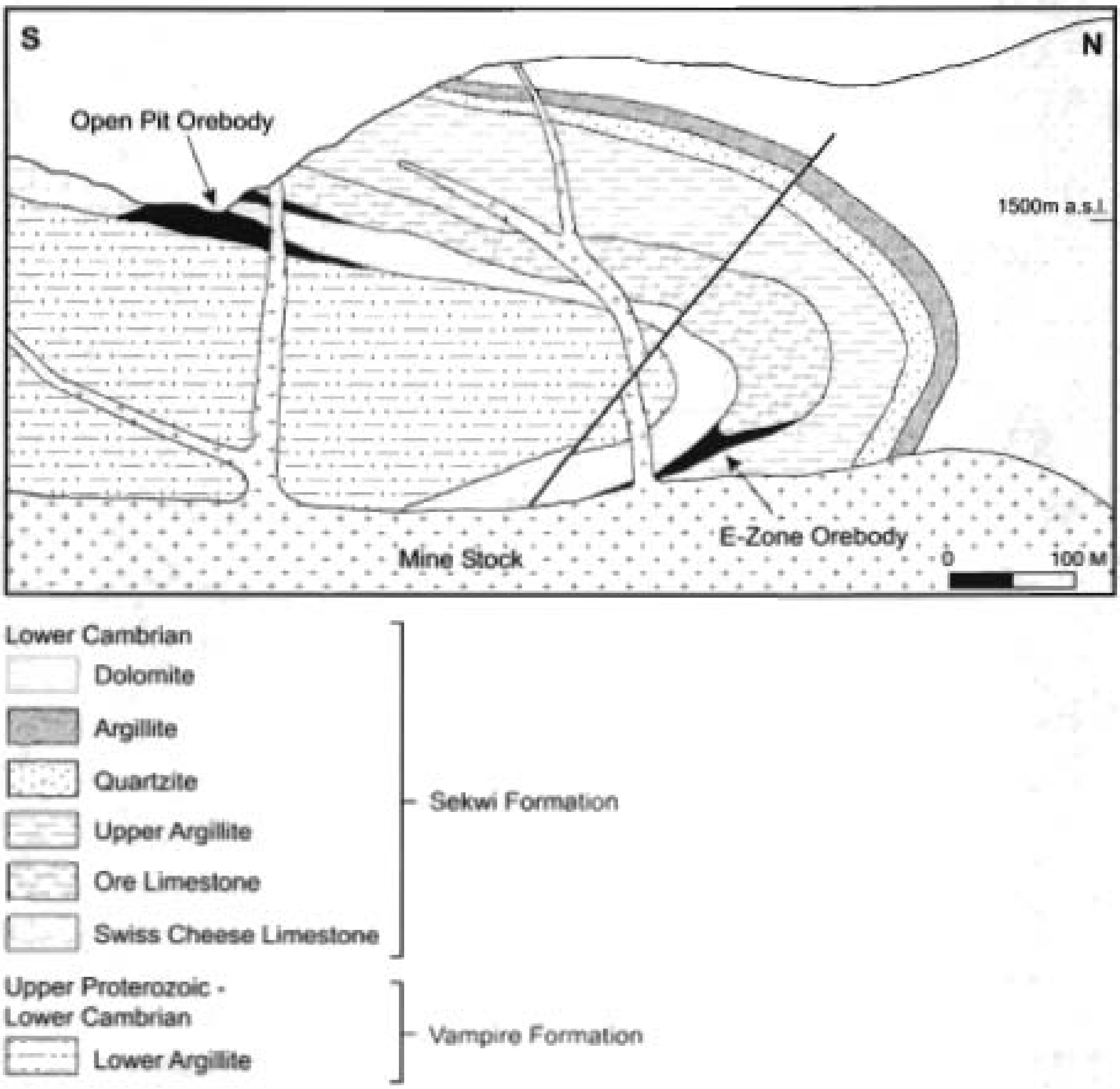


Figure 76. Canada Tungsten W skarn deposit, Selwyn metallogenic belt, Canadian Cordillera. Schematic cross section. Adapted from Gordey and Anderson (1993).

Sa Dena Hes, Quartz Lake, and Prairie Creek Skarn and Manto Zn-Pb-Ag Deposits

Zn-Pb-Ag skarn deposits occur in several belts adjacent to the Mount Billings batholith in southeastern Yukon Territory, and the Flat River and smaller stocks in southwestern Northwest Territories. The associated granitoid plutonic rocks are part of the

Selwyn Plutonic Suite. The host rocks are mainly Early Cambrian limestone; the associated granitoid plutons range from high-silica leucogranite and topaz granite to syenite. Diorite dikes also occur. In most cases, Zn skarns occur distally with respect to associated igneous rocks (Dawson, 1996a).

The Sa Dena Hes deposit at Mount Hundere, near Watson Lake, Yukon Territory consists of at least four tabular skarn and manto ore bodies (Abbott, 1981; Bremner and Ouellette, 1991; Northern Miner, October 7, 1991). The ore bodies are concordant to bedding in a deformed, Late Proterozoic and Early Cambrian craton margin sequence of limestone and phyllite. No nearby igneous rocks are exposed. The limestone is replaced by coarse-grained actinolite-hedenbergite-grossularite skarn, with pyrrhotite, magnetite, sphalerite, pyrite, and galena, and retrograde quartz and fluorite. The deposit has pre-production reserves of 4.8 million tonnes grading 12.7% Zn, 4% Pb, and 59 g/t Ag (Dawson and Dick, 1978; Dawson, 1996a).

The Quartz Lake (McMillan) deposit is a pyrite-bearing Zn-Pb-Ag manto which is probably related to small, nearby Cretaceous plutons. The deposit occurs in southeastern Yukon and consists of a series of tabular and concordant bodies, lenses, and disseminations which replace limy quartzite and argillite of the Late Proterozoic to Early Cambrian Hyland Group of the North American Craton Margin. The deposit consists pyrite, galena, and sphalerite, with minor arsenopyrite, boulangerite, tetrahedrite, and chalcopyrite. Galena-lead isotopes indicate an age of ca. 100 Ma, similar to which of intrusives of the Selwyn suite (Godwin and others, 1988). Estimated reserves are 1.5 million tonnes grading 6.6% Zn, 5.5% Pb, and 102 g/t Ag (Morin, 1981; Vaillancourt, 1982).

Recent exploration at the Prairie Creek (Cadillac) prospect, which occurs near the South Nahanni River, Northwest Territories, reveals a stratabound deposit with characteristics of a Zn-Pb-Ag manto which occurs at depth beneath an extensive vein zone. No plutons are associated with the deposit which consists of galena and sphalerite, with minor tetrahedrite and chalcopyrite hosted in a quartz-carbonate gangue. The deposit occurs along a strike length of 10 km in 12 lenticular, stratabound vein zones which are hosted in shale and dolomite of the Middle Devonian Arnica Formation. Six deeper concordant ore lenses in the subjacent Ordovician Whittaker Formation are over 22 m thick. An estimated resource of 6.2 million tonnes grades 13% Zn, 12% Pb, and 180 g/t Ag (San Andreas Resources Corp., News Releases, 1992, 1993, 1994, 1995; Dawson, 1996a).

Origin of and Tectonic Controls for Selwyn Metallogenic Belt

The Selwyn metallogenic belt contains one of the world's largest reserves and resources of W skarn deposits. The associated plutons, part of the Selwyn Plutonic Suite, are mainly equant, high level bodies of granite, granodiorite and quartz syenite with pronounced S-type characteristics, which discordantly intrude Late Proterozoic to early Paleozoic carbonate and pelitic rocks of the North American Craton Margin (fig. 62). The Selwyn Plutonic Suite is interpreted to have formed from thickening and melting of the continental crust in the outer part of a miogeoclinal sedimentary wedge during regional compression (Woodsworth and others, 1991). Skarn W deposits commonly are associated with marginal or satellite phases of two-mica granites with aluminous accessory minerals (Anderson, 1983b). Radiometric ages for the plutonic suite range from 88 to 114 Ma, but most skarns are associated with early-phase plutons which range in age between 112 and 100 Ma (Mortensen and others, 1994).

The Selwyn Plutonic Suite is part of the collisional mid-Cretaceous Omineca-Selwyn plutonic belt which extends from the southern part of the Canadian Cordillera, across Interior Alaska, northwestward into the Russian Northeast, and consists chiefly of granodiorite, granite, quartz syenite and minor syenite plutons of Early to mid-Cretaceous age (110-90 Ma) (Monger and Nokleberg, 1996; Nokleberg and others, 1994c; 2000). The spatial location of the belt, about 200 km west of the eastern limit of Cordilleran deformation, and chemistry suggests an anatectic origin of partial melting of cratonic crust during thickening caused by Cretaceous contraction (Monger and Nokleberg, 1996; Nokleberg and others, 2000) which was associated with orthogonal convergence between the Farallon Oceanic Plate and North America (Englebretson and others, 1985; 1992), and subsequent regional extension (Pavlis and others, 1993). Other metallogenic belts of granitic-magmatism-related deposits hosted in the Omineca-Selwyn plutonic belt in the Canadian Cordillera, Alaska, and the Russian Northeast include the Bayonne, Cassiar, Tombstone, and Whitehorse belts (fig. 62; tables 3, 4). Two other interpretations for the origin of the Omineca-Selwyn plutonic belt and related metallogenic belts are: (1) formation during A-type subduction of the miogeocline and transtensional tectonics (Woodsworth and others, 1991; or (2) formation in the rear of a single broad, mid-Cretaceous, Cordillera-wide, subduction-related arc (Armstrong, 1988).

Tombstone Metallogenic Belt of Ag Polymetallic Vein, Au-Sb Vein, and W-Sn-Au and Cu-Au Skarn Deposits, Central Yukon Territory (Belt TS)

The Tombstone metallogenic belt of Ag polymetallic vein, Au-Sb vein, and W-Sn-Au and Cu skarn deposits (fig. 62; tables 3, 4) occurs in the central Yukon Territory, and is associated with late Early Cretaceous mafic to intermediate, alkalic plutons of the Tombstone Plutonic Suite which occurs in the Tombstone and Syenite Ranges of the northwestern Yukon Territory (Woodsworth and others, 1991; Mortensen and others, 1994). The belt contains major Ag polymetallic vein deposits at Keno Hill (Galena Hill), Craig (Tara, Nadaleen Mountain), and Rusty Mountain (Vera, Val, Cavey), a Sb-Au vein at Brewery Creek (Loki Gold), and a W skarn deposit at Ray Gulch (Potato Hills, Mar; table 4) (Nokleberg and others 1997a, b, 1998). An exploration model for intrusion-related Au systems has been developed from the Tombstone Plutonic Suite by Lang and others (2000).

Keno Hill-Galena Hill District of Ag Polymetallic Vein Deposits

The Keno Hill-Galena Hill district of Ag polymetallic vein deposits (fig. 77) consists of argentiferous galena, freibergite, and pyrargyrite with minor polybasite, stephanite, argentite and native silver which occur in fault veins, breccias and sheeted zones (Watson, 1986; Lynch, 1989; Murphy and Roots, 1992; Yukon Minfile, 1992). The deposit is hosted predominantly within the Keno Hill Quartzite of the Early Mississippian Upper Earn Group which forms part of a Devonian and Mississippian clastic wedge in the North American Craton Margin. Two stages of veining occur: an earlier stage of quartz-pyrite-arsenopyrite-sulphosalts and trace Au which formed prior to movement on fault veins; and a post-fault set of siderite-galena-sphalerite-pyrite-friebergite-pyrargyrite. A K-Ar isotopic age of 90 Ma age, which is interpreted as age of deposit, may be related to granitoid intrusions of similar age to the north and south of Keno Hill. Between 1921 and 1988, estimated production was 6769 t of Ag, half of which came from the Elsa, Keno No. 9, Lucky Queen, Silver King, Sadie-Ladue, and Husky Mines. Total production was 4.87 million tonnes of ore of average grade 1412 g/t Ag, 6.8% Pb, 4.6% Zn and 0.02 g/t Au (Yukon Minfile, 1992). More than 65 ore deposits and prospects occur in the district. The Keno Hill-Galena Hill district is the second largest silver producer in Canada. Similar Ag polymetallic vein districts occur to the west and northwest of Keno Hill at Nadaleen Mountain, Rusty Mountain, Kathleen Lakes, and McKay Hill.

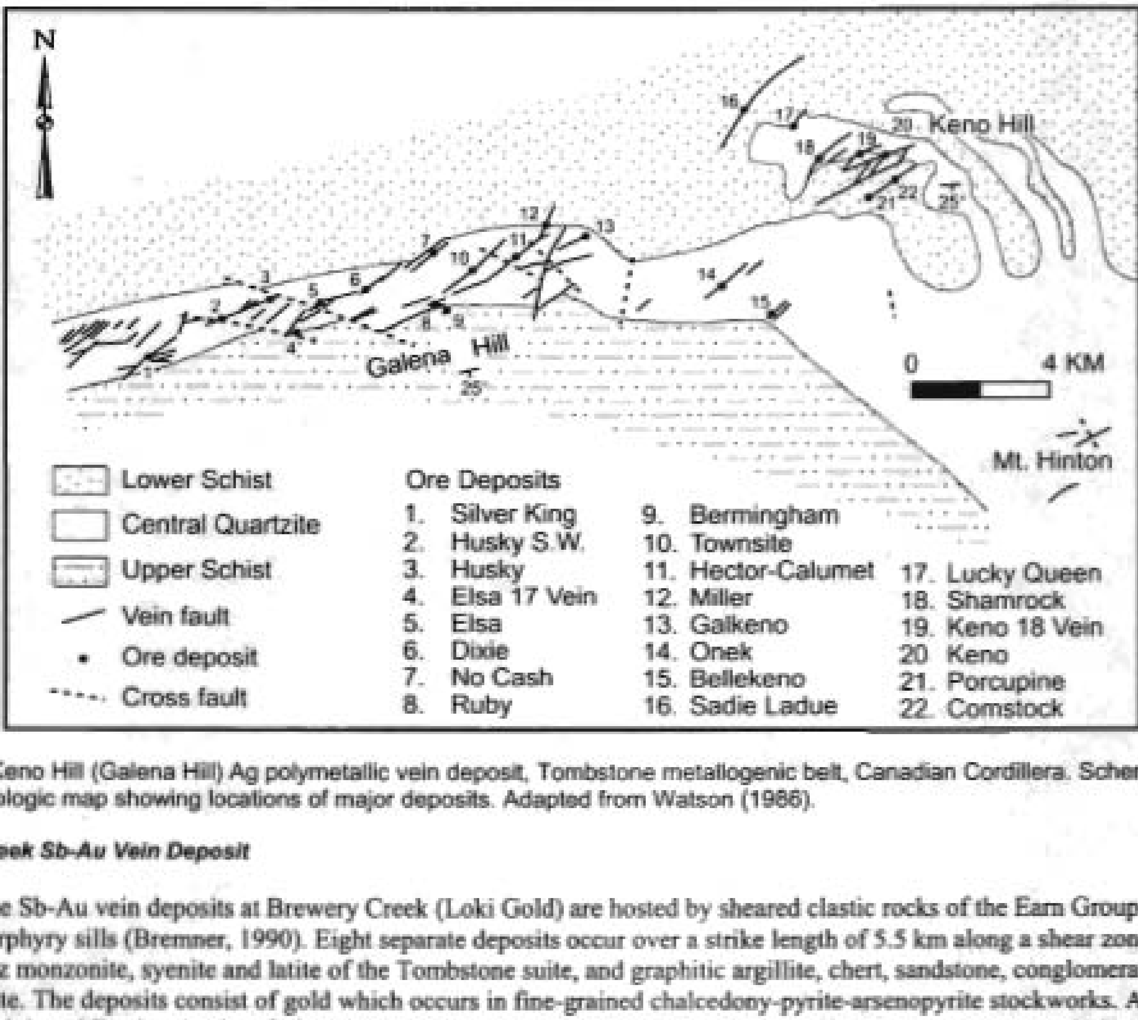


Figure 77. Keno Hill (Galena Hill) Ag polymetallic vein deposit, Tombstone metallogenic belt, Canadian Cordillera. Schematic regional geologic map showing locations of major deposits. Adapted from Watson (1986).

Brewery Creek Sb-Au Vein Deposit

The Sb-Au vein deposits at Brewery Creek (Loki Gold) are hosted by sheared clastic rocks of the Earn Group and adjacent porphyry sills (Bremner, 1990). Eight separate deposits occur over a strike length of 5.5 km along a shear zone between a sill of quartz monzonite, syenite and latite of the Tombstone suite, and graphitic argillite, chert, sandstone, conglomerate and bedded barite. The deposits consist of gold which occurs in fine-grained chalcedony-pyrite-arsenopyrite stockworks. About 90% of the deposit is oxidized at depths of 10-110 m. Narrow quartz-stibnite veins post-date the Au veins. An open pit, heap-leach mine started at the deposit in 1995 with estimated pre-production reserves of 19.2 million tonnes grading 1.53 g/t Au (Bremner, 1990; Loki Gold Corp., News Release, January 11, 1994). Other Au-Sb (W-Pb-Ag) veins in the region are at Antimony Mountain, West Ridge, and Spotted Fawn.

Eagle (Dublin Gulch) Porphyry Au-W Deposit

The Eagle (Dublin Gulch) porphyry Au-W deposit consists of granitoid-related Au vein stockworks which are similar to the Fort Knox deposits near Fairbanks, Alaska (Mortensen and others, 1994; Hitchins and Orssich, 1995). The Late Cretaceous Dublin Gulch biotite granodiorite stock, with a K-Ar isotopic age of 95-87 Ma, contains: (1) sheeted Au-As-Cu-Bi-W quartz veins along the western end in the Eagle Zone; (2) scheelite-quartz veins in the east-central part; and (3) Au-sulfide quartz veins along the northern contact and to the west. The associated Ray Gulch (Mar) W skarn deposit occurs on the south side of the Dublin Gulch stock, and cassiterite breccia deposits occur 2 km north of the stock. The Au quartz veins in the Eagle Zone range from 1 to 2 cm wide, and are associated with potassic and phyllic envelopes which coalesce to form pervasive alteration which contain the closely-spaced quartz veins. Vein mineral assemblages, in addition to free gold grains up to 1 mm in diameter, are arsenopyrite, pyrrhotite, chalcopyrite, pyrite, bismuthinite, tetradymite, tellurobismuthinite, native bismuth, and rare molybdenite and scheelite. Estimated resources are 64.5 million tonnes grading 1.03 g/t Au (Hitchins and Orssich, 1995).

Ray Gulch W Skarn Deposit

The Ray Gulch W skarn deposit consists of scheelite which occurs as disseminations and tabular layers in sulfide-free diopside-amphibole-epidote skarn. The deposit is hosted in calcareous metasedimentary rocks and tuff of the Late Proterozoic Hyland Group which is intruded by quartz monzonite sills which dip gently northward towards the Potato Hills stock, part of the mid-Cretaceous Tombstone Plutonic Suite. Eight separate skarn zones comprise a resource of 5.44 million tonnes of material grading 0.82% WO_3 (Lennan, 1986). Other W skarns are at Scheelite Dome, Lugdush, and Rhosgobel. Sn skarns occur in the Keno Hill-McQuesten River region, and include Oliver Creek, Boulder Creek, East Ridge, and Barney Ridge. Also occurring in the area are several vein and breccia Sn-W deposits which are hosted by Late Proterozoic to Mississippian metasedimentary rocks and associated felsic granitoid stocks of the Tombstone Plutonic Suite (Emond and Lynch, 1992). Small Cu-Au skarns deposits occur at Marn, Brenner, and Ida.

Origin of and Tectonic Controls for Tombstone Metallogenic belt

The Tombstone metallogenic belt is hosted in the mid-Cretaceous Tombstone Plutonic Suite which intrudes the Proterozoic Hyland and Cambrian through Devonian Rocky Mountain Assemblage, and the Devonian and Mississippian clastic wedge rocks of Earn Group of the North American Craton Margin (fig. 62). The Tombstone Plutonic Suite, which has isotopic ages of 95-89 Ma, consists mainly of alkaline plutons which include syenite, hornblende-biotite granodiorite, quartz monzonite, and quartz-feldspar porphyry. The plutonic suite includes some felsic, peraluminous, two-mica granite and quartz monzonite plutons which were previously included in the slightly older Selwyn Plutonic Suite which has isotopic ages of 97 to 112 Ma. The granitoid rocks of the Tombstone Plutonic Suite, which are part of the Omineca-Selwyn plutonic suite, are similar in age, geochemistry, and petrology to mid-Cretaceous plutons which intrude the Yukon-Tanana terrane to the west in Alaska across the Denali fault, and the suites of lode deposits associated with each suite of granitoid rocks are similar. The Tombstone metallogenic belt contains Ag polymetallic vein, granitoid-related Au, Sb-Au vein, W-Sn-Au skarn, and Cu-Au skarn deposits. The older (mid-Cretaceous) part of the East-Central Alaska metallogenic belt contains granitoid-related Au, Sb-Au vein, Pb-Ag-Zn-Au polymetallic vein, and W-Au skarn deposits. In recent years, the name *Tintina Gold Belt* (Tucker and Smith, 2000) has been used for granitoid-related Au deposits and occurrences which occur throughout the Yukon Territory and in the East-Central Alaska metallogenic belt (described below) of Nokleberg and others (1995a, 1996, 1997a), and in the correlative Tombstone metallogenic belt of Nokleberg and others (1995a, 1996, 1997a) which occurs to the east in the central Yukon Territory. Because the term *Tintina Gold Belt* includes deposits of several ages and differening origins, the term is not used in this study. Bundtzen and others (2000) introduced the term *Tintina Gold Province* to denote Mesozoic and Tertiary plutonic-related gold deposits which are related to which occur throughout the Yukon Territory and Interior Alaska.

As described above for the correlative East-Central Alaska metallogenic belt (mid-Cretaceous), the polymetallic, Sb-Au vein, and granitoid-related Au deposits of the Tombstone metallogenic belt are generally hosted in, or near mid-Cretaceous granitoid plutons (Nokleberg and others, 1995a; McCoy and others, 1997; Smith, 1999; Smith and others, 1999, 2000; Goldfarb and others, 2000). In both East-Central Alaska and the Central Yukon Territory, these plutons are interpreted as intruding during the waning stages of a major mid-Cretaceous collision of the Wrangellia superterrane with the previously-accreted Yukon-Tanana terrane (Stanley and others, 1990; Dusel Bacon and others, 1993; Pavlis and others, 1993; Nokleberg and others, 2000). The collision and associated metamorphism and deformation is interpreted as forming in two phases: (1) a relatively older period of collision and thrusting, associated with high-temperature and high-pressure metamorphism; and (2) a slightly younger period of extension associated with lower greenschist facies metamorphism. The mid-Cretaceous granitoid rocks and relatively younger quartz veins intrude and crosscut both the relatively older, higher-grade, and relatively younger, lower grade metamorphic fabrics in the region (Dusel Bacon and others, 1993; Pavlis and others, 1993). These relations suggest that the the Tombstone metallogenic belt formed in the waning stages of this complex deformation event (Nokleberg, 1997e, 2000). Other metallogenic belts of granitic-magmatism-related deposits hosted in the Omineca-Selwyn plutonic belt in the Canadian Cordillera, Alaska, and the Russian Northeast include the Bayonne, Cassiar, Selwyn, and Whitehorse belts (fig. 62; table 3).

Cassiar Metallogenic Belt of Porphyry Mo-W; W Skarn, Zn-Pb-Ag Manto, Sn Skarn, and Au Skarn Deposits (Belt CA) Northern British Columbia and Southern Yukon Territory

The Cassiar metallogenic belt of porphyry Mo-W; W skarn, Zn-Pb-Ag manto, Sn skarn, and Au skarn deposits (fig. 62; tables 3, 4) occurs in northern British Columbia and southern Yukon Territory. The belt contains a variety of mineral deposit types which are related to granitoid plutons of the mid-Cretaceous Cassiar Plutonic Suite which forms a narrow, linear belt of dominantly biotite granite and granodiorite plutons which is part of the Omineca-Selwyn plutonic belt (fig. 62). The significant deposits in the belt are a Porphyry W-Mo deposit at Logtung (Logjam Creek), a Pb-Zn-Ag skarn and manto deposit at Midway (Silver Tip), a W skarn deposit at Risby (Cab), a Zn-Ag polymetallic vein deposit at Logan, and a Sn skarn deposit at JC or Viola (table 4) (Nokleberg and others 1997a, b, 1998). The Logan polymetallic Zn-Ag vein deposit is hosted by the Marker Lake Batholith (Dawson, 1996a).

Logtung Porphyry Mo-W Deposit

The large Logtung (Logjam Creek) porphyry Mo-W deposit consists of disseminated scheelite, molybdenite and powellite with minor associated fluorite and beryl in garnet-diopside skarn, quartz vein stockwork and fractures (EMR Canada, 1989; Dawson and others, 1991; Yukon Minfile, 1991; Noble and others, 1995). The deposit contains estimated reserves of 230 million tonnes grading 0.104% WO_3, 0.05% MoS_2. The deposit is hosted in a large quartz porphyry dike which is related to a nearby mid-Cretaceous quartz monzonite stock with a K-Ar isotopic age of 109 Ma which is part of the Cassiar Plutonic Suite. The Logtung deposit is typical of a group of deposits (as at Stormy and Molly) which contain a molybdenite-rich stockwork in a granitoid pluton and a scheelite-rich garnet-diopside skarn assemblage in the wall rocks (Dawson, 1996c). At the Logtung deposit, early quartz-scheelite veins are related to a monzogranite stock, a later stage of quartz-scheelite-molybdenite-pyrite-fluorite veins is related to a felsic dyke complex, and a final stage of polymetallic W-Mo veins which form a large zone is centered on the dyke complex (Noble and others, 1984). Both mid-Cretaceous intrusives are part of the Cassiar Plutonic Suite. The wall rocks are Mississippian and Pennsylvanian chert, argillite, and quartzite of the Cassiar continental margin terrane.

Risby Skarn W Deposit

The significant, but undeveloped Risby (Cab) skarn W deposit consists of two diopside-garnet skarns which occur in Early Cambrian carbonates which are intruded by granitoid sills of the Cassiar Plutonic Suite (EMR Canada, 1989; Yukon Minfile, 1990; Mining Review, 1992). The No. 1 zone has a high pyrrhotite and low chalcopyrite content, whereas the No. 2 zone, which is intruded by a sill, has higher WO_3 mineralization and low sulfide content (Sinclair, 1986). The deposit has a drilled resource of 3.2 million tonnes grading 0.82% WO_3. The mineral assemblage is typical of W skarn deposits associated with plutons of the Omineca-Selwyn plutonic belt.

Midway (Silvertip) Manto Pb-Zn-Ag Deposit

The Midway (Silvertip) manto Pb-Zn-Ag deposit consists of generally coarse-grained assemblage of sphalerite-galena-pyrite which contains elevated Ag, and minor Au, Sb and Bi values which occur as irregular, pipe-like, open-space filling and replacement bodies in limestone of the Middle Devonian McDame Group of the Cassiar continental margin terrane (Bradford and Godwin, 1988; EMR Canada, 1989). The nearest intrusive rock, interpreted as the source of mineralizing fluids, is a group of quartz-feldspar porphyry dikes which are about 2 km from the deposit. The dikes intrude clastic sedimentary rocks of the Earn Group which unconformably overlie the McDame Group. The wall rocks exhibit sericite alteration. The dikes exhibit a K-Ar isotopic age of 66 Ma. Estimated reserves are 2.6 million tonnes grading 8.8% Zn, 6.4% Pb, and 3258 g/t Ag according to drilling and underground exploration (Bradford and Godwin, 1988; Mining Review, summer 2000; Peruvian Gold/Imperial Metals release, February 10, 2000). The deposit does not contain a calc-silicate gangue typical of skarn Zn deposits, and exhibits only minor amounts of a silica and carbonate gangue adjacent to replacement bodies, similar to the alteration in the large Ag-Zn-Pb manto deposits of northern Mexico. At both the Midway and the nearby YP manto deposits, a crude zonation in metal distribution exists wherein Au is concentrated commonly in massive sulfide zones which are rich in Fe, Cu, and Zn, rather than in more distal Pb- and Ag-rich zones (Dawson, 1996a). An origin similar to which of Sa Dena Hes Zn-Pb-Ag manto deposit near Watson Lake, Yukon is proposed, where mantos are developed distally to an intrusion inferred to underlie the deposit at depth (Dawson, 1996a).

Ketza River Manto Au Deposit

The Ketza River manto Au deposit consists of Au-quartz-sulfide veins and massive pyrrhotite-arsenopyrite-pyrite-chalcopyrite-Au mantos which occur in a central part; and (2) mantos and veins of similar mineralogy which contain lower amounts of sulfide minerals which occur in a outer part; and (3) Ag-Pb veins and mantos which occur in the periphery (Cathro, 1990). The deposit is hosted by Early Cambrian sedimentary rocks of Cassiar continental margin terrane. The district is interpretec as underlain by a mid-Cretaceous pluton of the Cassiar Plutonic Suite which is interpreted as emplaced along the Ketza-Seagull Arch, a major structural feature (Abbott, 1986a). Hornfels underlies the deposit and exhibits a K-Ar whole-rock isotopic age of

101 Ma (K.M. Dawson, unpublished data, 1986). The mine at the deposit operated between 1988 and 1990 with initial oxide ore reserves of 282,000 tonnes averaging 13.45 g/t Au (Canamax Resources Inc., 1988 Annual Report).

JC Skarn Sn Deposit

The JC Sn skarn deposit consists of malayite, stannite, stanniferous tetrahedrite and cassiterite in hedenbergite-diopside skarn which occur along the contact between Devonian and Mississippian carbonate rocks and porphyritic granite of the mid-Cretaceous Seagull Batholith (Layne and Spooner, 1986; EMR Canada, 1989; Yukon Minfile, 1991). The Seagull Batholith consists of a two-mica A-type granite which is also associated with the F-, Cl-, and B-rich, Sn skarn deposits at Val A and Viola, and with Zn-Pb-Ag skarn deposits at Atom, Bom, and Bar (Dawson and Dick, 1978). At the JC deposit, hedenbergite-diopside-andradite prograde skarn contains elevated Sn in a distinctive green garnet skarn, and is replaced by a retrograde assemblage of cassiterite, stannite, tetrahedrite, sphalerite, and malayite. Axinite and fluorite fill interstices in a pipe-like breccia. Estimated resources are 1.25 million tonnes grading 0.54% Sn (Layne and Spooner, 1986).

Origin of and Tectonic Controls for Cassiar Metallogenic Belt

The Cassiar metallogenic belt is hosted in the Cassiar Plutonic Suite which is lithologically similar to the Bayonne Plutonic Suite, but the generally elongate plutons of the Cassiar Suite exhibit post-emplacement deformation (Woodsworth and others, 1991). The plutons and most of the associated deposits are hosted by the Cassiar terrane which is interpreted as a displaced fragment of North American Craton Margin (Monger and others, 1972, 1992; Monger and Nokleberg, 1996; Nokleberg and others, 2000) and is composed of Proterozoic to Carboniferous sedimentary rocks. The Cassiar Plutonic Suite is part of the collisional mid-Cretaceous Omineca-Selwyn plutonic belt which extends from the southern part of the Canadian Cordillera, across Interior Alaska, and northwestward into the Russian Northeast, and consists chiefly of granodiorite, granite, quartz syenite and minor syenite plutons of Early to mid-Cretaceous age (110-90 Ma; Monger and Nokleberg, 1996; Nokleberg and others, 1994c; 2000). The spatial location of the belt, about 200 km west of the eastern limit of Cordilleran deformation, and chemistry suggests an anatectic origin of partial melting of cratonic crust during thickening caused by Cretaceous contraction (Monger and Nokleberg, 1996; Nokleberg and others, 2000) which was associated with orthogonal convergence between the Farallon Oceanic Plate and North America (Englebretson and others, 1985; 1992), and subsequent regional extension (Pavlis and others, 1993). Other metallogenic belts of granitic-magmatism-related deposits hosted in the Omineca-Selwyn plutonic belt in the Canadian Cordillera, Alaska, and the Russian Northeast include the Bayonne, Selwyn, Tombstone, and Whitehorse belts (fig. 62; table 3).

Whitehorse Metallogenic Belt of Cu-Fe Skarn, Porphyry Cu-Au-Ag, and Au-Ag Polymetallic Vein Deposits (Belt WH) Southern Yukon Territory

The Whitehorse metallogenic belt of Cu-Fe skarn, porphyry Cu-Au-Ag, and Au-Ag polymetallic vein deposits (fig. 62; tables 3, 4) occurs in the southern Yukon Territory, and is hosted in the Whitehorse Plutonic Suite. These plutonic rocks intrude a large area of the northern Stikinia and Cache Creek terranes, and Yukon-Tanana terrane in the northern Canadian Cordillera (fig. 62). The Whitehorse Plutonic Suite, which is part of the Omineca-Selwyn plutonic belt, consists predominantly of mid-Cretaceous, granodiorite plutons (Woodsworth and others, 1991). The significant deposits in the belt are Cu skarn deposits near Whitehorse (Little Chief, War Eagle), and Hopkins or Giltana (table 4) (Nokleberg and others 1997a, b, 1998).

Whitehorse Copper Belt of Cu Skarn Deposits

The Whitehorse Copper Belt (fig. 78) comprises thirty-two Cu-Fe (Mo-Au-Ag) calc-silicate skarn deposits hosted by both calcareous and dolomitic units of the upper Triassic Lewes River Group of Stikinia terrane (Dawson and Kirkham, 1996). The skarns contain bornite, magnetite, and chalcopyrite, and minor native copper, tetrahedrite, and molybdenite. The skarns occur in a 30-km-long belt along irregular contacts of the Whitehorse Batholith which consists of a composite calc-alkaline granodiorite pluton with a diorite margin (Meinert, 1986; Dawson and others, 1991; Yukon Minfile, 1991). The calcic or magnesian skarn mineralogy is a largely a function of the skarn protolith (Morrison, 1981). The bulk of sulfide minerals and highest average Au and Ag grades occur in structurally controlled retrograde skarn alteration assemblages (Meinert, 1986). From 1898 to 1982 estimated production was 142,000 tonnes Cu, 7,090 kg Au and 90,000 kg Ag from 5.2 million tones ore. Combined production and reserves are 13.2 million tonnes grading an average of 1.4% Cu, 0.7 g/t Au, and 8.9 g/t Ag (Dawson and others, 1991; Watson, 1984).

Two small skarns are the Cu (Mo-Ag-Au) Hopkins and the Zn (Cu-Ag) Sekulmun skarns (Dawson and others, 1991) which occur in carbonate rocks of the Cambrian through Devonian Nasina Assemblage of the Yukon-Tanana terrane where intruded by the Nisling Range granodiorite pluton (Dawson and others, 1991). Significant Au-Ag polymetallic vein deposits which occur at Mount Nansen and Mount Freegold (Dawson and others, 1991) are hosted in intermediate to felsic volcanic rocks of the Mount Nansen Group which are interpreted as coeval and probably comagmatic the Whitehorse Suite (Woodsworth and others, 1991). Small, polymetallic Au-Ag veins are hosted by granitioid plutons in the Moosehorn Range on the border between Alaska and the Yukon Territory.

Origin of and Tectonic Controls for Whitehorse Metallogenic Belt

The Whitehorse metallogenic belt is hosted by the Whitehorse Plutonic Suite which has an isotopic age range 103 to 112 Ma. The suite includes the Coffee Creek Plutonic Suite south of Dawson (Mortensen and others, 1994). The Whitehorse Plutonic Suite is part of the collisional mid-Cretaceous Omineca-Selwyn plutonic belt which extends from the southern part of the Canadian Cordillera, across Interior Alaska, and northwestward into the Russian Northeast (figs. 61, 62). The belt consists chiefly of granodiorite, granite, quartz syenite and minor syenite plutons of Early to mid-Cretaceous age (110-90 Ma; Monger and Nokleberg, 1996; Nokleberg and others, 1994c; 2000). The spatial location of the belt, about 200 km west of the eastern limit of Cordilleran deformation, and chemistry suggests an anatectic origin of partial melting of cratonic crust during thickening caused by Cretaceous contraction (Monger and Nokleberg, 1996; Nokleberg and others, 2000) which was associated with orthogonal convergence between the Farallon Oceanic Plate and North America (Englebretson and others, 1985; 1992), and subsequent regional extension (Pavlis and others, 1993). Other metallogenic belts of granitic-magmatism-related deposits hosted in the Omineca-Selwyn plutonic belt in the Canadian Cordillera, Alaska, and the Russian Northeast include the Bayonne, Cassiar, Selwyn, and Tombstone belts (fig. 62).

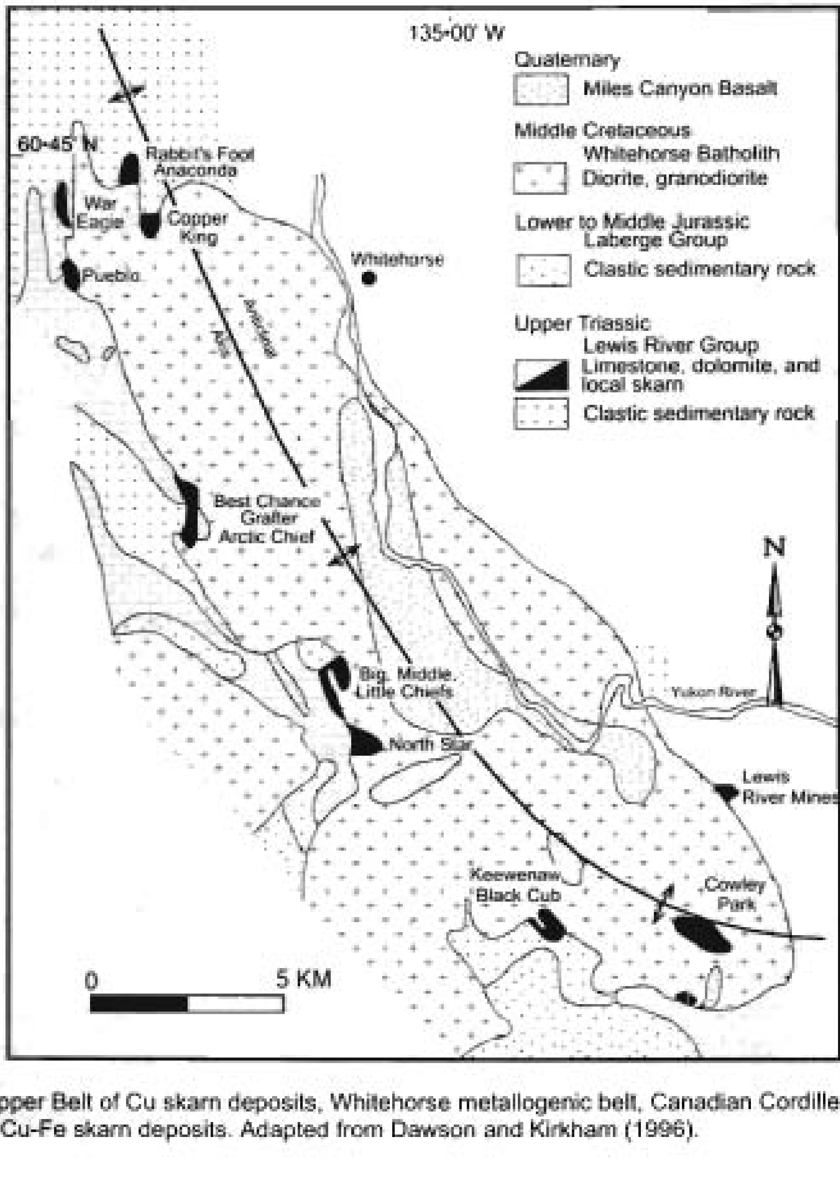


Figure 78. Whitehorse Copper Belt of Cu skarn deposits, Whitehorse metallogenic belt, Canadian Cordillera. Schematic map showing location of major Cu-Fe skarn deposits. Adapted from Dawson and Kirkham (1996).

Bayonne Metallogenic Belt of Porphyry Mo and Cu-Mo-W-Zn Skarn Deposits (Belt BA) Southern British Columbia

The Bayonne metallogenic belt of porphyry Mo and Cu-Mo-W-Zn skarn deposits (fig. 62; tables 3, 4) occurs in southern British Columbia and is hosted in the mid-Cretaceous Bayonne Plutonic Suite which is the extreme, southern part of the Omineca-Selwyn plutonic belt. The intrusions typically are S-type, felsic, enriched in large-ion lithophile elements, and have initial Sr ratios in the range 0.710 to 0.740 (Armstrong, 1988). Most of the suite forms roughly equant, plutons and large stocks of mainly granodiorite or granite; the stocks are strongly discordant with the wall rocks of the Quesnellia and Kootenay terranes and the North American Craton Margin. The significant deposits in the belt are porphyry Mo deposits at Boss Mountain and Trout Lake, a W skarn deposit at Emerald-Invincible, a Zn-Pb skarn and manto deposit at Mineral King, a Mo skarn deposit at Red Mountain Moly (Coxey, Novelty, Nevada), and a Cu-Au skarn deposit at Phoenix-Greenwood (table 4) (Nokleberg and others 1997a, b, 1998).

Boss Mountain Porphyry Mo Deposit

The Boss Mountain porphyry Mo deposit consists of molybdenite in quartz veins, fracture zones and in collapse breccias which are hosted by a granodiorite phase of the composite Early Jurassic Takomkane batholith which is intruded by the mid-Cretaceous Boss Mountain stock (Soregaroli and Nelson, 1976; MacDonald and others, 1995). The emplacement of the stock was accompanied by rhyolite dikes, brecciation and multiple stages of veining and Mo deposition. Molybdenite was mined from a sheeted vein system which describes a partial annulus centered upon the apical region of the stock. Alteration assemblages consists of garnet, hornblende, biotite, sericite, potassium feldspar, chlorite and talc. Pyrite forms a 1.5 km-wide halo. Between 1965 and 1971, about 2.97 million tonnes were milled with an average grade of 0.26% Mo. Between 1974 and 1980, 3.6 million tonnes were milled with an average grade of 0.188% Mo. Estimated remaining reserves are 3.84 million tonnes grading 0.135% Mo (Soregaroli and Nelson, 1976; MacDonald and others, 1995).

Trout Lake Porphyry Mo Deposit

The Trout Lake porphyry Mo deposit consists of molybdenite and pyrite in quartz veins, and also scheelite, pyrrhotite, chalcopyrite, with lesser amounts of galena, sphalerite and tetrahedrite in peripheral skarns (Boyle and Leitch, 1983; Linnen and others, 1995). The deposit is hosted mainly in limestone, schist, and quartzite of the Paleozoic Lardeau Group. A minor part of the deposit is hosted in altered granodiorite and tonalite of the Late Cretaceous Trout Lake stock which forms part of the Bayonne Plutonic Suite. Skarn calc-silicate alteration includes prograde clinopyroxene-garnet, and retrograde tremolite-clinozoisite with scheelite. Potassic (biotite) alteration overprints retrograde skarn and forms envelopes around quartz-albite Mo veins in skarn and hornfels, whereas K-feldspar replaces plagioclase in the intrusion. The highest Mo grades are associated with the later quartz-K-feldspar-muscovite alteration. Estimated resources are 49 million tonnes l grading 0.19% Mo (Boyle and Leitch, 1983; Linnen and others, 1995).

Red Mountain Mo Skarn Deposit

The Red Mountain Mo skarn deposit (Coxey, Novelty, Giant) consists of molybdenite, pyrrhotite, chalcopyrite, arsenopyrite, scheelite, pyrite, magnetite, bismuthinite, galena and sphalerite which occur in veins, disseminations and shears within skarn and contact-metamorphosed siltstone and breccia of the Pennsylvanian to Permian Mount Roberts Formation (Ray and Webster, 1991; Ray and Dawson, 1998). The small porphyritic intrusions of granite and granodiorite are interpreted to be associated with, and a late phase of the Early to Middle Jurassic subvolcanic, monzonite Rossland intrusion which is associated with large Au-bearing pyrrhotite-chalcopyrite vein deposits of the adjacent Rossland district (Hoy and others, 1998). An alternative interpretation is that the intrusions associated with the deposit are part of the mid-Cretaceous Bayonne Plutonic Suite. At Coxey, molybdenite and minor scheelite are associated with a prograde assemblage of pyroxene-garnet-vesuvianite and a retrograde assemblage of epidote-actinolite-chlorite. The Novelty and Giant Mo skarns contain abundant arsenopyrite, and minor pyrrhotite, pyrite, chalcopyrite, cobaltite, bismuthinite, native Bi, and Au. The Novelty deposit also contains some uraninite. Estimated production and reserves are 1.31 million tonnes grading 0.20% Mo (Ray and Webster, 1991; Ray and Dawson, 1998).

Emerald-Invincible W-Mo Skarn Deposit

The Emerald-Invincible W-Mo skarn deposit consists of scheelite, wolframite, molybdenite, pyrrhotite, pyrite and chalcopyrite which generally occur as disseminations, but locally occur as massive lenses with pyrite and pyrrhotite with associated gold (Ray and Webster, 1991; Dawson and others, 1991). The deposit is hosted in the Early Cambrian Laib Formation along the contact of the Reeves Member Limestone with the Emerald Member argillite, as well as along the contact of the limestone with the Cretaceous Emerald and Dodger Stocks. The skarn consists of garnet, diopside, tourmaline, powellite, calcite, biotite, and K-feldspar. Sericite alteration is predominant; but kaolinite, tremolite and silica alteration also occur. The Emerald deposit has produced approximately 7,416 tonnes of Mo-W concentrate. The Pb-Zn deposits at the nearby Jersey and Emerald mines are interpreted as distal skarns relative to the W skarn; however others have interpreted the Pb-Zn deposits as syngenetic (Dawson, 1996a).

Phoenix-Greenwood Cu Deposit

The Phoenix-Greenwood Cu-Au skarn deposit consists of chalcopyrite, pyrite, pyrrhotite, magnetite plus minor sphalerite and galena which occur in a garnet-rich calc-silicate skarn assemblage of andradite, clinozoisite, diopside and quartz (Church, 1986; Schroeter and Lane, 1991; MINFILE, 2002). The skarn hosted by Triassic carbonate, clastic, and volcanic rocks of the previously-accreted Quesnellia terrane in proximity to contacts with Middle Jurassic and mid-Cretaceous granitoid intrusive rocks. Production from 1893 to 1985 was 270,000 tonnes Cu, 36 tonnes Au, and 117 tonnes Ag. The deposit age is interpreted as Middle Jurassic to Early Cretaceous.

Mineral King Zn-Pb-Ag Skarn and Manto Deposit

The Mineral King deposit consists of sphalerite, galena and pyrite with bournonite and rare meneghinite which occur in steeply-dipping pipes or as manto-style replacements along steeply dipping shear zones associated with a synclinal wedge between two faults. The deposit is hosted in the Middle Proterozoic Mount Nelson Formation composed of dolomite and dolomitic quartzite. The mine at the deposit produced an estimated 2.1 million tonnes grading 4.12% Zn, 1.70% Pb, and 24.8 g/t Ag (Fyles, 1960). Estimated current reserves are 72,576 tonnes grading 34.3 g/t Ag, 2.5% Pb, and 4.5% Zn.. No intrusive rock is exposed, but the deposit is interpreted as a Zn-Pb skarn and manto distally related to a buried intrusion (Dawson and others, 1991) of the Bayonne Plutonic Suite.

Origin of and Tectonic Controls for Bayonne Metallogenic Belt

The Bayonne metallogenic belt is hosted in the extreme, southern part of the Omineca-Selwyn plutonic belt (fig. 62). The lithophile geochemistry of the plutonic suite is reflected in the abundance of porphyry Mo and related skarn deposits. The Omineca-Selwyn plutonic belt extends from the southern part of the Canadian Cordillera, across Interior Alaska, and northwestward into the Russian Northeast, and consists chiefly of granodiorite, granite, quartz syenite and minor syenite plutons of Early to mid-Cretaceous age (110-90 Ma; Monger and Nokleberg, 1996; Nokleberg and others, 1994c; 2000). The plutons in the belt form an extensive linear array of discrete intrusions, and many plutons exhibit S-type character. Extrusive equivalents (such as the South Fork Volcanics in the Yukon Territory) are rare. The plutons commonly have high initial strontium ratios (about 0.710), indicating partial derivation from old cratonic crust (Armstrong, 1988: Woodsworth and others, 1991). The spatial location of the belt, about 200 km west of the eastern limit of Cordilleran deformation, and chemistry suggests an anatectic origin of partial melting of cratonic crust during thickening caused by Cretaceous contraction (Monger and Nokleberg, 1996; Nokleberg and others, 2000) which was associated with orthogonal convergence between the Farallon Oceanic Plate and North America (Englebretson and others, 1985; 1992), and subsequent regional extension (Pavlis and others, 1993). Other metallogenic belts of granitic-magmatism-related deposits hosted in the Omineca-Selwyn plutonic belt in the Canadian Cordillera, Alaska, and the Russian Northeast include the Cassiar, Selwyn, Tombstone, and Whitehorse belts (fig. 62; table 3).

Early Late Cretaceous Metallogenic Belts (100 to 84 Ma; Figures 79, 80)

Overview

The major early Late Cretaceous metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 79 and 80. The major belts are as follows. (1) In the Russian Southeast, the Kema (KM), Lower Amur (LA), Luzhkinsky (LZ), Sergeevka (SG), and Taukha (TK) belts, which contain a large array of granitic-magmatism-related deposits, are hosted in or near the East Sikhote-Aline volcanic-plutonic belt and are interpreted as forming during subduction-related granitic plutonism which formed the East Sikhote-Aline continental margin arc. (2) In the same region was the Aniva-Navil (ANN) metallogenic belt of volcanogenic Mn and Fe and Cyprus massive sulfide deposits that are interpreted as forming in guyots, and oceanic crustal and island arc assemblages that were subsequently tectonically incorporated into the Aniva and Nabilsky terranes accretionary wedge and subduction zone terranes. (3) Also in the same region, continuing on from the late Early Cretaceous was the Badzhal-Ezop-Khingan (BZ-KH) belt of granitic-magmatism-related deposits, which is hosted in the Khingan-Okhotsk volcanic-plutonic belt, and is interpreted as forming in the Khingan continental-margin arc. (4) In the Russian Northeast are the Chaun (CN), Dogdo-Erikit (DE), Korkodon-Nayakhan (KN), Koni-Yablon (KY), Okhotsk (OH), Omsukchan (OM), Verkhne-Kolyma (VK) zones which constitute various parts of the Eastern Asia belt. In the same region and also part of the are the Eastern Asia metallogenic belt are the Adycha-Taryn (AT), Chokurdak (CD), and Vostochno-Verkhoyansk

(VV) belts. These zones and belts all contain a rich array of granitic-magmatism-related deposits which are interpreted as forming during

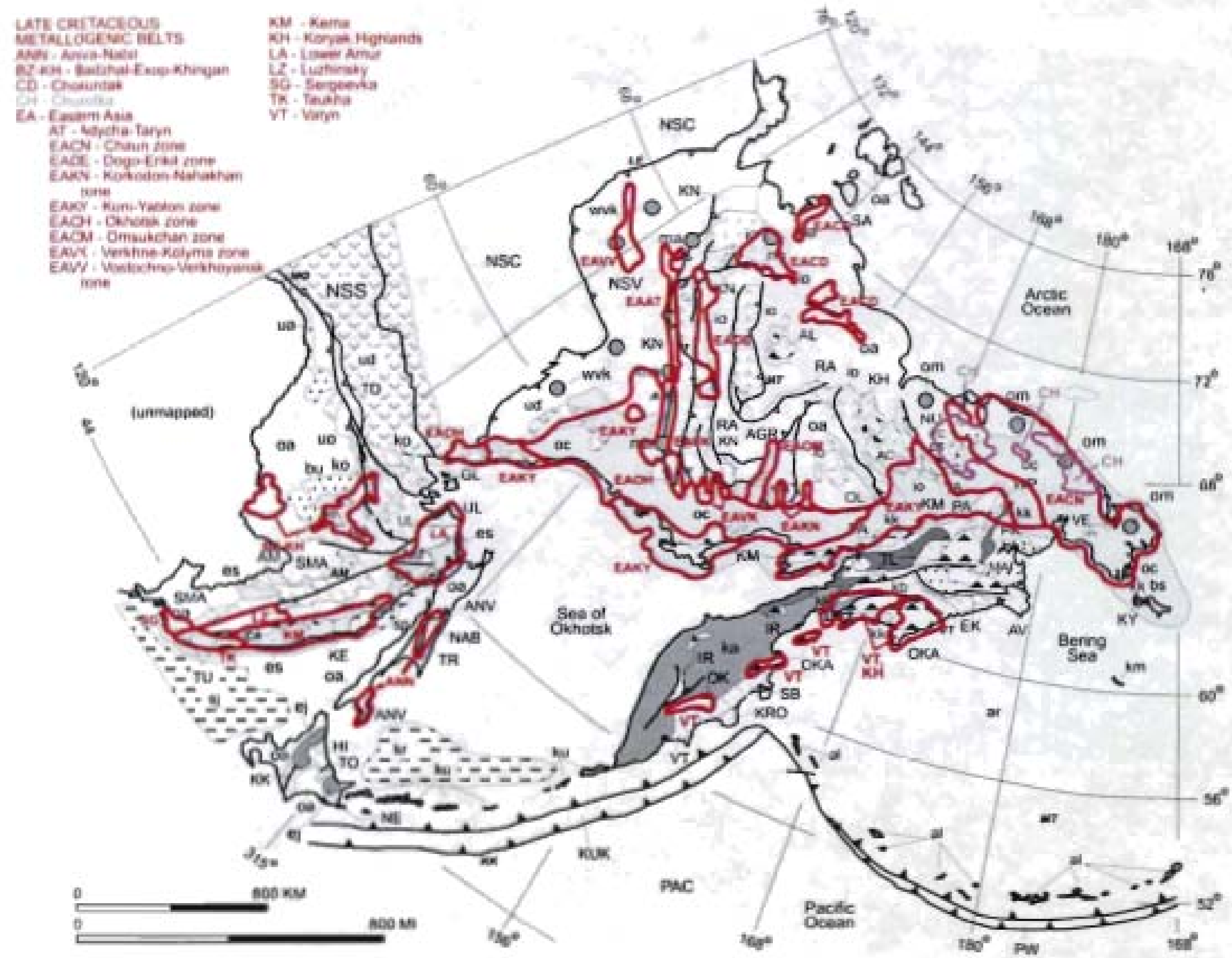


Figure 79. Generalized map of major Late Cretaceous metallogenic belts, overlap assemblages, and tectonically-linked subduction-zone or accretionary-wedge terranes for Russian Far East, northern Japan, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 59 for explanation.

subduction-related granitic plutonism which formed the Okhotsk-Chukotka continental-margin arc. The Eastern Asia metallogenic belt of granitic-magmatism-related deposits contains a complex array of zones (fig. 79, table 3). Each zone contains a characteristic suite of mineral deposit types which are herein interpreted as reflecting the underlying terranes through which the granitic magmas ascended. (5) On northern Kamchatka Peninsula, in the Koryak Highlands in the Russian Far East are two metallogenic belts which are hosted in the Olyutorka-Kamchatka island-arc terrane. The Koryak Highlands (KH) belt contains zoned mafic-ultramafic PGE and Cu massive sulfide deposits, and the Vatyn (VT) belt contains volcanogenic Mn and Fe deposits. Both belts are interpreted as forming in different parts of the Olyutorka island arc. (6) In the Russian Northeast, the Chukotka (CH) belt, which contains mainly Au quartz vein deposits, is hosted in the Chukotka passive continental-margin terrane and is interpreted as forming during regional metamorphism and anatectic granitic plutonism associated with accretion of the Chukotka passive continental-margin terrane to the North Asian Craton Margin. (7) In East-Central and Southern Alaska, are three metallogenic belts which are interpreted as forming during regional metamorphism associated with accretion of Wrangellia superterrane to southern Alaska. These belts are the: (a) the Yukon-Tanana Upland (YT) belt, which contains Au quartz vein deposits and is hosted in the metamorphosed continental-margin Yukon-Tanana terrane; (b) the East-Central Alaska (older part) (ECA) belt, which contains granitic-magmatism-related deposits and is hosted in the Yukon-Tanana terrane; and (c) the Wrangell Mountains (WR) belt, which contains Cu-Ag quartz vein and Kennecott Cu deposits and is hosted the Wrangellia island-arc superterrane. And (8) in the Canadian Cordillera, continuing on from the late Early Cretaceous were the Bayonne (BA), Cassiar (CA), Selwyn (SW), and Whitehorse (WH) belts, which contain granitic-magmatism-related deposits, and are hosted in or near anatectic granitic plutons of the Omineca-Selwyn plutonic belt which is interpreted as forming during final accretion of Wrangellia superterrane to North American continental margin. In the below descriptions of metallogenic belts, a few of the noteable or signficant lode deposits (table 4) are described for each belt.

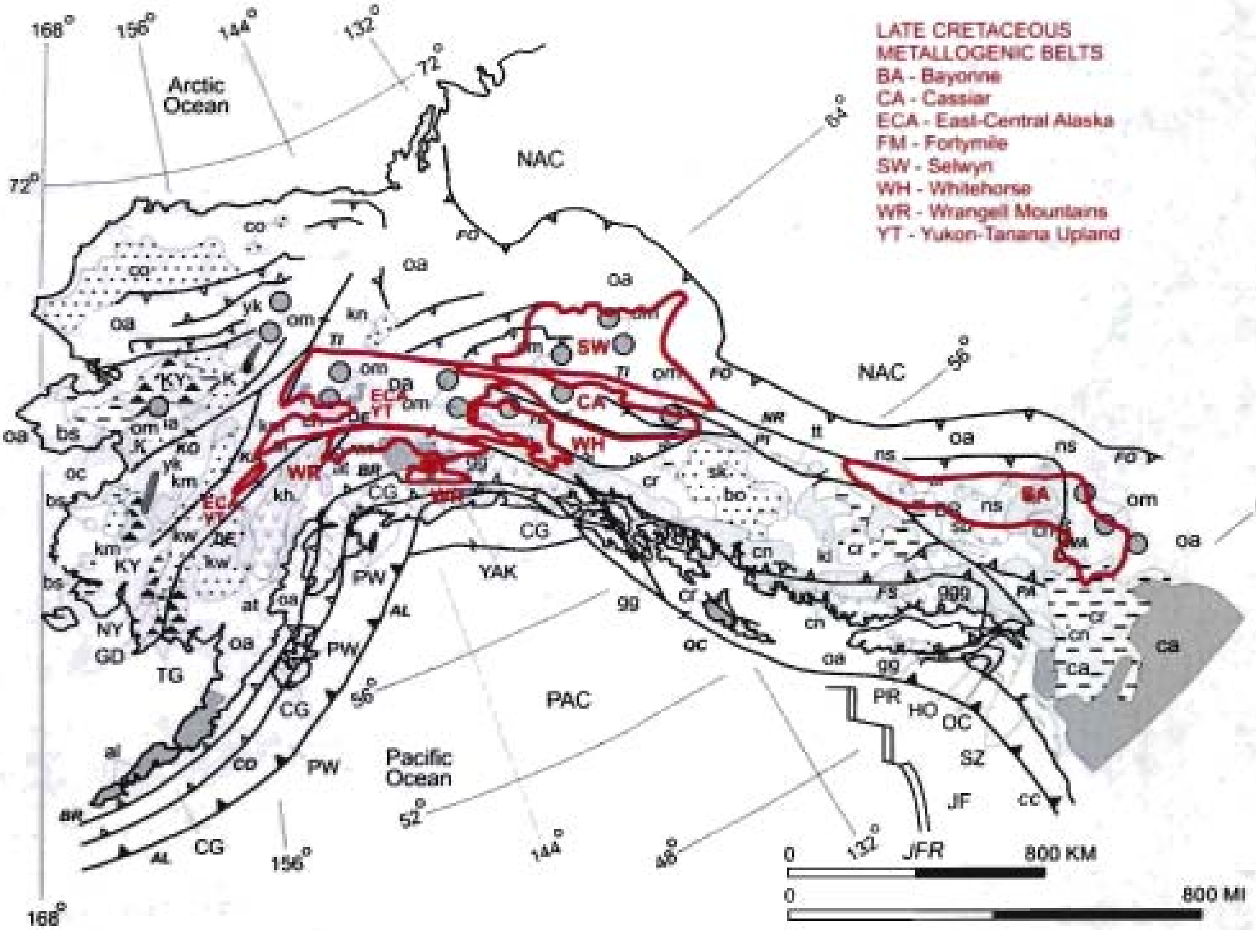


Figure 80. Generalized map of major Late Cretaceous metallogenic belts, overlap assemblages, and tectonically-linked subduction-zone or accretionary-wedge terranes for Alaska, Canadian Cordillera, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 60 for explanation.

Metallogenic-Tectonic Model for Early Late Cretaceous (100 to 84 Ma; Figure 81)

During the early Late Cretaceous (Cenomanian though Santonian - 100 to 84 Ma), the major metallogenic-tectonic events were (fig. 81; table 3): (1) establishment of a series of continental-margin arcs and associated metallogenic belts, and companion subduction-zone assemblages almost continuously around the Circum-North Pacific; (2) continued opening of an ocean which would become the Amerasia, Canada, and Eurasia Basins; (3) completion of accretion of the Wrangellia superterrane and formation of associated metallogenic belts; and (4) in the eastern part of the Circum-North Pacific, a change to orthogonal compression between the Farallon Ocean plate and North America.

Specific Events for Early Late Cretaceous

(1) At about 32° to 60° paleolatitude, the Olyutorka island arc commenced activity. Parts of the arc are preserved in the Nemuro (NE), Kronotskiy (KRO), and Olyutorka-Kamchatka (OKA), Iruneisky (IR), Shmidt (SHT), and Terpeniya (TR) terranes. Forming in the Olyutorka arc were the Koryak Highlands metallogenic belt, which contains zoned mafic-ultramafic PGE and Cu massive sulfide deposits, and the Vatyn (VT) metallogenic belt, which contains volcanogenic Mn and Fe deposits. Also associated with the arc was subduction of part of adjacent oceanic plate to form the Vetlovskiy (VT) terrane. This arc and companion subduction zone migrated northward toward the Okhotsk-Chukotka continental-margin arc.

(2) The East Sikhote-Alin (es) continental-margin arc was initiated. This major Andean-type arc overlapped previously accreted adjacent terranes in both the Russian Southeast and to the south. This arc extended for a distance of over 1,600 km along the active Russian Southeast continental margin. Forming as part of the arc was the West Sakhalin (WSA) turbidite basin terrane. Forming in the East-Sikhote arc were the Kema, Lower Amur, Luzhkinsky, Segeevka, and Taukha metallogenic belts. Also associated with the East-Sikhote arc was oblique subduction of part of the Ancestral Pacific Ocean plate (PAC) to form the Hidaka (HI), Aniva (ANV), and Nabilsky (NAB) terranes. Incorporated into the Aniva and Nabilsky terranes were the volcanogenic Fe and

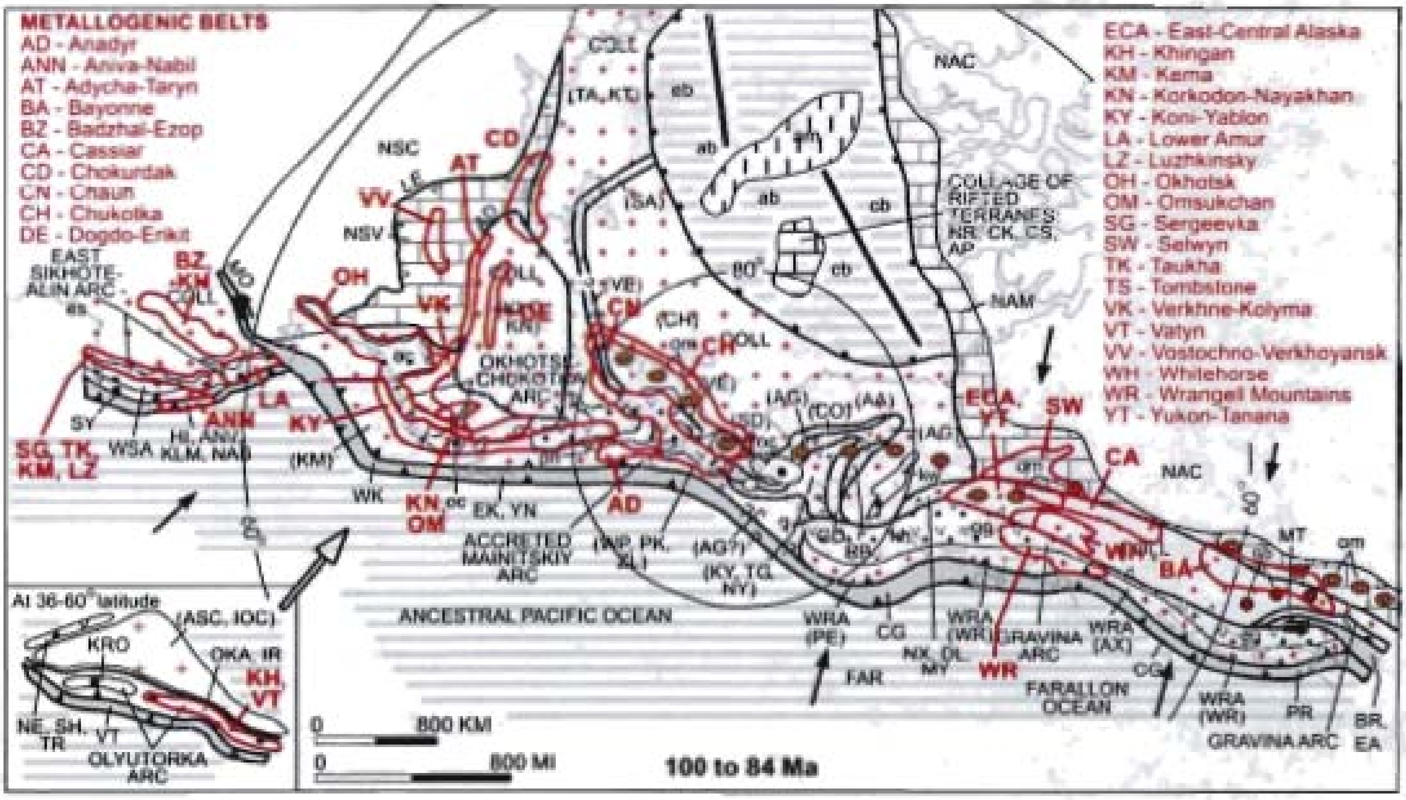


Figure 81. Early Late Cretaceous (Cenomanian through Santonian - 100 to 84 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

Mn and Cyprus massive sulfide deposits of the Aniva-Nabil (ANN) metallogenic belt that formed in Late Cretaceous oceanic crust and island arc rocks.

(3) The Khingan continental margin arc (ko) continued activity. Continuing in the arc was the Badzhal-Ezop-Khingan (BZ-KH) belt of granitic-magmatism-related deposits.

(4) Subduction stepped seaward, after the accretion of the Mainitskiy arc with the consequent inception of the Okhotsk-Chukotka continental-margin arc (oc) and related Penzhina (forearc) sedimentary basin (pn) along the new continental margin. This major Andean-type arc overlapped the previously accreted Kolyma-Omolon superterrane, part of the North Asian Craton Margin (NSV), and adjacent terranes in Russian Northeast and Western Alaska, and extended for about 3,500 km along an active continental margin. Associated with the arc was oblique subduction of part of the ancestral Pacific Ocean plate to form the West Kamchatka (WK), Ekonay (EK), and Yanranay (YN) terranes. Forming in the Okhotsk-Chukotka arc was the Eastern Asia metallogenic belt of granitic-magmatism-related deposits which contained a complex array of zones. The zones were the Chaun (CN), Dogdo-Erikit (DE), Korkodon-Nayakhan (KN), Koni-Yablon (KY), Okhotsk (OH), Omsukchan (OM), and Verkhne-Kolyma (VK) zones. Each zone contains a characteristic suite of mineral deposit types which are herein interpreted as reflecting the geochemical signature of the underlying terranes through which the granitic magmas ascended. Also forming in the Okhotsk-Chukotka volcanic-plutonic belt, and peripherally related to the Eastern Asia metallogenic belt, were the Adycha-Taryn (AT), Chokurdak (CD), and Vostochno-Verkhoyansk (VV) metallogenic belts.

(5) In the Arctic Ocean, sea-floor spreading and associated rifting continued (Lawver and Scotese, 1990; Grantz and others, 1990, 1991, 1998) with the formation of new oceanic crust and the combined Alpha and Mendeleev Ridges (am) which are interpreted as large piles of hot-spot basalt and associated deposits (Grantz and others, 1990, 1991, 1998). The large Amerasia (ab), Canada (cb) and Eurasia (eb) Basins continued to form. During the opening of the basin, North American continental margin terranes, including the Arctic Alaska superterrane (AA) and the Chukotka terrane (CH), and outboard oceanic and island terranes

migrated towards the North Asian Craton and previously accreted Kolyma-Omolon superterrane (KLO). The opening of the Amerasia (ab), Canada (cb) and Eurasia (eb) Basins is interpreted as causing oroclinal warping of Northern Alaska and the northern part of the Russian Far East.

(6) Also during the opening of the Amerasia (ab), Canada (cb), and Eurasia (eb) Basins, the South Anyui and Angayucham Oceans were closed, and the Chukotka (CH) and Arctic Alaska terranes (AA) were accreted to Northeast Asia. During accretion, the Chukotka metallogenic belt, which contains Au and Sn quartz vein deposits, was formed. Also during accretion, the major Nutesyn and Koyukuk island arcs and companion subduction zones were thrust onto the continental margin Chukotka terrane (CH) and Arctic Alaska superterrane (AA) in thrust sheets which are up to 150 km wide in Northern Alaska. The overthrust subduction zone terranes include the South Anyui (SA), Velmay (VE), Angayucham (AG), and Goodnews (GD) terranes. The overthrust island arc terranes include the Nutesyn (NU), Koyukuk (KY), and Togiak (TG) terranes. A final stage of blueschist-facies metamorphism of oceanic and continental-margin terranes occurred during thrusting. The lack evidence of a huge Himalayan-type mountain range in the Russian Northeast suggests either which: (1) strike-slip translation was more dominant than rifting in formation of the Canada Basin (Lane, 1994, 1997); and (or; 2) a major part of the rift migration of the Russian Northeast away from the Canada Basin was absorbed in the subduction zone associated with formation of the Okhotsk-Chukotka arc.

(7) During accretion, the southern margin of the eastern Chukotka terrane (CH), southern part of the Arctic Alaska superterrane (AA), and the outboard Seward (SD), Coldfoot (CO), Goodnews (GD), and Ruby (RB) terranes continued to be intensely deformed and metamorphosed. At the end of accretion, a period of extensional deformation occurred along the southern margin of the Arctic Alaska superterrane (AA; Miller and Hudson, 1991).

(8) Back-arc continental-margin sedimentation in Kuskokwim basin (kw) occurred in a dextral wrench-fault setting (Bundtzen and Miller, 1997).

(9) The final stage of accretion of the Wrangellia superterrane (WRA) was completed at about 95 Ma. Forming during the final stage of accretion in Alaska were: (a) the Yukon-Tanana metallogenic belt (YT) which contains Au quartz vein deposits; (b) the East-Central Alaska metallogenic belt (older part, ECA) which contains granitic magmatism-related deposits; and (c) the Wrangell Mountains metallogenic belt (WR) which contains Cu-Ag quartz vein and Kennecott Cu deposits. Several major geologic events are interpreted as caused by the accretion of the Wrangellia superterrane. (a) The extensive Gravina island arc, which formed along the leading edge of the superterrane, and the Spences Bridge volcanic-plutonic belt (sb) ceased activity after accretion. (b) The Kahiltna (kh) and Gravina-Nutzotin-Gambier (gg) assemblages were thrust under the North American continental margin (Stanley and others, 1990; McClelland and others, 1991, 1992a, b; Nokleberg and others, 1994a) and were intensely deformed during a major period of orthogonal convergence which replaced the previous sinistral convergence. (c) The northeastern-most boundary of the accreted Wrangellia superterrane became the locus of Late Cretaceous high-grade metamorphism, plutonism, contractional deformation, crustal thickening, uplift, and erosion which characterizes the Coast Mountains of the Canadian Cordillera, Southeastern Alaska, and South-Central Alaska (McClelland and others 1991, 1992a, b; Pavlis and others, 1993; Plafker and Berg, 1994; Monger and Nokleberg, 1996). (d) A regional core complex formed in the previously-accreted Yukon-Tanana terrane (part of the collage in present-day Alaska) and developed a subhorizontal fabric, imbricate thrusting of large subhorizontal nappes, and subsequent extension and removal of as much as 10 km of crust (Pavlis and others, 1993). (e) The southern part of Gravina arc and companion subduction zone was doubled during the latest stage of sinistral-slip faulting during accretion of the Wrangellia superterrane (McClelland and others 1991, 1992a, b; Monger and others, 1994; Monger and Nokleberg, 1996). The Methow turbidite-basin terrane (MT), an Early and mid-Cretaceous forearc part of the Gravina arc, and the companion Bridge River (BR) and Easton (EA) subduction-zone terranes were structurally imbricated behind the southern part of the Gravina-Nutzotin-Gambier (gg) assemblage (Monger and others, 1994). (f) The mainly orthogonal convergence and accretion of the Wrangellia superterrane initiated eastward thrusting of the North American Craton Margin (NAM) over the North American Craton (NAC). (g) Coeval with thrusting, and occurring along the axis of thrusting was intrusion of the Omineca-Selwyn granitic belt (om) which occurs along the length of Canadian Cordillera, Alaska, and the northern part of the Russian Northeast. The belt was generated during an intense period of anatectic melting, major regional thrusting, and crustal shortening and thickening, all related to orthogonal convergence. Continuing to form in or near the Omineca-Selwyn granite belt were the Bayonne (BA), Cassiar (CA), Selwyn (SW), and Whitehorse (WH) metallogenic belts which contain granitic-magmatism-related deposits. Alternatively, the Wrangellia superterrane accreted far to the south at about 35° paleolatitude along the margin of Baja British Columbia (latitude of present-day Baja California).

Metallogenic Belt Formed in Late Mesozoic Part of East Sikhote-Aline Continental-Margin Arc, Russian Southeast

Sergeevka Metallogenic Belt of Granitoid-Related Au Deposits (Belt SG) Southern Part of Russian Southeast

The Sergeevka metallogenic belt of granitoid-related Au deposits (fig. 79; tables 3, 4) occurs in the southern part of the Russian Far East. The Au deposits occur in or near Late Cretaceous, post-accretionary granitoid plutons and dikes which intrude gneissic gabbro and Cambrian metamorphosed sedimentary rocks in the western part of the Sergeevka continental-margin arc terrane of the Khanka superterrane (fig. 79). The principal deposits are at Askold, Balykovskoe, Krinichnoe, Porozhistoe, and Progress (table 4) (Nokleberg and others 1997a, b, 1998). The deposits are small and generally consist of Au-bearing quartz veins with minor sulfides, mainly pyrite and arsenopyrite. The deposits are generally small.

Progress Granitoid-Related Au Deposit

The Progress granitoid-related Au deposit (A.N. Rodionov, written commun., 1991) consists of sulfide-poor veins and small veinlets which contain pyrite, arsenopyrite, quartz, and gold. In addition the deposit contains poorly mineralized fracture zones, mylonite zones, and zones of metasomatically-altered carbonate-chlorite-sericite rock. Mineralization occurs in a near a Late Cretaceous granitoid pluton and dikes which intrude Cambrian granitic and gabbro rocks of Sergeevka Complex. The average grade is 5.89 g/t Au. The deposit is also the source for local placer Au mines.

Askold Granitoid-Related Au Deposit

The Askold granitoid-related Au deposit (fig. 82) (M.I. Efimova and others, written commun., 1971; Efimova and others, 1978) consists of a Au-quartz vein stockwork in a greisenized Mesozoic granite which intrudes Paleozoic volcanic and sedimentary rocks. A K-Ar muscovite age for alteration associated with the vein is 83.2 Ma (Ishihara and others, 1997). The deposit is prospected to depths of more than 100 m. The deposit is of medium size with an average grade of 5.9-7.6 g/t Au.

Origin of and Tectonic Controls for Sergeevka Metallogenic Belt

The Sergeevka metallogenic belt is hosted in or near Cretaceous granitoid plutons and dikes which intrude the complex continental-margin arc Sergeevka terrane which consists of: (1) migmatized, Cambrian gneissic gabbro and quartz diorite with a U-Pb zircon isotopic age of 500 to 527 Ma (J.N. Aleinikoff, written commun., 1992) which contain large xenoliths of amphibolite, quartzite, marble, and calc-schist; and (2) the Early Ordovician biotite-muscovite Taphuin Granite with a muscovite Ar-Ar age of 491 Ma. Along with other units of the Khanka superterrane, the Sergeevka terrane is overlapped by Devonian continental-rift-related volcanic and sedimentary rocks, middle Paleozoic granitoid rocks, late Paleozoic granitoid rocks, and Permian back-arc-rift-related volcanic rocks.

The Cretaceous granitoid rocks hosting the Sergeevka metallogenic belt are probably part of the East Sikhote-Aline volcanic-plutonic belt (fig. 79) of Late Cretaceous and early Tertiary age (Nokleberg and others, 1994c. These igneous belt consists chiefly of five major units (Nokleberg and others, 1994c): (1) Early Cenomanian rhyolite and dacite; (2) Cenomanian basalt and andesite; (3) thick Turonian to Santonian ignimbrite sequences; (4) Maastrichtian basalt and andesite; and (5) Maastrichtian to Danian (early Paleocene) rhyolite. The East Sikhote-Alin belt also contains coeval, mainly intermediate-composition granitoid plutons. The East-Sikhote-Alin belt is equivalent to Okhotsk-Chukotka volcanic-plutonic belt on strike to the north in Russian Northeast, and is tectonically linked to the Aniva, Hidaka, and Nabilsky accretionary wedge and subduction-zone terranes (Nokleberg and others, 2000). Other related, coeval metallogenic belts hosted in the East-Sikhote-Aline volcanic belt are the Kema, Luzhkinsky, Lower Amur, and Taukha, belts (fig. 79; table 3).

Taukha Metallogenic Belt of B Skarn, Pb-Zn Skarn, Pb-Zn Polymetallic Vein, and Related Deposits (Belt TK) Eastern Part of Russian Southeast

The Taukha metallogenic belt of B skarn, Pb-Zn skarn, Pb-Zn polymetallic vein, and related deposits (fig. 79; tables 3, 4) occurs in the eastern part of the Russian Southeast (Vasilenko and Valuy, 1998). The deposits in the metallogenic belt are mainly B skarn, and Pb-Zn skarn, and Pb-Zn polymetallic vein deposits which are hosted in or near mid- and Late Cretaceous and early Tertiary granitoid rocks of the East Sikhote-Alin volcanic-plutonic belt (Radkevich, 1991). This granitoid rocks of this belt intrude the intensely-deformed Taukha accretionary-wedge terrane (Nokleberg and others, 1994c, 1997c). The major B skarn deposit is at Dalnegorsk; Pb-Zn skarns occur at Nikolaevskoe, Partizanskoe, polymetallic vein deposits occur at Fasolnoe, Krasnogorskoe (table 4), Lidovskoe, Novo-Monastyrskoe (fig. 83; table 4), and Shcherbakovskoe, and a Fe skarn deposit occurs at Belogorskoe (fig. 84; table 4) (Nokleberg and others 1997a, b, 1998; Valuy and Rostovsky, 1998). An isolated porphyry Cu deposit occurs at Plastun, and an isolated Au-Ag epithermal vein deposit occurs at Soyuz (Valuy and Rostovsky, 1998).

The B skarn deposits of the Taukha metallogenic belt are interpreted as forming early in the history of the East Sikhote-Alin igneous belt, from about 90 to 70 Ma when part of the Taukha terrane was overlapped by ignimbrite sequences. Pb-Zn skarn deposits occur in the central part of the Taukha metallogenic belt, mainly in the Dalnegorsk district has produced about forty percent of Russia's zinc and lead. The Pb-Zn skarn deposits are interpreted as forming after the B skarn deposits during a later stage of post-accretion volcanism, with K-Ar ages of 70-60 Ma, and composed mainly of rhyolite and dacite. The skarn deposits generally occur in large limestone blocks enclosed in Early Cretaceous olistostromes. The skarns occur along the contacts between limestone and clastic rocks and chert, and between limestone and overlying post-accretion volcanic rocks which overlie the Early Cretaceous olistostrome.

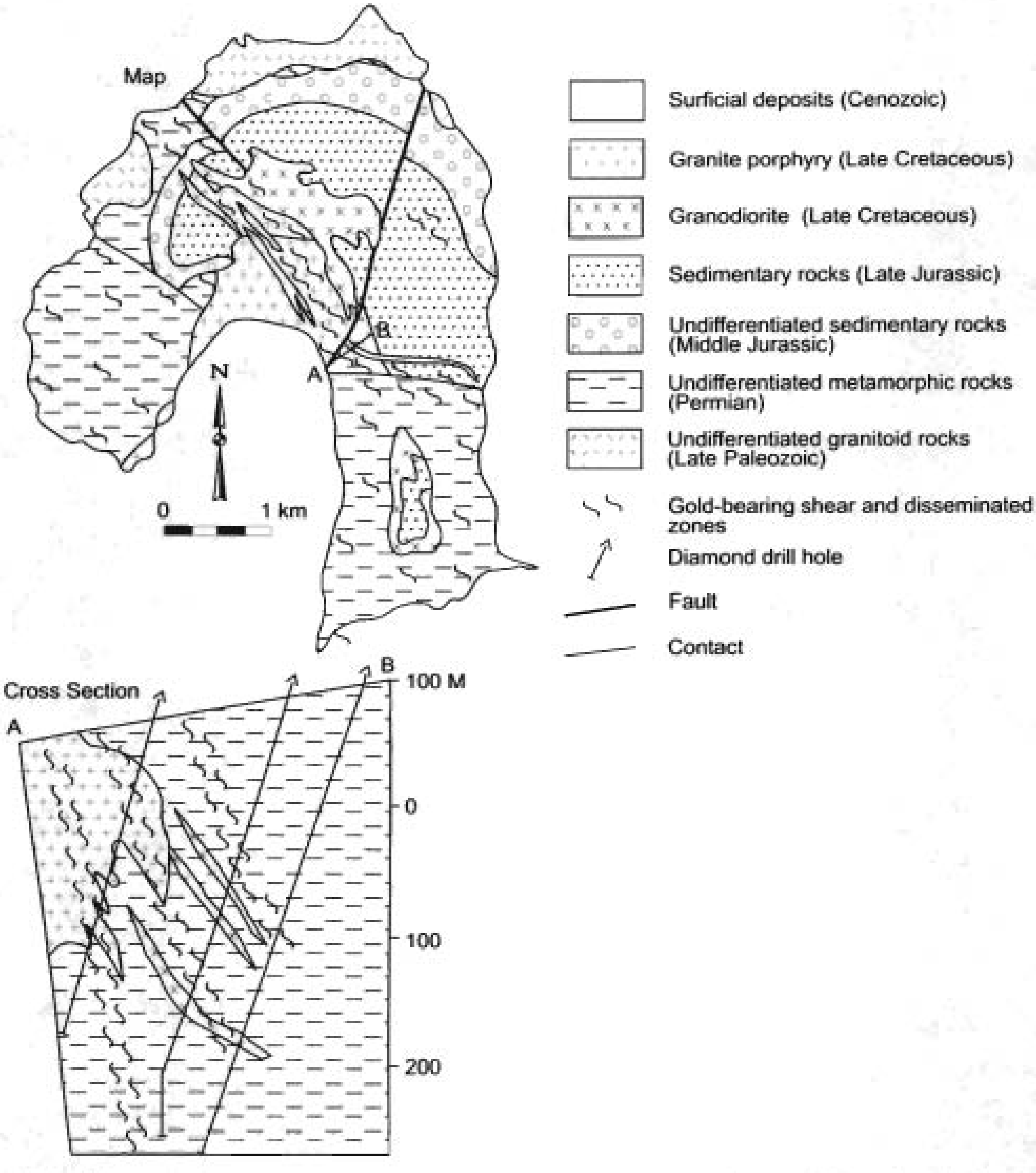


Figure 82. Askold Au granitoid-related Au deposit, Sergeevka metallogenic belt, Russian Southeast. Schematic geologic map and cross section. Adapted from Goryachev (1995a).

The Pb-Zn polymetallic vein deposits are coeval with the Pb-Zn skarn deposits, but occur only in clastic and volcanic rocks. Unlike the skarn deposits, the polymetallic vein deposits contain stannite and lesser cassiterite, in addition to mainly galena, sphalerite, and chalcopyrite. The lower levels of the polymetallic vein deposits contain about 3% Ag in galena, with much less Ag in the upper levels. Some polymetallic vein deposits, as at Lidovskoe, occur in the apices of granodiorite intrusions omagmatic with dacite. The polymetallic vein deposit at Krasnogorskoe are associated with volcanic breccias which are spatially related to a volcanic vent. The breccias also contain syngenetic disseminated galena, sphalerite, pyrite, and cassiterite. This relation suggests a gradation from Pb-Zn polymetallic vein into porphyry Sn deposits (Ratkin and others, 1990). K-Ar isotopic studies indicate an age of about 60 Ma for the volcanic rocks hosting the Pb-Zn polymetallic vein deposits. Sparse disseminated and porphyry Cu deposits, as at Plastun, occur in Maastrichtian to Danian (early Paleocene) volcanic rocks. A small Au-Ag epithermal quartz vein deposit at Soyuz contains Ag-sulfosalts and is hosted in Late Cretaceous rhyolite and tuff.

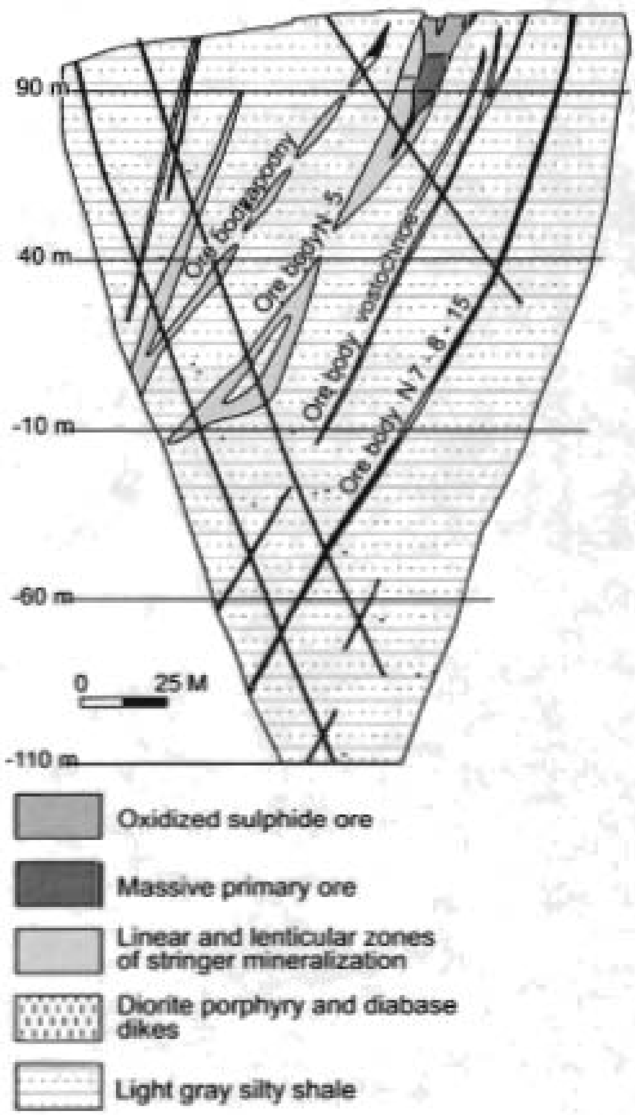


Figure 83. Novo-Monastyrskoe Pb-Zn polymetallic vein deposit, Taukha metallogenic belt, Russian Southeast. Schematic cross section. Adapted from Valuy and Rostovsky (1998).

Dalnegorsk B Skarn Deposit

The major, world-class B deposit at Dalnegorsk (fig. 85) (Ratkin, 1991; Ratkin and Watson, 1993; Layer, Ivanov, and Bundtzen, 1994; Vasilenko and Valuy, 1998; Shkolnik and others, 2003) occurs in a thick skarn formed in a large, upturned olistolith of bedded Triassic limestone enclosed in Early Cretaceous clastic sedimentary rocks. The skarn extends to a depth of approximately 1 km, where it is cut off by a granitic intrusion. The skarn formed in two stages, with a second-stage skarn over-printing an earlier skarn. The two stages of skarn formation are separated in time by intrusion of intermediate-composition magmatic bodies (with approximate K-Ar ages of 70 Ma). The first stage consists of grossular-wollastonite skarn and concentrically zoned, finely banded aggregates with numerous finely crystalline datolite and druse-like accumulations of danburite crystals in paleohydrothermal cavities. The second stage skarn consists predominantly of long, radiated hedenbergite and andradite with coarsely-crystalline datolite, danburite, quartz, axinite, and calcite. The arcuate nature of metasomatic mineral zonation in the skarn is interpreted by Shkolnik and others (2003) as replacement of stromatolite build-ups in the host Triassic Limestone. The complex layering are relict biogenic features of the stomatolite-bearing limestone. An Ar-Ar age for orthoclase indicates an age for the late-stage skarn assemblage of 57 Ma. The silicate mineralogy of the early-stage skarn is similar to which in Pb-Zn skarn deposits in this same region. B isotopic studies indicate a magmatic source for boron (Ratkin and Watson, 1993). The deposit is

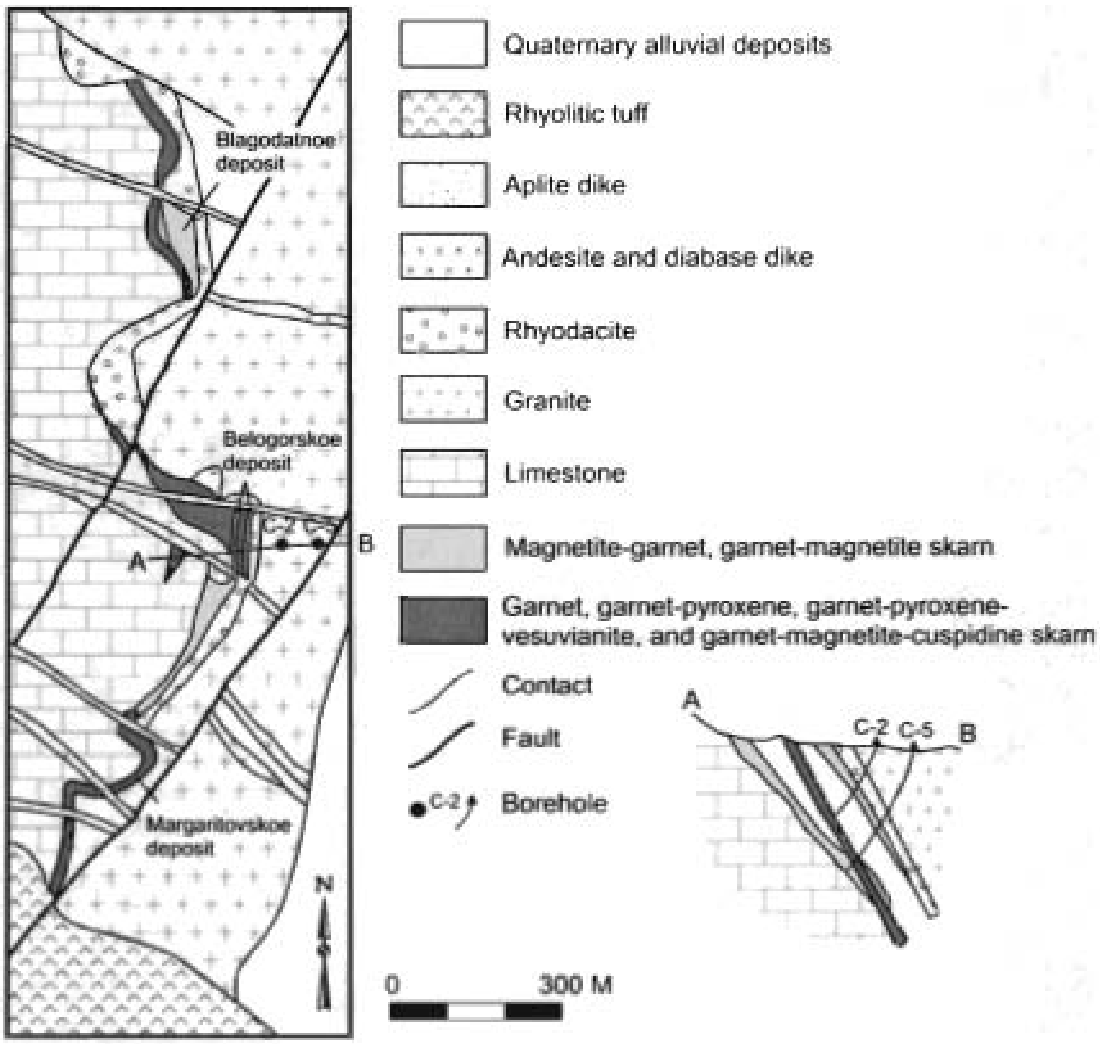


Figure 84. Belogorskoe Fe skarn deposit, Taukha metallogenic belt, Russian Southeast. Adapted from Valuy and Rostovsky (1998).

very large and had been mined from 1970's to present. The deposit produces over 90% of all borate in Russia. The Dalnegorsk open-pit mine at the deposit is prospected to the depth of 1 km.

Nikolaevskoe Pb-Zn Skarn Deposit

The Nikolaevskoe Pb-Zn skarn deposit (fig. 86) (Garbuzov and others, 1987; V.V. Ratkin, this study; Vasilenko and Valuy, 1998) consists of large, layered ore bodies formed in a giant olistolith of Triassic limestone which is part of an Early Cretaceous accretionary-fold complex. The skarn occurs at the contacts of limestone with hosting siltstone and sandstone, and with overlying felsic volcanic rocks of a Late Cretaceous to Paleogene post accretionary sequence. Small ore bodies also occur in limestone blocks in the volcanic rocks which were torn off the underlying basement. The ore minerals are dominantly galena and sphalerite which replace an earlier hedenbergite skarn near the surface, and, at depth, replace a garnet-hedenbergite skarn. Subordinate ore minerals are chalcopyrite, arsenopyrite, pyrite, pyrrhotite, fluorite, and Ag-sulfosalts. K-Ar isotopic studies indicate which an age of mineralization between 60 and 80 Ma. A 60 K-Ar Ma isotopic age is obtained for an unmineralized basalt dike which cuts the deposit, and a K-Ar age of 70-80 Ma is obtained for a mineralized ignimbrite which overlies the olistolith. The deposit is currently being mined. Average grades are 62 g/t Ag, 1.5-8.7% Pb, and, 1.36-10.5% Zn. The deposit has been mined from 1970's to present. The main shaft is about 500 m deep.

Partizanskoe Pb-Zn Skarn Deposit

The Partizanskoe Pb-Zn skarn deposit (fig. 87) (Ratkin, Simanenko, and Logvenchev, 1991) consists of numerous small steeply-dipping ore bodies which occur at the contact of a Triassic limestone olistolith surrounded by Early Cretaceous clastic

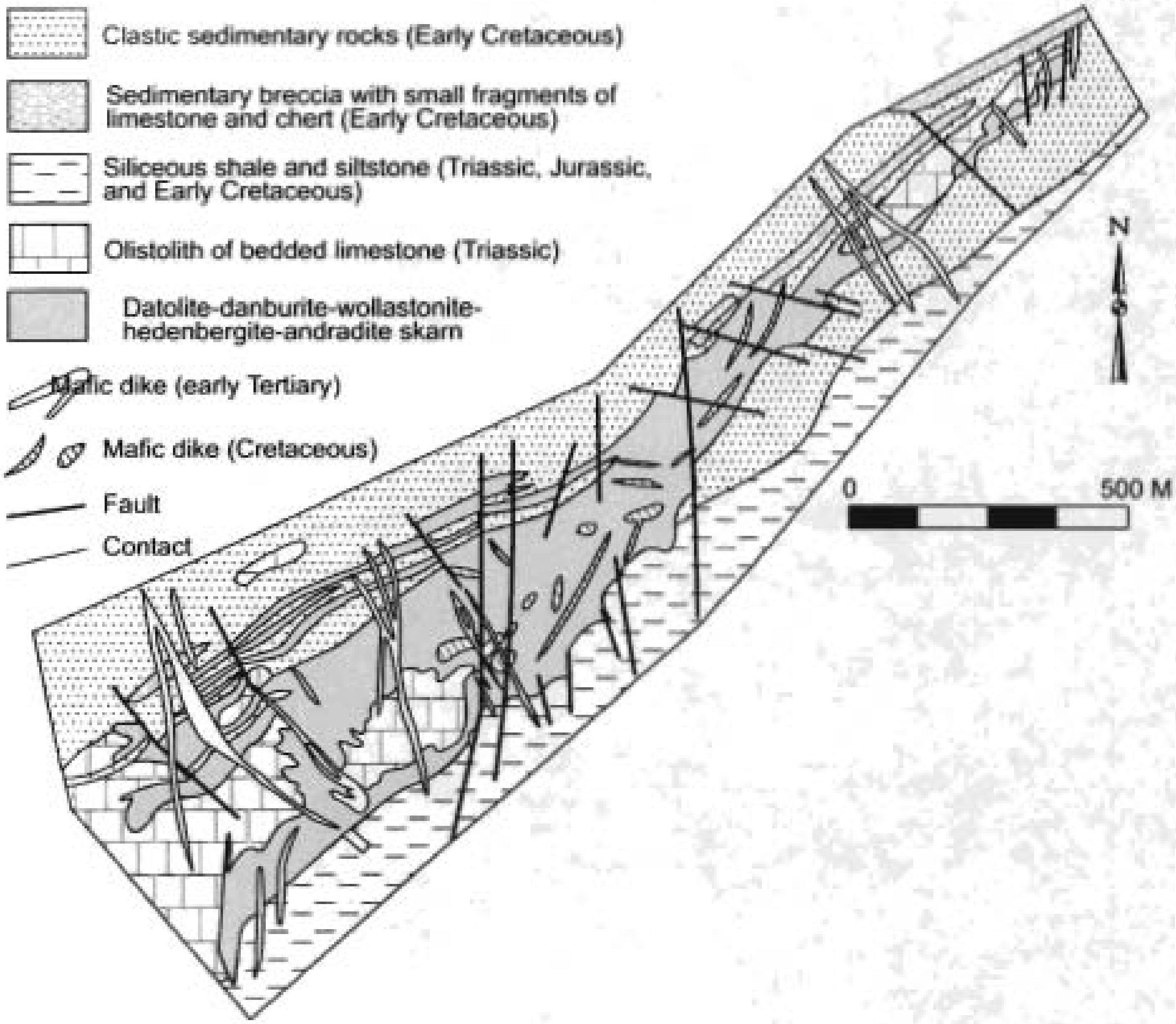


Figure 85. Dalnegorsk B skarn deposit, Taukha metallogenic belt, Russian Southeast. Schematic geologic map. Adapted from Nosenko and Chernyshov (1987).

rocks. The ore bodies merge and form a single skarn deposit about 400 m below the surface, and pinch out at a depth of approximately 600 m. The ore and skarn assemblages are vertically zoned; higher temperature assemblages occur deeper. Massive, densely disseminated Ag-Pb-Zn ore (Pb/Zn ratio of about 1.0) occurs above a quartz-calcite aggregate in the upper part of the deposit. Massive, densely-disseminated Pb-Zn ore (Pb/Zn ratio of about 0.8) is associated with Mn-hedenbergite skarn and occurs at the middle part of the deposit. And disseminated Zn ore (Pb/Zn ratio of about 0.5) occurs in ilvaite-garnet-hedenbergite skarn in the lower part of the deposit. Galena and sphalerite are the dominant ore minerals; chalcopyrite and arsenopyrite are common; minor magnetite, pyrrhotite, and marcasite also occur. Silver-bearing minerals are Ag- and Sb-sulfosalts in the upper part of the deposit and galena in the lower part. Galena contains Ag as a solid solution of matildite. The age of mineralization is bracketed between 60 and 70 Ma by basalt dikes, with K-Ar isotopic ages of 60-70 Ma, which cut the deposit at the contact of olistolith, and by the lower part of the overlying volcanic strata, with K-Ar ages of 70-80 Ma, which are cut by ore body. The deposit consists of four or more related ore bodies which occur over about 5 km strike length, including the Soviet 2, Partizansk East, Partizansk West, and Svetlotvod ore bodies. The underground workings for the ore bodies follow contacts, and have a total length of about 11 km. The deposit is of medium size. Average grades are 67.6 g/t Ag., 1.5-3 % Pb, and 0.6-4 Zn %. The deposit has been mined from the 1950's to present.

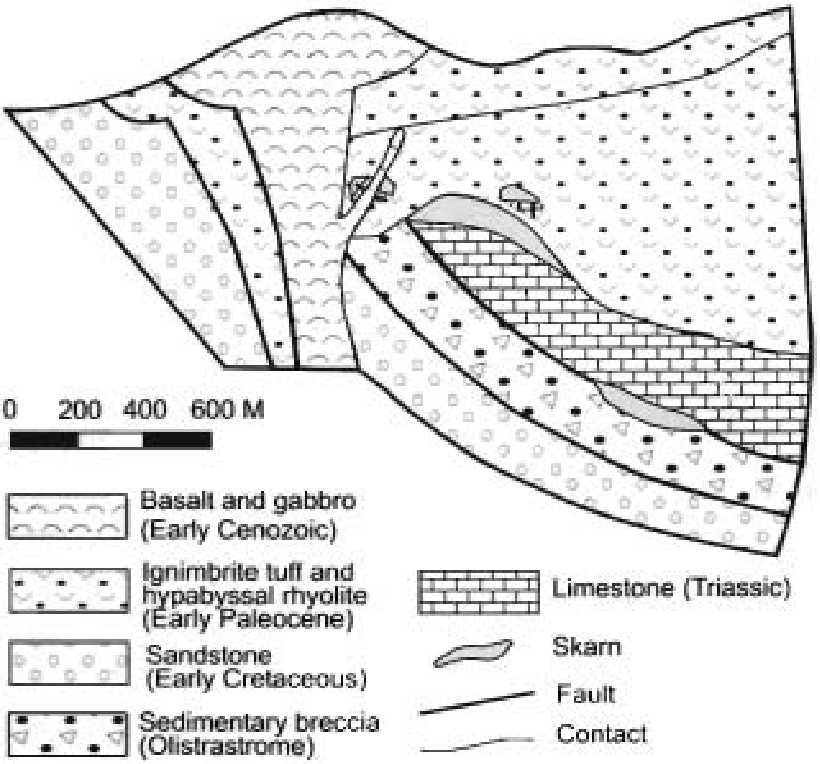


Figure 86. Nikolaevskoe Pb-Zn skarn deposit, Taukha metallogenic belt, Russian Southeast. Schematic cross section adapted from Ratkin (1995).

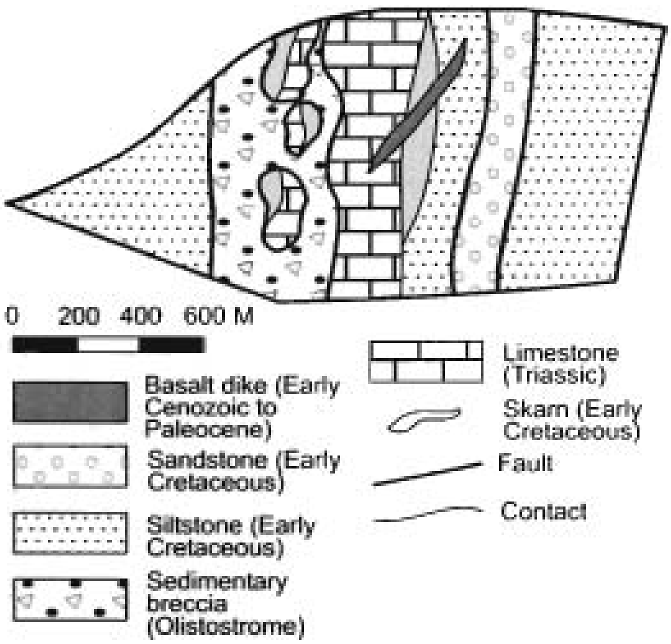


Figure 87. Partizanskoe Pb-Zn skarn deposit, Taukha metallogenic belt, Russian Southeast. Schematic cross section adapted from Ratkin (1995).

Krasnogorskoe Pb-Zn Polymetallic Vein Deposit

The Krasnogorskoe Pb-Zn polymetallic vein deposit (fig. 88) (Ratkin and others, 1990) consists of steeply-dipping quartz-sulfide veins, up to several hundred m length along strike and from 0.2 to 1.5 m thick, which cut a sequence of Late Cretaceous (Cenomanian to Turonian) ash flow tuff. Sphalerite and galena are the dominant ore minerals; the flanks of veins contain pyrite-marcasite-pyrrhotite, with lesser Sb-Ag-sulfosalts. At the deeper levels of the ore bodies, galena contains up to several percent Ag and Bi in matildite. The volcanic rocks adjacent to the polymetallic veins are altered to quartz and chlorite. In the core of the veins, chlorite, Mn-calcite, rhodochrosite, rhodonite, and spessartine occur with quartz gangue. The veins occur near an Late Cretaceous-Paleocene (Maastrichtian to Danian) volcanic vent. The vent breccia also contains disseminated sphalerite, galena, and cassiterite. The veins formed immediately after mineralization of vent breccia, which were dated as approximately 65 Ma by K-Ar isotopic studies. The deposit is of medium size. Average grades are 62 g/t Ag, 5 % Pb, 0.26 % Sn, and 6.77 % Zn.

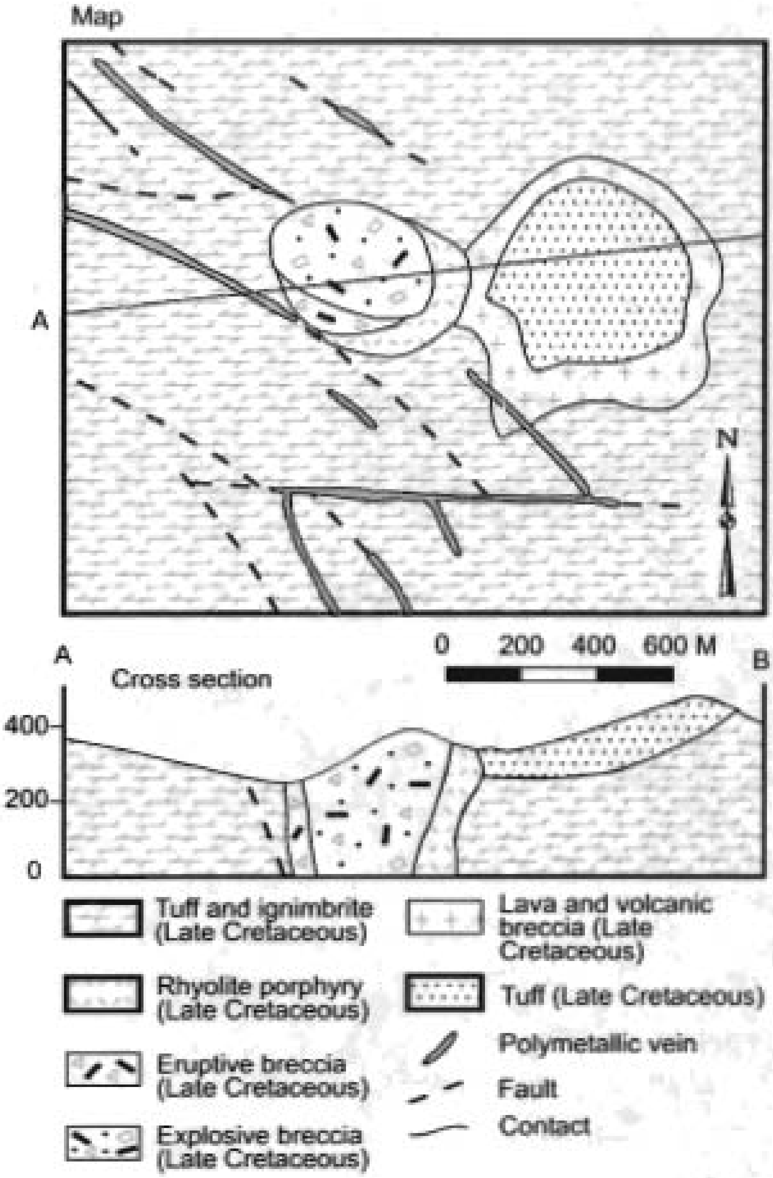


Figure 88. Krasnogorskoe Pb-Zn polymetallic vein deposit, Taukha metallogenic belt, Russian Southeast. Generalized geologic map and cross section. Adapted from Ratkin and others (1990).

Origin of and Tectonic Controls for Taukha Metallogenic Belt

The Cretaceous granitoid rocks hosting the Taukha metallogenic belt are part of the East Sikhote-Alin volcanic-plutonic belt (fig. 79) of Late Cretaceous and early Tertiary age (Vasilenko and Valuy, 1998). The volcanic and plutonic units are widespread and are controlled by NE-trending strike-slip and pull-apart structures. The B and Pb-Zn-Ag sulfide deposits are hosted in tectonic lenses of limestone or marble which occur in the Tauka accretionary-wedge terrane. The terrane consists of mainly of Neocomian turbidite deposits and olistostromes composed Paleozoic and Mesozoic guyots, formed of limestone caps which overlying basalt pedestals, and Carboniferous through Jurassic chert, Berriasian through Valanginian turbidite, and Permian, Triassic, and Berriasian through Valanginian shelf sandstone and turbidite deposits (Nokleberg and others, 1994c, 1997c).

Like the Kema and Luzhkinsky metallogenic belts, the coeval Taukha metallogenic belt is hosted by East Sikhote-Alin volcanic-plutonic belt of Late Cretaceous and early Tertiary age (fig. 79) which is described in the above section the origin of the Taukha metallogenic belt. Other related, coeval metallogenic belts hosted in the East-Sikhote-Aline volcanic belt are the Kema, Luzhkinsky, Lower Amur, and Sergeevka (SG) belts (fig. 79; table 3). The differences between the coeval metallogenic belts are interpreted as due to the host igneous rocks intruding different bedrock. The Taukha metallogenic belt contains mainly B skarn, Pb-Zn skarn, and Pb-Zn polymetallic vein deposits, and is hosted in or near igneous rocks of the East Sikhote-Alin belt which intrude the Taukha accretionary-wedge terrane which contains a complex assemblage of abundant Paleozoic and early Mesozoic oceanic rocks and lesser Jurassic and Early Cretaceous turbidite deposits. In contrast, the Luzhkinsky metallogenic belt contains mainly Sn greisen and Sn polymetallic vein, and porphyry Sn deposits, and is hosted in or near granitoid rocks of the East Sikhote-Alin belt which intrude the Zuravlevksk-Tumnin turbidite basin terrane which contains mainly Late Jurassic and Early Cretaceous turbidite deposits.

Kema Metallogenic Belt of
Ag-Au Epithermal Vein, and
Porphyry Cu-Mo Deposits (Belt KM)
Eastern Part of Russian Southeast

The Kema metallogenic belt of Ag-Au epithermal vein and porphyry Cu-Mo deposits (fig. 79; tables 3, 4) occurs in the eastern part of the Russian Southeast. The deposits in the metallogenic belt are hosted in or near Late Cretaceous and early Tertiary granitoid rocks of the East Sikhote-Alin volcanic-plutonic belt which intrude or overlie the Kema island-arc terrane (Nokleberg and others, 1994c, 1997c).

The major Au-Ag epithermal vein deposits in the Kema metallogenic belt are at Burmatovskoe, Glinyanoe, Salyut, Sukhoe, Tayozhnoe, Verkhnezolotoe, and Yagodnoe (table 4) (Nokleberg and others 1997a, b, 1998). Porphyry Cu deposits are at Nesterovskoe and Nochnoe, porphyry Cu-Mo deposits are at Sukhoi Creek, and a porphyry Mo deposit is at Moinskoe. The Ag epithermal vein deposits, as at Tayoznoe, also occur in Early Cretaceous clastic and volcaniclastic rocks and in overlying Late Cretaceous and Paleogene, subalkalic, postaccretionary volcanic rocks of the East Sikhote-Alin igneous belt. Ag sulfosalt minerals predominate in the deposits. Concentrations of Ag are much greater than Au, and Ag/Au ratios generally are greater than 25 to 30. Rare Pb-Zn polymetallic vein deposits occur in the metallogenic belt, but are not economic (P.I. Logvenchev, O.L. Sveshnikova, and V.A. Pakhomova, written commun., 1994; Pakhomova and others, 1997). However, these deposits are generally of little commercial value at the present. The epithermal vein deposits generally occur mostly in or near Danian (early Paleocene) and Paleocene volcanic rocks; however, a few occur in granodiorite plutons (Khomich and others, 1989).

Porphyry Cu-Mo deposits in the Kema metallogenic belt occur mainly in the northern part of the belt at Moinskoe, Nochnoe, and Sukhoi Creek. These deposits generally consist of disseminations and veinlets in and near the intrusive rocks and coeval volcanic rocks which often contain notable amounts of Pb, Zn, W, Au, and Ag in addition to Cu and Mo. The deposits occur in Late Cretaceous to Paleogene granitic and diorite intrusions. A porphyry Cu deposit occurs in the southern part of the belt at Nesterovskoe. In the western part of the belt, in the eastern part of the adjacent Luzhkinsky terrane, are porphyry Sn deposits, as at Mopau.

Glinyanoe Ag Epithermal Vein Deposit

The rich Glinyanoe Ag epithermal vein deposit (A.N. Rodionov, written commun., 1986) consists of adularia-quartz, sericite-chlorite-quartz, and carbonate-chlorite-quartz mineralized veins and zones which contain pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, argentite, acanthite, Ag-tellurides, and native gold and silver. The veins and zones occur in altered, silicified volcanic rocks which overlie Late Cretaceous (Santonian) felsic volcanic rocks. The deposit is interpreted to have occurred in four stages: (1) gold-pyrite-quartz; (2) quartz-hydromica and quartz-carbonate; (3) gold-silver; and (4) quartz-chlorite-adularia with Ag-sulfosalts. The age of the deposit is interpreted as Late Cretaceous to Paleogene. The deposit is judged to be small. Average grades are 8.3 g/t Au and 122 g/t Ag.

Sukhoi Creek Porphyry Cu-Mo Deposit

The Sukhoi Creek porphyry Cu-Mo deposit (Petrachenko and others, 1988) consists of stockworks which reach several hundred m across, and in altered zones. Polymetallic ore dominates in some stocks. The ore minerals are chalcopyrite, molybdenite, sphalerite, galena, cassiterite, scheelite, and pyrite; with significant Au and Ag contents. The deposit occurs in Early Cretaceous sedimentary rocks which are overlain by Late Cretaceous volcanic rocks and are crosscut by ore-bearing granitic intrusions with a K-Ar isotopic age of 73 Ma. The Porphyry Mo mineralization is related to several granodiorite and granite stocks which are intensely hydrothermally altered. Quartz-sericite alteration and medium-temperature epidote-prehnite-chlorite propylitic alteration occur at the core and grade into micaceous-chlorite-carbonate propylite at the periphery. The granite is locally altered to quartz-muscovite greisen with tourmaline and sphene, and in a few places into a peculiar garnet-phlogopite rock with apatite. The host siltstone and sandstone are altered to orthoclase-actinolite-chlorite hornfels and the felsic extrusive rocks are altered to quartz and phyllite. Average Cu and Mo contents are low, up to 0.2 and 0.01% respectively. The deposit is not explored at depth.

Tayozhnoe Ag Epithermal Vein Deposit

The Tayozhnoe Ag epithermal vein deposit (A.N. Rodionov and others, written commun., 1976; Pakhomova and others, 1997) consists of steeply-dipping quartz veins which occur along northwest to north-south fractures which cut coarse-grained, Early Cretaceous sandstone. The veins are 100 to 500 m long and 0.5 to 2 m thick, and also occur laterally under the contact between sandstone and overlying 50-m-thick section of Late Cretaceous felsic volcanic rocks. The ore minerals occur within the veins, and in metasomatic zones along the sub-horizontal contact between veins and overlying volcanic rocks. The major Ag-bearing minerals are Ag sulfosalts and sulfides. Pyrite and arsenopyrite are rare and formed before Ag-bearing minerals. In the upper part of veins, Ag occurs in tetrahedrite, freibergite, stephanite, pyrargyrite, and polybasite. At middle depths, Ag occurs in acanthite and stephanite dominate, along with arsenopyrite and allargentum also occur, whereas acanthite dominates at depth. The deposit is medium size with an average grade of 50-2000 g/t Ag and 1 g/t Au. The deposit has been mined since the 1980's, and is assumed to be related to a Paleocene rhyolite volcano-plutonic assemblage.

Verkhnezolotoe Porphyry Cu Deposit

The Verkhnezolotoe porphyry Cu deposit (Orlovsky and others, 1988) occurs at the northwest margin of a caldera which contains dike-like bodies of calc-alkaline andesite porphyry which is interpreted as tongues of a dome-like subvolcanic intrusion. A stockwork occurs in a circular aureole of hydrothermally altered rocks, with dimensions of 200 m^2, occurs over the intrusive dome. Successive alterations consist of: (1) quartz-biotite-actinolite with pyroxene and epidote; (2) quartz-biotite-actinolite; (3) quartz-biotite-sericite and local chlorite; and (4) quartz-hydromica with carbonate. The stockwork includes the first three alterations and consists of a thick network of quartz-epidote-actinolite veinlets and lenses up to 2 to 3 cm thick with chalcopyrite, bornite, and pyrite. The stockwork is related to a diorite stock. The stockwork boundary coincides with the aureole of the biotite alteration. An intensely-fractured breccia of mineralized siliceous siltstone was encountered by drill holes which extend to 100 m depth. The ore minerals in breccia zones are chalcopyrite, bornite, molybdenite, pyrite, rarely pyrrhotite, cubanite, arsenopyrite, galena, and sphalerite. Carbonate-chalcopyrite veinlets also occur. A zone of oxidized ore up to 20 to 30 m deep caps the deposit. The deposit is small with average grades of 3 g/t Au, 86 g/t Ag, 0.35-2.27% Cu, 0.69% Pb, and 0.26% Sn.

Origin of and Tectonic Controls for Kema Metallogenic Belt

The Cretaceous granitoid rocks hosting the Kema metallogenic belt are part of the East Sikhote-Alin volcanic-plutonic belt of Late Cretaceous and early Tertiary age (fig. 79) which is described in the above section the origin of the Taukha metallogenic belt. Other related, coeval metallogenic belts hosted in the East-Sikhote-Aline volcanic belt are the Luzhkinsky, Lower Amur, Sergeevka (SG), and Taukha (TK)belts (fig. 79; tables 3, 4). In the Kema metallogenic belt, the Cretaceous granitoid rocks of the East Sikhote-Alin belt intrude the Kema island-arc terrane which consists chiefly of distal turbidite deposits, andesite and basalt flows, breccia, tuff, and interbedded shallow-marine volcaniclastic rocks which contain Aptian to Albian pelecypods (Nokleberg and others, 1994c). The volcanic rocks range mainly from tholeiitic and calc-alkalic. In the Kema metallogenic belt, the volcanic rocks are mostly intermediate and moderately felsic, mainly rhyolite and lesser basalt with K-Ar ages of about 55 to 60 Ma. In contrast to the nearby Taukiha metallogenic belt, the Kema metallogenic belt contains mainly Ag-Au epithermal deposits and is hosted in or near granitoid rocks of the East Sikhote-Alin belt where it intrudes the Cretaceous island-arc rocks of the Kema terrane.

Luzhkinsky Metallogenic Belt of Sn Greisen, Sn Polymetallic Vein, Sn silica-sulfide vein, and Porphyry Sn Deposits (Belt LZ) Southern Part of Russian Southeast

The Luzhkinsky metallogenic belt of Sn greisen and Sn polymetallic vein, and porphyry Sn deposits (fig. 79; tables 3, 4) occurs in the southern part of the Russian Southeast (Gonevchuyk and Kokorin, 1998). The belt is hosted in the Late Cretaceous and early Tertiary granitoid rocks of the East Sikhote-Alin volcanic-plutonic belt which intrude the southern part of the Zhuravlesk-Tumnin turbidite basin terrane (Nokleberg and others, 1994c, 1997c). The Luzhkinsky metallogenic belt contains one of the major group of Sn mines in the Russian Southeast (Vasilenko and others, 1986; Radkevich, 1991; Gonevchuk and others, 1998). The significant deposits in the belt are Sn silicate-sulfide vein deposits at Arsenyevsoe, Khrustalnoe, and Vysokogorskoe (fig. 89), Sn polymetallic vein deposits at Dalnetayozhnoe, Iskra (fig. 90), Nizhnee, and Zimnee, a polymetallic vein deposit at Yuzhnoe, porphyry Cu and porphyry Cu-Mo deposits at Lazurnoe, Malinovskoe, Verkhnezolotoe, and Zarechnoe, porphyry Sn deposits at Yantarnoe and Zvezdnoe, and Sn-W greisen deposits at Tigrinoe and Zabytoe (table 4) (Nokleberg and others 1997a, b, 1998; Gonevchuk and others, 1998).

Sn greisen and Sn polymetallic Vein Deposits

The Sn greisen and Sn polymetallic vein deposits of the Luzhkinsky belt formed in the mid-Cretaceous and early Tertiary between about 90 to 100 and 60 Ma (Gonevchuk and Korkorin, 1998). The older deposits formed in the early Late Cretaceous (90 to 100 Ma), are typical Sn greisen deposits, and are associated with Li-F granitoid rocks. These Sn greisen deposits contain notable amounts of W, as at the Tigrinoe deposit which occurs in the eastern part of the metallogenic belt adjacent to the Samarka W skarn accretionary metallogenic belt (fig. 79). Intermediate-age deposits, formed in the late Late Cretaceous (75-85 Ma), are Sn polymetallic vein deposits, as at Zimnee, which are interpreted as forming in coeval andesite, monzodiorite, and granodiorite intrusions. These Sn polymetallic vein deposits occur in the western part of the Luzhkinsky metallogenic belt. The younger deposits

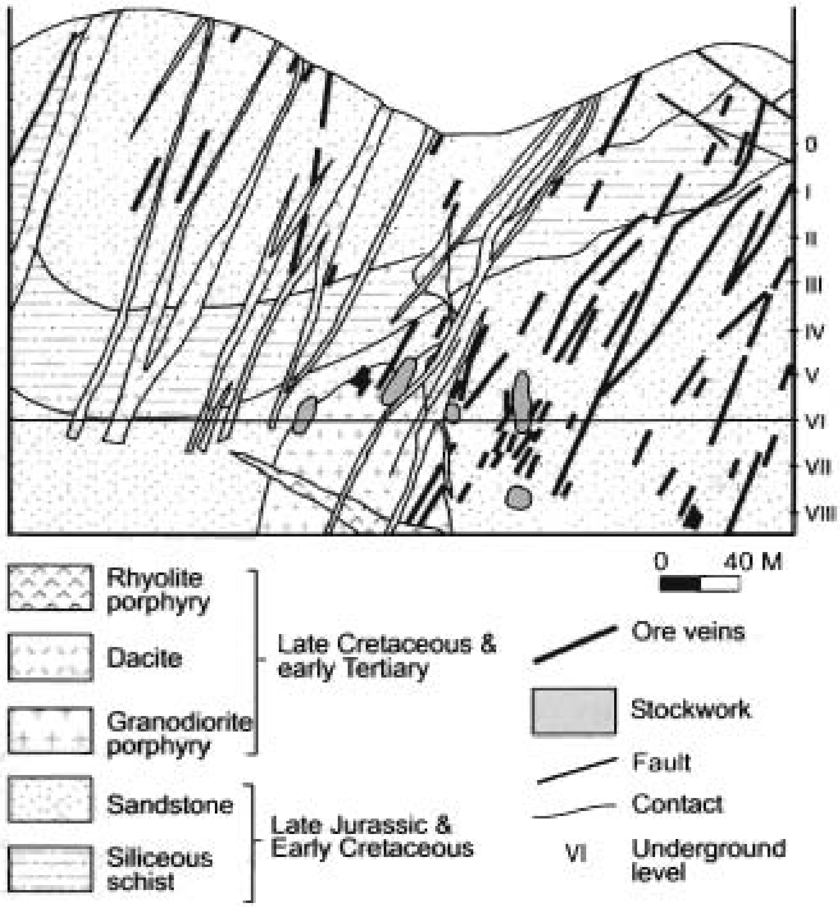


Figure 89. Vysokogorskoe Sn silicate-sulfide vein deposit, Luzhkinsky metallogenic belt, Russian Southeast. Schematic cross section. Adapted from Gonevchuk and others (1998).

formed in the Late Cretaceous and early Tertiary (70-60 Ma) and are Sn silica-sulfide vein deposits, as at Arsenyevsky which are composed mainly of cassiterite and silicate minerals. These deposits are often generally spatially related to the older Sn polymetallic deposits and formed simultaneously with Zn-Pb skarn deposits of the post-accretionary Taukha metallogenic belt to the east. The Late Cretaceous and early Tertiary Sn silica-sulfide vein deposits are interpreted as related to the formation of ultrapotassic rhyolite volcanic porphyries; however, any direct relation to intrusion rocks is quite obscure.

Tigrinoe Sn Greisen Deposit

The Tigrinoe Sn greisen deposit (fig. 91) (Rodionov and Rodionova, 1980; Rodionov and others, 1984; Ruchkin and others, 1986; Rodionov and others, 1987; Korostelev and others, 1990; Gerasimov and others, 1990; Gonevchuk and Gonevchuk, 1991; Gonevchuk and others, 1998) is a complex Sn-W deposit consisting of: (1) a stockwork of quartz-topaz-micaceous greisen along the contact of a massif of Li-F granite; (2) a linear stockwork consisting of a thick network (5 to 10 to 70 veinlets per meter) of parallel north-south-trending quartz-topaz veins from 3 to 100 cm thick which are hosted in contact-metamorphosed sedimentary rocks adjacent to the granite intrusion; and (3) a sulfide breccia pipe consisting of rock fragments of the stockwork and greisen cemented by quartz with lesser carbonate, fluorite, and sulfides. Three stages of mineralization are distinguished: (1) early quartz-molybdenite-bismuthinite; (2) middle-stage REE greisen of wolframite-cassiterite with high contents of Sc, Ni, and Ta; and (3) late hydrothermal quartz-fluorite-carbonate-sulfide veins. In, Cd, Ag, and Se are enriched in sulfides of the two last stages. A Rb-Sr age of the lithium-fluorine granite is 86 ± 6 Ma with an initial Sr ratio of 0.7093. A Rb-Sr age of the greisen is 73 ± 18 Ma with an initial Sr ratio of 0.7105. The average grade is 0.14% Sn and 0.045% W_2O_3. The deposit is of medium size.

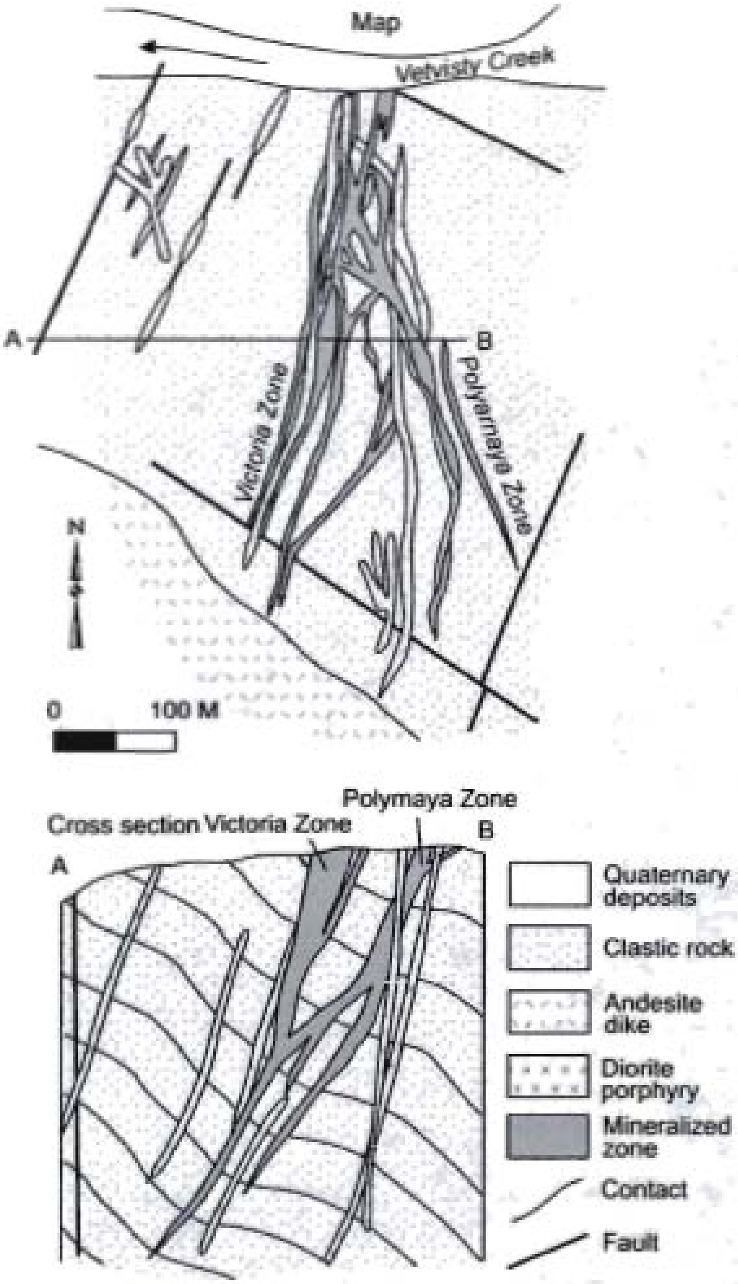


Figure 90. Iskra deposit Sn polymetallic vein deposit, Luzhkinsky metallogenic belt, Russian Southeast. Schematic geologic map and cross section. Adapted from Gonevchuk and others (1998).

Zimnee Sn Polymetallic Vein Deposit

The Zimnee Sn polymetallic vein deposit (P.G. Korostelev and others, written commun., 1980; Nazarova, 1983; Gonevchuk and others, 1998) consists of mineralized breccia, breccia- and fracture-filling veins, zones of closely spaced veinlets, and pockets which occur in fracture zones. The Sn polymetallic ore bodies have strike lengths up to 1200 m, are extensive down dip, and vary in thickness from several tenths of a meter to several tens of meters. The deposit occurs near a granodiorite body and consists mainly of pyrrhotite, pyrite, arsenopyrite, sphalerite, stannite, and cassiterite. Ore far from the granodiorite and in the upper part of veins is mostly galena with fine-grained cassiterite. Near the granodiorite, the ore consists of breccia-bearing fragments of tin-sulfide minerals which are cemented by a quartz-micaceous (greisen) aggregate with arsenopyrite and cassiterite. The K-Ar age of altered rocks associated with the Sn-polymetallic ores is 75 Ma. The age of greisen assemblage is approximately 50 Ma as determined by a K-Ar age of 50 Ma for the granodiorite. The deposit exhibits regional metamorphism, cataclasis, and is small. Average grades are 0.1-3.0% Cu, 3.18% Pb, 0.59% Sn, and 4.09% Zn.

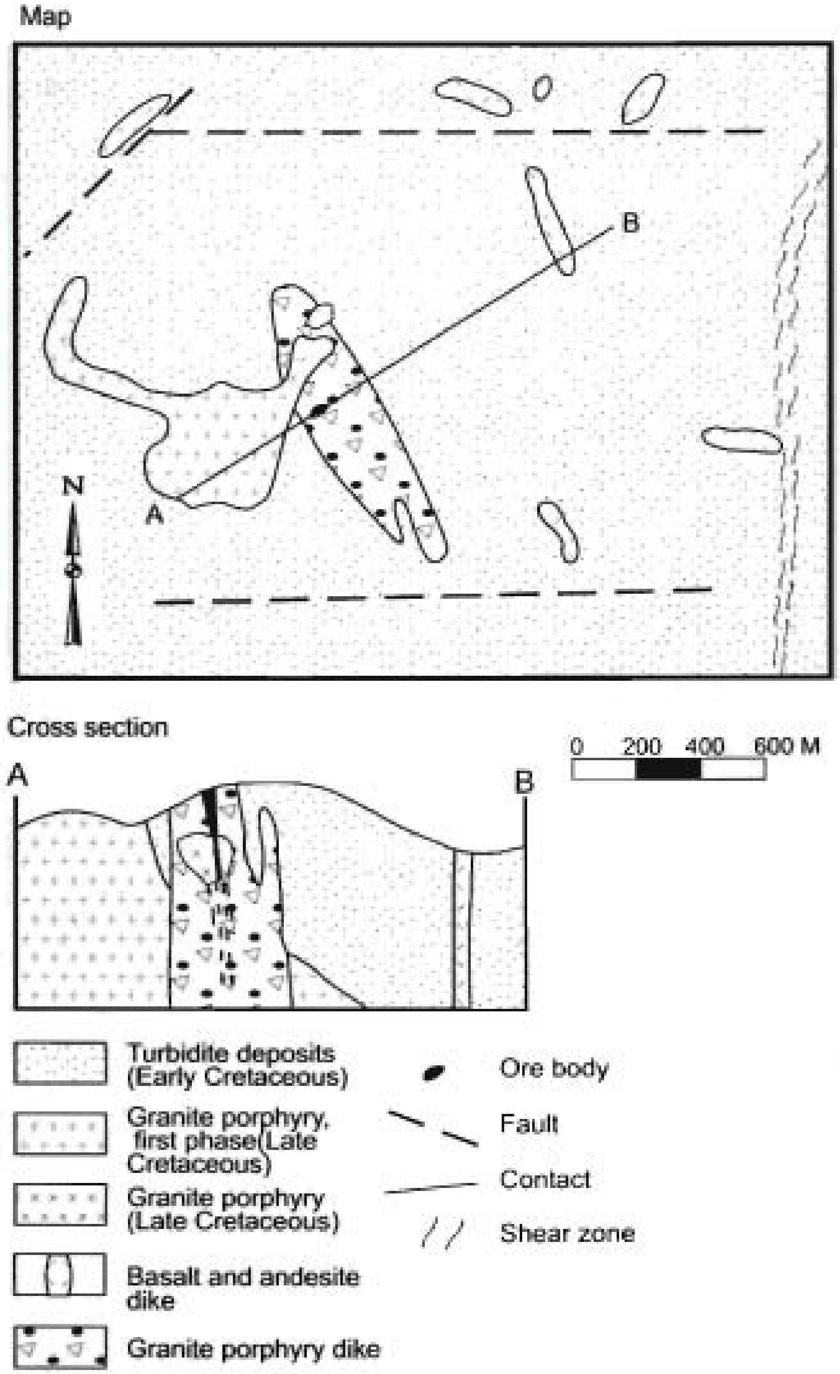


Figure 91. Tigrinoe Sn-W greisen deposit, Luzhkinsky metallogenic belt, Russian Southeast. Schematic geologic map and cross section. Adapted from Korostelev and others (1990).

Arsenyevskoe Sn Silica-Sulfide Vein Deposit

The Arsenyevskoe Sn silicate-sulfide vein deposit (fig. 92) (Rub and others, 1974; Radkevich and others, 1980; Gonevchuk and others, 1998), one of the larger Sn vein mines in the Luzhkinsky belt, consists of a series of parallel, steeply-dipping quartz veins up to 1000 m along strike and 600 to 700 m down dip. The deposit is closely associated with moderate- to steeply-dipping rhyolite dikes with K-Ar isotopic ages of 60 Ma (early Tertiary). The ore mineral assemblage is vertically zoned. From the top downwards, the assemblages are: quartz-cassiterite, quartz-arsenopyrite-pyrrhotite, polymetallic, and arsenopyrite-pyrrhotite. The rhyolite exhibits quartz-sericite alteration. Local miarolithic cavities are filled with cassiterite. The deposit is of medium size. Sn content ranges from 0.1 to 20-25% and averages 2-3%, WO_3 content ranges from 0.1-0.5%, Pb and Zn from 1-2%, Ag content is about few hundred ppm. The deposit has been mined since the 1970's.

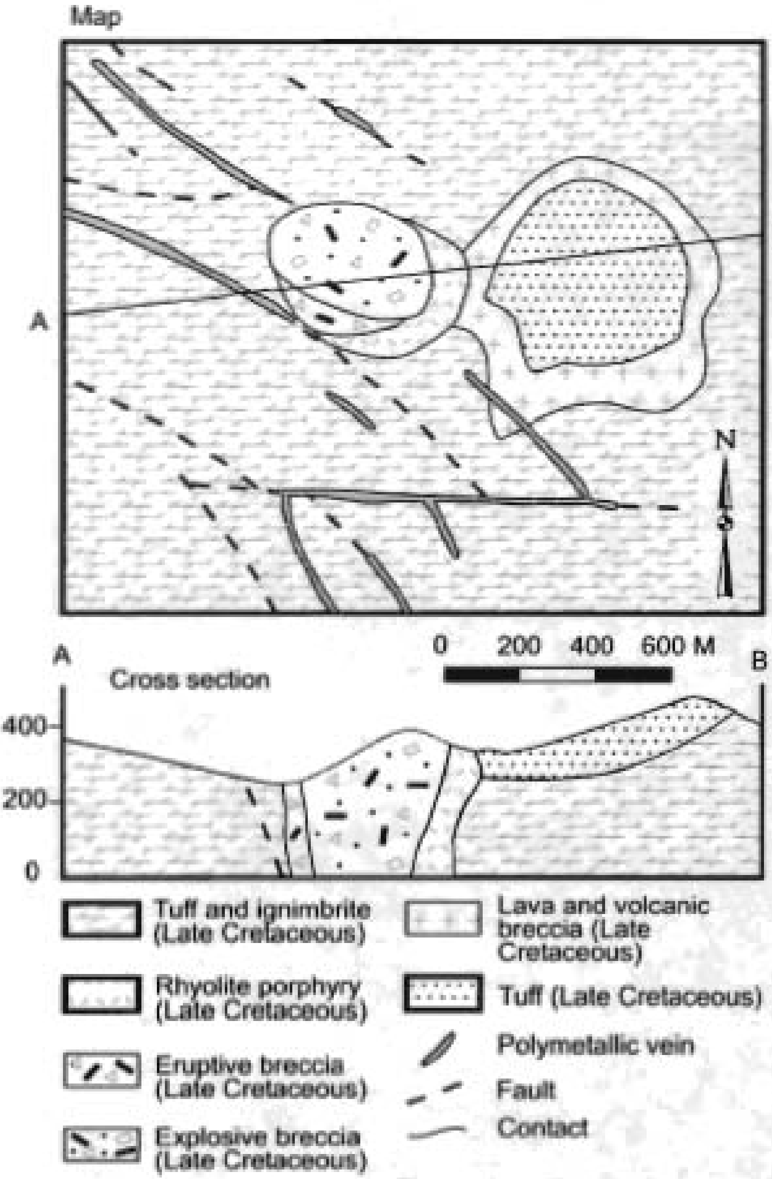


Figure 92. Arsenyevskoe Sn silicate-sulfide vein deposit, Luzhkinsky metallogenic belt, Russian Southeast. Schematic geologic map. Adapted from Ratkin (1995).

Yantarnoe Porphyry Sn Deposit

Porphyry Sn deposits, as at Yantarnoe, occur in the northern part of the Luzhkinsky belt. These deposits are poorly studied, although they are very promising economically. The Yantarnoe deposit (Rodionov, 1988), consists of veinlets and disseminations of cassiterite and sulfide minerals in a pipe-like body and a volcanic breccia composed of trachyandesite and rhyolite which intrude Early Cretaceous clastic sedimentary rocks. The earliest mineralization was associated with rhyolite in the pipe-like body and volcanic breccia and produced mainly pyrite-chalcopyrite. The major part formed after the intrusion of an explosive breccia and consists of metasomatic quartz-chlorite, quartz-sericite, and quartz-chlorite-sericite alterations which contain a sulfide-free cassiterite-chlorite-quartz assemblage, and a Sn-polymetallic assemblage rich with galena, sphalerite, and chalcopyrite. The host igneous rocks are spatially related to volcanic vents of Paleocene age with K-Ar isotopic ages of about 65 Ma. The deposit is small. Average grades are 0.1-2.17% Cu, 0.03-1.02% Pb, 7.3% Sn, and 0.7-2.22% Zn.

Also in the same area are younger, generally uneconomic Sn greisen occurrences with K-Ar isotopic ages of 60-50 Ma age. In addition to Sn deposits, the northern part of the Luzhkinsky metallogenic belt includes sparse small porphyry Cu deposits, as at Verkhnezolotoe, which are associated with Senomanian and Turonian monzodiorite in the northwestern part of the belt near the Samarka accretionary-wedge terrane which contains abundant oceanic lithologies. The porphyry Cu deposits are coeval with the Sn deposits of the Luzhkinsky metallogenic belt, but presumably reflect the anomalous Cu-rich characteristics of the oceanic Samarka terrane.

Origin of and Tectonic Controls for Luzhkinsky Metallogenic Belt

The Luzhkinsky metallogenic belt hosts the Kavalerovo ore district which has produced about 30% of the tin mined in the former USSR (Gonevchuk and Kokorin, 1998). The belt is interpreted as forming in the back-arc part of the East Sikhote-Alin volcanic plutonic belt which forms a major continental-margin arc in the Russian Southeast.

The Cretaceous granitoid rocks hosting the Luzhkinsky metallogenic belt are part of the East Sikhote-Alin volcanic-plutonic belt (fig. 79) of Late Cretaceous and early Tertiary age (Gonevchuk and Kokorin, 1998) which is described in the above section the origin of the Taukha metallogenic belt. Other related, coeval metallogenic belts hosted in the East-Sikhote-Aline volcanic belt are the Kema (KM), Lower Amur, Sergeevka (SG), and Taukha (TK) belts (fig. 79; table 3). The differences between the coeval metallogenic belts are interpreted as the result the igneous rocks which host these metallogenic belts intruding different bedrock. In contrast, to the nearby Kema metallogenic belt, the Luzhkinsky metallogenic belt occurs in the part of the East Sikhote-Alin igneous belt which intrudes the southern part of the Zuravlevksk-Tumnin turbidite basin terrane (fig. 79) (Nokleberg and others, 1994c, 1997c). Additional possible controls for the Luzhkinsky metallogenic belt are: (1) the turbidite deposits in the Zuravlevksk-Tumnin terrane are enriched in Sn; and (2) the Luzhinsky belt occurs in the back-arc part of the East Sikhote-Alin igneous belt in which magnetite-series granitoid rocks predominate.

Lower Amur Metallogenic Belt of Au-Ag Epithermal Vein, Porphyry Cu, and Sn Greisen Deposits (Belt LA) Northern Part of Russian Southeast

The Lower Amur metallogenic belt of Au-Ag epithermal vein, porphyry Cu, and Sn Greisen deposits (fig. 79; tables 3, 4) occurs in the northern part of the Russian Southeast. The deposits in the metallogenic belt are hosted in or near mid- and Late Cretaceous and early Tertiary granitoid igneous rocks of the East Sikhote-Alin volcanic-plutonic belt which intrude or overlie the Amur River and Kiselyovka-Manoma accretionary-wedge terranes. The major Au-Ag epithermal vein deposits are at Belaya Gora, Bukhtyanskoe, and Mnogovershinnoe; a porphyry Cu deposit is at Tyrskoe, and a Sn greisen deposit is at Bichinskoe (table 4) (Nokleberg and others 1997a, b, 1998).

The Au-Ag epithermal vein deposits, as at Mnogovershinnoe, range from medium to large size and are generally hosted in Paleocene alkaline granitoid rocks which are closely associated with coeval andesite to dacite volcanic rocks. Some Au-Ag epithermal vein deposits are associated with Eocene and Oligocene volcanism (Khomich and others, 1989). The Au-Ag epithermal vein deposits, as at Belaya Gora and Bukhtyanskoe, are closely associated with rhyolite and trachyrhyolite flows and vent rocks which are commonly hydrothermally-altered to siliceous and adularia phases. Au is either disseminated throughout the hydrothermally-altered rocks or is concentrated in small quartz veins. The adularia phases also locally contain Au. Placer Au deposits, as at Kolchanskoe, Ulskoe, and Oemku, are associated with the Au-Ag epithermal vein deposits. In addition to the Au-Ag epithermal vein deposits, the Lower Amur metallogenic belt includes few small W skarn, porphyry Cu, and Sn greisen deposits which are all hosted in or near Paleogene alkaline granitoid rocks.

Mnogovershinnoe Au-Ag Epithermal Vein Deposit

The large Mnogovershinnoe Au-Ag epithermal vein deposit (fig. 93) (Zalishchak and others, 1978) consists of hydrothermally altered, adularia-sericite-quartz vein-like zones up to 800 m long. The zones contain a series of adularia-quartz veins and veinlets. Some ore bodies consist of rhodonite-carbonate veins, and lenses of skarns and sulfides. The ore minerals include pyrite, marcasite, gold, argentite, Au- and Ag-tellurides, galena, sphalerite, chalcopyrite, and freibergite. The ore minerals comprise up to 1% of veins. The Au:Ag ratio is 1:1. The deposit is hosted in Paleocene andesite-dacite which is genetically related to a multiphase intrusion of highly alkaline granitoid rocks. K-Ar isotopic studies indicate an age of mineralization of 49 to 69 Ma. During formation of local Au-bearing skarns, which presumably formed during intrusion of Paleogene subalkaline granites, Au was remobilized (Ivanov and others, 1989). Placer Au deposits are associated with the Au-Ag epithermal vein deposits.

Belaya Gora Au-Ag Epithermal Vein Deposit

The medium-size Belaya Gora Au-Ag epithermal vein deposit (Mel'nikov, 1978) consists of disseminated and stockwork-type Au-Ag ore which occurs in extrusive bodies of subalkalic rhyolite-dacite and explosive breccia of an Eocene-Oligocene igneous complex. Alteration minerals are quartz (50-90%), kaolinite, dickite, sericite, hydromica, and adularia. The ore minerals are gold, silver, argentite, pyrite, marcasite, chalcopyrite, sphalerite, galena, hematite, and cinnabar. The ore assemblages are Au-quartz and Au-sulfosalts-sulfide-quartz. Gold distribution is highly irregular and the ore bodies do not have clear boundaries. The deposit extends to 100 m deep.

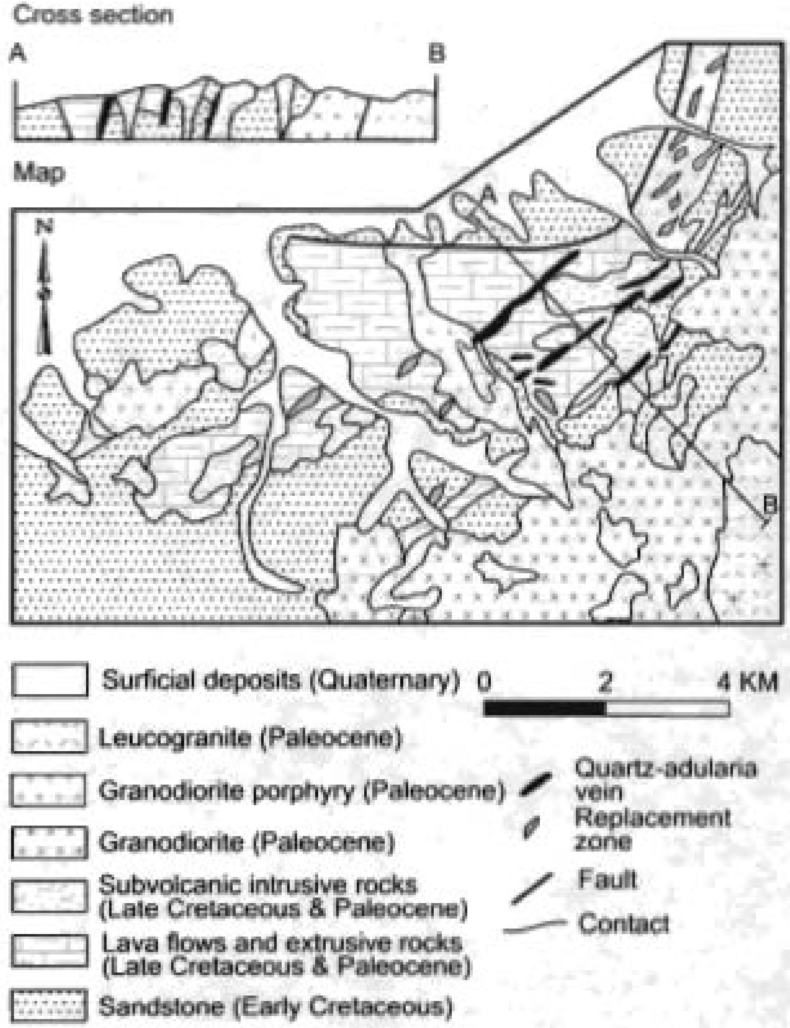


Figure 93. Mnogovershinnoe Au-Ag epithermal vein deposit, Lower Amur metallogenic belt, Russian Southeast. Schematic geologic map and cross section. Adapted from Ratkin (1995).

Origin of and Tectonic Controls for Lower Amur Metallogenic Belt

The Cretaceous granitoid rocks hosting the Lower Amur metallogenic belt are part of the East Sikhote-Alin volcanic-plutonic belt (fig. 79) of Late Cretaceous and early Tertiary age which is described in the above section the origin of the Taukha metallogenic belt. Other related, coeval metallogenic belts hosted in the East-Sikhote-Aline volcanic belt are the Kema (KM), Luzhkinsky (LZ), Sergeevka (SG), and Taukha (TK) belts (fig. 79; table 3). The differences between the coeval metallogenic belts are interpreted as the result the igneous rocks which host these metallogenic belts intruding different bedrock. In contrast to these other coeval and related belts, the Lower Amur metallogenic belt occurs where Cretaceous granitoid rocks of the East Sikhote-Aline belt intrude the Amur River and Kiselyovka-Manoma accretionary-wedge terranes.

Metallogenic Belt Formed in Late Mesozoic Oceanic Crust and Island Arc Terranes, Russian Southeast

Aniva-Nabil Metallogenic Belt of Volcanogenic Mn and Fe and Cyprus Massive Sulfide Deposits (Belt ANN) Sakhalin Island, Southeastern Part of Russian Far East

The Aniva-Nabil metallogenic belt of volcanogenic Mn and Fe, and Cyprus Cu massive sulfide deposits occurs on Sakhalin Island in the southeastern part of the Russian Far East (fig. 79; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt occurs in the Aniva subduction-zone terrane and in the related Nabilsky accretionary-wedge terrane in the central part of the island

(Nokleberg and others, 1994c, 1997c). The volcanogenic Mn deposits, as at Bereznyakovskoe and Lyukamskoe (Sidorenko, 1974), generally consist of small quartz-rhodonite lenses, with surficial pyrolusite and psilomelane, which are derived from carbonate and Mn-oxide assemblages. Associated with the occurrences are hydrothermal quartz, sericite, and carbonate alteration. The volcanogenic Fe deposits are mainly quartz-hematite lenses which are derived from carbonate and Fe-oxide assemblages. During subsequent accretion and companion metamorphism, the carbonate-oxide assemblages recrystallized to hematite-rhodonite-quartz and hematite-quartz. The Cyprus massive sulfide deposits, as at Novikovskoe and Rys'e (Sidorenko, 1974), occur in highly-deformed mafic volcanic rocks with chalcopyrite and pyrite, and subordinate galena, bornite, tetrahedrite, chalcocite and covellite.

Both the volcanogenic Mn and volcanogenic Fe deposits, occur in fault-bounded jasper-bearing volcanic assemblages. The Cyprus massive sulfide deposits occur in fault-bounded fragments of mafic volcanic rocks. The host rocks are highly-deformed fragments of Late Cretaceous turbidites, limestone blocks derived from oceanic crustal and island arc assemblages, including blocks of volcanic-jasper deposits, and metamorphosed gabbro and ultramafic igneous rocks. These units are interpreted as subducted oceanic crust and island arc fragments now contained in the highly deformed Aniva and Nabilsky subduction zone and accretionary-wedge terranes. These terranes are interpreted tectonically linked to the Cretaceous East Sikhote-Alin volcanic-plutonic belt (Nokleberg and others, 1994c, 1997c, 2000).

Metallogenic Belts Formed in Late Mesozoic and Early Cenozoic Olyutorka Island Arc, Russian Northeast

Koryak Highlands Metallogenic Belt of Zoned Mafic-Ultramafic PGE and Cu Massive Sulfide Deposits (Belt KH) East-Central Part of Russian Northeast

The Koryak Highlands metallogenic belt of zoned mafic-ultramafic PGE deposits occurs in the southern Koryak Highlands in the east-central part of the Russian Northeast (fig. 79; tables 3, 4). The belt extends northeast for 1,000 km from the Sredinny Range in central Kamchatka Peninsula to the Koryak Highlands in the northern Peninsula (Bundtzen and Sidorov, 1998; Kozin and others, 1999; Melkomukov and Zaitsev, 1999). The belt is hosted in the Olyutorka subterrane of the Olyutorka-Kamchatka island-arc terrane (Nokleberg and others, 1994c, 1997c). The metallogenic belt contains several PGE and Cr deposits which occur in zoned, Alaskan-Uralian type plutons composed of gabbro, dunite, and clinopyroxenite. The significant deposits in the belt are the Snezhnoe zoned mafic-ultramafic Cr-PGE deposit, the Galmeononsky-Seinavsky zoned mafic-ultramafic PGE (Alaskan-Uralian PGE), and a rare gabbroic Cu massive sulfide prospect at Karaginsky (table 4) (Melnikova, 1974; Kepezhinskas and others, 1993), L.V. Melnikov, written commun., 1993; Nokleberg and others 1997a, b, 1998; Bundtzen and Sidorov, 1998). The Karaginsky deposit consists of sulfide lenses hosted in spillite and siltstone, and sulfide disseminations hosted in serpentinized ultramafic olistoliths. The sulfide minerals are chalcopyrite and pyrite, local sphalerite, and locally abundant magnetite, and. In addition to Cu, the deposit contains Ni, Co, PGE, Zn, Au, and Ag.

Snezhnoe Podiform Cr Deposit

The Snezhnoe zoned mafic-ultramafic Cr-PGE deposit (Kutyev and others, 1988a, b; Kutyev and others, 1991) occurs in a small round stock, about 2 km wide, composed of ultramafic rocks. The stock is zoned with a core of dunite, and an outer zone of wehrlite-pyroxenites and pyroxenites. The ultramafic rocks in the stock intrude Late Cretaceous volcanogenic-sedimentary rocks which are contact metamorphosed near the stock. Chromite occurs in the dunite core and occurs as small lenses and veins in streaky and veinlet structures. These ore bodies range up to 1 m wide and several meters long. Ferruginous chromite occurs with up to 48% Cr_2O_3. Titanomagnetite and Cu sulfides occur in the peripheral pyroxenites. PGE minerals occur in association with chromite and form in chrome-spinel as small idiomorphic crystals, and as xenomorphic inclusions in interstices. Fe and Pt alloys are predominant and contain inclusions of native Os. The chrome-spinel interstices are is dominated by sperrylite and tetraferroplatinum. PGE grains range up to 1 mm diameter. PGE minerals are similar in composition to those in podiform Cr deposits in southeastern Alaska and in the Urals Mountains.

Galmeononsky-Seinavsky PGE Occurrences

The Galmeonsky-Seinavsky PGE (Alaskan PGE) occurrences are located in zoned mafic-ultramafic complexes in the geographic center of the Koryak Highlands metallogenic belt (locally in Russia called the Koryak-Kamchatka platinum belt) (Bundtzen and others, 2003a, b). The surface area of the Galmeonsky pluton is about 45 km^2, and the pluton is about 16 km long and 3 to 4 km wide. An $^{40}Ar/^{39}Ar$ isotopic age of 60-73.9 Ma has been obtained for the pluton (Bundtzen and others, 2003b). The pluton contains a dunite core which comprises about 70 percent of the body and in the periphery is dunite which is successively rimmed by wehrlite, olivine-magnetite pyroxenite, and gabbro. Chromite-bearing dunite zones contain up to 100 g/t Pt (Kozin and others, 1999).

The Seinavsky pluton occurs 7 km northeast of the Galmeononsky pluton, and covers an area of about 40 km^2. Dunite constitutes about 20 percent of pluton and the rest is mainly wehrlite and pyroxenite (Melkomukov and Zaitsev, 1999). A $^{40}Ar/^{39}Ar$ isotopic age of 60-73.9 Ma has been obtained for the pluton (Bundtzen and others, 2003b). Chromite-rich dunite grades up to 12 g/t Pt, and pyroxenite contains up to1 g/t Pd (Kozin and others, 1999). The PGE mineral the pluton and associated placer deposits is isoferroplatinum. Occurring in the region are native osmium, iridium, ruthenium, and platosmiridium which comprise a few percent of the total PGE. About 4% gold occurs in concentrates along with PGE arsenides and alloys (Melkomukov and Zaitsev, 1999; Bundtzen and Sidorov, 1998).

Since 1994, rich PGE placers have been mined in six streams which radially drain both complexes. Approximately 18.1 tonnes PGE were mined from 1994 to 1998 (Kozin and others, 1999). Production in 2000 was approximately 3.4 tonnes PGE (A. Koslov, written commun., 2000). The production from the Galmeononsky-Seinavsky district comprises a considerable percentage of total Russian PGE production.

Origin of and Tectonic Controls for Koryak Highlands Metallogenic Belt

The zoned mafic-ultramafic plutons which host the Koryak Highlands metallogenic belt intrude the Late Cretaceous volcanogenic-sedimentary rocks of the Olyutorka subterrane of the Olyutorka-Kamchatka terrane (Nokleberg and others, 1994c, 1997c). The Olyutorka subterrane consists of a major sequence of late Mesozoic and early Cenozoic island arc volcanic and sedimentary rocks and occurs in a large nappe which is obducted onto the Ukelayat subterrane of the West Kamchatka turbidite basin terrane (Nokleberg and others, 1994c, 1997c). The Olyutorka subterrane consists of: (1) a lower part composed of volcanic and siliceous oceanic rocks (Albian to Campanian Vatyn series); and (2) an upper part of Maastrichtian to Paleocene volcanic and clastic island arc deposits (Achayvayam and Ivtiginskaya formations). The subterrane is locally intruded by zoned intrusives range from dunite to clinopyroxenite to gabbro. The succession from pluton cores to margins is generally dunite which grades into pyroxenite which grades into gabbro and gabbro-diabase. Intrusion occurred in the latest Cretaceous and the plutons are interpreted as the deep-level, magmatic roots of an island arc (Bogdanov and others, 1987). The available geologic and petrologic and geochemical data indicate that the zoned PGE-bearing plutons formed in a marginal-oceanic basin and frontal island arc during subduction of an oceanic plate (Bogdanov and others, 1987). Recent isotopic studies suggest intrusion of the zoned mafic-ultramafic plutons in the Late Cretaceous, as young as 71 Ma (Kepezhinskas and others, 1993; Sidorov and others, 1997; Bundtzen and Sidorov, 1998). The Olyutorka-Kamchatka terrane is interpreted as an island arc rock sequence underlain by oceanic crust. The Olyutorka subterrane is intricately faulted with, and thrust over the nearly coeval, Late Cretaceous and Paleogene Ukelayat turbidite basin subterrane of the West Kamchatka turbidite basin terrane to the northwest (fig. 79). The Late Cretaceous to early Tertiary Olyutorka-Kamchatka island-arc terrane is was tectonically linked to the Vetlovskiy accretionary-wedge terrane (Nokleberg and others, 2000).

Kepezhinskas and others (1993) interpret that the zoned mafic-ultramafic complexes near Epilchak Lake at the northern end of metallogenic belt were emplaced as part of calc-alkaline magmas related to Late Cretaceous subduction during a short period of crustal extension. They interpret tha the mafic Late Cretaceous lavas which crop out near Epilchak Lake and in the Galmeononsky-Seinavsky areas (part of the Olyutorka-Kamchatka island arc terrane) may be co-magmatic with the zoned mafic-ultramafic plutons. Preliminary Ar-Ar isotopic ages from the Epilchak Lake and Galmeononsky zoned plutonic bodies range from 69 to 71 Ma (P.W. Layer, written communication, 1998).

Vatyn Metallogenic Belt of Volcanogenic Mn and Fe Deposits (Belt VT) Southeastern Part of Russian Northeast

The Vatyn metallogenic belt of volcanogenic Mn and Fe deposits (fig. 79; tables 3, 4) occurs in the southeastern part of the Russian Northeast. The belt occurs in several fragments, strikes east-west, is up to 680 km long, and ranges from 5 up to 100 km wide. The belt is hosted mainly in the oceanic crustal and ophiolite rocks of the Late Carboniferous through Early Jurassic and Cretaceous Olyutorka-Kamchatka island-arc terrane, and to a lesser extent in the Yanranay accretionary-wedge terrane (Nokleberg and others, 1994c, 1997c). In basalt flows in the Yanranay accretionary wedge-oceanic terrane are small occurrences of chert-hosted Fe- and Mn-bearing layers and crusts which occur at the surfaces of basalt flows. The significant deposit in the belt is the Itchayvayam volcanogenic Mn deposit (table 4) (Nokleberg and others 1997a, b, 1998).

Itchayvayam Volcanogenic Mn Deposit

The Itchayvayam and similar deposits in the metallogenic belt (Egiazarov and others, 1965) occur in a sequence of chert and basalt. The deposits consist of massive, patchy, and brecciated Mn ores which occur as concordant, lens-like bodies 1 to 30 m long and 0.3 to 10 m thick which are hosted in siliceous rocks. The main ore mineral is braunite, but pyrolusite occurs locally. Mn also occurs in veins of metamorphic origin which range from 2 to 10 m long and contain 11 to 47 % Mn. The deposits occur in the Albian-Campanian Vatyn Formation which contains abundant basalt and chert.

Origin of and Tectonic Controls for Vatyn Metallogenic Belt

The volcanogenic Mn and Fe deposits of the Vatyn metallogenic belt are interpreted as forming in a deep marginal-sea or oceanic basin environment during submarine basalt eruption as part of the Olyutorka subterrane of the Olyutorka-Kamchatka island-arc terrane (fig. 79) which is described in the above section on the Koryak Highlands metallogenic belt. After deposition, the Mn and Fe deposits were metamorphosed and locally redeposited as cross-cutting veins (Kolyasnikov and Kulish, 1988).

Eastern Asia-Arctic Metallogenic Belt Formed in Late Mesozoic Part of Okhotsk-Chukotka Continental-Margin Arc, Russian Northeast

General Setting of Metallogenic Zones in Eastern Asia-Arctic Metallogenic Belt

The major Eastern Asia-Arctic metallogenic belt of igneous-arc-related lode deposits occurs for several thousand kilometers along the eastern margin of the Russian Northeast (fig. 79, tables 3, 4). The mineral deposits of the belt occur in, and or are adjacent to the Cretaceous and early Tertiary Okhotsk-Chukotka volcanic-plutonic belt (Gelman, 1986; Nokleberg and others, 1994c, 1997c). The major deposit types in the belt are porphyry Cu-Mo, Au-Ag epithermal vein, disseminated Au-sulfide, granitoid-related Au, Sn-Ag polymetallic vein, porphyry, and skarn, Hg, Sb, and associated deposits. The Eastern Asia-Arctic metallogenic belt includes the rear, frontal and perivolcanic zones of the Okhotsk-Chukotka volcanic-plutonic belt.

The major Eastern Asia-Arctic metallogenic belt is subdivided into smaller metallogenic zones which each exhibit a distinctive suite of felsic-magmatism-related lode deposits (fig. 79; table 4). In alphabetical order, the zones are: Anyui-Beringov, Chaun-Seward, Chukotka, Dogdo-Erikit, Koni Yablon, Okhotsk, Omusukchan, Verkhne-Kolyma, and the Verkhne-Yukonsky. These distinctive suites of lode deposits in each zone are defined or subdivided on the basis of: (1) the terrane(s) which locally underlies the zone; (2) the occurrence of longitudinal and orthogonal faults which trend north-south or northwest; and (3) regional magmatic zonation of the Okhotsk-Chukotka volcanic-plutonic belt (fig. 79). In some cases, the longitudinal and orthogonal faults extend several hundreds of kilometers to the northwest away from the northeast-trending mass of the Okhotsk-Chukotka volcanic-plutonic belt;

Origin of and Tectonic Controls for Eastern Asia-Arctic Metallogenic Belt

The Eastern Asia-Arctic metallogenic belt is hosted in or near the Okhotsk-Chukotka volcanic-plutonic belt which constitutes a major Early Cretaceous, Late Cretaceous, and locally Paleocene age assemblage which overlaps previously-accreted terranes. The igneous belt extends for 3,000 km along western margin of Sea of Okhotsk, and across the Bering Straits into the Seward Peninsula (figs. 79, 80), and consists mainly of gently dipping basalt, andesite-basalt, andesite, dacite, rhyolite, and tuff (Nokleberg and others, 1994c, 1997c). Rare beds of nonmarine clastic rocks, with conglomerate, grit, and sandstone occur at the base. The belt also contains local widespread silicic volcanic rock (mainly ignimbrites) and associated tonalite, quartz-diorite, and spar granite. To the northwest, into the continent, Late Cretaceous plutonic rocks grade into subalkalic and alkalic granite. The Paleocene part of the igneous belt locally consists mainly of plateau theoleiitic basalt.

The Okhotsk-Chukotka belt overlies the southeastern margin of the North Asian Craton and the Kolyma-Omolon superterrane, as well as the Chukotka, Kony-Murgal, Okhotsk, Seward, South-Anyui, and Zolotogorskiy terranes of the Russian Northeast (fig. 79). The Okhotsk-Chukotka belt is interpreted as a Pacific-facing, continental-margin arc which formed the Albian through Campanian and locally Paleocene boundary of northeastern Asia. The frontal part of the Okhotsk-Chukotka volcanic-plutonic belt is dominated by basalt, and the rear zone is dominated by andesite and rhyolite. Coeval granitic through gabbroic intrusions also occur in the rear zone (Bely, 1977, 1978; Filatova, 1988). The Okhotsk-Chukotka belt is equivalent to the East Sikhote-Alin volcanic-plutonic belt (unit es) in the Russian Southeast (fig. 79). Together, these two igneous belts constitute a major continental-margin arc of Cretaceous and early Tertiary age which were tectonically linked subduction zone assemblages. To the north, the Okhotsk-Chukotka igneous belt was tectonically linked to the Ekonay oceanic crust, and the West Kamchatka turbidite basin and Yanranay accretionary-wedge terranes; to the south, the East Sikhote-Alin igneous belt was tectonically linked to the Aniva, Hikada, and Nabilsky accretionary wedge and subduction-zone terranes (Nokleberg and others, 2000).

Eastern Asia-Arctic Metallogenic Belt:
Dogdo-Erikit Metallogenic Zone of
Au-Ag Epithermal Vein, Sn-polymetallic vein
(Southern Bolivian type?), and Volcanic-Hosted
Hg (Plamennoe type) Deposits (Belt DE)
West-Central Part of Russian Northeast

The Dogdo-Erikit metallogenic zone of Au-Ag and Ag-Sb epithermal vein, and volcanic-hosted Hg deposits (fig. 79; tables 3, 4) extends for about 1,000 km and up to 50 to 70 km wide in a narrow band from the northwest to the southeast in the west-central part of the Russian Northeast (Goryachev, 1998, 2003). This belt is hosted in the volcanic rocks of the Uyandin-Yasachen volcanic belt and the clastic deposits of the Inyali-Debin flysch basin (both parts of the Indigirka-Oloy sedimentary-volcanic assemblage), and the underlying carbonate rocks of the passive continental margin Omulevka terrane of the Kolyma-Omolon superterrane.

The Dogdo-Erikit zone contains significant Au-Ag epithermal vein deposits, as at Kysylga, Tikhon, and Shirokoe, Sn-polymetallic vein (Southern Bolivian type?) deposits at Solkuchan, and a volcanic-hosted Hg deposit Dogdo (table 4) (Nokleberg and others 1997a, b, 1998). The Au-Ag epithermal vein deposits are closely related to Late Cretaceous hypabyssal rhyolite bodies with K-Ar isotopic ages of 90 to 56 Ma. The hypabyssal rhyolites crosscut contact metamorphic aureoles of older Cretaceous granitoid plutons (Gamyanin and Goryachev, 1988). The Dogdo volcanic-hosted Hg deposit and similar deposits are hosted in Early Cretaceous(?) felsic volcanic rocks which are associated with rhyolite and andesite hypabyssal bodies with K-Ar ages of 125 to 63 Ma (Ganeev, 1974). The volcanic-hosted Hg deposits are small, uneconomic, and occur in the northwest part of the metallogenic belt which overlies the Selennyakh metallogenic belt of pre-accretionary Hg deposits (fig. 79). The Dogdo-Erikit metallogenic zone is interpreted as forming in a transverse (orthogonal) limb of the Cretaceous Okhotsk-Chukotka volcanic-plutonic belt (Goryachev, 1998, 2003).

Kysylga Au-Ag Epithermal Vein Deposit

The Kysylga Au-Ag epithermal vein deposit (Shoshin and Vishnevsky, 1984; Yu.A. Vladimirtseva, written commun., 1985; Nekrasov and others, 1987; Gamyanin and Goryachev, 1988) consists of veins in a zone which varies from 0.60-1.25 m thick and up to 400 m long. The veins are composed of quartz, calcite, and ore minerals (1-5%) including arsenopyrite, pyrite, Ag-tetrahedrite, pyrrhotite, sphalerite, galena, chalcopyrite, boulangerite, Ag-jamesonite, and a low gold fineness (638). The veins strike from roughly east-west to northeast and dip steeply to south. The veins exhibit breccia or, less commonly, comb and massive structures, and often grade into stringer lodes. The deposit occurs in feathered fissures of a northwest-striking major fault and is hosted in Late Triassic sandstone and siltstone which exhibits linear folding and intense contact metamorphic alteration adjacent to a granitic intrusive. Wallrocks display sericite, chlorite, and feldspar alteration. Average grades are 3.0-84.5 g/t Au, 1-37 g/t Ag; 0.01-0.1 As; 0.01-0.04% Sb; 0.002% Sn, and 0.03% Pb.

Solkuchan Sn-Ag Polymetallic Vein
(Southern Bolivian type?) Deposit

The Solkuchan Sn-polymetallic vein (Southern Bolivian type) deposit (S.M. Khaustova and Yu.A. Vladimirtseva, written commun., 1987; Nekrasov and others, 1987; Shkodzinsky and others, 1992) consists of three steeply-dipping quartz-carbonate-sulfide veins which occur in an Early Cretaceous subvolcanic dacite stock. The veins are up to 3.4 m thick and up to 900 m long. The ore minerals are pyrite, pyrrhotite, arsenopyrite, sphalerite, galena, Ag-tetrahedrite (31-39% Ag), boulangerite, pyrargyrite, canfieldite, electrum (fineness 685), cassiterite, covellite, scorodite, cerussite, smithsonite, melnikovite, and Fe-hydroxides. Anomalous Cu, Sb, Ge, and Id are present. The deposit is of medium size. Average grades are 200 g/t Ag, from 0.04 to 2.16% Sn, 0.03 to 2.71% Pb, and 0.02 to 5.85% Zn.

Dogdo Volcanic-Hosted Hg (Plamennoe type) Deposit

The Dogdo volcanic-hosted Hg (Plamennoe type) deposit (Klimov, 1979; Yu.A. Vladimirtseva, written commun., 1987) consists of four lenticular and podiform ore bodies which occur in strongly silicified Late Jurassic andesite-dacite tuff. The ore bodies are 20 to 100 m long and 2 to 8 m wide. The ore minerals are quartz, calcite, barite with disseminations and stringers of cinnabar, pyrite, arsenopyrite, sphalerite, galena, and chalcopyrite. The ore district is characterized by a close correlation between Hg content and barite. Mineralization is controlled by a northwestern thrust fault, secondary quartzite occurrences, and occurrence of ore bodies along feathering fractures of the thrust fault. The deposit is of minor-to-medium size. Average grades are 0.35 to 0.90% Hg.

Eastern Asia-Arctic Metallogenic Belt: Okhotsk Zone of Au-Ag Epithermal Vein Deposits (Belt EAOH) Southeastern Part of Russian Northeast

The Okhotsk zone of Au-Ag epithermal vein deposits (fig. 79; tables 3, 4) occurs in the southeastern part of the Russian Northeast (Goryachev, 1998). The metallogenic belt is more than 1,500 km long and locally more than 100 km wide. The metallogenic belt occurs mainly in the rear of the Okhotsk-Chukotka volcanic-plutonic belt (Nokleberg and others, 1994c, 1997c). The significant deposits in the zone are (table 4) (Nokleberg and others 1997a, b, 1998): Au-Ag epithermal vein deposits at Agat, Aldigych, Burgagylkan, Druchak, Evenskoe, Irbychan, Julietta, Karamken, Kegali, Khakandzhinskoe (Khakandzha), Kolkhida, Krasivoe, Nevenrekan, Oira, Olyndja, Sentyabr, Spiridonych, Teply, Utessnoe, Verkhnenyotskoe, Vetvisty, Yurievka; a granitoid-related Au deposit at Maltan Stock; epithermal vein and volcanic-hosted Sb vein deposits at Senon, Utro, and Serebryanoe; a Sn silicate-sulfide vein deposit at Kinzhal; and a Pb-Zn-Ag skarn deposit at Skarnovoe.

The typical environments for the Au-Ag deposits are (Goryachev, 1998): (1) volcanic fields and resurgent subvolcanic domes which are associated with calderas of 10 to 60 km diameter; (2) contrasting volcanic sequences with high explosive indexes and injection breccias; (3) abundant rhyolite and dacite, with less abundant latite and trachyandesite; (4) combinations of well-defined or concealed basement faults with conformal, ring, arched, and radial fractures; (5) areas of propylitic alteration; and (6) volcanic rocks with high initial Sr ratios of greater than 0.708. Isotopic and paleontological ages for the Au-Ag epithermal vein deposits are Late Cretaceous to Paleocene. However, older deposits, such as the Albian(?) Nyavlenga deposit exist.

The epithermal Au-Ag deposits are generally characterized by (Goryachev, 1998): (1) low or moderate sulfide contents; (2) widespread Ag-Sb sulfosalts, sulfides, selenides, and sparse Ag tellurides which occur in association with electrum and other Au and Ag intermetallides; (3) veins composed of adularia, carbonate, chalcedony, and quartz; (4) wall rock alteration to adularia, sericite, and hydromica; (4) Au:Ag ratio dominated by Ag (1:1 to 1:2 to 1:300); (5) an obvious vertical zoning of deposits with a stage-like occurrence of ore shoots; and (6) indications of ore regeneration caused by hydrothermal temperature inversion. The major Au deposits occur in the middle parts of the Okhotsk zone at Karamken, Agatovskoe, Oira, Burgagylkan, and Julietta. The significant deposit in the northern part of the belt is at Evenskoe. The significant deposits in the southern part of the belt are at Khakandja and Yuryevka. Mining is underway at Karamken, Agat, and Oira.

Karamken Au-Ag Epithermal Vein Deposit

The Karamken Au-Ag epithermal vein deposit (fig. 94) (Krasilnikov and others, 1971; Nekrasova, 1972; Goldfrid, Demin, and Krasilnikov, 1974; Nekrasova and Demin, 1977; Sidorov, 1978; Layer, Ivanov, and Bundtzen, 1994) consists of numerous adularia-quartz and adularia-carbonate-quartz veins more than 200 m long and more than 0.2 m thick. The veins are controlled by arcuate and linear faults which define and crosscut a caldera filled with Late Cretaceous dacite, andesite-basalt, and rhyolite. The Main deposit, which contains about 80-90% of the reserves, is confined to few major veins which are spatially related to a hypabyssal body cut by circular faults and composed of andesite, andesitic dacite, volcanic breccia of andesite-dacite composition, and rhyolite. The most productive veins are associated with an altered zone comprised of adularia-hydromica and quartz; and explosion and hydrothermal breccia bodies. A zone of kaolinite, alunite, and quartz alteration occurs in higher parts of the ore deposit. The ore minerals are pyrite, sphalerite, chalcopyrite, canfieldite, freibergite, tennantite, naumannite (Ag_2Se), polybasite, electrum, küstelite, native silver, and other less common sulfides, selenides, sulfostannates, and sulfosalts of silver. The Au:Ag ratio is 1:3 to 1:4 in the richest portions of the Glavnaya vein. The veins form in clusters, which converge at depth. The gold-canfieldite-freibergite-chalcopyrite and gold-pyrite-sphalerite zones are the most productive; at depth they are succeeded by a galena-canfieldite zone with tin-silver minerals. The deposit is medium and is mostly mined. The deposit was discovered in 1964 and produced 40 tonnes Au from 1978 to 1992. The average grade was 100 to 129 g/t Au in 1978 and 16-18 g/t Au in 1992. Ar-Ar age isotopic study of adularia in Au-Ag vein yields an age of 79 Ma (Layer, Ivanov, and Bundtzen, 1994).

Julietta Au-Ag Epithermal Vein Deposit

The Julietta Au-Ag epithermal vein deposit (S.F. Struzhkov, O.B. Ryzhov, and V.V. Aristov, written commun., 1994; Struzhkov and others, 1994) consists of Au-Ag sulfide-carbonate-quartz veins which occur inside a large Early Cretaceous caldera. The volcanic rocks in the caldera and associated subvolcanic intrusive rocks comprised of andesite, andesite-basalt, and andesite-dacite. The veins dip steeply and vary from 200 to 500 m length and from 1 to 4 m wide. The major ore minerals are native gold and silver, freibergite, polybasite, galena, sphalerite, chalcopyrite, hessite, acantite, cubanite, pyrrhotite, and naumannite. Associated minerals in adjacent metasomatically-altered volcanic rocks are ankerite, calcite, chlorite, epidote, and hydromica. The ore minerals formed in two stages, an older gold-polymetallic stage, and a younger Au-Ag-sulphosalt stage. The deposit is medium size with an average grade of 29 g/t Au, 325 g/t Ag. Proven reserves as of 1994 were 18 tonnes Au and 200 tonnes Ag. Estimated resources are 40 tonnes Au and about 1,000 tonnes Ag. A Rb-Sr adularia isotopic age of 136 Ma (Struzhkov and others, 1994) suggests that the Julietta deposit and host rocks may be part of an undefined pre-accretionary metallogenic belt which would be hosted in the early and middle Mesozoic Kony-Murgal island-arc terrane. Additional isotopic studies are needed. The deposit is currently being developed by Bema Gold Corporation and other partners.

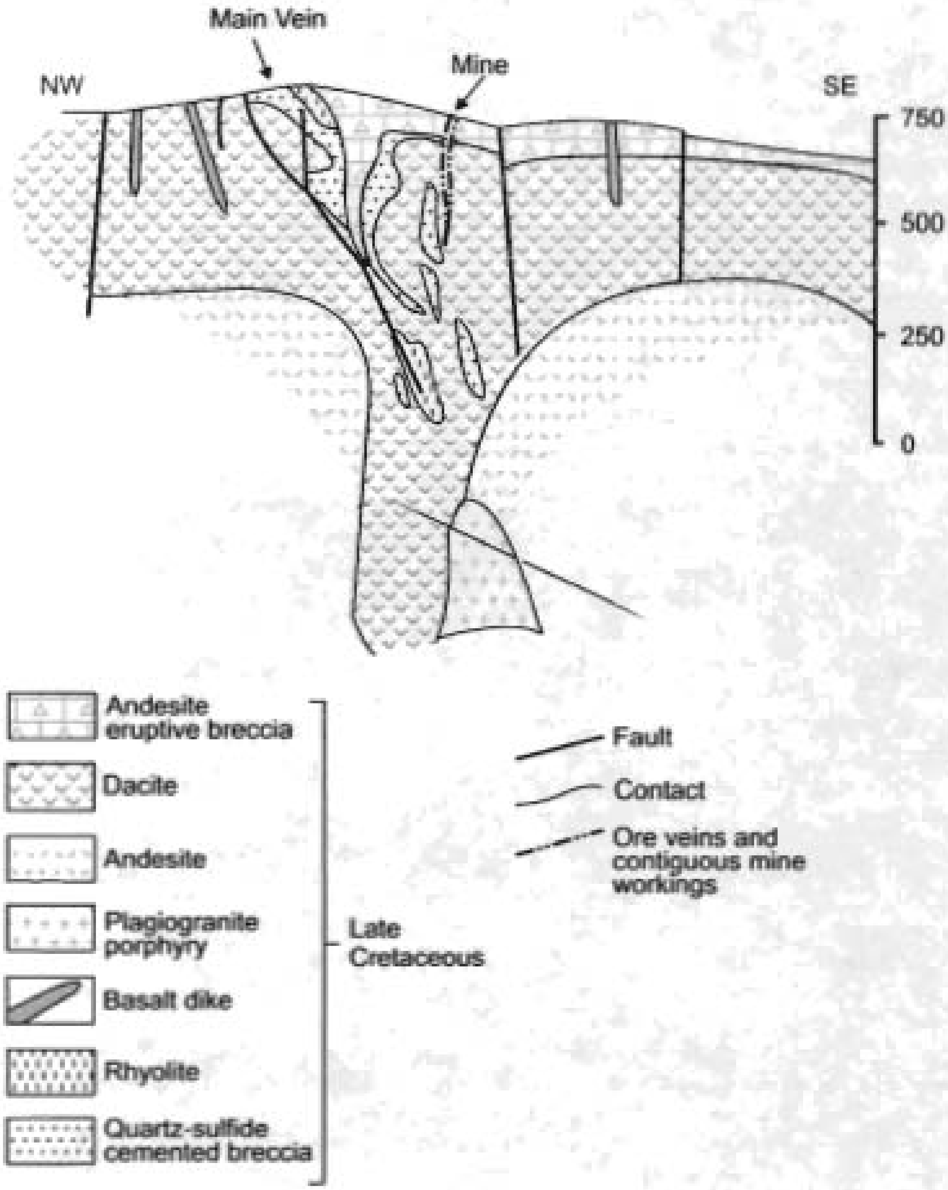


Figure 94. Karamken Au-Ag epithermal vein deposit, Okhotsk zone, Eastern Asia-Arctic metallogenic belt, Russian Northeast. Schematic cross section showing generalized geology of Armanskaya volcanic structure. Adapted by N.A. Shilyaeya, using materials of R.B. Umitbaev, R.A. Eremin, G.P. Demin, and A.A. Krasil'nikov, and from Sidorov and Goryachev and others (1994).

Agat Au-Ag Epithermal Vein Deposit

The Agat Au-Ag epithermal vein deposit (V.I. Naborodin, written commun., 1971, 1977) consists of several tens of quartz, carbonate-quartz, and sulfide-quartz veins which occur in sheets of propylitically-altered Cretaceous andesite. The veins are generally simple and are controlled by northwest- to north-south-trending fissures. The ore bodies usually range from tens to hundreds of meters long, but sometimes are up to 2 km long; they average from 0.2 to 1 m thick but are 50 m thick. The veins are usually altered to hydromica, chlorite, and silica; however less eroded veins display weak adularia alteration. The veins generally display a symmetrical crustification-banding and complex deformation structures. The main ore minerals are galena, sphalerite, chalcopyrite, marcasite, and pyrite. Locally present are arsenopyrite, pyrrhotite, tetrahedrite-tennantite, tellurides, Ag-sulfosalts, and other minerals. The main gangue minerals are quartz and carbonates, including calcite, dolomite, siderite, Mn-rich siderite, rhodochrosite, and kutnahorite. Barite, chalcedony, and opal occur near the periphery of the deposit. Gold occurs as electrum. The veins average 5 to 10% sulfide, but locally ranges up to 20 to 30% sulfide. A gold-sphalerite-galena-quartz assemblage is the most productive, and is present in most veins. This assemblage also contains chalcopyrite, tetrahedrite-tennantite, Au- and Ag-tellurides, pyrargyrite, stephanite, and argentite. The Au:Ag ratio varies from 5:1 to 1:100, and averages about 1:2 to 1:5. The deposit contains estimated reserves of 3.8 tonnes Au and 70 tonnes Ag. The deposit averages 6.5 to 11.8 g/t Au and 65 to 174 g/t Ag. Bonanza ores contain up to 30 kg/t Au.

Eastern Asia-Arctic Metallogenic Belt:
Koni-Yablon Zone of Porphyry Cu-Mo and
Cu-Mo Skarn Deposits (Belt EAKY)
Southern Part of Russian Northeast

The Koni-Yablon zone of porphyry Cu-Mo and Cu-Mo skarn deposits (fig. 79; tables 3, 4) occurs in the southern part of the Russian Northeast. The zone occurs in the front of the Okhotsk-Chukotka volcanic-plutonic belt along the northwest margin of the Sea of Okhotsk and in plutons which intrude the Koni-Murgal island-arc terrane. The significant deposits in the zone are (table 4) (Nokleberg and others 1997a, b, 1998): porphyry Mo deposits at Guan-Ti (Arkhimed), Khakandya, Molybdenitovy, Tikas, and Travka; porphyry Cu-Mo deposits at Etandzha, Gora Krassnaya, Ikrimun, Osennee, Oksa, Usinskoe, Viking, porphyry Cu deposits at Lora, Nakhtandjin, and Yapon; a granitoid-related Au deposit at Tsirkovy; Au-Ag epithermal vein deposits at Berezovogor, Irgunei, Nyavlenga, Sergeev, and Serovskoe; a Cu skarn deposit at Maly Komui; a Mo greisen and vein deposit at Lastochka; and a volcanic-hosted Hg deposit at Uralskoe. The porphyry Cu-Mo deposits occur in parts of the volcanic-plutonic belt which are uplifted along major faults, as in the Okhoto-Kuhtui, Chelomdja-Yana, and Anadyr zones. Some of these zones occur along a regional gravity gradient between the front and rear zones of the volcanic-plutonic belt.

In the northeastern part of the Koni-Yablon zone, the Primagadan area, the best known part of the Koni-Yablon zone, extends along the coast of the Sea of Okhotsk for about 500 km and contains the Osenee, Usinskoe,, Nakhatandjin-Lori, Ikrimum, and other deposits. These deposits occur in multiphase, large, Na-series Early Cretaceous gabbro, tonalite, granodiorite, and plagiogranite plutons which display low initial Sr ratios (<0.705). The ore deposits occur along circular caldera structures which range from 7 to 12 km diameter. The porphyry deposits generally contain chalcopyrite, molybdenum, and other minerals in stringers, disseminations, veins, and stockworks (Skibin, 1982; Anorov and Mayuchaya, 1988). Across the Okhotsk-Chukotka volcanic-plutonic belt, the porphyry deposits display a zonation. From the coast into the continent, porphyry Cu deposits are successively replaced by porphyry Mo-Cu and porphyry Mo-W deposits. The zonation is correlated with a greater thickness of the granitic layer of continental crust and with the increase of leucocratic granite and granite porphyries into the continent. Ag concentrations in the porphyry deposits also increase into the continent.

In the Yablon River Basin and the Anadyr fault zone, in the extreme northeastern part of the Koni-Yablon zone, porphyry Cu-Mo deposits are associated with Cretaceous plutons of gabbro, diorite, and alkalic granite. The deposits may be controlled in part to the underlying Oloy metallogenic belt of porphyry Cu-Mo and Au-Ag epithermal vein deposits which is hosted in the younger (Neocomian) part of Late Jurassic-Neocomian Oloy-Svyatoy Nos volcanic belt (Nokleberg and others, 1994c, 1997c). Similar relations occur in the southwestern part of the Koni-Yablon zone where the significant deposits are the porphyry Cu-Mo deposit at Etandzha and the Cu-Mo skarn deposit at Muromets. These deposits are associated with Early Cretaceous tonalite and quartz monzodiorite which intrude Cambrian dolomite and with Early Cretaceous volcanic rocks. Some deposits grade from porphyry to skarn.

Nakhatandjin-Lori Porphyry Cu Deposits

The Nakhatandjin-Lori porphyry Cu deposit (Skibin, 1982; V.B. Vorob'ev, written communication, 1986.) consists of a stockwork of sulfide, sulfide-quartz, and sulfide-chlorite-quartz veinlets associated with disseminated sulfides occurs along east-, northeast-, and northwest-trending fault zones at the southeast and northern contacts of Srednin granitoid pluton. The pluton intrudes Triassic-Jurassic and Early Cretaceous volcaniclastic and volcanic rocks. Early Cretaceous tonalite, granodiorite, and explosive breccias which host the deposit are weakly sericitized and propylitized. Ore minerals are pyrite, chalcopyrite, and molybdenite, with subordinate magnetite and ilmenite. Deposit is closely associated with a pipe of explosive breccias. The deposits are medium to large with a probable resource of 178 million tonnes grading at least 0.5% Cu, 0.025% Mo, and 2.1 g/t Ag. The deposit is explored with about 100 shallow drill holes.

Osennee Porphyry Cu-Mo Deposit

The Osennee porphyry Cu-Mo deposit (L.V. Firsov and A.E. Soboleva, written commun., 1952; S.V. Sendek, written commun., 1965) form a crescent-shaped ore body which occurs in a north-south-trending, fractured and foliated zone within the granitoid rocks of the Cretaceous part of the Magadan batholith. The deposit is more than 400 m long, about 30 m thick, and dips at 35° to 65°. The host rocks are gabbro, granodiorite, subalkalic granite and syenite, granite porphyry, and lamprophyre. Molybdenite is accompanied by pyrite and lesser pyrrhotite, sphalerite, chalcopyrite, and scheelite. The molybdenite and associated minerals occur in quartz, quartz-feldspar, and quartz-tourmaline veinlets and veins; as disseminations in porphyry; and in veinlets in igneous rocks displaying silicic, sericite, chlorite, K-feldspar, and pyrite alteration along a fault and in adjacent areas. The deposit is small to medium, and contains from 0.1 to 0.33% Mo and up to 0.1% Cu, and up to 5 g/t Ag. Associated, undefined amounts of U is also present in the porphyry deposit.

Etandzha Porphyry Cu-Mo and Muromets Cu-Mo Skarn Deposits

The Etandzha porphyry Cu-Mo deposit (N.L. Kobtseva and T.G. Devyatkina, written commun., 1988) consists of stringers and disseminations of molybdenite and chalcopyrite which occur in Cretaceous quartz diorite. The deposit occurs along a northeast-trending zone with surface dimensions of 400 by 200 m. Average grades are 0.02 to 2.0 % Cu; 0.02 to 0.74 % Mo; up to 4 g/t Au; up to 15 g/t Ag, and unspecified amounts of U.

The Muromets Cu-Mo skarn deposit (Nikitin, Rasskazov, 1979; Krasny, Rasskazov, 1975) occurs along the contact of metasomatized Middle Cambrian dolomite and limestone which is intruded by Early Cretaceous quartz monzodiorite. The skarns occur in a zone which is 1 km long and dips gently (20 to 40°) under the intrusion. Individual skarns range from 6 to 12 km thick and contain disseminated, stringer-disseminated, and less common massive ore. Skarns are abundant and contain salite, diopside, scapolite, grossular, and andradite. The ore minerals are magnetite, chalcopyrite, molybdenite, scheelite, pyrrhotite, bornite, pyrite, galena, and sphalerite. Magnesian skarns are less abundant and contain spinel, forsterite, phlogopite, tremolite, diopside, and serpentine. The skarns developed in several stages: (1) magnesian skarn with magnetite; (2) calcareous pyroxene-garnet skarn with magnetite and scheelite; and (3) metasomatic quartz-feldspar rocks with molybdenite and Cu-sulfides. Copper sulfide disseminations also occur in altered quartz monzodiorite and form a porphyry Cu deposit. The deposit is small-to-medium size and contains up to 10 % Cu, up to 0.92 % WO_3, and up to 0.3% Mo.

**Eastern Asia-Arctic Metallogenic Belt:
Korkodon-Nayakhan Zone of Porphyry Mo and
Granitoid-Related Au Deposits (Belt EAKN)
East-Central Part of Russian Northeast**

The Korkodon-Nayakhan zone of porphyry Mo and granitoid-related Au deposits (fig. 79; tables 3, 4) occurs in two parts in the east-central part of the Russian Northeast. Each part is about 200 km long. The zone contains a small porphyry Mo deposit at Orlinoe, a granitoid-related Au deposit at Khetagchan, a Fe skarn deposit at Skarn, a Au-Ag polymetallic vein deposit at Verkhny-Koargychan, and a Fe-Pb-Cu-Ag-Au skarn deposit at Sedoi (table 4) (Nokleberg and others 1997a, b, 1998). Both types of deposits are related to subalkalic felsic and intermediate composition intrusions of granite and granosyenite. The deposits generally occur either in the apical parts of the intrusive rocks or in the adjacent wall rocks. The granitoid-related Au deposits are characterized by Ag tellurides. The deposits are generally small. Most of the lode deposits in the zone consist of sulfides disseminations and stringers. The granitoid rocks hosting the Korkodon-Nayakhan zone form a belt which is transverse or orthogonal to the Okhotsk-Chukotka volcanic-plutonic belt. The relation of the origin of the granitoid rocks to the Okhotsk-Chukotka volcanic-plutonic belt is unclear.

Orlinoe Porphyry Mo Deposit

The Orlinoe porphyry Mo deposit (V.N. Okhotnikov, written commun., 1957) consists of a steeply-dipping stockwork which extends for tens of meters. The stockwork consists of thin quartz veins and veinlets with disseminations and masses of molybdenite. Subordinate minerals are pyrite, chalcopyrite, wolframite, powellite, muscovite, fluorite, calcite, chlorite, and garnet. The deposit occurs in contact-metamorphosed, Late Triassic sedimentary rocks and in Late Cretaceous granite which intrudes the sedimentary rocks. The deposit is small and averages 0.01 to 0.03% Mo, but locally ranges up to 8.5% Mo.

Khetagchan Porphyry Granitoid-Related Au Deposit

The Khetagchan porphyry granitoid-related Au deposit (V.A. Sidorov, written commun., 1990) consists of zones of sulfide-quartz and sulfide-chlorite-quartz veins and veinlets up to 150 m long and 10 to 15 m thick. The veins and veinlets occur along the contacts of a Late Cretaceous granodiorite; both within and adjacent to the intrusion. The ore minerals are galena, sphalerite, chalcopyrite, wolframite, pyrite, arsenopyrite, bismuthinite, native bismuth, gold, electrum, tetrahedrite-tennantite, Ag-sulfosalts, and argentite. The deposit is judged as small and contains up to 20 g/t Au and up to 50 to 60 g/t Ag.

**Eastern Asia-Arctic Metallogenic Belt:
Verkhne-Kolyma Zone of Sn-Ag Polymetallic Vein
(Southern Bolivian type), Sn Polymetallic Vein,
Rhyolite-Hosted Sn, and Granitoid-Related Au Deposits
(Belt EAVK) Southeastern Part of Russian Northeast**

The Verkhne-Kolyma zone of Sn polymetallic vein (Southern Bolivian type), Sn-Ag polymetallic vein, rhyolite-hosted Sn deposits, and granitoid-related Au deposits (fig. 79; tables 3, 4) occurs in the southeast part of the Russian Northeast. The belt trends mainly northwest-southeast, extends for about 700, km and ranges up to 100 km wide. The metallogenic belt is associated with Cretaceous plutonic rocks which intrude the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV) and the Viliga passive continental-margin terrane (Nokleberg and others, 1994c, 1997c). These plutonic rocks form an orthogonal branch of the Okhotsk-Chukotka volcanic plutonic belt. Sn polymetallic vein (Southern Bolivian type) and Sn-Ag polymetallic vein deposits are hosted mainly in Late Cretaceous dacite and rhyolite subvolcanic dikes and stocks. The significant deposits in the zone are (table 4) (Nokleberg and others 1997a, b, 1998): Sn silicate-sulfide and Sn polymetallic vein deposits at Baryllyelakh-Tsentralny, Bogatyr, Dneprov, Kandychan, Kharan, Khenikandja, Kheta, Khuren, Kuranakh-Sala, Kyurbelykh, Porozhistoe, Svetloe, and Tigrets-Industriya; a Sn greisen deposit at Ossolony; a rhyolite-hosted Sn deposit at Suvorov; Au-Ag epithermal vein deposits at Aida and Zerkalnoe; Pb-Zn-Ag vein or skarn deposits at Bulunga and Tektonicheskoe, granitoid-related Au deposits at Netchen-Khaya, Shkolnoe, a porphyry Mo deposit at Tankist; and a Co-Bi-As vein deposit at Verkhne-Seimkan. The Co and Bi deposits, as at Verkhny Seimkan, are associated with Cretaceous granitoid plutons of the Okhotsk-Chukotka volcanic-plutonic belt. The deposits are generally small, and either exhausted, partly mined, or starting to be mined, as at Shkolnoe. Local Sn deposits with Ag, Pb, and Zn, may be of future economic interest.

Tigrets-Industriya Sn Polymetallic Vein Deposit

The small Tigrets-Industriya Sn polymetallic vein deposit (Lychagin, 1967; Plyashkevich, 1990) consists of quartz-carbonate-sulfide, quartz-sulfide, and sulfide-quartz veins, and lenticular bodies and zones of veinlets which occur in weakly metamorphosed Late Permian sedimentary rocks intruded by a Late Cretaceous granite porphyry. The ore bodies occur along northeast-trending fractures, are 100 to 200 m long, and range from 0.1 to 0.8 m thick. Late Cretaceous siliceous lava flows occur peripheral to the mineralized area. Several Sn and Ag mineral assemblages occur in the deposit. A period of deformation separated early and late stages. The early assemblage consists of quartz-cassiterite and polysulfide containing cassiterite, arsenopyrite, pyrite, chalcopyrite, sphalerite, galena, canfieldite, Fe-freibergite, stannite, and pyrargyrite. The late seleno-canfieldite-quartz assemblage contains quartz, pyrite, sphalerite, galena, stannite, selenocanfieldite, and Mn-calcite.

Kandychan Sn Polymetallic Vein Deposit

Sn polymetallic vein deposits, as at Kandychan and Kheta, are hosted mainly in Late Cretaceous subvolcanic and flow rocks of moderately felsic to felsic composition. The Kandychan deposit (Firsov, 1972; Lugov and others, 1974a, b; N.E. Savva, written commun., 1980) consists of groups of veins and veinlets which occur in a generally north-south-trending band more than 2 km long and from 500 to 600 m wide. The host volcanic rocks are propylitized, silicified, and argillized. The ore bodies consist of quartz-chlorite-cassiterite-sulfide veins with various carbonates (calcite, siderite, dolomite), sericite, hydromica, kaolinite, dickite, pyrophyllite, fluorite, and tourmaline. The sulfide minerals are mainly stannite, pyrargyrite, hessite, and argentite; and lesser pyrite, chalcopyrite, arsenopyrite, marcasite, pyrrhotite, sphalerite, galena, bornite, and covellite. The deposit is characterized by high Ag, Bi, Co, and Au. The sulfide veins with colloform cassiterite near the surface change with depth to low-sulfide chlorite-quartz veins with crystalline cassiterite. The deposit is small, is partly mined, and has produced 2,000 tonnes Sn.

Suvorov Rhyolite-Hosted Sn Deposit

Rhyolite-hosted Sn deposits, as at Suvorov, and Sn polymetallic vein and Sn greisen deposits, as at Dneprovskoe and Khenikandja, are associated with small Cretaceous granitoid plutons. The Suvorov rhyolite-hosted Sn deposit (Lugov and others, 1974a, b; Flerov, 1974) consists of colloform cassiterite nodules (wood tin) which occur in intensely silicified and kaolinized, fluidal rhyolite, agglomerate vitric tuff flows, and tuff- and lava-breccia. The host Late Cretaceous volcanic rocks form various volcanic vent facies. Cassiterite is associated with fine-grained quartz, hematite, chlorite, kaolinite, pyrite, and arsenopyrite. The ore is characterized by high Fe and In. The deposit is small.

Shkolnoe Granitoid-Related Au and Au Quartz Vein Deposit

The Shkolnoe granitoid-related Au and Au quartz vein deposit (fig. 95) (Orlov and Epifanova, 1988; S.V. Voroshin and others, written commun., 1990; Palymsky and Palymskaya, 1990; V.A. Banin, written commun., 1993; Goncharov, 1995; Goryachev, 1998, 2003) consists of an en echelon system of quartz veins which trend generally east-west. The veins occur in a multiphase granitoid stock about 4 km^2 composed mainly of granodiorite and adamellite. The stock is intruded by dikes of granite-porphyry, rhyolite, pegmatite, aplite, and lamprophyre. The quartz veins are surrounded by zones of beresitic and argillic alteration, and skarn and greisen alteration also locally is present. The deposit occurred in two stages separated by intrusion of lamprophyre dikes (Goryachev, 1998): (1) an older granitoid-related Au vein deposit containing molybdenite, arsenopyrite, löellingite, native bismuth, Bi-tellurides, and native gold (herein interpreted as part of the Yana-Kolyma metallogenic belt); (2) the most economically-important stage, a Au quartz vein deposit containing arsenopyrite, pyrite, galena, sphalerite, gold, electrum, freibergite, tetrahedrite, Pb-Sb and Ag-sulfosalts, argentite, and stibnite. The Au ore bodies extend to great depth into a large zone of complicated mineralogy, geochemistry, and structure. The total reserves are estimated at 32 tonnes Au averaging 29 g/t Au and 45 g/t Ag. The mine at the deposit has produced 17 t Au and 17 t Ag from 1991 to 1997.

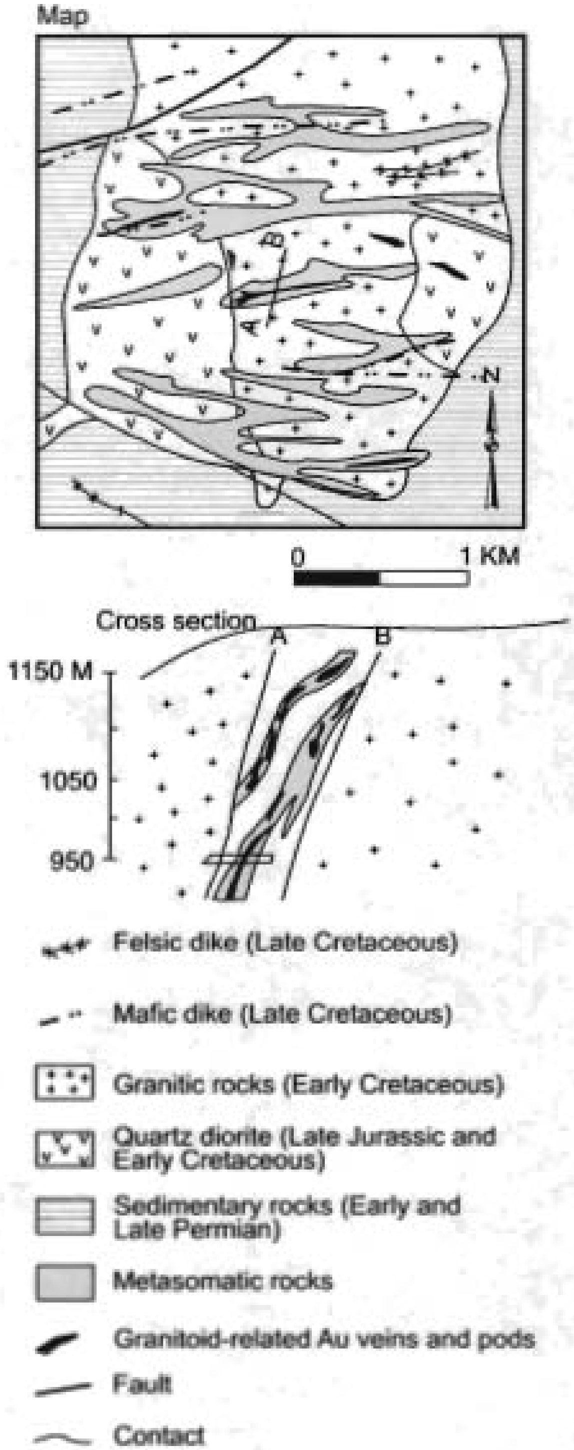


Figure 95. Shkolnoe granitoid-related Au deposit, Verkhne Kolyma zone, Eastern Asia-Arctic metallogenic belt, Russian Northeast. Schematic geologic map and cross section. Adapted from Sidorov and Goryachev (1994) and Sidorov and Eremin (1995).

Eastern Asia-Arctic Metallogenic Belt: Vostochno-Verkhoyansk Zone of Ag Polymetallic Vein and Clastic Sediment-Hosted Hg Deposits (Belt VV) West-Central Part of Russian Northeast

The Vostochno-Verkhoyansk metallogenic zone of Ag polymetallic vein and clastic sediment-hosted Hg deposits (fig. 79; tables 3, 4) occurs in two fragments, each 250 km long and 20-50 km wide, in the west-central part of the Russian Northeast

(Goryachev, 1998, 2003). The deposits are hosted in Carboniferous and Permian clastic rocks of the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV; Nokleberg and others, 1994c, 1997c). The Vostochno-Verkhoyansk metallogenic belt is the loci of old mining which started in the 18th century. The belt contains newly-discovered deposits which are currently being developed for mining. The significant deposits in the belt are Ag polymetallic vein deposits at Altaiskoe, Bezymyannoe, Kuolanda, Mangazeika, Prognoz, and Verkhnee Menkeche, and a Sn polymetallic vein deposit at Imtachan (table 4) (Nokleberg and others 1997a, b, 1998). Ag polymetallic vein deposits and occurrences, as at Altaiskoe, Mangazeika, and Menkeche, occur in longitudinal and diagonal faults which crosscut the hinges of major folds.

The age of mineralization for the Vostochno-Verkhoyansk metallogenic belt is interpreted as Late Cretaceous to Paleogene because the deposits formed prior to the development of the clastic sediment-hosted Hg deposits of the Verkhoyansk-Indigirka metallogenic belt in the same region (Indolev, 1979; Goryachev, 1998). The Vostochno-Verkhoyansk metallogenic zone is interpreted as forming in the rear (back-arc) part of the Cretaceous and early Tertiary Okhotsk-Chukotka volcanic-plutonic belt (fig. 79).

Mangazeika Ag Polymetallic Vein Deposit

The Mangazeika deposit (N.A. Tseidler, written commun., 1985; Goryachev, 1998) consists of polymetallic veins which occur in Early Permian argillite and sandstone which occur in gently-plunging tight folds. The veins fill fissures between argillite and sandstone layers and are conformable to bedding. The veins range from 50 to 1,300 m long, and from 3 cm to 1 m thick. The main ore minerals are galena and sphalerite; minor minerals are pyrite, arsenopyrite, chalcopyrite, owyheeite, freibergite, diaphorite, boulangerite, pyrargyrite, miargyrite, cassiterite, stannite, and native gold, native silver, and argentite. Gangue minerals are manganosiderite, quartz, ankerite, sericite, chlorite, and tourmaline. This and similar deposits do not contain significant amounts of sulfide minerals; silver amalgam is locally present. Other deposits, as at Menkeche and Bezymyannoe, are associated with Early and Late Cretaceous basaltic dikes and associated Sn polymetallic vein deposits. Wallrock alteration, including carbonization and silicification, is not significant. Estimated reserves are 62,375 tonnes Pb, 2,900 tonnes Zn, and 324 tonnes Ag. Estimated total resources are more than 1,000 tonnes Ag. Average grades are 75% Pb; 0.3-5% An; 500-3,938 g/t Ag; and 0.1-0.5 g/t Au. Silver was mined from 1915-1922.

Eastern Asia-Arctic Metallogenic Belt: Adycha-Taryn Zone of Au-Ag Epithermal Vein, Ag-Sb Polymetallic Vein, and Clastic Sediment-Hosted Sb-Au Deposits (Belt AT) Western Part of Russian Northeast

The Adycha-Taryn metallogenic zone forms a linear array of clastic sediment-hosted Sb-Au, Au-Ag epithermal vein, and Ag-Sb polymetallic vein associated deposits (fig. 79; tables 3, 4) which occur adjacent to the Adycha-Taryn fault in the western part of the Russian Northeast (Goryachev, 1998). The Adycha-Taryn fault is a major collisional suture zone between the Kular-Nera accretionary-wedge terrane of the Kolyma-Omolon terrane to the northeast and the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV) to the southwest (Nokleberg and others, 1994c, 1997c). The metallogenic belt is about 750 km long and 5 to 10 km wide. Several groups of deposits occur in the metallogenic belt (table 4) (Nokleberg and others 1997a, b, 1998): (1) small Au-Ag epithermal vein deposits, as at Ak-Altyn; (2) small Ag-Sb polymetallic vein occurrences; and (3) high-grade clastic-sediment-hosted Au-Sb deposits, as at Billyakh, Sarylakh, Sentachan, and Uzlovoe. Many of the clastic-sediment-hosted Au-Sb deposits, as at Sarylakh, are partly mined out.

The age and genesis of the Adycha-Taryn zone is more complex than previously interpreted because some of the deposits: (1) are not evidently magmatism-related; (2) are relatively younger than Au quartz vein and Sn-W vein deposits which occur in the same area; and (3) locally crosscut hornfels near granite intrusions which exhibit K-Ar isotopic ages of 110 to 90 Ma. Three possible origins are suggested for the genesis of the Au-Sb deposits in the Adycha-Taryn metallogenic belt. (1) A deep and possible mantle origin may be indicated by the local occurrence of native metals in the Au-Sb deposits (Anisimova and others, 1983). (2) The clastic-sediment-hosted Au-Sb deposits, which occur in and near the major Adycha-Taryn fault, may have formed in an accretionary environment and are related to metamorphism which occurred immediately after collision and accretion of the Kolyma-Omolon superterrane to the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV, fig. 79) along the Adycha-Taryn fault (Berger, 1978, 1993; Nokleberg and others, 2000). And (or; 3) the Au-Sb epithermal deposits and the polymetallic vein deposits may have formed in a post-accretional environment and are related to younger, Cretaceous and Paleogene basaltic magmatism in the region (Indolev and others, 1980). Alternatively, the clastic-sediment-hosted Au-Sb deposits may be part of a suite of quartz vein deposits and are part of the Yana-Kolyma metallogenic belt (Berger, 1978, 1993). The epithermal and polymetallic vein deposits of the Adycha-Taryn metallogenic zone are herein interpreted as forming in the rear and transverse part of the Cretaceous to early Tertiary Okhotsk-Chukotka volcanic-plutonic belt (fig. 79) which forms a major, post-accretionary continental-margin arcs in the Russian Northeast (Nokleberg and others, 1994c, 1997c; 2000).

Sentachan Clastic-Sediment-Hosted Au-Sb Deposit

The Sentachan clastic-sediment-hosted Au-Sb deposit (Shur, 1985; Indolev and others, 1980; V.V. Maslennikov, written commun., 1985) consists of two rod-like veins which vary from 85 to 200 m long and up to 3.1 m thick which occur in northwest-striking shear zones in northwest-trending faults which are part of the Adycha-Taryn fault zone. The veins are hosted in Late Triassic (Norian and Rhaetian) clastic rocks which are deformed northwest-trending gently-plunging folds parallel to the fault. The main minerals are stibnite and quartz; subordinate minerals are ankerite, muscovite, pyrite, arsenopyrite, dickite, and hydromica. Rare minerals are sphalerite, gold, chalcostibnite, berthierite, tetrahedrite, zinkenite, jamesonite, aurostibnite, and chalcopyrite. The wallrocks exhibit silicic, carbonate, hydromica, and dickite alteration. The grade varies from 3.2 to 40.3% Sb. Mined and proven reserves total 100,000 tonnes Sb, making the Sentachan Au-Sb deposit one of Asia's largest Sb deposits.

Ak-Altyn Au-Ag Epithermal Vein Deposit

The small Ak-Altyn Au-Ag epithermal vein deposit (Yu.A. Vladimirtseva, written commun., 1985) consists of quartz and quartz-carbonate veins, up to 2 to 3 m thick and stringers which occur in a zone 10-30 m wide and 150 m long. The deposit is hosted in gently-dipping Middle Triassic (Ladinian) terrigenous rocks which are intruded by Early Cretaceous diorite porphyritic dikes. The ore is dominated by fine-grained quartz (chalcedony) with sparse sulfides (about 1%), including galena, sphalerite, chalcopyrite, arsenopyrite, and pyrite. Gold fineness is low. Average grades are 0.2-60.4 g/t Au; and 0.1-1% combined Ag, Hg, Pb, Sb, Zn, As, and Cu.

Eastern Asia-Arctic Metallogenic Belt: Omsukchan Zone of Sn Polymetallic Vein, Sn Silicate-Sulfide, Porphyry Sn, Au-Ag Epithermal Vein, Porphyry Mo-Cu, and Associated Deposits (Belt EAOM) Southeastern Part of Russian Northeast

The Omsukchan metallogenic zone (fig. 79; tables 3, 4) occurs in the southeastern part of the Russian Northeast and forms an extensive transverse (orthogonal) branch of the East Asian-Arctic metallogenic belt. The zone occurs in and near the Okhotsk-Chukotka volcanic-plutonic belt (Nokleberg and others, 1994c, 1997c), is more 150 km long, and ranges from 10 to 15 up to 60 to 70 km wide. The significant deposits in the zone are Sn polymetallic vein deposits at Maly Ken and Trood, Sn silicate-sulfide vein deposits at Egorlyk, Galimoe, Khataren-Industrial, and Okhotnichie, Au-Ag epithermal vein deposits at Arylakh, Dukat, and Rogovik, porphyry Sn deposits at Ircha, Nevskoe, and Novy Djagyn, and Sb-Au and polymetallic vein deposits at Elombal, Mechta, Tidit, and Yakor (table 4) (Nokleberg and others 1997a, b, 1998). Mainly Sn and Ag polymetallic vein, and W, Au, and Co vein deposits occur in the northern and middle parts of the belt, whereas mainly Au-Ag epithermal vein and porphyry Mo-Cu deposits occur in the southern part.

The Omsukchan metallogenic belt occurs in a unique, local extensional tectonic environment in continental crust up to 52 km thick, which in herein interpreted as forming in the back-arc portion of the Okhotsk-Chukotka volcanic-plutonic belt. The rift-trough is filled by Early Cretaceous volcanic and sedimentary sequences of continental coal-bearing molasse which are unconformably overlain by Albian through Cenomanian andesite, rhyolite, and ignimbrite. The total thickness is greater than 3,000 m. The lower part of the molasse includes the Aptian Ascoldin Formation which is composed of high-siliceous, ultra-potassic rhyolite. The plutonic rocks associated with the metallogenic belt are dominated by the potassic biotite granite of the Omsukchan Complex which has a K-Ar isotopic age of approximately 90 Ma, and a Rb-Sr whole-rock isochron age of 80 Ma (Goryachev, 1998).

The significant Sn and Sn-Ag deposits, mainly Sn polymetallic vein, Sn silicate-sulfide, and porphyry Sn deposit types, are at Nevskoe, Galimoe, Ircha, Khataren-Industrial, Trood, Novy Djagyn, and Maly Ken. Some of these deposits were recently discovered. Most of the numerous, small, but rich and quickly exploited Sn deposits were exhausted in the 1940's. Various types of Sn deposits are associated with the Omsukchan granite and comagmatic extrusive-subvolcanic complexes. At depths, these Sn deposits are associated mainly with granitoid plutonic rocks. At intermediate levels, the Sn deposits are associated with volcanic and plutonic rocks. Near the surface, the Sn deposits are associated with volcanic rocks, and consist mainly of Sn-Ag deposits, and associated Ag-polymetallic and Au-Ag epithermal vein deposits. The significant Ag-polymetallic vein deposits are at Mechta and Tidit.

Nevskoe Porphyry Sn Deposit

The Nevskoe porphyry Sn deposit (Lugov, Makeev, and Potapova, 1972; Lugov, 1986) consists of fine-grained, complexly intergrown pyrophyllite, topaz, quartz, muscovite, and cassiterite. Also widespread are tourmaline, chlorite, wolframite, arsenopyrite, chalcopyrite, galena, sphalerite, pyrite, pyrrhotite, marcasite, tetrahedrite-tennantite, stannite, rutile, and scheelite. Semseyite, guanajuatite, laitakarite, silver, zunyite, apatite, fluorite and other minerals are rare. Sn content decreases with depth, as does topaz and pyrophyllite; quartz content increases with depth. The deposit occurs in a district which extends north-northwest along a zone of intensely fractured Early Cretaceous clastic sedimentary rocks. The zone has surface dimensions of 180 by 350 m.

The clastic sedimentary rocks are replaced by quartz, tourmaline, pyrophyllite, kaolinite, and locally, by dumortierite and topaz. The ore bodies coincide with the most altered rocks, are pipe-like, and extend along strike for hundreds of meters. The mine at the deposit is of small to medium size and is mostly exhausted.

Mechta Ag-Polymetallic Vein Deposit

The Mechta Ag-polymetallic vein deposit (V.I. Tkachenko and others, written commun., 1976-1979; Plyashkevich, 1986; V.I. Kopytin, written commun., 1987) consists of a set of en-echelon, generally north-south-trending, arcuate fracture zones which range from 3.5 to 4 km wide and 10 km long. The zones contain quartz-chlorite-sulfide veins and veinlets. The ore bodies form a fan-like structure which branch at the upper levels and are hosted by Late Cretaceous ignimbrites with propylitic and argillic alteration. The main vein minerals are Ag-bearing galena, sphalerite, chalcopyrite, pyrite, arsenopyrite, freibergite, pyrargyrite, stephanite, famatinite, tennantite, argentite, quartz, chlorite, and hydromica. Subordinate minerals are pyrrhotite, stannite, native gold and silver, feldspar, kaolinite, and carbonate. Ores are dominated by galena-sphalerite and chalcopyrite-freibergite associations. The deposit is of medium size with average grades of about 1% Pb, and 0.74% Zn, and up to 310 g/t Ag and 0.3 g/t Au.

Dukat Ag Epithermal Vein Deposit

The major Ag epithermal vein deposit at Dukat (fig. 96) (Brostovskay and others, 1974; Savva and Raevskaya, 1974; Kalinin, 1975a, 1986; Raevskaya, Kalinin, and Natalenko, 1977; Sidorov, 1978; Natalenko and others, 1980; Sakharova and Bryzgalov, 1981; Sidorov and Rozenblum, 1989; Shergina and others, 1990; Goncharov, 1995) consists of numerous, extensive disseminated replacement zones, and quartz-adularia-rhodochrosite-rhodonite veins with diverse Ag- and base metal sulfide minerals. The estimated reserves are 15,000 tonnes silver (Natalenko and others, 1980; Konstantinov and others, 1998). The deposit occurs in ultra-potassic rhyolite, part of the Early Cretaceous Askoldin igneous complex which occurs over a concealed cupola of the Omsukchan granite. This deposit differs from similar precious metal epithermal deposits by a predominance of Ag and multi-stage formation from the Early Cretaceous through the early Paleogene. This rich vein deposit is interpreted as forming during partial Ag remobilization of the disseminated sulfide minerals which were deposited during Early Cretaceous Askoldin magmatism (Milov and others, 1990). This mining district has potential for additional, undiscovered deposits, similar to Dukat, with bulk-mineable low-grade Ag deposits similar to Waterloo, and other Ag pipe-like deposits in Mexico (Natalenko and Kalinin, 1991).

Eastern Asia-Arctic Metallogenic Belt: Chokurdak Zone of Granitoid-Related Sn Greisen, Sn-Polymetallic Vein, Sn Greisen, and Au-Ag Epithermal Vein Deposits (Belt EACD) Northern Part of Russian Northeast

The Chokurdak metallogenic zone of granitoid-related Sn greisen, Sn polymetallic vein, and Au-Ag epithermal deposits (fig. 79; tables 3, 4) occurs in the northern part of the Russian Northeast. The deposits are closely related to mid-Cretaceous felsic volcanic rocks and associated Late Cretaceous leucocratic granite dikes and plutons with K-Ar isotopic ages of 90 to 105 Ma (Nokleberg and others, 1994c, 1997c). The significant deposits in the zone are Sn silicate-sulfide vein deposits at Chokurdakh, Churpunnya, and Sigilyakh, Sn polymetallic vein and Sn greisen deposits at Pavel-Chokhchurskoe, Deputatskoe, Djaktardakh, Khomustak, Odinokoe, and Ukachilkan, and Sn and Au-Ag polymetallic vein deposits at Polevaya, Primorskoe, and Yuzhnoe (table 4) (Nokleberg and others 1997a, b, 1998). The Chokurdak metallogenic belt is hosted in one of the rear, mid- to Late Cretaceous parts of the Okhotsk-Chukotka volcanic-plutonic belt (Nokleberg and others, 1994c, 1997c).

The Sn polymetallic vein deposits, as at Primorskoe, Deputatskoe, and Dyaktardak, are associated with small intrusions of moderately felsic granite and quartz monzonite with K-Ar isotopic ages of 110 to 100 Ma, and with subalkalic mafic and intermediate dikes with K-Ar isotopic ages of 100-70 Ma. These granitoid rocks constitute one of the rear parts of the Okhotsk-Chukotka volcanic-plutonic belt. Sn greisen deposits, as at Khomustak and Odinakoe, occur in the apical portions of granitic intrusions or in subvolcanic rhyolite bodies, as at Churpunya and Odinokoe. Economic Sn deposits occur at Deputatskoe and Churpunnya. The Sn deposits are the sources for commercial cassiterite place deposits in the region, including a coastal belt of Sn placer deposits.

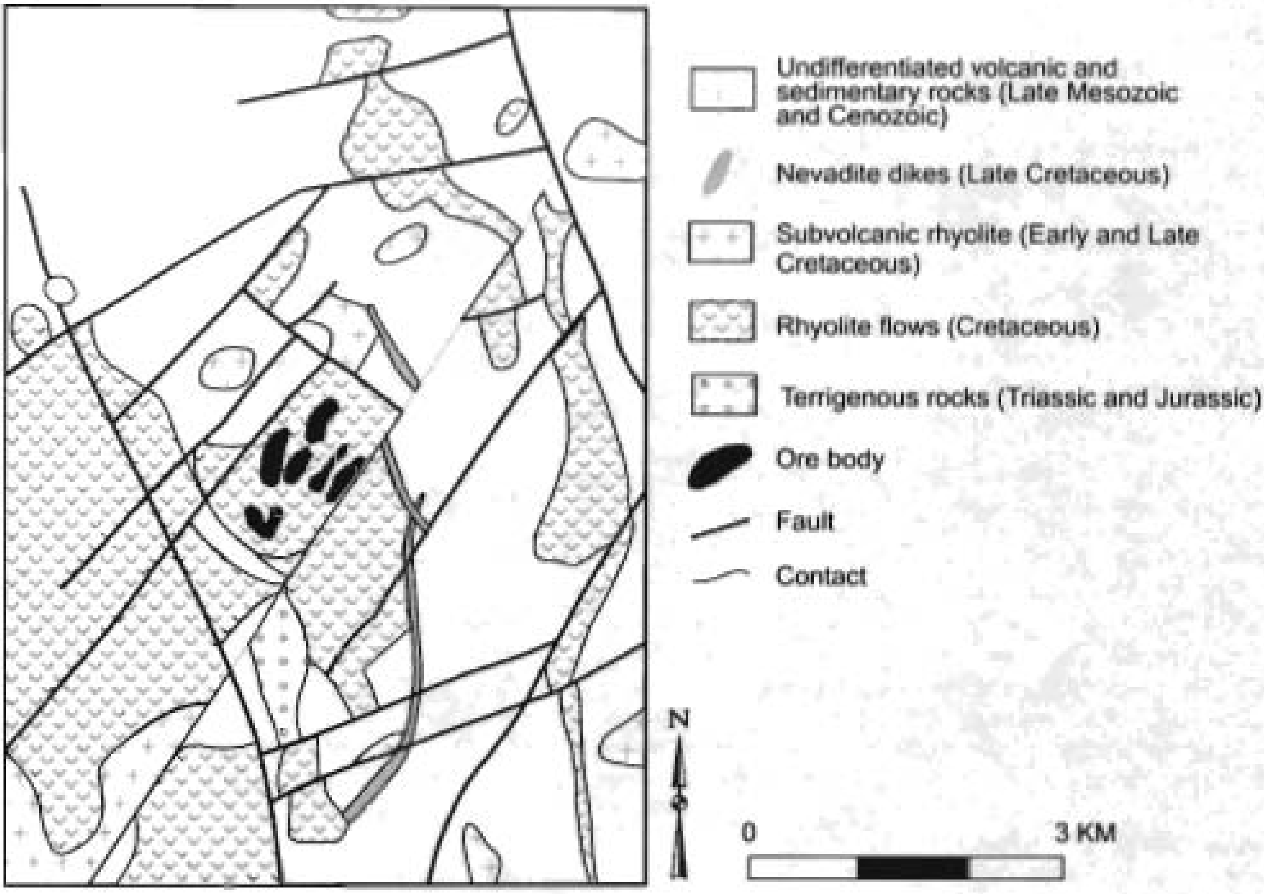


Figure 96. Dukat Au-Ag epithermal vein deposit, Omsukchan zone, Eastern Asia-Arctic metallogenic belt, Russian Northeast. Schematic geologic map of deposit and surrounding area. Adapted from Goncharov (1995a).

Deputatskoe Sn Polymetallic Vein(?) Deposit

The Deputatskoe Sn polymetallic vein(?) deposit (Flerov, 1974) includes about 150 separate ore bodies which occur in shear zones, veins, and linear stockwork zones. The main ore bodies occur in mineralized zones which are explored to depths of more than 350 m with adits and drillholes. The deposit ranges up to 18 m thick and up to 1400 m long. Major and minor minerals are quartz, tourmaline, chlorite, axinite, fluorite, pyrrhotite, cassiterite, chalcopyrite, pyrite, siderite, ankerite, sphalerite, galena, marcasite, wolframite, stannite, franckeite, boulangerite, bismuth, bismuthine, topaz, apatite, scheelite, and sulfosalts. The wallrocks altered to silica, tourmaline, chlorite, and less common greisen and sulfides. The deposit is large with an average grade of 0.3-0.7% Sn, and local high-grade zones with up to 10% Sn. The deposit hosted in contact metamorphosed Middle Jurassic shale and in an unexposed granite stock which is penetrated by drilling at 377 m depth. The stock exhibits a K-Ar isotopic age of 108 to 104 Ma. Pre-deposit, coeval and post-deposit dikes of mafic, intermediate, and felsic intrusive rocks are wide-spread. Many of the polymetallic veins occur in felsic and intermediate dikes. The Deputatskoe deposit has been the largest producer of Sn in the Russian Far East.

Churpunnya Sn silicate-Sulfide Vein Deposit

The Churpunnya Sn silicate-sulfide vein deposit (Nekrasov and Pokrovsky, 1973; Flerov and Shur, 1986; A.I. Kholmogorov, written commun., 1987) consists of shear zones, stringers, and veins with tourmaline and quartz-tourmaline; cassiterite (up to 10%), sericite, marcasite, and 1-2% arsenopyrite, bismuth, bismuthine, wolframite, pyrrhotite, chalcopyrite, stannite, valleriite, siderite. The ore zones range from 0.1 to 0.7 m thick, are about one hundred meters long, and are drilled to a depth of 150 to 200 m. The deposit is small and locally contains up to 10% Sn. The deposit hosted in intensely tourmalinized and silicified rhyolite-dacite volcanic rocks and in a related Early Cretaceous granitoid stock. (Layer and others, 1999.)

Eastern Asia-Arctic Metallogenic Belt: Chaun Zone of Granitic-Magmatism-Related Deposits (Belt EACN) Northeastern Part of Russian Northeast

The Chaun zone of felsic-magmatism-related deposits (fig. 79; tables 3, 4) occurs in the northeastern part of the Russian Northeast (Goryachev, 1998, 2003; this study). The principal deposit types in the Chaun zone are Sn silicate-sulfide vein, Sn greisen, Sn skarn, porphyry Sn, Sn and Sn-Ag polymetallic vein, and granitoid-related Au deposits. The zone occurs in the rear of the Okhotsk-Chukotka volcanic-plutonic belt and adjacent areas (Nokleberg and others, 1994c, 1997c), and extends approximately east-west for about 1,300 km from the mouth of the Kolyma River to Uelen. The Chaun zone is correlated across the Bering Straits with the Seward Peninsula metallogenic belt in northwestern Alaska which contains similar deposits (fig. 80). The significant deposits in the zone are (table 4) (Nokleberg and others 1997a, b, 1998): Sn silicate-sulfide vein and Sn polymetallic vein deposits at Dioritovoe, Elmaun, Erulen, Eruttin, Ichatkin, Kekur, Kukenei, Lunnoe, Mramornoe, Mymlerennet, Telekai, Valkumei, and Vodorazdelnoye; porphyry Sn deposits at Ekug and Pyrkakai; granitoid-related Au deposits at Kanelyveen and Kuekvun; porphyry Cu-Mo and porphyry Mo deposits at Granatnoe and Shurykan; Pb-Zn skarn and Fe-Pb-Zn-Sn deposits at Chechekuyum, Enpylkhkan, Melyul, Reechen, and Serdtse-Kamen; an Au-Ag epithermal vein deposit at Pepenveem; a disseminated Au-sulfide deposit at Tumannoe; and a clastic sediment-hosted Hg or hot-spring Hg deposit at Yassnoe.

The Sn and associated lode deposits of the Chaun zone are generally hosted in: (1) volcanic rocks and rhyolite subvolcanic intrusions and extrusions which often have anomalous In and Ag; (2) major plutons of Late Cretaceous leucocratic biotite granite with K-Ar isotopic ages of 95-70 Ma; and (3) late Early Cretaceous diorite (Kanelyveen deposit). The deposits generally occur in the apical parts of the granitic intrusions and in the intrusive domes. The typical deposit minerals are quartz, tourmaline, chlorite, and sulfide minerals. In western Chukotka, the significant deposits are at Valkumei, currently being mined, and at Pyrkakai, Ekug, Telekai, and Kukenei, and a possible granitoid-related Au deposit at Kanelyveen. In eastern Chukotka, significant Sn-Ag skarn and polymetallic vein deposits at Chechekuyum, Reechen, and Enpylhkan are hosted in Paleozoic carbonate rocks.

Also part of the Chaun zone of felsic-magmatism-related deposits is a group of Sn and complex Sn-W polymetallic vein, minor associated Sn greisen deposits which occur in middle Paleozoic and early Mesozoic sandstone, argillite, and rare carbonate rocks of the Chauna subterrane (fig. 79). The polymetallic lode deposits are closely associated with Early and mid-Cretaceous anatectic, leucocratic, potassic granitoid plutons. The main Sn-W vein deposits occur to the east in the Iultin ore district. The Iultin, Svetloe, Chaantal, Tenkergin, and associated deposits of this district contain the most of the inferred tungsten reserves for the region, and the Iultin and Svetloe deposits produce all of the tungsten and by-product tin in the Russian Northeast.

Iultin Sn-W Polymetallic Vein and Greisen Deposit

The Iultin Sn-W polymetallic vein and greisen deposit (fig. 97) (Zilbermints, 1966; Lugov, Makeev, and Potapova, 1972; Lugov, 1986) consists of quartz veins, mineralized stockwork zones, and disseminated veinlets hosted in greisen. The stockwork zones and veinlets are both steeply-dipping and gently-dipping. Some ore bodies wedge out vertically. The W ore bodies occur over the top of a leucogranite pluton which is about 300 m below the surface; and the Sn ore bodies occur in the marginal zone of the leucogranite. Approximately 65 minerals are known with the most common being quartz (95%), muscovite, fluorite, albite, cassiterite, wolframite, arsenopyrite, and löellingite. Less common are topaz, pyrite, pyrrhotite, bismuthinite, stannite, chalcopyrite, sphalerite, galena, molybdenite, scheelite, hematite, and native silver and bismuth. Cassiterite is commonly associated with wolframite, arsenopyrite, and muscovite. Cassiterite occurs as short, columnar crystals up to 10 cm across. Large (up to 4-9 cm) and gigantic (up to 0.5 m) wolframite crystals and crystal intergrowths are present. The vertical extent of the ore bodies exceeds 900 m. The deposit occurs along the contact of the mid-Cretaceous Iultin granite with a K-Ar age of 90-110 Ma which intrudes and contact metamorphosed and metasomatizes Early and Late Triassic sandstone and shale. The biotite granite has a Rb-Sr isotopic age of 85.1 Ma with an initial Sr ratio of 0.7088 (Dudkinsky and others, 1986). The late stage of the Iultin intrusive complex consists of leucocratic granite with a Rb-Sr isotopic age of 76.3 Ma and an initial Sr ratio of 0.717. The deposit is large and has been mined since 1959 with an average grade of 0.43% Sn and 1.29% WO_3. The Iutin deposit has produced significant W and Sn in past years, but is now inoperative.

Svetloe Sn-Quartz Vein Deposit

The Svetloe Sn-quartz vein deposit (Lugov, 1986; Kuleshov, Pristavko, and Plyashkevich, 1988) consists of en-echelon sets of quartz veins and veinlets which form two zones which diverge to the southeast. Each zone contains several tens of larger veins which vary from 0.2 to 1.5 m thick and are several hundreds of meters long; and about one hundred smaller veins. The ore is dominated by Sn minerals with abundant sulfide minerals which occur over a buried stock of greisenized granite. The veins are hosted in metamorphosed Triassic sandstone and shale and are cut by granite porphyry and aplite dikes of the Cretaceous Iultin complex. Successive mineral assemblages are: (1) topaz-fluorite-muscovite greisen; (2) cassiterite-wolframite-quartz assemblage with topaz, löellingite, and fluorite (the most productive assemblage); (3) arsenopyrite-quartz with cassiterite and native bismuth; (4) stannite-chalcopyrite with small amounts of bismuthinite, sphalerite, galena, pyrrhotite, and bornite; (5) scheelite-fluorite-albite with chlorite, pyrite, marcasite, and cassiterite; and (6) fluorite-calcite with kaolinite. A complex cassiterite-wolframite assemblage is dominant in the upper portion of the deposit whereas W minerals are dominant at depth. The deposit is of medium size and has been mined from 1979 to the mid-1990's.

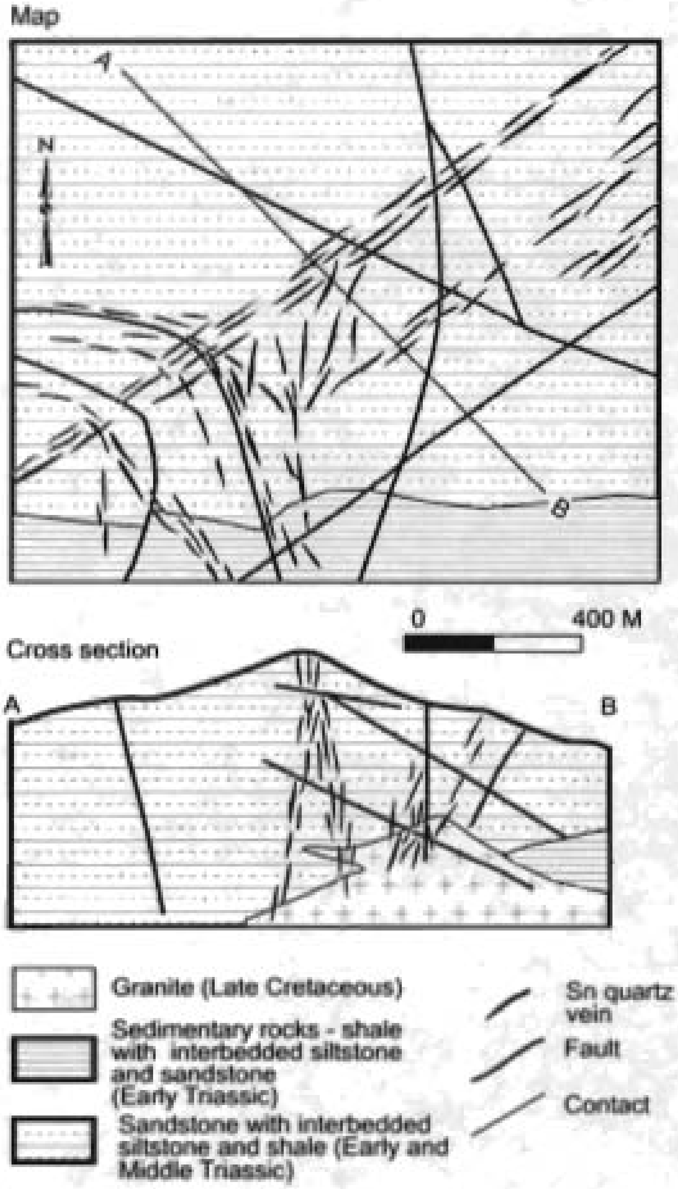


Figure 97. Iultin Sn quartz vein deposit, Chukotka metallogenic belt, Russian Northeast. Schematic geologic map and cross section. Adapted from Lugov (1986).

Valkumei Sn Silicate-Sulfide Vein Deposit

The Valkumei Sn silicate-sulfide vein deposit (Lugov, Makeev, and Potapova, 1972; Lugov, 1986) consists of simple and complex veins, mineralized zones, and less common linear stockworks. The deposit occurs mainly within the marginal zone of the Late Cretaceous Pevek pluton, composed of granite, adamellite, and granodiorite, and to a lesser degree in Cretaceous sandstone and shale which host the pluton. Mineralization occurs in a north-northwest-trending zone alone the contact of the pluton. The ore bodies commonly consist of a conjugate system of: (1) major north-south veins and feathered veinlets; and (2) a zone of approximately east-west- and northwest-trending veins. Seventy minerals occur in the deposit but the majority of the veins are composed dominantly of tourmaline, with quartz, chlorite, albite, arsenopyrite, cassiterite, pyrrhotite, chalcopyrite, stannite, sphalerite, stibnite, fluorite, and various carbonates. The ore bodies are vertically extensive. The cassiterite-quartz-tourmaline veins are replaced by sulfide veins at depth. The deposit is large, was discovered in 1935, and has been mined from 1941 to the mid-1990's. The average grade is 0.4 to 1.2 % Sn.

Chechekuyum Pb-Zn Skarn Deposit

The Chechekuyum Pb-Zn skarn deposit (G.A. Zhukov and others, written commun., 1953) dips gently, is about 18 m thick and 30 m long along strike, and is composed of pyrrhotite, sphalerite, galena, chalcopyrite, magnetite, pyrite, niccolite, marcasite, calcite, garnet, diopside, and quartz. The skarn occurs along a fracture zone in Middle Devonian limestone, which is overlain by Late Cretaceous felsic extrusive rocks and intruded by granite porphyry and spessartite dikes. Massive and disseminated pyrrhotite ore occurs in the hanging wall. Massive galena, and less abundant sphalerite-galena ore, occur in the middle part of the skarn. Sparse massive sphalerite ore is prominent in the footwall. The skarn also contains sparsely disseminated ore minerals. The skarn contains anomalous Sn, Cd, Co, Bi, and Ag. The deposit is judged as small.

Metallogenic Belt Formed During Late Mesozoic Collision and Accretion of Chukotka Superterrane, Russian Northeast

Chukotka Metallogenic Belt of Au Quartz Vein and Related Deposits (Belt CH) Northern Part of Russian Northeast

The Chukotka metallogenic belt of Au quartz vein, Sn and Sn-W polymetallic vein, and minor associated Sn greisen deposits (fig. 79; tables 3, 4) occurs in the northern part of the Russian Northeast (Goryachev, 1998, 2003) in the central and western parts of the Paleozoic and early Mesozoic Chukotka passive continental margin terrane (Nokleberg and others, 1994c, 1997c). The significant deposits in the belt are (table 4) (Nokleberg and others 1997a, b, 1998): Au quartz vein deposits at Dvoinoi, Karalveem, Lenotap, Ozernoe, Ryveem, Sredne-Ichuveem, and Svetlin; Sn quartz vein deposits at Chaantal, Svetloe, and Tenkergin; and a Sn-W polymetallic vein and greisen deposit at Iultin.

Au Quartz Vein Deposits

The Au quartz vein and associated Au shear zones deposits occur in the Anyui and Chauna subterranes of the Chukotka passive continental margin terrane (fig. 79). The significant deposits are at Karalveem, Ozernoe, Sredne-Ichuveem, Draznyaschy, Upryamy, and Lenotap. The Au-quartz vein deposits and Au shear zones deposits generally occur in anticlinal structures formed in Triassic siltstone, shale, and sandstone which are intruded by widespread Triassic gabbro-diabase sills, and by Early Cretaceous granitic dikes. The Au deposits are controlled by major, north-west-trending faults and feathering fault zones which formed during low-grade, greenschist facies metamorphism. A few Au-quartz vein deposits also occur in thrust zones in middle Paleozoic clastic and carbonate rocks, and in Late Jurassic and Early Cretaceous volcanic and sedimentary rocks. The Au quartz vein and Au shear zones deposits of the Chukotka metallogenic belt are probably the main lode source for numerous placer Au deposits of northern Chukotka. However, in detail, the known lode Au deposits do not correspond to the known large placer Au deposits. This observation suggests which undiscovered Au quartz vein or other types of undiscovered deposits may exist in the region.

Karalveem Au Quartz Vein Deposit

The only commercial Au quartz vein deposit at Karalveem (fig. 98) (Olshevsky, 1974, 1976, 1984; Davidenko, 1975, 1980; Skalatsky and Yakovlev, 1983) consists of numerous longitudinal, transverse, and diagonal, steeply-dipping ladder quartz veins up to several meters thick which occur in Triassic gabbro-diabase sills, especially near contacts with Triassic sandstone and shale. The sedimentary rocks and sills are strongly deformed into narrow, steep, northwest-trending folds. The ore bodies are controlled by strike-slip faults associated with the folding. Host rocks exhibit greenschist facies metamorphism. The Au quartz veins consist of 95-97% quartz with segregations of arsenopyrite and lenses of scheelite, albite, ankerite, and muscovite. Also widespread are calcite, dolomite, white mica, galena, native gold, aquamarine, sphalerite, pyrite, and pyrrhotite. Gold occurs mainly in bluish-gray quartz veinlets in a matrix of coarse-grain quartz and arsenopyrite, in the upper horizons of the deposit. Silica-carbonate and sulfide alteration occur adjacent to ore zones. Near the surface, quartz veins often host druse-like intergrowths of large, well-crystallized quartz and isometric gold crystals. Coarse-grained masses of gold, and less common dendritic gold, up to 1 cm diameter, are characteristic of the deposit. At depth, the gold occurs mainly as fine, dispersed masses in arsenopyrite. The deposit is of medium size, and has been prospected and developed preparatory to mining.

Origin of and Tectonic Controls for Chukotka Metallogenic Belt

The Au quartz vein and Au shear zones deposits of the Chukotka metallogenic belt are herein interpreted as forming in the Late Cretaceous during regional deformation and associated metamorphism and anatectic granite magmatism (Goryachev, 1998, 2003) which occurred during a major period of collision and accretion of the Chukotka terrane (Nokleberg and others, 2000). Preceding the accretion was: (1) Early Cretaceous opening of the Canada (Arctic Ocean) Basin; (2) migration of the Chukotka superterrane to the southwest; and (3) closure of the late Paleozoic(?) and early Mesozoic South Anyui Ocean. After closure, the Chukotka superterrane was accreted against the South Anyui and Velmay subduction-zone terranes, and the Nutesyn island-arc terrane which in turn collided with the Kolyma-Omolon superterrane farther southwest (present-day coordinates). The Au quartz vein deposits are interpreted as forming during the early stage of the accretion. Similar origin and coeval Au quartz vein deposits occur to the east in the Southern Brooks Range metallogenic belt of Au quartz vein deposits (fig. 80). Anatexis or partial melting is interpreted as occurring during the final stage of accretion and associated crustal thickening. The Sn polymetallic vein deposits are interpreted as forming during the final stage of accretion.

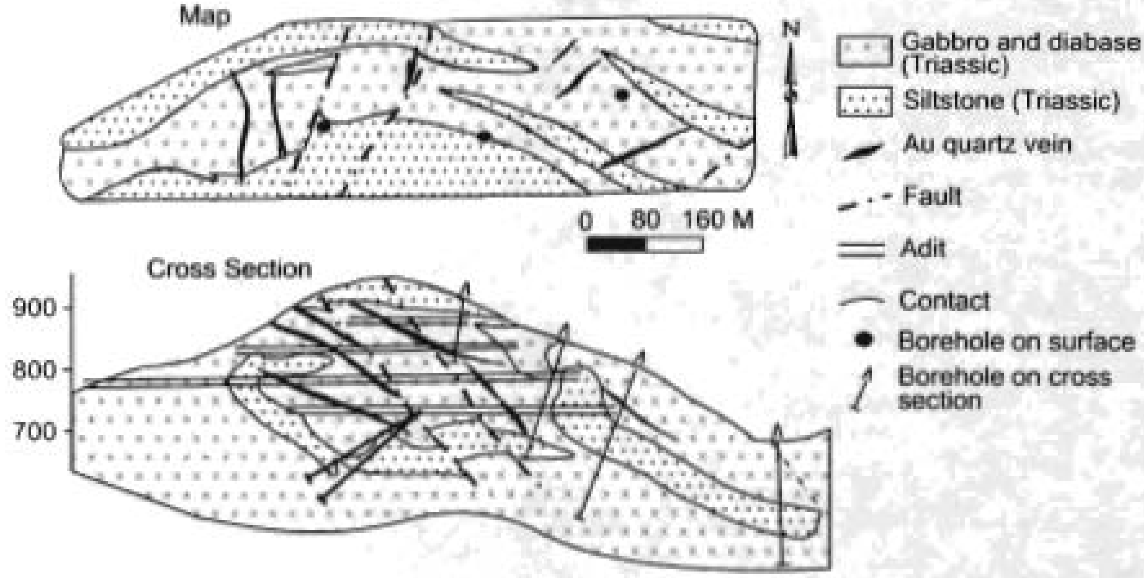


Figure 98. Karalveem Au quartz vein deposit, Chukotka metallogenic belt, Russian Northeast. Schematic geologic map and cross section. Adapted from Goryachev and others (1996) and Eremin and Sidorov (1995).

Metallogenic Belts Formed in Late Mesozoic Collision and Accretion of Wrangellia Superterrane, Southern Alaska

East-Central Alaska Metallogenic Belt of Granitic Magmatism Deposits (Older, Mid-Cretaceous Part; Belt ECA) East-Central Alaska

The East-Central Alaska metallogenic belt of granitic magmatism deposits (older, mid-Cretaceous part) fig. 80; tables 3, 4) (Nokleberg and others, 1995a, 1996, 1997a) consists of two parts, an older, mid-Cretaceous part, described and interpreted herein, and a younger Late Cretaceous and early Tertiary part, described in a subsequent section. The mid-Cretaceous part contains a wide variety of granitoid-related Au, Sb-Au vein, Pb-Ag-Zn-Au polymetallic vein, and W-Au skarn deposits (table 4). The East-Central Alaska belt is hosted mainly by mid Cretaceous granitoid rocks in the Yukon-Tanana Upland (Miller, 1994; McCoy and others, 1997) which are part of the Yukon-Tanana igneous belt (Moll-Stalcup, 1994). Recently, the name was described in a series of papers in the volume edited by Tucker and Smith (2000). However, their usage woas for both granitoid-related Au deposits and occurrences in the East-Central Alaska metallogenic belt and in the correlative Tombstone metallogenic belt that is described above.

Three major groups of deposits occur in the East-Central Alaska metallogenic belt (table 4). (1) In the north-central part of the belt, in the Manley and Livengood area, the significant lode deposits are a Pb-Ag-Zn-Au polymetallic vein deposit at Hot Springs Dome (mid-Cretaceous?), an Sb-Au vein deposit at Sawtooth Mountain (mid-Cretaceous), and Sb-Au and Au quartz vein deposits at Gertrude Creek, Griffen, and Ruth Creek (table 4) (Nokleberg and others 1997a, b, 1998). (2) In the central part of the belt are a variety of granitoid-related deposits in the Fairbanks area. And (3)in the southern part of the belt are polymetallic and Sb-Au vein deposits in the Kantishna area in the northern Alaska Range (Bundtzen, 1981; McCoy and others, 1997). Described below are the major granitoid-related deposits at Fort Knox, Democrat, and Pogo in the Fairbanks area, and vein deposits in the Kantishna district. The Fairbanks area is underlain by multiply metamorphosed and penetratively deformed, middle Paleozoic and older quartz-metasedimentary, sparse metavolcanic, and rare metagranitoid rocks of the Yukon-Tanana continental margin terrane (Nokleberg and others, 1994c, 1997c). The characteristics and origin of the mid-Cretaceous granitoid-related Au deposits in this area are described by McCoy and others (1997).

Fairbanks Area

In the eastern and southern parts of the belt in the Fairbanks area, a wide variety of granitoid-related deposits (Table 4) are spatially associated with mid-Cretaceous plutons. These deposits are: Sb-Au vein deposits at Dempsey Pup and Scrafford; a Sn polymetallic vein deposit at Table Mountain; polymetallic vein deposits at Cleary Summit, Ester Dome (Ryan Lode), Democrat (Mitchell Lode), Blue Lead, Tibbs Creek, and Gray Lead; a major granitoid-related Au deposit at Fort Knox; a high-grade, granitoid-related Au quartz vein deposit at Pogo; and an Au-As vein deposit at Miller House. The deposits at Scrafford, Cleary Summit, Gilmore Dome, Ester Dome, and Democrat are in the Fairbanks district.

Fort Knox Granitoid-Related Au Deposit

The Fort Knox granitoid-related Au deposit (fig. 99) (Blum, 1985; Robinson and others, 1990; A.A. Bakke, written commun., 1991; Bakke, 1995; Hollister, 1992, McCoy and others, 1997) occurs northeast of Fairbanks and consists of free gold, bismuthinite, and minor to trace molybdenite and chalcopyrite which occur in a sulfide-poor, quartz vein stockwork in the Fort Knox (porphyritic granodiorite) pluton. The stockwork is preferentially emplaced along a steeply dipping fracture system which trends 290°. The deposit is at least 1500 m long by 300 m wide, and 250 m deep, and contains an estimated reserve of 186.5 million tonnes grading 1.6 g/t Au (Bakke, 1995, 2000). The gold is remarkably pure (greater than or equal to 980 fine). The Fort Knox pluton is alkali-calcic and peraluminous. Mineralization is interpreted to have occurred either during the late stages of emplacement of the nearby Gilmore Dome stock which has a K-Ar biotite age of 92 Ma (McCoy and others, 1997). However, a younger, early Tertiary heating event that post-dates the older porphyry Mo-Bi-Cu-mineralization may have also introduced Au (Bakke, 1995).

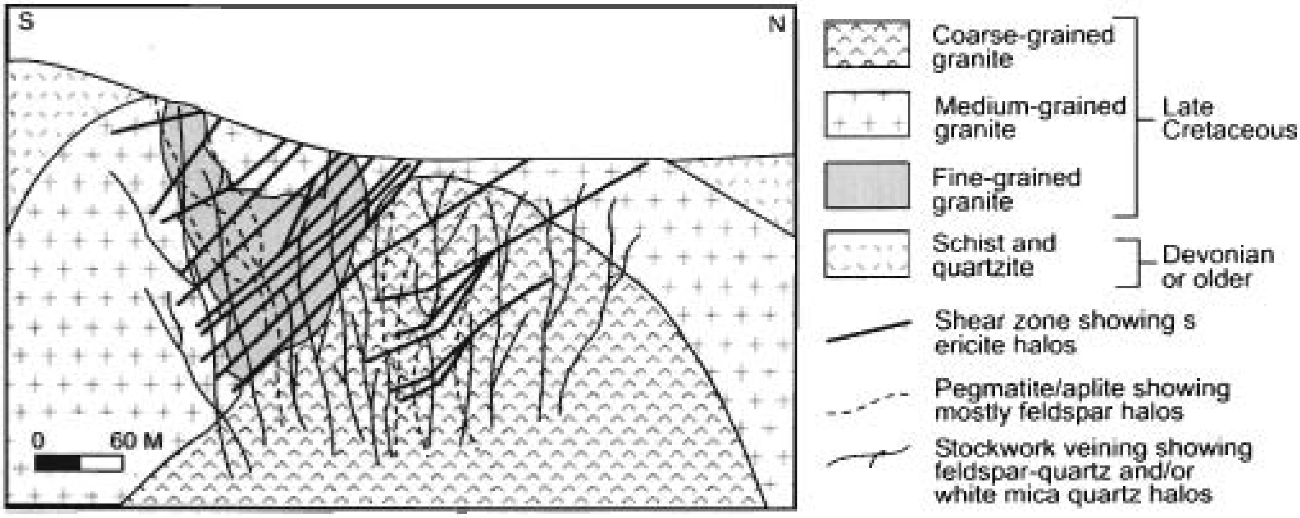


Figure 99. Fort Knox granitoid-related Au deposit, East-Central Alaska metallogenic belt, East-Central Alaska. Schematic cross section looking west. Adapted from Bakke (1994).

Democrat (Mitchell Lode) Granitoid-Related
Au Deposit

The Democrat (Mitchell Lode) granitoid-related Au deposit (fig. 100) (Bundtzen and Reger, 1977; T.K. Bundtzen and R.B. Forbes, written commun., 1990) occurs in the Richardson district south of Fairbanks, and consists of disseminated and stockwork tetrahedrite, galena, acanthite, owyheeite, other Ag-sulfosalts, free gold, and quartz in a hydrothermally altered granite porphyry. A strong sericite alteration halo surrounds the porphyry, which intrudes sillimanite-bearing metasedimentary schists of the Yukon-Tanana terrane. The granite porphyry has a K-Ar biotite age of 89.1 Ma and is part of a 35-km-long sill complex which intruded along the Richardson lineament. Free gold occurs as interlocking alloys of native silver and gold which average 67% Au and 33% Ag. Silver sulfosalts are abundant locally and exhibit very high grades of up to 66,000 g/t Ag. In 1989, a pilot mill produced 88,000 tonnes grading 2.2 g/t Au and 5.0 g/t Ag. The deposit is interpreted as forming during high level emplacement of a Late Cretaceous granite porphyry along the Richardson lineament.

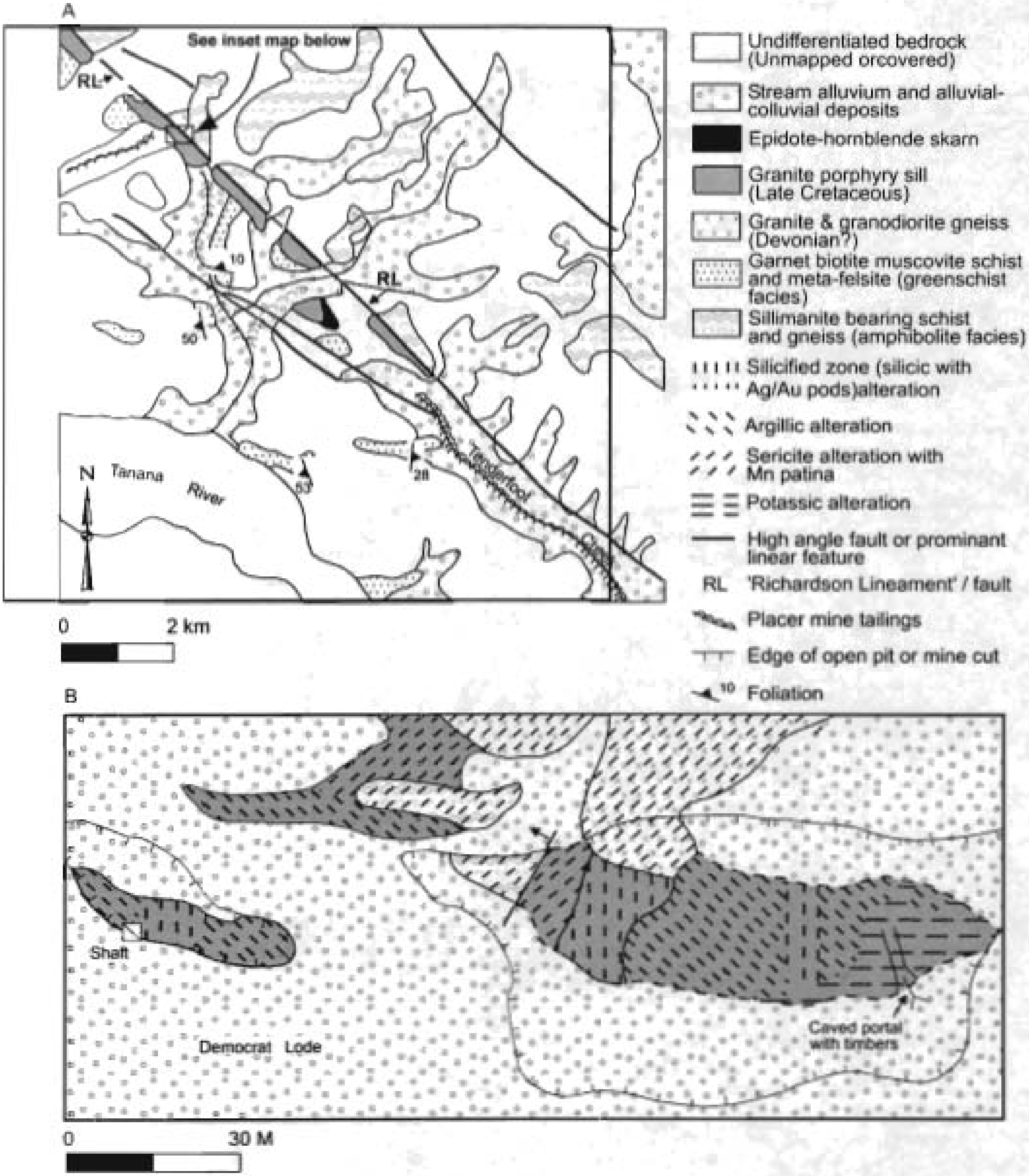


Figure 100. Democrat granitoid-related Au deposit. East-Central Alaska metallogenic belt, East-Central Alaska. A. Schematic geologic map of part of surrounding Richardson district. B. Schematic geologic map of Democrat deposit. Adapted from Bundtzen and Reger (1977), T.K. Bundtzen (written comm., 1989), and Nokleberg and others (1995).

The Pogo deposit (Liese Zone) consists of at least two, subparallel, gently dipping tabular quartz bodies which are hosted by Proterozoic to early Paleozoic paragneiss and minor orthogneiss of the Yukon-Tanana Terrane (Lefebure and Cathro, 1999; Smith, 1999; Smith and others, 1999, 2000). The deposit contains both vein and replacements quartz bodies, and consists mainly of three or more large, tabular, gently-dipping quartz bodies at L1, L2, and L3.. The quartz bodies, none of the bodies crop out at the surface, vary from 1 up to 21 meters thick, and the largest at L1 extends at least 1,300 meters along strike. The L2 quartz body underlies the eastern half of the L1 body. The quartz bodies lie from 1 to 215 m apart, range from 1 to over 20 m thick (average 7 m thick), are roughly parallel, and dip from 25 to 30 degrees. The bodies cut the foliation in the host rocks and are offset by high angle faults.

The quartz bodies contain three percent sulfide minerals. The ore minerals are pyrrhotite, pyrite, loellingite, arsenopyrite, chalcopyrite, bismuthinite, various Ag-Pb-Bi±S minerals, maldonite, native bismuth, galena and tetradymite. Native gold typically ranges from to -25 microns in diameter, and locally up to 100 microns. Gold is often rimmed by native bismuth. The deposit grade ranges up to more than 75 g/t Au over widths of several meters. High Au values are is associated with high values of Bi, Te, W, As, and possibly Sn. Both white and gray quartz occur; the former is associated pyrrhotite and loellingite and is interpreted as early-stage, while the latter is associated with arsenopyrite and pyrite and is interpreted as late stage. As of 1999, the L1 and L2 zone contained an estimated 9.05 millions tonnes grading 17.8 g/t for a total of 147,386,400 gm Au at a 3.42 g/t cutoff. Median grade for Ag in the mineralized zones is 2 g/t (Smith and others, 1999, 2000). One drill hole along steep shears and quartz-veins that average 8.6 g/t Au for over 75 meters. This area may be a possible feeder zone. The quartz is saccharoidal to polygonal. Biotite alteration envelopes up to 0.5 meters wide occur adjacent to veins, and are overprinted by younger, widespread, quartz-sericite stockwork, and sericite-dolomite alteration.

The host rocks consist of highly deformed, amphibolite-grade, mainly metasedimentary which rocks are intruded by diorite, granodiorite pegmatite and aplite dikes and sills and a granodiorite intrusion. The deposit is younger than a granite dike which exhibits a preliminary U-Pb monazite isotopic age of 107 Ma, and is older than a cross-cutting diorite that has a preliminary U-Pb zircon isotopic age of 94 Ma. The Pogo deposit shares a number of characteristics with plutonic-related quartz veins in the Fairbanks district and Yukon, including a similar geological setting, a close association with Cretaceous granitoid rocks, low sulfide content, and similar geochemistry. The Pogo deposit may represent a deeper, higher-temperature part of a plutonic-related Au system (D. McCoy, personal communication, 1999).

Kantishna District

At least seventy polymetallic and Sb-Au vein deposits occur in the Kantishna district in the western part of the southern Yukon-Tanana terrane in the northern Alaska Range (Bundtzen, 1981; McCoy and others (1997). The significant deposits are Sb-Au vein deposits at Caribou, Eagles Den, Slate Creek, and Stampede, and polymetallic vein deposits at Banjo, Quigley Ridge, and Spruce Creek (Table 4) (Nokleberg and others 1997a, b, 1998). The polymetallic vein deposits occur in middle Paleozoic or older, polymetamorphosed and poly-deformed submarine metavolcanic and metasedimentary rocks of the Yukon-Tanana terrane, which also hosts an extensive belt of middle Paleozoic kuroko massive sulfide deposits described previously (Aleinikoff and Nokleberg, 1985; Nokleberg and Aleinikoff, 1985). Most of the polymetallic vein deposits occur as crosscutting quartz-carbonate-sulfide veins and are confined to a 60-km-long, northeast-trending fault zone which extends from Slate Creek to Stampede (Bundtzen, 1981). Mineralization occurred before, during, and after fault-zone movement, as illustrated by both crushed and undeformed ore shoots in the same vein system. ^{39}Ar-^{40}Ar isotopic ages indicate vein formation was from 91 to 88 Ma (McCoy and others, 1997).

Origin of and Tectonic Controls for East-Central Alaska metallogenic (mid-Cretaceous part)

The mid-Cretaceous granitoid rocks of the older part of the Yukon-Tanana igneous belt (Moll-Stalcup, 1994), which host the older part of the East-Central Alaska metallogenic belt, occurs in large batholiths, and small, isolated granitoid plutons (Foster and others, 1987; Miller, 1994). The plutons range in area from smaller than 1 to larger than 300 km^2. The irregular-shaped plutons were intruded after a period of intense metamorphism and deformation in the mid-Cretaceous. The plutonic rocks exhibit K-Ar mineral, Rb-Sr whole rock, and U-Pb zircon ages which range from about 100 to 90 Ma (Wilson and others, 1994; Smith and others, 1999, 2000).

The polymetallic, Sb-Au vein, and granitoid-related Au deposits of the mid-Cretaceous part of the East-Central Alaska metallogenic belt, and similar deposits in the Tombstone metallogenic belt to the east, are generally hosted in or near mid-Cretaceous granitoid plutons (Nokleberg and others, 1995a; McCoy and others, 1997; Smith, 1999, 2000) and are herein interpreted as forming during the waning stages of a major mid-Cretaceous collision of the Wrangellia superterrane with the previously-accreted Yukon-Tanana terrane (Stanley and others, 1990; Dusel Bacon and others, 1993; Pavlis and others, 1993; Nokleberg and others, 2000). The collision and associated metamorphism and deformation is interpreted as forming in three phases: (1) a relatively older period of collision and thrusting, associated with high-temperature and high-pressure metamorphism; (2) a slightly younger period of extension associated with lower greenschist facies metamorphism; and (3) intrusion of anatectic granitoid plutons and relatively younger Au quartz veins. The mid-Cretaceous granitoid rocks and relatively younger quartz veins intrude and crosscut both the relatively older, higher-grade, and relatively younger, lower grade metamorphic fabrics in the region (Dusel Bacon and others, 1993; Pavlis and others, 1993). These relations suggest that the granitoid-related Au deposits of the older part of the East-Central Alaska metallogenic belt, and the Tombstone belt to the east, formed in the waning stages of this complex deformational event (Nokleberg, 1997e, 2000). Alternatively, McCoy and others (1997) interpret the mid-Cretaceous granitoid-related Au deposits as forming in a continental-margin arc related to subduction.

Misused Name: Tintina Gold Belt

In recent years, the name *Tintina Gold Belt* (as described and interpreted in a series of papers by by Goldfarb and others (2000), Flanigan and others (2000), Hart and others (2000), Mortensen and others (2000), Newberry (2000), O'Dea and others (2000), and Smith (2000) in the volume edited by Tucker and Smith (2000) has been used for granitoid-related Au deposits and occurrences in the East-Central Alaska metallogenic belt of Nokleberg and others (1995a, 1996, 1997a) and in the correlative Tombstone metallogenic belt (described below) of Nokleberg and others (1995a, 1996, 1997a) which occurs to the east in the central Yukon Territory. Because the *Tintina Gold Belt* actually includes a number of belts of differing ages and tectonic origins, the term is not used in this study.

Bundtzen and others (2000) have introduced the term *Tintia Gold Province* to denote Cretaceous and early Tertiary intrusive-hosted gold deposits in East-Central Alaska and the Yukon Territory. This province includes the following metallogenic belts which are described and interpreted in this study: East-Central Alaska (older part; ECA), Kuskokwim Mountains (KM), Tombstone (TS), and metallogenic belts (table 3). These distinct belts are separately described and interpreted herein because they: (1) formed over a relatively long time span; (2) are hosted in a diverse array of host rocks; and (3) formed at different times in strongly contrasting tectonic environments, either collisional or subduction-related environments.

Yukon-Tanana Upland Metallogenic Belt of Au-quartz vein Deposits (Belt WT) East-Central Alaska

The Yukon-Tanana Upland metallogenic belt of Au-quartz vein deposits occurs in east-central Alaska (fig. 80; tables 3, 4) (Nokleberg and others, 1997b, 1998). The metallogenic belt is hosted in the Devonian and Mississippian metasedimentary and lesser metavolcanic rocks of the southern Yukon-Tanana displaced-continental margin terrane, and in the Stikinia(?) island-arc terrane (Nokleberg and others, 1994c, 1997c). The known deposits occur in parts of these terranes which display greenschist facies and associated major metamorphism which ended in the mid-Cretaceous. The significant deposit is at Purdy.

Purdy Au Quartz Vein Deposit

The small Purdy Au quartz vein deposit (H.L. Foster, written commun., 1984; W.D. Menzie, written commun., 1985) contains a large quartz-calcite fissure vein and smaller veinlets that contain spectacular lace gold. The deposit consists mainly of this one large vein which extends for about 2 m and is terminated by a fault. The large vein and smaller veinlets intrude mid-Paleozoic or older metasedimentary schist of the Stikinia(?) terrane. The large vein was mined out by 1960. Small veins and veinlets were mined in 1969 and early 1970's.

Origin of and Tectonic Controls for Yukon-Tanana Upland Metallogenic Belt

The Yukon-Tanana Upland metallogenic belt is associated with a major, low-grade regional metamorphism and intense deformation of the Stikinia(?) and structurally subjacent Yukon-Tanana terranes in east-central Alaska (Dusel-Bacon and others, 1993; Pavlis and others, 1993; Nokleberg and others, 1994c, 1997c). As with the East-Central Alaska metallogenic belt describe and interpreted above, the Yukon-Tanana belt is interpreted as forming during the third stage of a mid- to Late Cretaceous complex deformational event that ended with intrusion of anatectic granitoid plutons and relatively younger Au quartz veins. The quartz vein crosscut a subhorizontal, schistose fabric that exhibits the younger stage of greenschist facies metamorphism. This complex event occurred during final accretion of the Wrangellia superterrane to the active margin of the North American continental margin (Plafker and others, 1989; Stanley and others, 1990; Pavlis and others, 1993; Nokleberg and others, 2000).

Wrangell Mountains Metallogenic Belt of Cu-Ag Quartz Vein and Kennecott Cu Deposits (Belt WR) Eastern-South Alaska

The Wrangell Mountains metallogenic belt of Cu-Ag quartz vein and Kennecott Cu deposits (fig. 80; tables 3, 4) occurs in the eastern Alaska Range, Nutzotin Mountains, and Wrangell Mountains in eastern-southern Alaska. The metallogenic belt is hosted in the part of the Wrangellia island-arc terrane underlain by Late Cretaceous and older stratified rocks, particularly the Late Triassic Nikolai Greenstone, and older late Paleozoic sedimentary and volcanic rocks (Nokleberg and others, 1994c, 1997c; MacKevett and others, 1997). The extensive suite of minor Cu-Ag quartz vein deposits occurs mainly along the northern margin of the Wrangellia sequence of Wrangellia superterrane. The major Cu-Ag quartz vein deposits are at Kathleen-Margaret, Nugget

Creek, and Nikolai; the major Kennecott Cu deposits are in the Kennecott district at Kennecott and Westover; and a basaltic Cu deposit is at Erickson (table 4) (Nokleberg and others 1997a, b, 1998).

Kathleen-Margaret Cu-Ag Quartz Vein Deposit

The Kathleen-Margaret Cu-Ag quartz vein deposit (MacKevett, 1965) consists of quartz veins which are up to 140 m long and 3 m wide and contain disseminated to massive chalcopyrite, bornite, and malachite. The gangue is mainly quartz and minor calcite. The veins cut the Late Triassic Nikolai Greenstone, strike east-west, and are intruded along shear zones. Grab samples from the deposit contain up to 13% Cu, 3.2 g/t Au, 300 g/t Ag. About 1.8 tonnes of ore was produced in the 1950's. At the nearby Nugget Creek deposit slablike copper nuggets of several tonnes weight occur.

Kennecott Cu Deposits

The large Kennecott Cu deposits (fig. 101) (Bateman and McLaughlin, 1920; MacKevett, 1976; Armstrong and MacKevett, 1982; MacKevett and others, 1997) consist mainly of chalcocite and covellite, and also have minor enargite, bornite, chalcopyrite, luzonite, and pyrite. Tennantite, sphalerite, and galena are extremely rare. Local surface oxidation occurs with alteration of sulfides to malachite and azurite. Sulfide minerals occur mainly as large, irregular, massive, wedge-shaped bodies, mainly in dolomitic parts of the Late Triassic Chitistone or Nizina Limestone. The bodies are generally less than 100 m above a disconformity over the subjacent Middle and(or) Late Triassic Nikolai Greenstone. The largest ore body (Jumbo) consists of an almost pure chalcocite and covellite mass, which is about 110 m high, up to 18.5 m wide, and which extends 460 m along plunge. The Kennecott Cu mines were among the largest group of mines in Alaska from 1911 until 1938, when the ore was mostly exhausted. The district contains more than 96 km of underground workings. The major mines in district are the Jumbo, Bonanza, Erie, Mother Lode, and Green Butte. The district produced about 544 million kg Cu and 280 million g Ag from 4.3 million tonnes of ore.

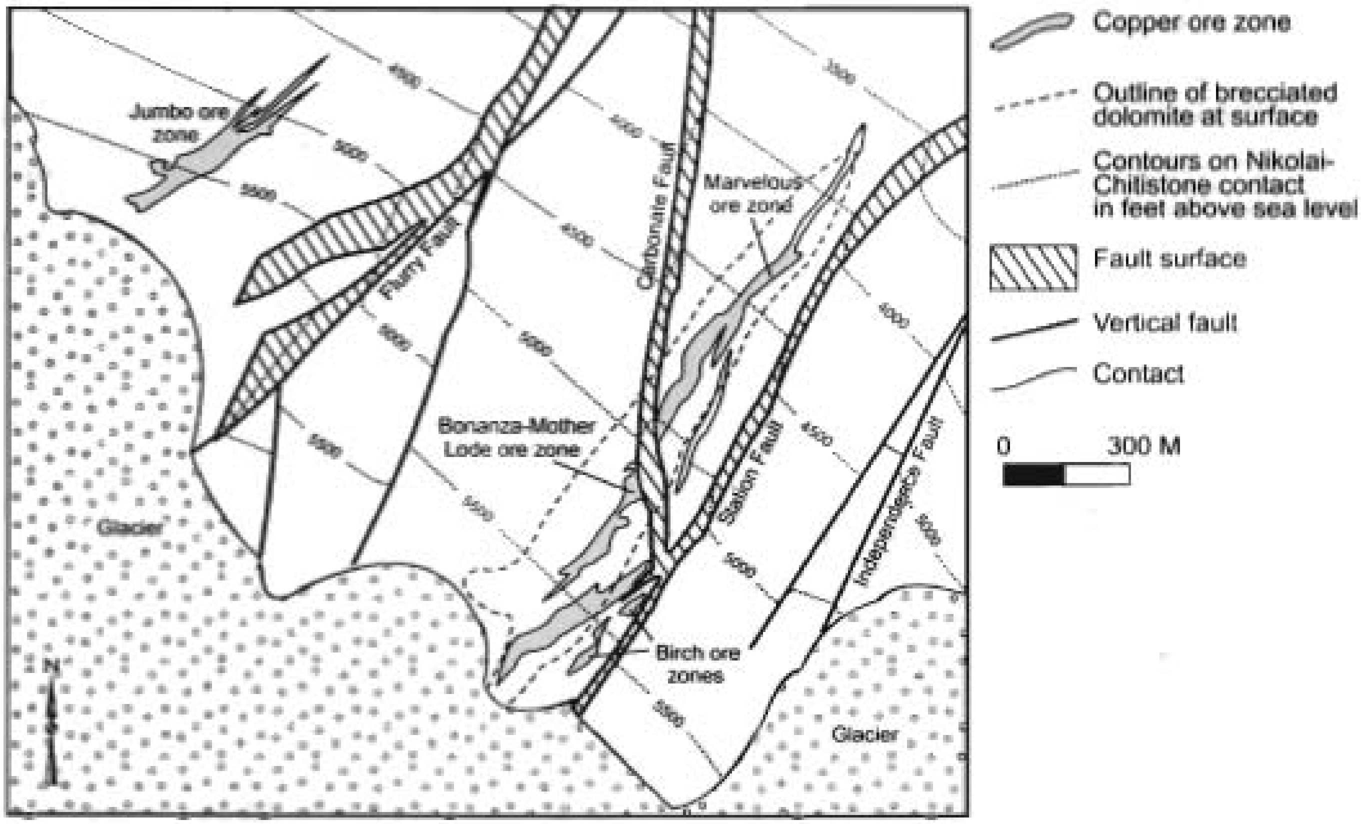


Figure 101A. Kennecott district of Kennecott Cu deposits, Wrangell Mountains metallogenic belt, Southern Alaska. Schematic geologic map showing the Bonanza-Mother Lode and Jumbo ore zones, major faults, and contours on contact between the Nikolai Greenstone and the Chitistone Limestone. Modified from MacKevett and others (1997).

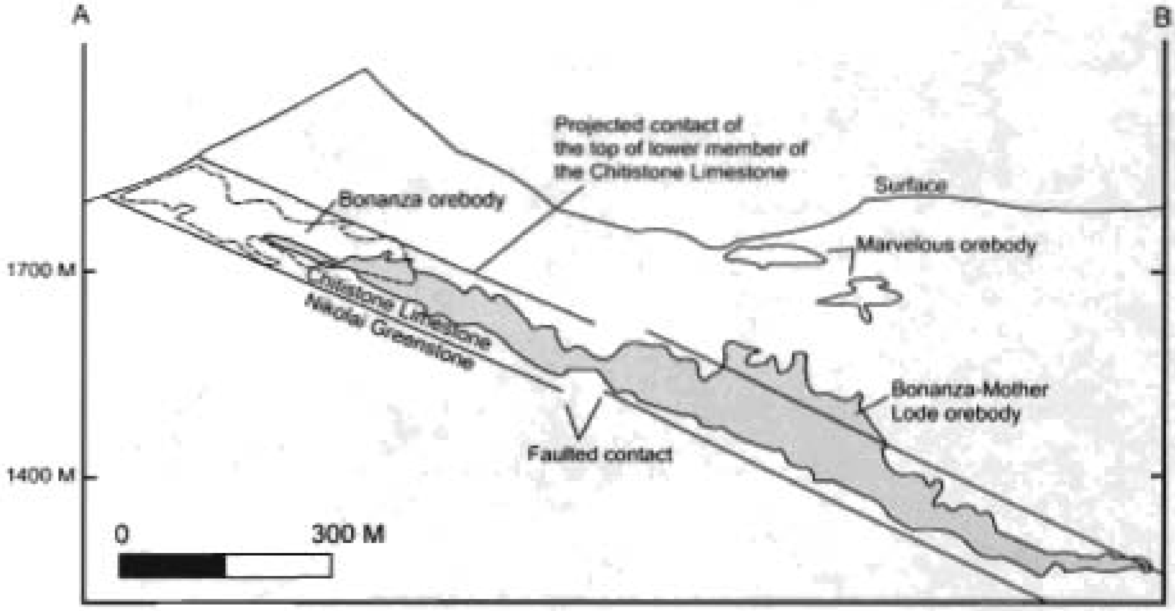


Figure 101B. Kennecott district of Kennecott Cu deposits, Wrangell Mountains metallogenic belt, Southern Alaska. Schematic cross section through Bonanza-Mother Lode ore zone. Shaded area represents the extent of Cu-rich veins and local massive sulfide bodies. Plane of section is N 35 E. Adapted from MacKevett and others (1977).

Origin of and Tectonic Controls for Wrangell Mountains Metallogenic Belt

Throughout the Nikolai Greenstone and older rocks in the Wrangellia terrane, quartz veins, which locally contain abundant Cu sulfides, grade into clots of quartz, chlorite, actinolite, and epidote (Nokleberg and others, 1985, 1994d). This relation suggests that the Cu-Ag quartz vein deposits formed during a period of lower greenschist facies regional metamorphism. The age of metamorphism is interpreted as mid-Cretaceous because Early Cretaceous and older units of the Wrangellia sequence were affected. The formation of the Cu-Ag quartz vein deposits and associated regional metamorphism are herein interpreted as occurring during mid-Cretaceous accretion and deformation of the Wrangellia superterrane to the active margin North American Cordillera (Nokleberg and others, 1985, 2000; Plafker and others, 1989).

The Kennecott Cu deposits are interpreted by Armstrong and MacKevett (1982) and MacKevett and others (1997) as forming by derivation of Cu from the Nikolai Greenstone, followed by deposition from oxygenated groundwater in the lower part of the overlying Chitistone Limestone along dolomitic sabkha interfaces, and as open-space fillings in fossil karsts. Armstrong and MacKevett (1982) interpreted the age of deposition as Late Triassic, but did not rule out possible later remobilization. Subsequently, MacKevett and others (1997) interpreted the hydrothermal event associated with formation of the Kennecott Cu and Cu-Ag quartz vein deposits in the Wrangell Mountains metallogenic belt as forming during nearby, mid-Cretaceous magmatism. In contrast, Nokleberg and others (1985, 1994d) and Goldfarb (1997) suggested that lower greenschist facies regional metamorphism of the Nikolai Greenstone, associated with mid-Cretaceous accretion of the Wrangellia superterrane, may have been the source of hydrothermal fluids which either deposited or further concentrated the Cu-sulfides in the Kennecott Cu deposits in the Kennicott district and in associated Cu-Ag quartz vein deposits in southern Alaska.

Late Cretaceous and Early Tertiary Metallogenic Belts (84 to 52 Ma) (Figures 102, 103)

Overview

The major Late Cretaceous and early Tertiary metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 102 and 103. The major belts are as follows. (1) In the Russian Southeast, continuing on from the early Late Cretaceous were the Kema (KM), Lower Amur (LA), Luzhkinsky (LZ), Sergeevka (SG), and Taukha (TK) belts, which contain a large array of granitic-magmatism-related deposits. The belts are hosted in or near the East Sikhote-Aline volcanic-plutonic belt and are interpreted as forming during subduction-related granitic plutonism which formed the East Sikhote-Aline continental margin arc. (2) In the Russian Northeast, continuing from the early Late Cretaceous are several zones of the Eastern Asia belt, along with formation of several new zones. The zones, which are all hosted in or near the

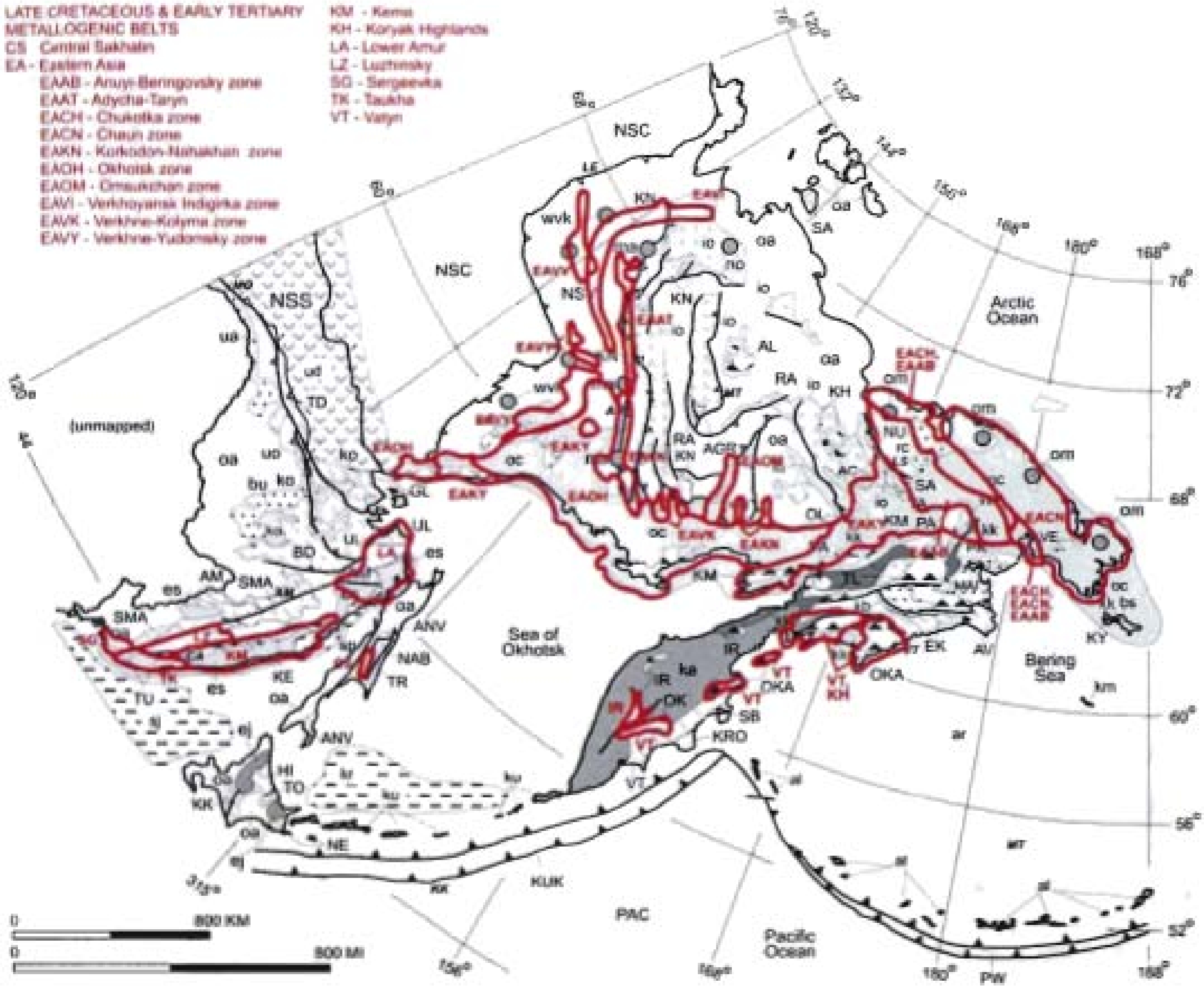


Figure 102. Generalized map of major Late Cretaceous and early Tertiary metallogenic belts, overlap assemblages, and tectonically-linked subduction-zone or accretionary-wedge terranes for Russian Far East, northern Japan, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 59 for explanation.

Okhotsk-Chukotka volcanic-plutonic belt, include the Adycha-Taryn (AT), Chaun (CN), Chukotka (CH), Korkodon-Nayakhan (KN), Okhotsk (OH), Omsukchan (OM), and Verkhne-Kolyma (VK), Verkhne-Yudomsky (VY), and Verkhoyansk-Indigirka (VI) zones. Together, these zones and belts of grantic-magmatism-related deposits are interpreted as forming during subduction-related granitic plutonism which formed the Okhotsk-Chukotka continental-margin arc. (3) Also in the Russian Northeast, continuing on from the early Late Cretaceous were the Koryak Highlands (KH) belt which contains zoned mafic-ultramafic PGE and Cu massive sulfide deposits, and the Vatyn (VT) belt which contains volcanogenic Mn and Fe deposits. Both belts are hosted in the Olyutorka-Kamchatka island-arc terrane and are interpreted as forming in different parts of the Olyutorka island arc. (4) Also in the Russian Northeast was the Iruneiskiy (IR) metallogenic belt of porphyry Cu deposits that also formed in the Olyutorka island arc. (5) In Northwestern Alaska, the Northwestern Koyukuk Basin (NWK), Seward Peninsula (SP), and West-Central Alaska (WCA) belts, which are hosted in the Alaska extension of the Okhotsk-Chukotka volcanic-plutonic belt, are also interpreted as forming during subduction-related granitic plutonism which formed the Okhotsk-Chukotka continental-margin arc. (6) In Southern Alaska, the East-Central Alaska (younger part; ECA), Southern Alaska (SA), and Kuskokwim Mountains (KM) belts, which are hosted in the Kuskokwim Mountains sedimentary and volcanic belt or the Alaska Range-Talkeetna Mountains igneous belt, are interpreted as forming during subduction-related granitic plutonism which formed the Kluane continental-margin arc. (7) In Southern and Southeastern Alaska, several belts are interpreted as forming during oblique subduction of the Kula-Farallon oceanic ridge under margin of Southern and Southeastern Alaska. In alphabetical order, these belts are the Baranof (BN), Chugach Mountains (CM),

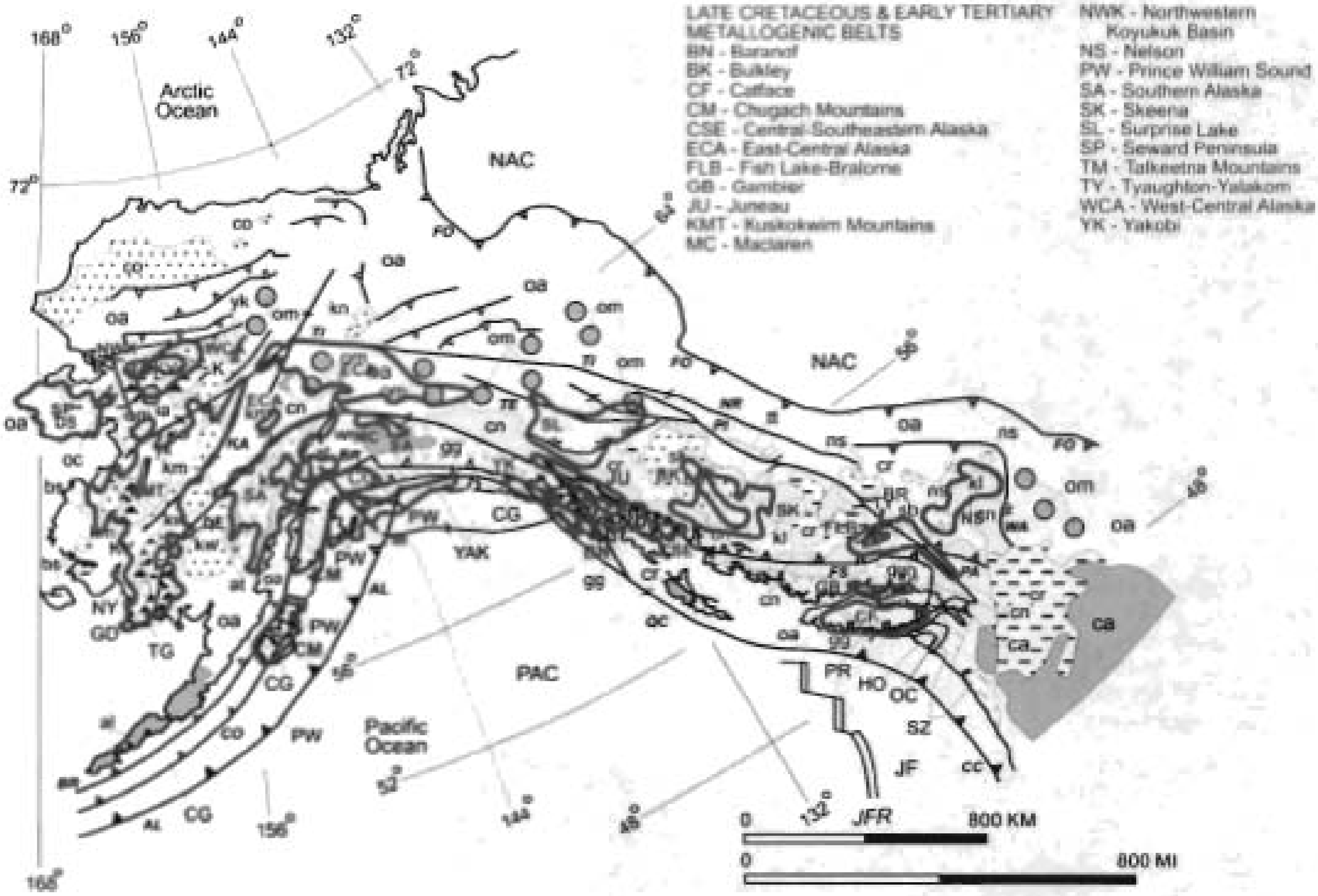


Figure 103. Generalized map of major Late Cretaceous and early Tertiary metallogenic belts, overlap assemblages, and tectonically-linked subduction-zone or accretionary-wedge terranes for Alaska, Canadian Cordillera, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 59 for explanation.

Juneau (JU), and Maclaren (MC), and Talkeetna Mountains (TM) belts, which contain Au quartz vein deposits, and the Yakobi (YK) belt which contains gabbroic Ni-Cu deposits. (8) Also in the same region, the Prince William Sound (PW) belt, which contains massive sulfide deposits related to marine mafic volcanism, is interpreted as forming during sea-floor spreading along the Kula-Farallon oceanic ridge before thrusting of the ridge beneath the margin of Southern Alaska. And (9) in Southeastern Alaska and the Canadian Cordillera are a large array of metallogenic belts which contain granitic-magmatism-related deposits which are hosted in or near the Coast-North Cascade plutonic belt. In alphabetical order, these belts are the Catface (CF), Central-Southeastern Alaska (CSE), Bulkley (BK), Fish Lake-Bralorne (FLB), Gambier (GA), Nelson (NS), Skeena (SK), Surprise Lake (SL), and Tyaughton-Yalakom (TY) belts. The belts are interpreted as forming during subduction-related granitic plutonism which formed the Coast continental margin arc. In the below descriptions of metallogenic belts, a few of the noteable or signficant lode deposits (table 4) are described for each belt.

Metallogenic-Tectonic Model for Late Cretaceous and Early Tertiary (84 to 52 Ma; Figure 104)

During the Late Cretaceous and early Tertiary (Campanian though Early Eocene - 84 to 52 Ma), the major metallogenic-tectonic events were (fig. 104; table 3): (1) the continuation of a series of continental-margin arcs, associated metallogenic belts, and companion subduction-zone assemblages around the Circum-North Pacific; (2) completion of opening of the Amerasia, Canada, and Eurasia Basins; (3) completion of accretion of the Wrangellia superterrane; (4) a change to dextral transpression in the eastern part of the Circum-North Pacific between the Kula Ocean plate and the North American continental margin; (5) oblique subduction of the Kula-Farallon oceanic ridge under the margins of Southern and Southeastern Alaska, and formation of associated metallogenic belts, and (6) northward migration of previously accreted terranes along the margin of the North American Cordillera.

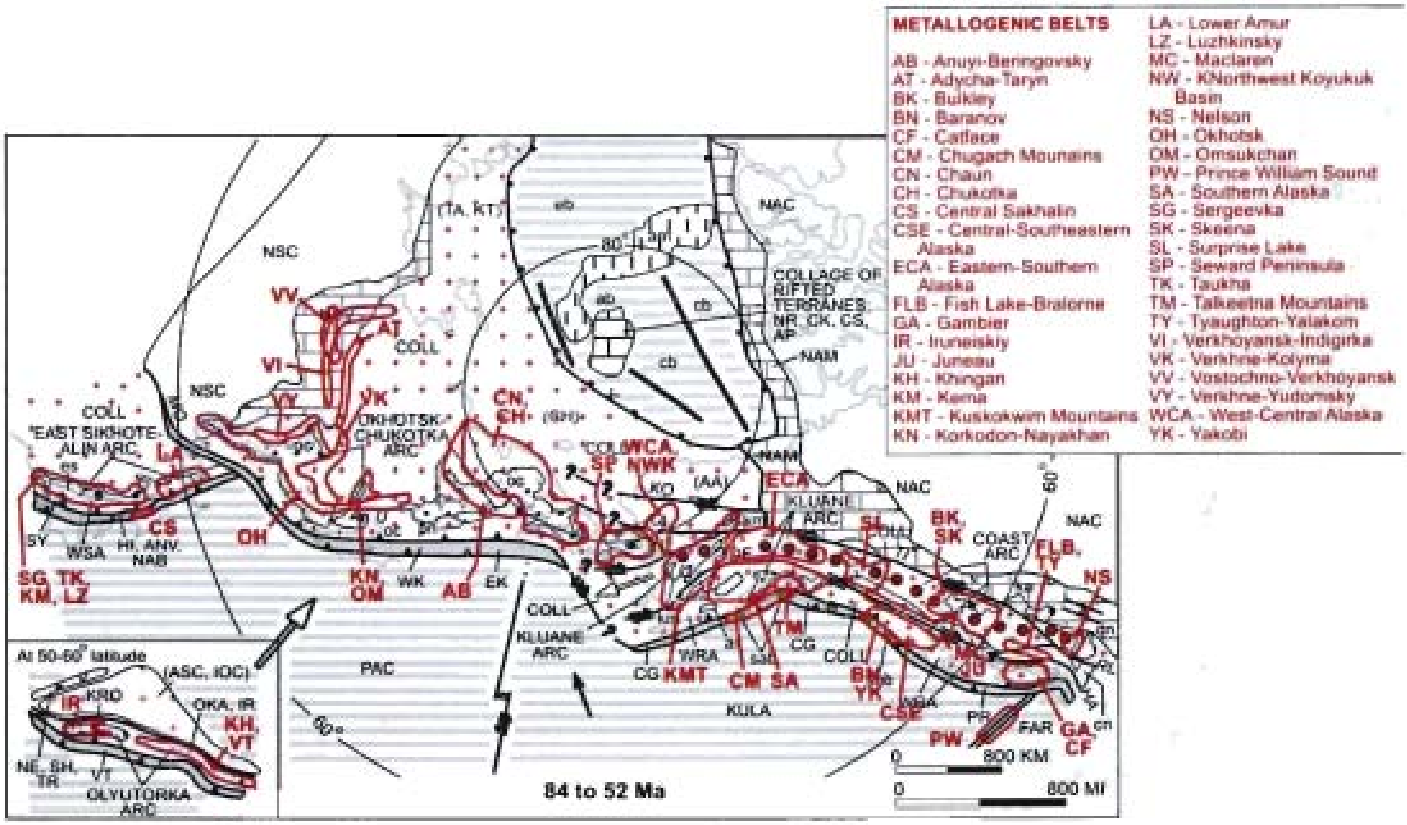


Figure 104. Late Cretaceous and early Tertiary (Campanian through early Eocene - 84 to 52 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

Specific Events for Late Cretaceous and Early Tertiary

(1) Far to the south, at about 50° to 60° paleolatitude, the extensive Olyutorka island arc continued to form. Parts of the arc are preserved in the Nemuro (NE), Kronotskiy (KRO), and Olyutorka-Kamchatka (OKA), and Iruneisky (IR) island-arc terranes. Continuing to form in the Olyutorka arc were the Koryak Highlands metallogenic belt, which contains zoned mafic-ultramafic PGE and Cu massive sulfide deposits, the Vatyn (VT) metallogenic belt, which contains volcanogenic Mn and Fe deposits. Also forming in Olyutorka arc was the Iruneiskiy (IR) metallogenic belt of porphyry Mo deposits. Associated with the arc was subduction of part of the adjacent oceanic plate to form the Vetlovskiy (VT) terrane. This arc and companion subduction zone migrated northward toward the Okhotsk-Chukotka continental-margin arc.

(2) Farther west, the East Sikhote-Alin continental-margin arc (es) and related deposits continued activity. Forming as part of the arc was the West Sakhalin (WSA) turbidite-basin terrane. Continuing to form in the East-Sikhote arc were the Kema, Lower Amur, Luzhkinsky, Segeevka, and Taukha metallogenic belts. Associated with the arc was oblique subduction of part of the Pacific Ocean plate (PAC) to form the Hikada (HI), Aniva (ANV), and Nabilsky (NAB) terranes.

(3) The Okhotsk-Chukotka continental-margin arc continued activity. Parts of the arc are preserved in the Okhotsk-Chukotka volcanic-plutonic belt (oc) and related Penzhina (forearc) sedimentary basin (pn). Associated with the arc was subduction of part of the Pacific Ocean plate (PAC) to form the West Kamchatka (WK) and Ekonay (EK) terranes. Local plutons in the Okhotsk-Chukotka volcanic-plutonic belt intruded under extension, probably as the result of rollback of the subduction slab during the Late Cretaceous (Amato and Wright, 1997). Also in the same region, the Okhotsk-Chukotka and East Sikhote-Alin continental-margin arcs were offset in a sinistral sense along the Mongol-Okhotsk fault system (*MO*). Continuing in the Okhotsk-Chukotka arc was the Eastern Asia metallogenic belt of granitic-magmatism-related deposits which contained a complex array of zones. Continuing or new zones were the Anuyi-Beringovsky (AB), Chaun (CN), Chukotka (CH), Korkodon-Nayakhan (KN), Okhotsk (OH), Omsukchan (OM), Verkhoyansk-Indigirka (VY), Verkhne-Kolyma (VK), Verkhne-Yudomsky (VY) zones. Also continuing to form in the Okhotsk-Chukotka volcanic-plutonic belt and peripherally related to the Eastern Asia metallogenic belt in the Russian Far East were the Adycha-Taryn (AT), and Vostochno-Verkhoyansk (VV) metallogenic belts. Forming in the Okhotsk-Chukotka volcanic-plutonic belt in western Alaska, and peripherally related to the Eastern Asia metallogenic belt, were the Northwestern Koyukuk Basin metallogenic belt (NWK) which contains felsic plutonic U deposits, the Seward Peninsula

metallogenic belt (SP) which contains Sn skarn and related deposits, and the West-Central Alaska metallogenic belt (WCA) which contains porphyry Cu deposits.

(4) Between the areas of the Russian Far East and Alaska, continental-margin arcs and companion subduction zones in each region were connected by a major transform fault. In the area of Western Alaska, tectonic escape (crustal extrusion) of terranes occurred along major dextral-slip faults, including the Denali (*DE*), Iditarod-Nixon Fork (*NF*), Kaltag (*KA*), and companion faults (Scholl and others, 1992, 1994). In association with movement on these major dextral-slip faults, dextral-wrench sedimentary basins formed, including the Kuskokwim basin (kw; Plafker and Berg, 1994; Bundtzen and Miller, 1997). The crustal extension and wrench faulting were associated with a major period of extension in Interior Alaska according to the interpretation of Miller and Hudson (1991). The middle and Late Cretaceous extension is interpreted as forming warm, thin continental crust which was favorable for crustal extrusion and dextral-wrench faulting (Scholl and others, 1992, 1994).

(5) By the early Tertiary, in the region of the Amerasia (ab), Canada (cb) and Eurasia (eb) Basins, sea-floor spreading and associated rifting was completed (Grantz and others, 1990, 1991, 1998), and sedimentation continued in the large Amerasia (ab), Canada (cb) and Eurasia (eb) Basins. The formation of the Alpha and Mendeleev Ridges (am), which are interpreted as large piles of hot-spot basalt and associated deposits, was completed (Grantz and others, 1990, 1991, 1998).

(6) In the Paleocene (about 56 to 60 Ma), in the area of the Bering Sea, major counter-clockwise rotation of the Pacific Ocean plate (PAC) occurred (at about 30° to 50° paleolatitude; Lonsdale, 1988). The rotation resulted from compression between Eurasia and North America (Plafker and Berg, 1994). At the same time, the extension of dextral-slip faults from the area of Western Alaska into the Bering Sea resulted in accretion and capture of a fragment of the Kula Ocean plate (KULA; Scholl and others, 1992, 1994).

(7) In response to oblique subduction of the Kula Ocean plate (KULA), the major Kluane continental-margin arc formed (Plafker, 1994; Nokleberg and others, 2000). Parts of the arc are preserved as the Kuskokwim Mountains volcanic-plutonic belt (km) and Alaska Range-Talkeetna Mountains igneous belt (at). The coeval Coast arc formed along the margin of the North American Cordillera. Parts of this arc are preserved in the Coast-North Cascade plutonic belt (cn) and the Kamloops magmatic belt (kl). These continental-margin arcs overlapped the previously accreted Wrangellia superterrane and adjacent inboard terranes and extended for a distance of more than 3,200 km along the active continental margin of the North American Cordillera. Associated with the Kluane continental-margin arc was the subduction of the laterally extensive Chugach terrane (CG) and the Pacific Rim terrane (PAR).

Forming in the Kluane arc in Southern Alaska were the East-Central Alaska (younger part; ECA), Southern Alaska (SA), and Kuskokwim Mountains (KMT) belts, which are hosted in the Kuskokwim Mountains sedimentary and volcanic belt or the Alaska Range-Talkeetna Mountains igneous belt. Forming in the Coast arc in Southeastern Alaska and the Canadian Cordillera were a large array of metallogenic belts which contain granitic-magmatism-related deposits which are hosted in or near the Coast-North Cascade plutonic belt. The belts include the Catface (CF), Central-Southeastern Alaska (CSE), Bulkley (BK), Fish Lake-Bralorne (FLB), Gambier (GA), Nelson (NS), Skeena (SK), and Surprise Lake (SL) belts. All these belts are interpreted as forming during subduction-related granitic plutonism.

(8) Along the active margin of the North American Cordillera, the rapid northward migration of the Kula Ocean plate (KULA), which started to form at about 85 Ma (Englebretson and others, 1985), resulted in formation of major dextral-slip faults, including the Denali (*DE*), Tintina (*TI*), Ross Lake (*RL*), and companion faults (Plafker and Berg, 1994). Oblique subduction of the Kula-Farallon oceanic ridge occurred at about 50 to 60 Ma along the margin of Southern Alaska (Bradley and others, 1993). The subduction of the oceanic ridge, locally partly preserved in ophiolites in the Prince William Terrane (Lytwyn and others, 1997; Kusky and Young, 2000), in the early Tertiary is interpreted as causing: (1) a regional metamorphic welt and formation of anatectic granites (Plafker and others, 1989b; 1994); (2) rapid changes in components strike-slip movements along the subduction zone bordering the early Tertiary continental margin (Bradley and others, 1993); and (3) formation of belts of early Tertiary granitic and mafic-ultramafic plutonic rocks of the Sanak-Baranof plutonic belt (sab; Hudson, 1979; Moll-Stalcup and others, 1994) in Southern and Southeastern Alaska which are interpreted as forming in a near-trench environment during subduction of the Kula-Farallon oceanic ridge (Bradley and others, 1993; Kusky and others, 1997).

In Southern and Southeastern Alaska, several metallogenic belts are interpreted as forming during oblique subduction of the Kula-Farallon oceanic ridge under margin of Southern and Southeastern Alaska. These metallogenic belts include the Baranof (BN), Chugach Mountains (CM), Juneau (JU), Maclaren (MC), and Talkeetna Mountains (TM) metallogenic belts, which contain Au quartz vein deposits, and the Yakobi (YK) metallogenic belt which contains gabbroic Ni-Cu deposits. (9) Also in the same region, the Prince William Sound (PW) metallogenic belt, which contains massive sulfide deposits related to marine mafic volcanic rocks, is interpreted as forming during sea-floor spreading along the Kula-Farallon oceanic ridge before subduction of the ridge beneath the margin of Southern Alaska.

(9) Regional extension occurred in the southern Canadian Cordillera and northeastern Washington. The extension is interpreted either as: (1) the result of a change from transpression to transtension at about 55 Ma (Parrish and others, 1988); (2) caused by a change of obliquity of convergence of the oceanic plate, or (3) alternatively, but likely, collapse of overthickened thrust units.

(10) The eastward thrusting of the North American Craton Margin (NAM) over the North American Craton (NAC) ended at about 60 Ma in the Canadian Cordillera.

Metallogenic Belt Formed in Late Mesozoic and Early Cenozoic Olyutorka Island Arc, Russian Northeast

Iruneiskiy Metallogenic Belt of Porphyry Cu Deposits (Map Unit IR) Southern Kamchatka Peninsula

The small Iruneiskiy metallogenic belt (IR) of porphyry Mo deposits (Vlasov, 1977) occurs in the southern part of the Kamchatka Peninsula in the Iruneiskiy island-arc terrane (fig. 102; tables 3, 4) (Nokleberg and others, 1994c, 1997b, c, 1998). The one economic porphyry Cu deposit in the belt at Kirganik (Vlasov, 1977; A.V. Ignatyev, written commun., 1980) consists of steeply-dipping, metasomatically altered zones of biotite and K-feldspar which occur in Late Cretaceous siliceous volcanic rocks. The altered zones contain veinlets and disseminations of pyrite, chalcopyrite, bornite, chalcocite, hematite, gold; the zone contain up to 0.8 g/t Au. The Late Cretaceous calc-alkalic volcanic rocks hosting the zones grade upward into Maastrichtian shoshonite which is intruded by dunite-clinopyroxenite-gabbro monzonite. The porphyry Cu deposits are interpreted as being related to the monzonite intrusions. The deposit has a K-Ar isotopic age of 75 to 65 Ma which is similar to which for the intrusion. The deposit is of medium size, and average grades are 0.1-1% Cu and 0.2 to 0.4 g/t Au in disseminated and veinlet ore, and up to 0.8 g/t Au in oxidized ore. The Iruneiskiy terrane is interpreted as part the Olyutorka-Kamchatka island-arc terrane which was accreted in the early Tertiary onto the North Asian continental margin (Nokleberg and others, 2000).

Metallogenic Belts Formed in Late Mesozoic and Early Cenozoic Part of Okhotsk-Chukotka Continental-Margin Arc, Russian Northeast and Western Alaska

Eastern Asia-Arctic Metallogenic Belt: Verkhne-Yudomsky (Yuzhno-Verkhoyansk) Zone of Sn and Ag Polymetallic Vein (Southern Bolivian type) Deposits (Belt VY) West-Central Part of Russian Northeast

The Verkhne-Yudomsky (Yuzhno-Verkhoyansk) metallogenic zone of Sn and Ag polymetallic vein (Southern Bolivian type) deposits (fig. 102; tables 3, 4) extends north-south for 400 km with a maximum width of 100 km. The belt occurs in the west-central part of the Russian Northeast, and is hosted by either the clastic sedimentary rocks of the North Asian Craton Margin (Verkhoyansk fold belt), the Okhotsk cratonal terrane, or the volcanic rocks of the Okhotsk-Chukotka volcanic-plutonic belt. The significant deposits in the zone are (table 4) (Nokleberg and others 1997a, b, 1998): Sn polymetallic vein deposits at Balaakkalakh, Diring-Yuryak, Khaardak, and Khoron; and various types of polymetallic vein deposits at Dzhaton, Kutinskoe, Nivandzha, and Zarnitsa.

The metallogenic zone is associated with major hypabyssal Early and Late Cretaceous felsic intrusions which occur in the landward part of the Cretaceous to early Tertiary Okhotsk-Chukotka volcanic-plutonic belt (unit ok, fig. 102) (Nokleberg and others, 1994c, 1997c). The deposits generally consist of quartz-chlorite-sulfide veins with cassiterite, hematite, sericite, fluorite, arsenopyrite, pyrite, chalcopyrite, galena, sphalerite, stannite, tetrahedrite, and gold which occur in steeply-dipping shear zones to 20 m thick and in elongate (stringer) masses in dacite, rhyolite, and granite porphyry. Wallrocks are generally altered to chlorite and sericite. Also associated with the Sn and Ag polymetallic vein deposits are small Sn (Bi, W) greisen deposits, generally small and uneconomic, which are related to leucocratic Late Cretaceous granitoid plutons. The major Sn and Ag polymetallic vein deposit is at Zarnitsa-Kutinskoe. The Verkhne-Yudomsky metallogenic zone is interpreted as forming in the rear of the perivolcanic zone of the Cretaceous to early Tertiary Okhotsk-Chukotka volcanic-plutonic belt (fig. 102).

Zarnitsa-Kutinskoe Pb-Zn-Ag Polymetallic Vein Deposit

The Zarnitsa-Kutinskoe Pb-Zn-Ag polymetallic vein deposit (V.I. Korostolev, written commun., 1963) consists of two polymetallic quartz-sulfide veins which contain galena, sphalerite, pyrite, chalcopyrite, and silver minerals. The larger vein is up to 500 m long and 6 m thick. The veins cut Late Cretaceous granite-porphyry and rhyolite and have a fringe of disseminated sulfides up to 20 m thick. The Kutinskoe deposit consists of one vein about 3 m thick and 400 m long which is composed of quartz, pyrite, galena, sphalerite, and pyrrhotite. The Kutinskoe vein cuts contact-metamorphosed Late Permian sandstone and shale. The deposit is medium size with average grades of 4.86-7.75% Pb, 4.1-5% Zn, and 44-3,268 g/t Ag.

Eastern Asia-Arctic Metallogenic Belt: Verkhoyansk-Indigirka (Dulgalak) Zone of Clastic Sediment-Hosted Hg and Sb-Au Vein Deposits (Belt EAVI) Western Part of Russian Northeast

The Verkhoyansk-Indigirka (Dulgalak) metallogenic zone of clastic sediment-hosted Hg, and Sb-Au vein deposits (fig. 102; tables 3, 4) occurs in a narrow arc in the western part of the Russian Northeast. The zone is more than 1,200 km long and up to 50 km wide. The zone mostly occurs within the North Asian Craton Margin (Verkhoyansk fold belt, unit NSV), to a lesser amount in the Kular-Nera accretionary-wedge terrane of the Kolyma-Omolon superterrane. The significant deposits in the belt are (table 4) (Nokleberg and others 1997a, b, 1998): clastic sediment-hosted Hg deposits at Erel, Iserdek, Kholbolok, Seikimyan, Singyami, Zagadka, and Zvezdochka; and Sb, Sb-As, Sb-Au, and Sb-Au-Hg vein deposits at Baidakh, Betyugen, Imnekan, Kyuchyuss, Selerikan, Senduchen, and Stibnitovoe. The one is locally extensively overlain by unconsolidated Cenozoic sedimentary deposits of the Primorskaya lowland. The Verkhoyansk-Indigirka metallogenic belt may be a portion of a greater Verkhoyansk-Chukchi mercury belt. The major clastic sediment-hosted Hg deposits are at Zagadka and Zvezdochka, and the major Sb-Au vein deposit is at Kyuchyuss (fig. 105). The clastic sediment-hosted Hg, and Sb-Au vein deposits are hosted mainly in clastic sandstone and shale and generally occur along the hinges of anticlines which are crossed by longitudinal and diagonal faults. The deposits generally are along deep faults which strike subparallel to the strike of the major folds. The Sb-Au vein deposits generally occur where the Verkhoyansk-Indigirka metallogenic zone overlies Au quartz vein deposits of accretionary metallogenic belts, such as the Kular metallogenic belt (fig. 11). This metallogenic zone contains abundant pre-mineralization subalkalic basalt dikes of Late Cretaceous and Paleogene age with K-Ar isotopic ages of 90 to 45 Ma. The Verkhoyansk-Indigirka metallogenic zone is interpreted as possibly forming in the rear (back-arc) portion of the Okhotsk-Chukotka volcanic-plutonic belt (Nokleberg and others, 1994c, 1997c).

Zagadka Clastic Sediment-Hosted Hg Deposit

The Zagadka clastic sediment-hosted Hg and associated deposits (V.V. Maslennikov, written commun., 1977, 1985) consists of cinnabar and metacinnabarite which are relatively younger than the Sb-Au vein deposits which consist of stibnite and berthierite. The Zagadka deposit occurs in Late Permian sandstone and siltstone which is gentle folded and cut by steeply-dipping faults. The deposit is located along a linear zone about 2.4 km long within one of the faults. The thickness and morphology of the ore bodies is influenced by shear zones and associated feathered veins and stringers. The ore bodies, mainly cinnabar, range from 0.4 to 3 m thick. Subordinate minerals are galena, sphalerite, stibnite, Pb-sulfosalts, and cassiterite. Gangue minerals are quartz, dickite, and carbonate minerals. The wall rocks exhibit dickite, quartz and carbonate alteration. Average grades are 0.22-6.2% Hg, 0.8-20% Pb, 2-10% Zn, 4-10% Sb, and up to 30 g/t Ag. Estimated resources are 1,718 tonnes mercury and 1,000 tonnes antimony.

Kyuchyus Sb-Au-Hg Vein Deposit

The Kyuchyus Sb-Au-Hg vein deposit (Ivensen and others, 1975; Indolev and others, 1980; Konyshev and others, 1993) occurs in steeply-dipping mineralized reverse shear zones up to 1 m thick and in veins up to 0.5 m thick. The shear zones and veins contain quartz-stibnite, cinnabar-stibnite-quartz, realgar-quartz and quartz, with various amounts of ankerite, calcite, kaolinite, dickite, arsenopyrite, pyrite, orpiment, berthierite, sphalerite, galena, bournonite, pyrrhotite, tetrahedrite, native mercury (up to 15%), and gold. The veins and shear zones crosscut a Middle Triassic (Anisian and Ladinian) sequence of sandstone and siltstone flysch. Alteration types include argillaceous, silicic, carbonate, and hydromica aureoles which occur near the deposit. Average grades are 4.5% As, up to 15% Sb, up to 0.6% Hg, and up to 300 g/t Au. The Sb-Au (Hg) vein deposits usually vary from small to medium in size, and are not economic.

Eastern Asia-Arctic Metallogenic Belt: Anuyi-Beringovsky Zone of Au-Ag Epithermal Vein and Disseminated Au Sulfide Deposits (Belt EAAB) Northeastern Part of Russian Northeast

The Anuyi-Beringovsky zone of and disseminated Au-sulfide deposits (fig. 102; tables 3, 4) occurs in the northeastern part of the Russian Northeast. The zone extends approximately east-west for more than 1,000 km and ranges from 200 to 250 km wide. The zone is hosted in the volcanic rocks of the Okhotsk-Chukotka volcanic-plutonic belt, and in adjacent areas of coeval granitoid plutons. Most of the deposits in the zone are near-surface, Au-Ag epithermal vein deposits of Late Cretaceous and early Paleocene age. These Au-Ag epithermal vein deposits occur mainly in volcanic rocks and are spatially related to disseminated Au-sulfide deposits which occur in clastic rocks of the Chukotka terrane which underlies the Okhotsk-Chukotka volcanic-plutonic belt. The significant deposits in the zone are (table 4) (Nokleberg and others 1997a, b, 1998): Au-Ag epithermal vein deposits at Chineyveem, Draznyaschy, Enmyvaam, Gornostai, Maly Peledon, Promezhutochnoe, Shakh, Zhilny, Sopka Rudnaya, Upryamy, and Valunistoe; a granitoid-related Au deposit at Pelvuntykoinen; and disseminated Au-sulfide deposits at Elveney and Maiskoe. The depositional environments, ore composition, and ore chemistry of the Anuyi-Beringovsky zone are similar to those of the

Okhotsk zone of Au-Ag epithermal vein deposits. Some post-tectonic Au-quartz vein deposits, as at Sypuchee, also occur in the Anyui-Beringovsky zone. These deposits display characteristics of mesothermal and epithermal deposition, and locally contain bonanza gold. However, their economic value is unknown.

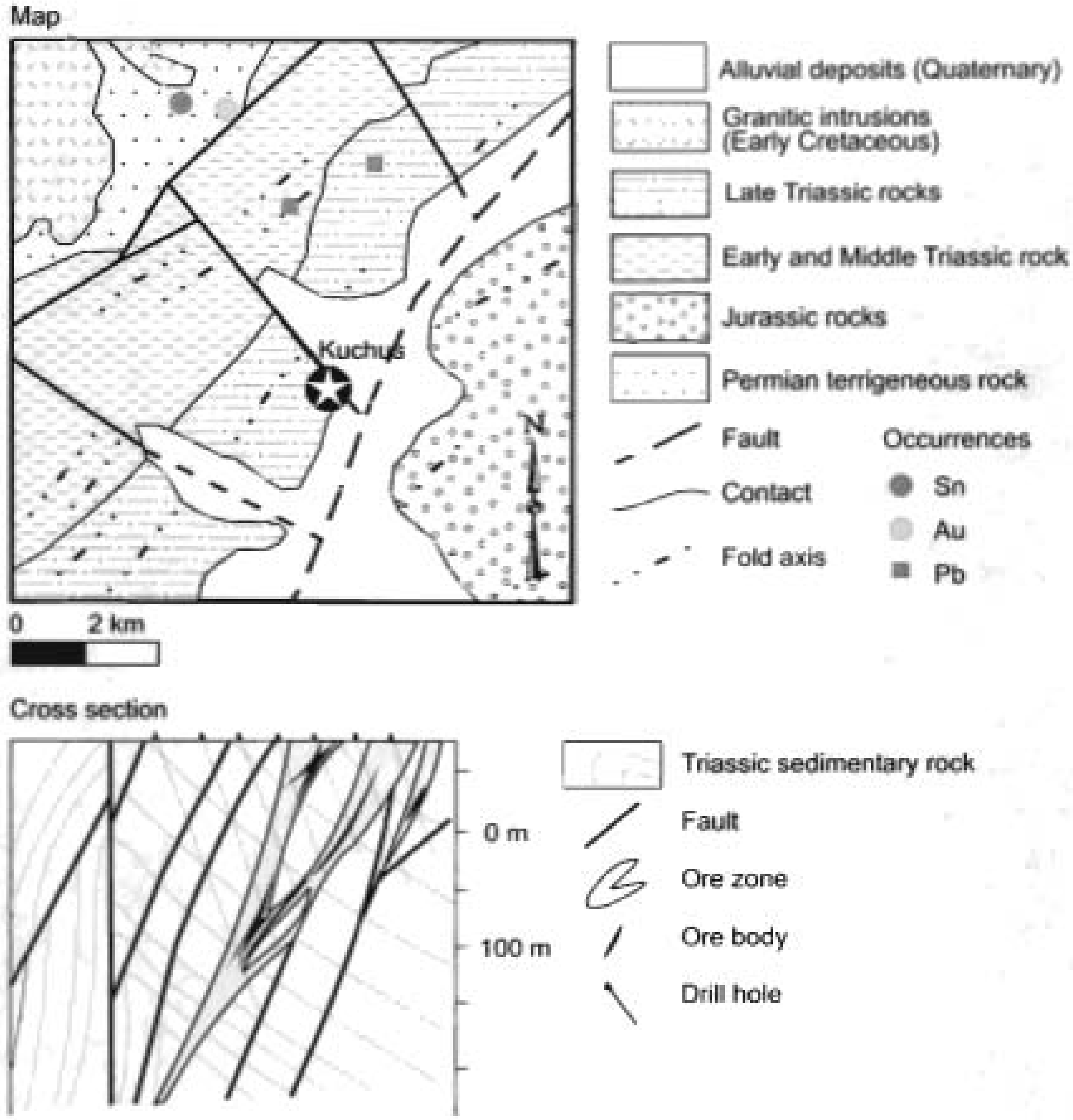


Figure 105. Kyuchyuss Sb-Au-Hg vein deposit, Verkhoyansk-Indigirka (Dulgalak) zone, Eastern Asia-Arctic metallogenic belt), Russian Northeast . Schematic regional geologic map of Kyuchyus area and cross section of deposit. Adapted from Ivensen and others (1975) and Konyshev and others (1993).

The disseminated Au-sulfide deposits of the Anuyi-Beringovsky zone occur mainly in large shear zones which contain veinlets and disseminations of arsenopyrite, pyrite, finely-dispersed gold, and stibnite. The significant deposits are at Maiskoe, being developed for mining, and at Elvenei and Tumanoe. About ninety percent of the gold occurs as inclusions in fine needles of arsenopyrite and As-bearing pyrite, and consequently the ore is difficult to mill. The deposits are concentrated in areas where flysch units of the Chukotka passive continental margin terrane and the Jurassic and Early Cretaceous Raucha sedimentary basin, are overlain by the Okhotsk-Chukotka volcanic-plutonic belt. The disseminated Au-sulfide deposits tend to occur in areas where (Sidorov, 1987): (1) transcurrent faults which crosscut older collisional structures, thrusts, intrusive domes and horsts; and (2) layers of clastic sediments which contain relatively high carbonaceous contents. The disseminated Au-sulfide deposits are interpreted as the roots for the Au-Ag epithermal vein deposits of the Anuyi-Beringovsky zone.

Valunistoe Au-Ag Epithermal Vein Deposit

The Valunistoe Au-Ag epithermal vein deposit (Berman and Trenina, 1968; Berman, 1969; Sidorov, 1978; P. Layer, V. Ivanov, and T.K. Bundtzen, written commun., 1994) consists of more than one hundred adularia-quartz, adularia-carbonate-quartz, and fluorite-quartz veins which comprise zones up to 1,500 km long and 400 m wide. The ore minerals are mainly finely disseminated electrum, argentite, aguilarite, stromeyerite, native silver, galena, sphalerite, and chalcopyrite. A gold-argentite assemblage is predominant in veins of the upper portions of the deposit. At depth, the gold-argentite assemblage is succeeded by a gold-chalcopyrite and gold-galena-sphalerite assemblages. The ore bodies occur in Late Cretaceous volcanic rocks in a volcanic dome structure which is located at the intersection of northwest- and northeast-trending faults. The wall rocks are dominated by andesite-dacite and dacite with quartz-adularia-hydromica and propylitic alteration. The quartz veins vary from lenticular to podiform, are commonly en-echelon, and locally grade into a stockwork of veinlets associated with hydrothermal and subvolcanic breccia. Ar-Ar isotopic studies of adularia in Au-Ag vein yields an age of 72 Ma. The deposit is of medium size and ranges from 1.4 to 787 g/t Au and 2 to 6,273 g/t Ag.

Maiskoe Disseminated Au-Sulfide Deposit

The Maiskoe disseminated Au-sulfide deposit (fig. 106) (Sidorov and others, 1978; Gavrilov, Novozhilov, and Sidorov, 1986; Olshevsky and Mezentseva, 1986; Sidorov, 1966, 1987; Benevolskyi and others, 1992) occurs in linear shear zones which generally trend north-south, have variable strike and dip, and are marked by distinctive cleavage, fissures, contortion, and boudinage. The deposit consists of veinlets and disseminations of Au-bearing pyrite and arsenopyrite. The veinlets and disseminations occur in the more plastic rocks such as siltstone, and silty shale, and shale which are part of a Middle(?) and Late Triassic flysch sequence. These sedimentary rocks are intruded by dikes of quartz-feldspar porphyry, granite, granosyenite porphyry, Early Cretaceous lamprophyre, Late Cretaceous rhyolite, as well as by vein-like bodies of intrusive breccia of Okhotsk-Chukota volcanic-plutonic belt. The igneous rocks are altered to beresite, kaolinite, sericite, carbonate, graphite, and irregular silicic alteration. The carbonaceous rocks sedimentary rocks are metamorphosed to phyllite. The ore consists mainly of disseminated high-grade Au in acicular arsenopyrite and As-rich pyrite. A later quartz-stibnite-native arsenic stage of mineralization is also widespread. Exterior to the ore zones, veins of molybdenite-quartz and REE-polysulfide-quartz occur mainly in sandstone. These veins contain cassiterite, scheelite, wolframite, Bi-minerals, tetrahedrite-tennantite, and Pb- and Ag-sulfosalts. A K-Ar adularia age for the vein is 79.4 Ma (Ishihara and others, 1997). The Au mineralization is vertically and areally extensive. The deposit contains proven reserves of 23 million tonnes with an average grade 12 g/t Au.

Eastern Asia-Arctic Metallogenic Belt: Chukotka Zone of Igneous-Related Hg Deposits (Belt EACH) Northeastern Part of Russian Northeast

The Chukotka zone of igneous-related Hg deposits (fig. 102; tables 3, 4) occurs in the northeastern part of the Russian Northeast. The Chukotka zone contains numerous Hg deposits and occurrences, trends roughly east-west, is about 1,000 km long and ranges from 100 to 150 km wide. The significant deposits in the belt are (table 4) (Nokleberg and others 1997a, b, 1998): clastic sediment-hosted Hg deposits at Kyttamlai and Palyan; volcanic-hosted Hg deposits at Kulpolney, Omrelkai, and Plamennoe; and a silica-carbonate Hg deposit at Matachingai. The deposits occur both in the Okhotsk-Chukotka volcanic-plutonic belt and in the igneous rocks which intrude the Jurassic and Early Cretaceous sedimentary rocks of the Raucha Basin (Nokleberg and others, 1994c, 1997c). The Chukotka zone partly overlies the Anyui-Beringovsky and Chaun metallogenic zones (fig. 102).

The Hg deposits in the Chukotka zone generally occur in linear belts up to several kilometers long, and are partly controlled by northwest-southeast-trending faults. The deposits are hosted in rhyolite, andesite, and more rarely in ultramafic rocks, and show a distinctive relation basalt and lamphrophyre dikes (Obolensky and Obolenskaya, 1971). The Hg deposits occur in faulted areas in volcanic domes, horsts, subsiding calderas, and anticlines. The deposits generally occur in stockworks and veins, and cinnabar is the predominant mineral, generally in association with ankerite, quartz, and dickite. The major Hg districts are at Tsentral Chukotsky, Sredne-Anadyrsky, and Vostochno-Chukotsky (Babkin, 1975; Kopytin, 1978). The Palyavaam area (Tsentral Chukotsky district) is the best studied, contains the Palyanskoe and Plamennoe deposits. Some deposits are economic.

Palyanskoe Clastic Sediment-Hosted Hg or Hot-Spring Hg(?) Deposit

The Palyanskoe clastic sediment-hosted Hg or hot-spring Hg(?) deposit (Syromyatnikov, 1972; Babkin, 1975; Syromyatnikov, Dubinin, 1978) consists of stockworks, veinlets, and disseminations, podiform occurrences which are hosted in Late Cretaceous sandstone and shale. The sedimentary rocks overly a deeply-eroded volcanic dome now exposed as a block of volcaniclastic rocks with an intrusive core. The Hg deposit formed in several stages. Most parts of the deposit occur at the intersections of major north-south- and east-west-trending faults. The ore bodies tend to occur along extensive layering in the volcanic rocks and along zones of tectonic disruption and explosive brecciation. More than 30 minerals are recognized, including quartz, dickite, dolomite, siderite, calcite, cinnabar, marcasite, pyrite, galena, sphalerite, native arsenic, and realgar, and nickel minerals. Wall-rock alteration is not identified. The deposit contains an estimated 10,117 tonnes Hg in ore grading 0.53% Hg.

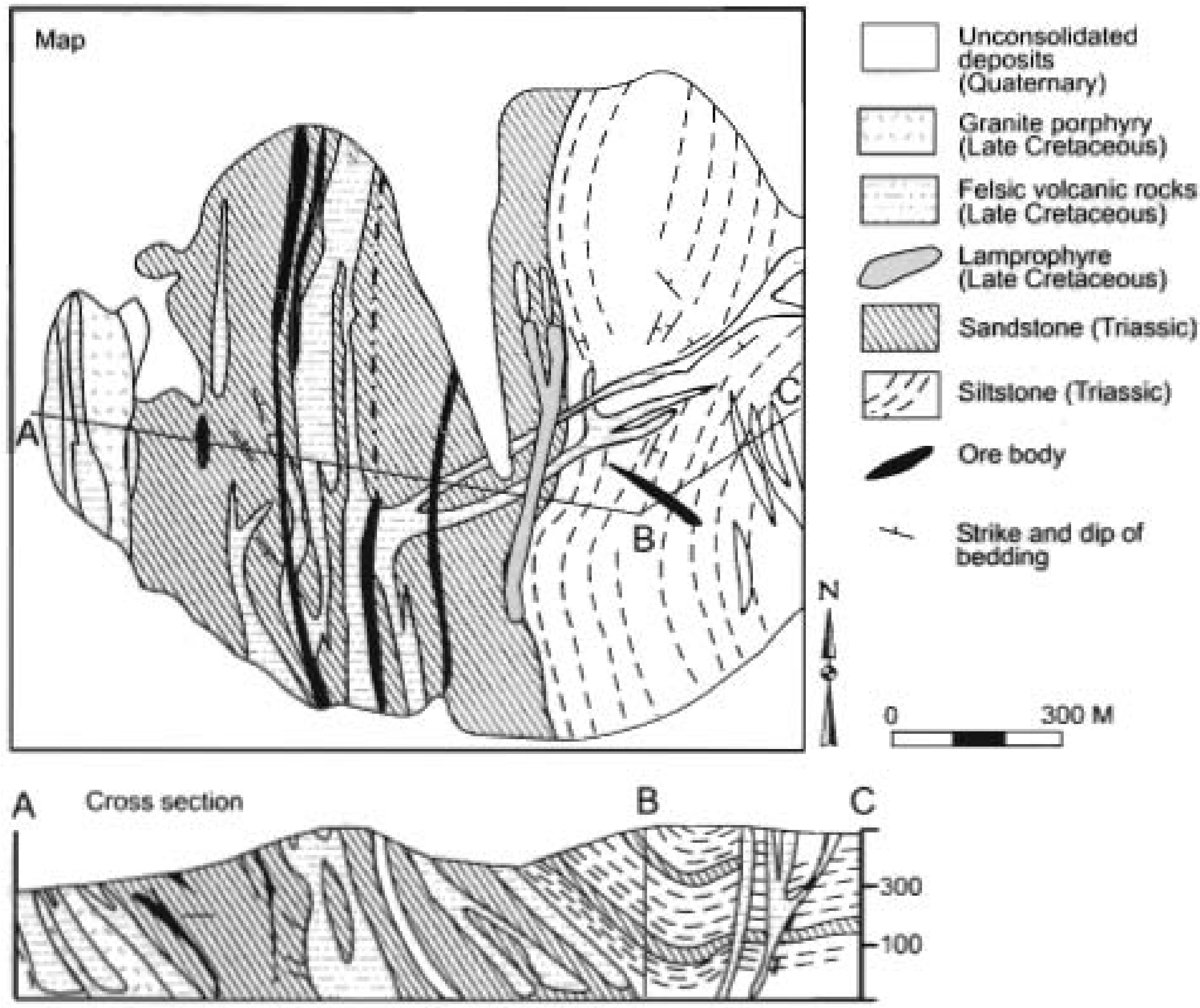


Figure 106. Maiskoe disseminated Au-sulfide deposit, Anuyi-Beringovsky zone, Eastern Asia-Arctic metallogenic belt, Russian Northeast. Schematic geologic map and cross section. Adapted from Sidorov and Eremin (1995).

Seward Peninsula Metallogenic Belt of Granitic Magmatism Deposits (Belt SP) Northwestern Alaska

The Seward Peninsula metallogenic belt of granitic magmatism deposits (fig. 103; tables 3, 4) occurs on the western part of the Seward Peninsula and St. Lawrence Island (not shown on fig. 103) in northern Alaska (Nokleberg and others, 1995a; Hudson and Reed, 1997). The metallogenic belt is hosted in the part of the region intruded by Late Cretaceous silicic granitoid plutons (Hudson and Arth, 1983). The deposit types are mainly Sn granite, porphyry Mo, polymetallic vein, and felsic plutonic U deposits. The significant deposits in the belt are (table 4) (Nokleberg and others 1997a, b, 1998): Sn quartz vein deposits at Cape Mountain and Potatoe Mountain; a Sn skarn deposit at Ear Mountain (Winfield); a complex Sn-W skarn, Sn greisen, Carbonate-replacement Sn(?) deposit at Lost River; a Sn greisen deposit at Kougarok; polymetallic vein deposits at Independence, Omilak, Quartz Creek, and Serpentine Hot Springs; a porphyry Mo deposit at Windy Creek; a sediment-hosted U deposit at Death Valley; and a felsic plutonic U deposit at Eagle Creek. The deposits and host granite plutons are interpreted as the extreme northeastern end of the Cretaceous and early Tertiary Okhotsk-Chukotka volcanic-plutonic belt which extends for several thousand kilometers to the west across the Bering Straits and southwest into the Russian Far East (Nokleberg and others, 1994c, 1997c). The various Sn deposits are commonly referred to as the Cretaceous tin province of the Seward Peninsula. The origins of many of the polymetallic vein deposits are somewhat enigmatic.

Lost River Sn-W Skarn and Sn Greisen Deposit

The classic Lost River Sn-W skarn and Sn greisen deposit (fig. 107) (Dobson, 1982; Hudson and Arth, 1983; Reed, Menzie, and others, 1989; Newberry and others, 1997) consists of several prospects and one mine in veins, skarns, greisens, and intrusion breccia formed above a shallow Late Cretaceous granite stock that intruded thick sequence of Early Ordovician limestone and argillaceous limestone. Early-stage andradite-idocrase skarn and later fluorite-magnetite-idocrase vein skarns are altered to chlorite-carbonate assemblages which are contemporaneous with formation of cassiterite-bearing Sn greisen. The major ore minerals in skarn and greisen are cassiterite and wolframite, and lesser stannite, galena, sphalerite, pyrite, chalcopyrite, arsenopyrite, and molybdenite, plus a wide variety of other contact metasomatic and alteration minerals. The K-Ar isotopoic age of the granite is 80.2 Ma. Production of 320 tonnes Sn occurred mostly from 1951 to 1956 from underground workings a few hundred meters deep along the Cassiterite dike, a near-vertical rhyolite dike which is extensively altered to greisen over the buried granite. Similar smaller deposits nearby include Sn greisen and veins near the Tin Creek Granite and various polymetallic veins and skarns near the Brooks Mountain Granite. A large beryllium deposit occurs peripheral to the skarns and consists of limestone replaced by fluorite-white mica veins which contain diaspore, chrysoberyl, and tourmaline. The Be deposit is probably associated with early stages of granite intrusion. Some placer Sn was recovered from creek below Lost River mine. A major exploration program in early 1970's drilled several large Sn-W-fluorite-Be ore bodies. The deposit contains estimated reserves of 25 million tonnes grading 0.15% Sn, 0.03% WO_3, 16.3% CaF_2 (WGM, Inc., written commun., 1975).

Felsic Plutonic U and Sandstone U deposits

A complex, multi-phase, 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. The felsic plutonic deposit consists of disseminated U-, Th-, and REE-minerals, which occur 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 mainly of metaautunite in Paleocene sandstone along the margin of a Tertiary sedimentary basin (Dickinson and Cunningham, 1984; Dickinson and others, 1987). The U in the sandstone probably was transported by groundwater from Cretaceous granitoid plutons to the west (Dickinson and Cunningham, 1984).

Origin of and Tectonic Controls for Seward Peninsula Metallogenic Belt

The felsic-magmatism-related deposits of Seward Peninsula metallogenic belt generally occur in, or adjacent to, moderate or highly silicic granites of latest Cretaceous age (Hudson and Arth, 1983; Nokleberg and others, 1995a). The porphyry Mo, felsic plutonic U, and polymetallic vein deposits occur in slightly older and slightly less siliceous granites, whereas the Sn granite and associated deposits occur in slightly younger and more silicic deposits. The granites associated with both groups of deposits are interpreted as forming during assimilation of the continental, Late Proterozoic and early and middle Paleozoic metasedimentary rocks of the Seward metamorphosed continental margin terrane (Hudson and Arth, 1983; Swanson and others, 1988). Alternatively, on the basis of trace element data, the Sn granite and related deposits are interpreted as forming during crustal extension (Newberry and others, 1997b).

On the basis of similar geochemistry, age, and spatial proximity, the host Late Cretaceous granitic rocks on the Seward Peninsular are interpreted as part of the eastern edge of the Okhotsk-Chukotka volcanic-plutonic belt which hosts the Seward Peninsula metallogenic belt extends for 3000 km along western margin of Sea of Okhotsk (Nokleberg and others, 2000). The Seward Peninsula metallogenic belt and the nearby Northwestern Koyukuk Basin metallogenic belt of felsic plutonic U deposits, described below, are interpreted herein as the eastern extension of the Eastern-Asian-Arctic metallogenic belt in the Russian Far East (figs. 102, 103). The Seward Peninsula metallogenic belt with Sn granite and related deposits, is correlated with the Chaun zone of the Eastern Asia metallogenic belt which contains similar deposits to the west in the Russian Northeast (fig. 102).

Northwestern Koyukuk Basin Metallogenic Belt of Felsic Plutonic U and Manto-Replacement (Polymetallic Pn-Zn, Au) Deposits (Belt NWK) West-Central Alaska

The Northwestern Koyukuk Basin metallogenic belt of felsic plutonic U and manto-replacement (polymetallic Pn-Zn, Au) deposits (fig. 103; tables 3, 4) occurs in the Purcell district and adjacent area in the northwestern Koyukuk Basin in west-central Alaska. The metallogenic belt is hosted in the part of the region underlain by the Late Cretaceous Hogatza plutonic belt (Miller, 1994). The significant felsic plutonic U deposits in the belt are at Clear Creek, Wheeler Creek, and Zane Hills (table 4) (Miller and Elliott, 1969; Miller, 1976; Jones, 1977; Nokleberg and others 1997a, b, 1998). These felsic plutonic U deposits and host plutonic rocks are interpreted as the extreme northeastern end of the Okhotsk-Chukotka volcanic-plutonic belt of the Russian Far East (Nokleberg and others, 1994c, 1997c, 2000). Also occurring in the metallogenic belt is a polymetallic (Au-Pb-Zn) vein and manto replacements(?) in the Illinois Creek area which produced 957 kg Au from 1997 to 1999, and is isotopically dated at 111 Ma, about the same age as the nearby Khotol pluton (Flanigan, 1998).

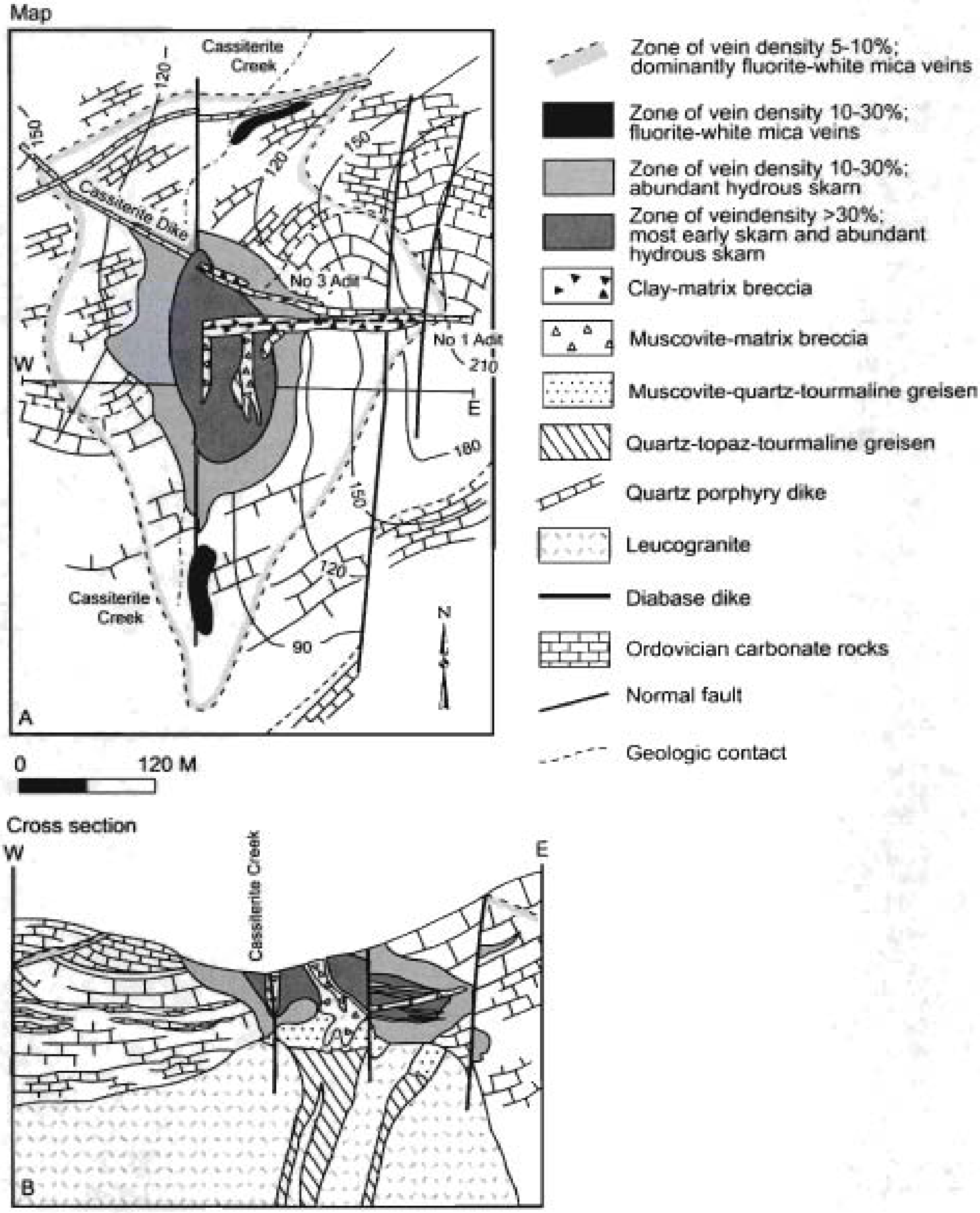


Figure 107. Lost River Sn-W skarn and Sn greisen deposit, Seward Peninsula metallogenic belt, Seward Peninsula, Alaska. Schematic geologic map and cross section. Adapted from Dobson (1982) and Hudson and Reed (1997).

Wheeler Creek, Clear Creek, and Zane Hills
Felsic Plutonic U Deposits

The felsic plutonic U deposits at Wheeler Creek, Clear Creek, and Zane Hills (Eakin and Forbes, 1976; Miller, 1976; Jones, 1977; Miller and Elliott, 1977) are of two main types: (1) uranothorite and gummite in quartz-rich veinlets in altered Late Cretaceous alaskite, uraniferous nepheline syenite and bostonite dikes which cut Early Cretaceous andesite; and (2) uranothorite, betafite, uraninite, thorite, and allanite in veinlets in a foliated monzonite border phase, that locally grades to syenite. Grab samples contain up to 0.027% U

Illinois Creek Manto-Replacement
(Polymetallic Pn-Zn, Au) Deposit

A structurally-controlled, plutonic-related epigentic deposit occurs at Illinois creek about 70 Km south of Galena (Flanigan, 1998; Bundtzen and others, 2000). The Illinois Creek deposit is a supergene oxidized deposit which occurs in an east-trending, moderately dipping shear zone. The deposit has with anomalous to ore-grade Au, Bi, AG, Cu, Pb, and Zn. The deposit contains supergene pyrolucite, limonite, geothite, and hemetite; sulfides are rare. Ar/Ar isotopic age, petrologic, and microprobe studies indicate that the Illinois Creek deposit is related to emplacement of the syn-collisional, 111.3 Ma Khotol Mountain granite (Flaniagn, 1998). The mine produced 957 kg gold from 1.22 million tonnes of ore prior to 1999 bankruptcy.

Origin of and Tectonic Controls for
Northwestern Koyukuk Basin
Metallogenic Belt

The calc-alkaline granitoid rocks which host the Northwestern Koyukuk Basin metallogenic belt extend about 300 km from Hughes on the Koyukuk River westward to near the Seward Peninsula. The granitoid plutonic rocks are mainly granodiorite and lesser tonalite and high-silica granite. The granites intrude a sequence of andesitic flows, tuffs, breccia, agglomerate, conglomerate, tuffaceous graywacke, and mudstone containing local intercalations of Early Cretaceous limestone which together form part of the Koyukuk island-arc terrane (Patton and others, 1994). These plutons are interpreted as forming in a subduction-related, continental-margin arc on the basis of a calc-alkaline composition, high sodium content, relatively, locally abundant mafic xenoliths, and low initial Sr ratios (Miller, 1994). The Northwestern Koyukuk Basin metallogenic belt and the nearby Seward Peninsula metallogenic belt, described above, are herein interpreted as the eastern extension of the Eastern-Asian-Arctic metallogenic belt which in the Russian Far East (figs. 102, 103). This major metallogenic belt, as described above, extends west and southwest for 3000 km along western margin of Sea of Okhotsk.

West-Central Alaska Metallogenic Belt of
Porphyry Cu-Au Deposits (Belt WCA)
West-Central Alaska

The West-Central Alaska (Hogatza) metallogenic belt of porphyry Cu-Au deposits (fig. 103; tables 3, 4) (Hollister, 1978; Nokleberg and others, 1995a) is hosted in a suite of Late Cretaceous quartz monzonite plutons of the Hogatza plutonic belt which intrude oceanic crust of the Yukon-Koyukuk island-arc terrane and overlapping Cretaceous flysch (Nokleberg and others, 1995a). Most of the older intrusions of the Hogatza plutonic belt exhibit K-Ar ages generally from 100 to 120 Ma, and are undersaturated, alkalic igneous complexes which tend to be barren of porphyry deposits. The significant deposits in the belt are at Indian Mountain, Purcell Mountain, and Zane Hills (table 4) (Nokleberg and others 1997a, b, 1998). All these deposits are hosted in oval-shaped, epizonal, forcefully injected plutons with K-Ar isotopic mineral ages of 80-82 Ma (Miller and others, 1966).

Indian Mountain and Purcell Mountain
Porphyry Cu-Au Deposits

The Indian Mountain and Purcell Mountain porphyry Cu-Au deposits occur in the middle Koyukuk River basin. The Indian Mountain deposit consists mainly of tourmaline-bearing breccias in the center of a quartz monzonite porphyry intrusion. The breccias contain chalcopyrite and surrounding the breccias are concentric phyllic-argillic-propylitic alteration halos. The quartz monzonite porphyry intrusion is approximatly 10 km^2 (Miller and Ferrians, 1968; Hollister, 1978). A pyrite halo rims the intrusion. Limited assays at Indian Mountain range from 0.07 to 0.15% g/t Cu and 0.1 to 1.5 g/t Au. Barite, galena, and sphalerite have also been identified at the prospect. The Purcell Mountain porphyry copper deposit consists of stockwork veins in a quartz monzonite porphyry intrusion. The veins contain chalcopyrite which are also associated with concentric phyllic-argillic-propylitic alteration halos. The quartz monzonite porphyry intrusion is about 12 km^2 (Hollister, 1978). A pyrite halo also rims the intrusion. The deposit contains 0.07 to 0.10% Cu but no Au; however, placer Au has been commercially recovered from streams draining both plutons.

Zane Hills Porphyry Cu-Au Deposit

The Zane Hills porphyry Cu-Au deposit consists of a stockwork and veins containing chalcopyrite and pyrite, and trace molybdenite and covellite that occur most commonly in a quartz gangue. The stockwork and veins occur in a small, 5 km^2 monzonite porphyry which intrudes older Jurassic andesite, and also in a mid-Cretaceous granodiorite pluton. The stockwork and veins occurs in both the Jurassic andesite and in the monzonite porphyry which has K-Ar age of 81 Ma. Like the deposits at Indian and Purcell Mountains, the phyllic-argillic-propylitic alteration assemblage which is annularly distributed around the core of the monzonite porphyry (Hollister, 1978). The deposit contains up to 2.0% Cu, 0.2% Mo, and 2.4 g/t Au (Miller and Ferrians, 1968). The Zane Hills deposit occurs about 4 km west of the Hog River placer deposit which has yielded about 6,842 kg of placer Au.

Origin of and Tectonic Controls for West-Central Alaska Metallogenic Belt

Isotopic trace element (initial Sr isotopic ratios) and isotopic age data reported from the Late Cretaceous and early Tertiary igneous rocks of western Alaska indicate a variety of source rocks for the parent magmas (Moll-Stalcup and Arth, 1991; Moll-Stalcup, 1994; Arth, 1994), including both contaminated crustal rocks and oceanic crust. On the basis of regional geologic relations, igneous rock composition, and ages of igneous rock, and tectonic environment, the West-Central metallogenic belt is herein interpreted as hosted in the extreme northeastern end of the Okhotsk-Chukotka volcanic-plutonic belt. Other related metallogenic belts to the west in Alaska are the Northwestern Koyukuk Basin metallogenic belt and the Seward Peninsula metallogenic belt of granitic magmatism deposits (fig. 103). To the west and southwest, the Okhotsk-Chukotka volcanic-plutonic belt, which also hosts the Northwestern Koyukuk Basin and Seward Peninsula metallogenic belts, extends for 3000 km along western margin of Sea of Okhotsk(Nokleberg and others, 1994c, 1997c). The Okhotsk-Chukotka belt is interpreted as a continental-margin arc marking the Albian through Campanian and locally Paleocene active continental margin of northern Asia (Nokleberg and others, 1994c, 1997c, 2000).

Metallogenic Belts Formed in Late Mesozoic and Early Cenozoic Kluane Continental-Margin Arc, Southern Alaska

Kuskokwim Mountains Metallogenic Belt of Granitic-Magmatism-Related Deposits (Belt SWK) Southwestern Alaska

Geologic Setting of Kuskokwim Mountains Metallogenic Belt

A major Au-polymetallic metallogenic province associated with Late Cretaceous-early Tertiary granitoid plutons and associated volcanic fields occurs in the 650 long by 350 km wide Southwestern Kuskokwim Mountians metallogenic belt in western-southwestern Alaska (Nokleberg and others, 1995a). The metallogenic belt can be traced from Goodnews Bay in extreme Southwestern Alaska to Cosna Dome in the northeastern Kuskokwim Mountains, a distance of more than 650 km (fig. 103). Bundtzen and Miller (1997), have included the precious metal and related deposits of Late Cretaceous and early Tertiary age through out much of this region into the *Kuskokwim Mineral Belt* which is named after the Kuskokwim Mountains where most of the deposits occur. This name has also been adopted by other authors including Lange and others (2000) and Goldfarb and others (2000). Smith (2000), and Flanigan and others (2000), as stated above, regard the same area as a southwest extension of the Tintina gold belt, a belt of granitoid-related Au plutons of mainly Mesozoic age which spans the region of central Alaska and the Yukon Territory.

During the twentieth century, lode and placer deposits derived from Cretaceous and early Tertiary igneous complexes within the Kuskokwim Mineral Belt have produced approximately 110,000 kg Au, 9,500 kg Ag, 3,842 kg Cu, and 1.5 million kg Hg (Bundtzen and others, 1992; Miller and Bundtzen, 1994; Nokleberg and others, 1996; Bundtzen and Miller, 1997; Bundtzen, 1999). However, some of the placer gold is interpreted as derived from older bedrock sources: (1) about 15 percent of the Au production of 16,900 kg has been from placer deposits containing detritus from mid-Cretaceous (108 Ma) plutonic complexes in the Nyac district; (2) one percent (970 kg) was mined from placers eroding Jurassic ultramafic rock complexes in the Goodnews Bay region;

The significant deposits in the belt (Nokleberg and others 1995, 1996, 1997a, 1998; Bundtzen and Miller, 1997) include: the McLeod, and Molybdenum Mountain porphyry Mo prospects; the important Donlin Creek and Vinasale Mountain porphyry Au-polymetallic deposits; the Chicken Mountain, Von Frank, and Golden Horn porphyry Cu-Au prospects; Au-polymetallic vein and replacement prospects at Fortyseven Creek south of Sleetmute; the Arnold prospect near Marshall; the Mission Creek Owhat and Headwall prospects in the Russian Mountains; Cu-Au-Bi skarn deposits in the Nixon Fork area; a small Fe skarn occurrence at Medfra; the Bismarck Creek, Win, and Won Sn-W-Ag polymetallic, greisen, vein, and skarn deposits; and epithermal Hg-Sb-

Au vein,and hots spring deposits at Red Devil, Kaiyah, Kagati Lake, Kolmakof, Snow Gulch-Donlin, Cinnabar Creek, DeCourcey, and Gemuk Mountain; and felsic-plutonic U prospects at Wolf Creek Mountain and Sichu Creek.

The lode deposits in the occur in veins, stockworks, breccia pipes, skarns and replacement deposits which formed in upper mesothermal to epithermal environments (Bundtzen and Miller, 1991; 1997; Gray and others, 1997). A plausible metallogenic model suggests which most of these deposits are similar vertically-zoned hydrothermal systems which are exposed at various erosional levels within the late Cretaceous and early Tertiary igneous complexes and wall rocks. Selected deposits and environments include: (1) the Cirque, Tolstoi, Headwall, Mission Creek, Win, Won, and Bismarck Creek, greisen Sn-Cu-Ag-As deposits (formed in upper mesothermal environment); (2) the Golden Horn, Chicken Mountain, and Von Frank porphyry Cu-Au deposits (formed in lower mesothermal envirohment); and (3) the Red Devil, DeCoursey, Donlin, and Mountain Top Hg-Sb (Au) deposits (epithermal deposits). The important Donlin Creek and Vinasale gold-polymetallic deposits resemble porphyry Au deposits (Wilson and Keyser, 1988; Hollister, 1992), but lack metallic, fluid inclusion, and wallrock alteration more typical of porphyry Au systems (Bundtzen and Miller, 1997; Ebert and others, 2000). Unusual, U-rich, REE deposits occur in ultra-potassic felsic igneous rocks at Sischu Mountain and Wolf Creek Mountain (Patton and others, 1994; Bundtzen, 1998). The various Au-polymetallic and other mineral deposits in the are interpreted as forming in a distinctly higher, structural level than the deeper, mesothermal systems in the East-Central Alaska metallogenic belt described below. Selected examples of important deposits in the Kuskokwim Mineral Belt are described below.

The Southwestern Kuskokwim Mountians metallogenic belt is hosted in the Kuskokwim Mountains sedimentary and volcanic belt that consists of three major types of igneous complexes: (1) calc-alkalic, metaaluminous granite and quartz monzonite of Early and mid-Cretaceous age (about 109 to 98 Ma); (2) peraluminous to metaaluminous, alkali-calcic to quartz alkalic, volcanic-plutonic complexes which contain plutons ranging in composition from alkali gabbro to quartz syenite and average about 70 Ma; and (3) peraluminous granite porphyry sills and dikes which range from 58 to 70 Ma. The various units of the Kuskokwim Mountains sedimentary and volcanic belt intrude and overlie several major bedrock units, including the Proterozoic to Paleozoic Ruby terrane, the Paleozoic Nixon Fork terrane, the Late Paleozoic-Mesozoic Innoko terrane, the Triassic to Early Cretaceous Gemuk Group, the Ordovician to Jurassic Goodnews terrane, the Late Cretaceous Kuskokwim Group, and other basement rocks (Moll-Stalcup, 1994; Bundtzen and Miller, 1997).

Kuskokwim Mountains Sedimentary and Volcanic Belt

The Kuskokwim Mountains sedimentary and volcanic belt which hosts the Kuskokwim metallogenic belt consists of interlayered volcanic and sedimentary rocks which are intruded by coeval plutonic rocks. Geochemical and isotopic studies of the igneous rocks of the belt reveal two types of igneous complexes (Bundtzen and Miller, 1997): (1) peraluminous to metaluminous, alkali-calcic to quartz alkalic and lesser calc-alkalic, volcanic-plutonic complexes composed of plutons ranging in composition from alkali gabbro, quartz diorite, granodiorite, monzonite, to syenite; and (2) peraluminous granite porphyry sills and dikes.. These two suites exhibit K-Ar crystallization ages ranging from 75 to 60 Ma (Late Cretaceous and early Tertiary).

The volcanic suite consists chiefly of rhyolite and dacite domes, flows, and tuff, and dacite, andesite, and basalt flows which exhibit K-Ar isotopic ages of 58 to 77 Ma (Bundtzen and Gilbert, 1983; Miller and Bundtzen, 1994; Moll-Stalcup, 1994; Moll-Stalcup and others, 1994). They display moderate-K, calc-alkalic to shoshonitic compositional trends with andesite and rhyolite being most common. REE patterns are variable, initial Sr ratios vary from 0.704 to 0.708, and trace element studies suggest assimilation of small amounts of continental crust of the metamorphosed continental margin Ruby terrane (Miller, 1994; Moll-Stalcup, 1994; Moll-Stalcup and others, 1994). An unusually large range of incompatible elements occur in the igneous rocks and their significance is not well understood (Moll-Stalcup, 1994).

Sedimentary rocks underlying the Kuskokwim Mountains igneous belt include the mid- and Late Kuskokwim Group (Cady and others, 1955) and Cretaceous flysch of the Yukon-Koykuk basin (Patton and others, 1994). The Kuskokwim Group consists mainly of conglomerate to coarse-grained sandstone turbidites deposited in deep-marine conditions, and lesser sandstones and conglomerates deposited in shallow-marine to nonmarine conditions. The Kuskokwim Mountains igneous belt and the Kuskokwim Group are generally mildly folded and faulted, and, to the south, are interpreted to overlie the Kahiltna sedimentary and volcanic assemblage (fig. 103). To the east, the igneous belt locally overlies the Wrangellia superterrane. Bundtzen and Miller (1997) and Patton and others (1994) provide more detailed geologic frameworks for both of these areas.

Origin of and Tectonic Setting for Kuskokwim Mountains Metallogenic Belt

The Kuskokwim Mountains metallogenic belt is hosted by the Kuskokwim Mountains sedimentary and volcanic belt which is interpreted as the back-arc part of the extensive, subduction-related Kluane igneous arc which occurred along the Late Cretaceous and early Tertiary continental margin of southern and southeastern Alaska (Moll and Patton, 1982; Bundtzen and Gilbert, 1983; Swanson and others, 1987; Plafker and others, 1989; Szumigala, 1993; Miller and Bundtzen, 1994; Moll-Stalcup, 1994; Nokleberg and others, 1995a; Bundtzen and Miller, 1997). Supporting data for this interpretation include: (1) the alkali-calcic nature of the igneous rocks in the Kuskokwim Mountains igneous belt which are more alkalic than the coeval Alaska Range-Talkeetna Mountains igneous belt; (2) trans-tensional tectonism associated with the Kuskokwim Mountains igneous belt;

and (3) the existence of peraluminous igneous rocks and the deposits in the Kuskokwim Mountains igneous belt. In a similar setting, alkalic porphyry Cu-Au and polymetallic Sn deposits occur in back-arc extensional environments in South America (Hollister, 1978), and early Tertiary peraluminous intrusions in Yukon Territory are interpreted by Sinclair (1986) as forming during extensional, wrench fault tectonism related to strike-slip faulting. This interpretation is also advocated by Miller and Bundtzen (1994) for the mineralized plutons of the Kuskokwim Mountains igneous belt.

In Alaska, the other major parts of the Kluane arc are the Alaska Range-Talkeetna volcanic-plutonic belt to the southeast, the Yukon-Kanuti igneous belt to the northwest, and the Late Cretaceous and early Tertiary granitoid rocks of the Yukon-Tanana igneous belt to the northeast (Moll-Stalcup, 1994). The Kluane arc is interpreted as forming immediately after the accretion of Wrangellia superterrane in the mid-Cretaceous, and was consequently substantially dismembered by major dextral-slip faulting in the Cenozoic (Plafker and others, 1989; Nokleberg and others, 1994d, 2000). These belts and the Kuskokwim Mountains sedimentary and volcanic belt are interpreted as a subduction-related arc that was tectonically linked to the Late Cretaceous part of the Chugach accretionary-wedge terrane (Valdez Group and equivalent units) and to the early Tertiary part of the Prince William accretionary-wedge terrane (Orca Group and equivalent units) (Nokleberg and others, 2000).

Felsic Porphyry Mo Deposits - Kuskokwim Mountains Metallogenic Belt, Southwestern Alaska

A north-south-trending, linear belt of quartz monzonite to granite porphyry stocks and plutons, that host porphyry Mo deposits and prospects, intrude the Late Cretaceous flysch of the Kuskokwim Group and older metamorphic rocks of the Ruby terrane in the west-central Kuskokwim Mountains. From south to north along a linear distance of about 125 km, these deposits and prospects include the McLeod deposit in the eastern Kaiyuh Hills along the lower Innoko River Drainage and the Molybdenum Mountain deposit on the Owhat River. These two felsic porphyry Mo deposits are generally similar to the model of Lowell and Guilbert (1970). All three deposits and prospects contain concentric phyllic and argillic alteration zones, and plot in the granite field of a normative QAPF diagram, and are peraluminous.

McLeod Porphyry Molybdenum Prospect

The McLeod porphyry Mo deposit strikes east-northeast and consists of a molybdenite-bearing quartz stockwork in a quartz porphyry stock about 3 km^2 in area (Mertie, 1937a; Chapman, 1945; West, 1954; Nokleberg and others, 1995a). The stock intrudes undifferentiated Cretaceous greenstone of the Kuskokwim Group and is interpreted as associated with quartz latite dikes which occur near the eastern boundary of the pluton. In addition to quartz and molybdenite, the stockwork contains pyrite, pyrrhotite, and chlorite. The stockwork locally comprises up to 10% of the intrusion. Veinlets also occur in adjacent greenstone. The quartz-feldspar porphyry stock and latite dikes exhibit a phyllic alteration core flanked by silicic and argillic zones in a 300 by 1,100 m area. The stockwork averages 0.09% MoS_2 over a 30 by 350 m surface area. The quartz porphyry stock has a K-Ar biotite age of 69.3 Ma (T.K. Bundtzen, unpublished data, 1987).

Molybdenum Mountain Porphyry Molybdenum Prospect

The Molybdenum Mountain porphyry Mo prospect (T.K. Bundtzen, unpublished data, 1987; Nokleberg and others, 1995a) consists of a stockwork of vein quartz with massive and disseminated molybdenite, galena, and pyrite in the Molybdenum Mountain stock, a small, 2 km^2, hypabyssal felsic intrusion which occurs about 45 km northeast of Aniak. Alterations are mainly silicic and sericitic. A large, elongate contact metamorphic aureole surrounds the Molybdenum Mountain stock and several smaller intrusions which occur about 4 to 6 km to the northeast. Selected rock samples from the Molybdenum Mountain stock contain up to 5.0% MoS_2; however, average estimates of grade are not available. The stock intrudes contact-metamorphosed, Late Cretaceous flysch of the Kuskokwim Group along a large shear zone which is a splay of the Iditarod-Nixon-Fork Fault, a major dextral-slip Cenozoic fault in west-central Alaska. A K-Ar white mica age of 60.9 Ma is obtained from the stock.

Alkalic-Calcic Porphyry Cu-Au Prospects - Kuskokwim Mountains Metallogenic Belt

Alkalic-calcic, porphyry Cu-Au deposits and prospects have only been recently identified in the central Kuskokwim Mountains. The general geology structure, and alteration features of the porphyry deposits in the southwestern Kuskokwim Mountains metallogenic belt are generally those of the alkalic porphyry Cu-Au model of Lowell and Guilbert (1970) or to the porphyry Cu-Au deposit model of Cox (1986b), except that the classic alteration patterns are lacking. The significant deposits are at Chicken Mountain and Von Frank Mountain. These deposits, display similar characteristics, including tourmaline-bearing breccia pipes, stockworks, metal zoning, and petrology. The host plutons for the deposits range from 66 to 71 Ma and intrude Late Cretaceous flysch of the Kuskokwim Group.

Chicken Mountain Cu-Au Deposit

The Chicken Mountain porphyry Au and polymetallic vein deposit (fig. 108) (Bull, 1988; Bundtzen and others, 1992; Nokleberg and others, 1995a; Bundtzen and Miller, 1997) consists of a stockwork of gold-quartz sulfide and sulfide veinlets which occur in the cupola of the Chicken Mountain pluton. The pluton is zoned: older, peripheral alkali gabbro and wehrlite is successively intruded by monzonite, syenite, and local quartz monzonite. A dumbbell-shaped alteration zone of peripheral ankerite and sericite surrounds most of the known parts of the deposit. Large dolomite replacement zones formed synchronously with a sulfide mineral assemblage which includes arsenopyrite, stibnite, cinnabar, scheelite, chalcopyrite, molybdenite, various sulfosalts, and arsenopyrite. The sulfide minerals rarely comprise more than 5% of veins in the stockwork, and the veins typically are about 1 to 2 cm thick.

An apparent temperature-pressure zonation exists as determined by mineral assemblage, alteration, and fluid inclusion data (Bundtzen and others, 1992). A deuteric magmatic event which contained elevated Ta and Sn values was followed by formation of a black sulfide breccia rich in Cu and Mo; which was in turn followed by emplacement of As-W-Au veins and stockwork and Pb-Au-Sb sulfosalts. A final Sb-Au (Hg) quartz vein episode overprinted the older mineralizing events. K-Ar isotopic ages for both plutonic rocks and mineral veins average about 69.5 Ma. A secondary biotite age of 63.5 Ma from the Golden Horn deposit (Bundtzen and Miller, 1997) may postdate the late-stage Sb (Hg) epithermal vein mineralization. A drilling program conducted in 1989 through 1990 suggests a reserve of 14.5 million tonnes grading 1.2 g/t Au, 0.09% Cu, and 0.46% Sb to a depth of about 200 m (Bundtzen and others, 1992).

Cirque, Tolstoi, Bismarck Creek, and Win Sn-Ag Polymetallic Deposits

Sn-Ag-polymetallic deposits occur in the Beaver Mountains (fig. 109) west of McGrath, and in other areas of the Kuskokwim Mountains (Bundtzen and Laird, 1982; Miller and Bundtzen, 1994; Nokleberg and others, 1995a; Burleigh, 1992a,b; Bundtzen and Miller, 1997). The deposit consist of vein stockworks, replacements, and tourmaline breccias with anomalous Ag, Cu, Pb, W, Sn, Nb, and As, and uncommonly Au. The deposits occurs in both Late Cretaceous and early Tertiary plutons and in overlying contact-metamorphic hornfel. The significant lode prospects in the Beaver Mountains occur in a 15 km^2 area centered on the Cirque and Tolstoi prospects (Bundtzen and Laird, 1982) which are is called the South Quartz Zone by Szumigala (1993). A K-Ar biotite age of 70.3 Ma (Bundtzen and Laird, 1982) is obtained for quartz syenite near the northern margin of the Beaver Mountains pluton. The Cirque and Tolstoi deposits consist of a series of parallel tourmaline-axinite-sulfide fracture fillings and tourmaline-syenite breccia pipes which occur in the cupola of a quartz syenite phase of the Beaver Mountains pluton. Chip-channel samples range up to 21.0% Cu, 1,000 g/t Ag, 200 ppm Sn, and 1 g/t Au (Bundtzen and Laird, 1982; Miller and Bundtzen, 1994).

The Bismarck Creek deposit occurs in an east-west to northeast-trending zone of tourmaline-axinite-cassiterite-sulfide gossan in hornfels, about 70 km southwest of McGrath (Bundtzen and Miller, 1997). Secondary biotite is locally abundant and occurs in fine network veins and replacement zones in breccia. A 30-meter-wide zone extends for about 300 meters along strike. Based on extensive surface sampling and geological modeling, Bundtzen and Miller (1997) estimate that the Bismarck Creek deposit contains about 500,000 tonnes grading 0.137 percent Sn, 47.8 grams/tonne Ag, 0.26 percent Zn, and anomalous Cu, F, bi, Sb, and In. A nearby Sn granite intrusion on Granite Mountain is radiometrically dated at 61 Ma.

The Win and Won deposits, each of which contain 5 or more individual occurrences and prospects, are about 35 km apart. Both deposits occur north of McGrath, and contain some of the most important Sn-polymetallic resources in the Kuskokwim Mineral Belt and perhaps in all of Alaska. Both groups of deposits consist of polymetallic-sulfide and quartz-cassiterite assemblages in vein and breccia in quartz-tourmaline hornfels (Burleigh, 1992a, b; Bundtzen and Miller, 1997; Bundtzen, 1999). Although neither the Win nor Won deposits are isotopically dated, both are spatially associated with several sub-volcanic plutons which have isotopic ages ranging from 60 to 70 Ma (Moll and others, 1981). Sulfosalt-rich veins and breccias at the Win deposit contain up to 643 g/t Ag, and 6.97 percent Sn, but very little Au. The better studied Won deposit group is estimated to contain 1.94 millon tonnes grading 0.59 percent Sn and 42 g/t Ag. The Win and Won deposits are geologically and morphologically similar to the Bismarck Creek deposit described above.

Von Frank Mountain Porphyry Cu-Au Prospect

The Von Frank Mountain porphyry Cu-Au prospect (J. DiMarchi, written commun., 1994; Nokleberg and others, 1995a; Bundtzen, 1999) occurs about 100 km northeast of McGrath and consists of stockwork in a quartz diorite and augite-biotite granodiorite. These rocks occur in a down-dropped structural block along the southern limit of a volcanic-plutonic complex exposed at Von Frank Mountain. The stockwork consists of chalcopyrite and arsenopyrite, minor molybdenite, and free gold in quartz-carbonate veins in a cupola of the intrusive system. Alterations are sericite, silica, and dolomite replacements which are similar to those in the Chicken Mountain porphyry Au deposit (Bundtzen and others, 1992). A K-Ar mineral isotopic age of 69.9 Ma was obtained from a granitoid pluton north of the prospect (Moll and others, 1981). Bundtzen (1999) indicates which Cu and Au have a correlation coefficient of 0.92; coefficient values between Au and other metals are much lower. Grades range from 0.5 to 19.1 g/t Au and from 0.05% to 0.45% Cu. One drill hole intercepted about 45 m grading 1.2 g/t Au and 0.08% Cu. The Von Frank Mountain deposit is the most northeastern porphyry deposit known in the Kuskokwim Mountains metallogenic belt.

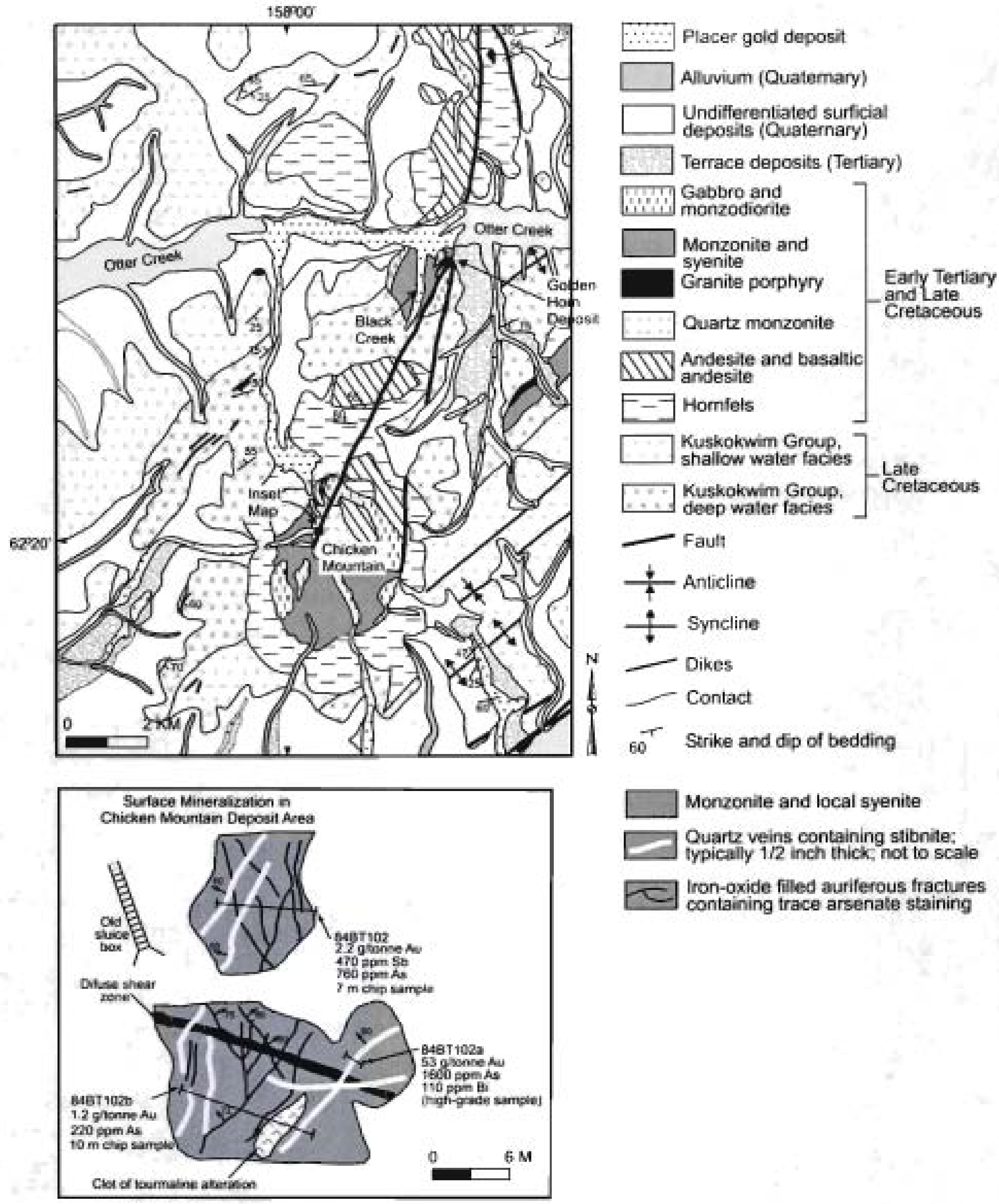


Figure 108. Chicken Mountain and Black Creek granitoid-related Au-Ag (Cu) deposits, Flat district, Kuskokwim Mountains metallogenic belt, Southwestern Alaska. Schematic geologic map showing locations of Au-bearing plutons. Note the radial distribution of placer gold deposits surrounding the mineralized plutons. Inset shows style of mineralization at the Chicken Mountain gold polymetallic deposit. Adapted from Bundtzen and others (1992), and Bundtzen and Miller (1997).

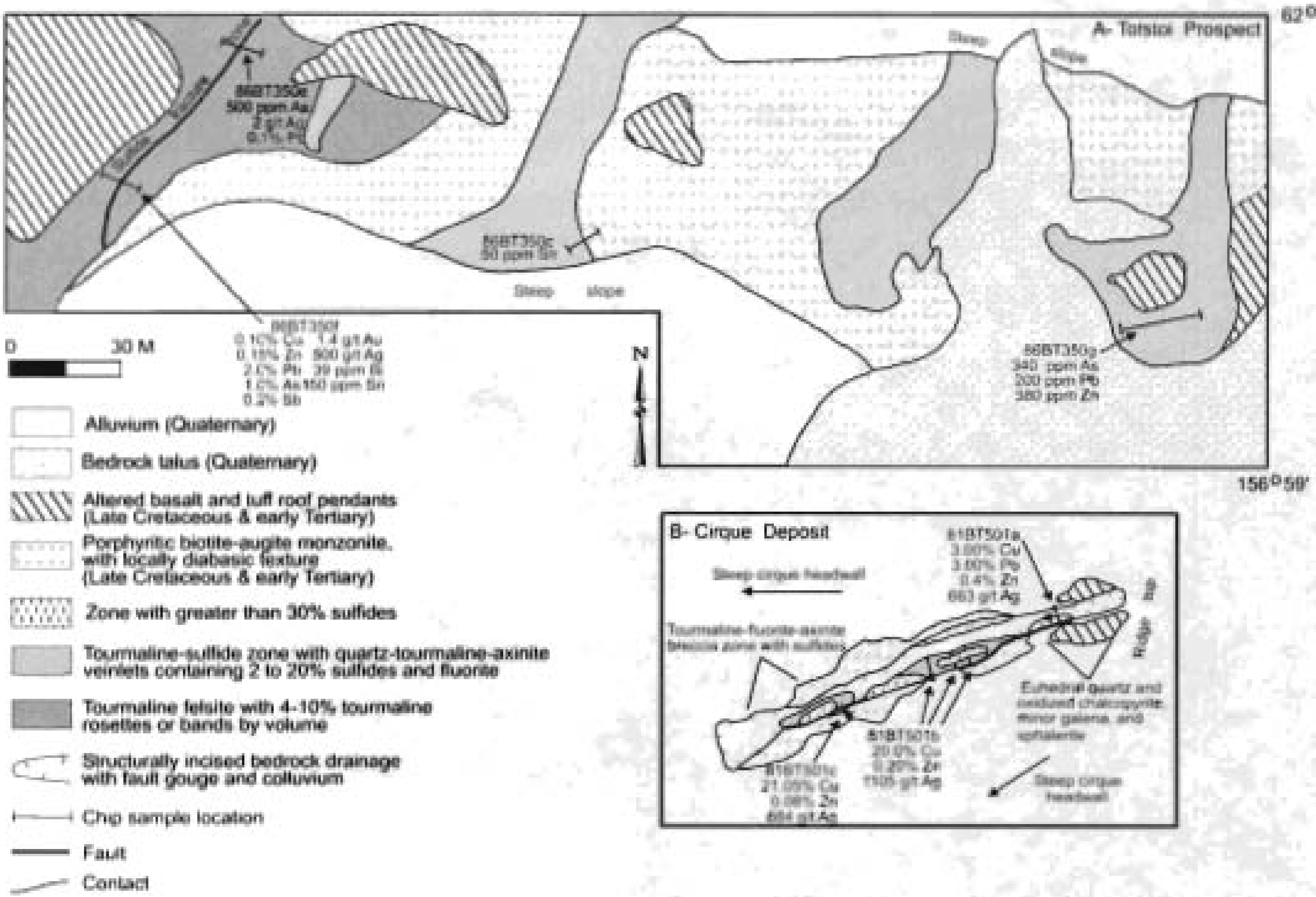


Figure 109. Beaver Mountains Ag-Sn polymetallic vein deposits, Kuskokwim Mountains metallogenic belt, Southwestern Alaska. Two examples of high-level, plutonic-related, B-enriched Ag-Sn polymetallic deposits or prospects. A - Tolstoi prospect, illustrating extensive tourmaline-sulfide breccia zones. B - Cirque Cu-Ag (Au) deposit, showing fracture zone and tourmaline-axinite-fluorite breccia zone. Both deposits occur just below roof pendants of basaltic andesite. Adapted from Bundtzen and Miller (1997).

Peraluminous Granite Porphyry Au Deposits - Kuskokwim Mountains Metallogenic Belt

Peraluminous granite porphyry Au deposits are only recently identified in the central Kuskokwim Mountains. Placer Au deposits in the area have been mined for many years (Mertie, 1936; Bundtzen and Laird, 1980; Bundtzen, 1986). The best examples of the porphyry deposits are at Donlin Creek, the Independence Mine on Ganes Creek in the Innoko District, and Vinasale Mountain, about 25 km south of McGrath. Nine other occurrences are located in the Iditarod Quadrangle (Bundtzen and others, 1985). K-Ar mineral ages for the igneous rock hosting all the deposits range from 69 to 71 Ma (Bundtzen and Laird, 1982; Solie and others, 1991; Miller and Bundtzen, 1994). A K-Ar sericite age of 68.1 Ma is reported for the Vinasale deposit by DiMarchi (1993) which within analytical uncertainty is the same age as the host pluton.

Donlin Creek Porphyry Au Deposit

The Donlin Creek porphyry Au deposit (fig. 110) is hosted in a porphyritic rhyodacite, granite porphyry, and minor granodiorite dike and sill complex which intruded a flysch of the Late Cretaceous Kuskokwim Group (Ebert and others, 2000; Cady and others, 1955). More than seven mineralized zones are known (Bundtzen and Miller, 1997). K-Ar isotopic ages range from 65.1 to 70.9 Ma for granite porphyry sills at the Snow Gulch portion of the property (Miller and Bundtzen, 1994); subsequent $^{40}Ar/^{39}Ar$ and U-Pb ages are similar. The Au-As-Sb-Hg deposit occurs in a 2 by 6 km area, and is associated with narrow, steeply-dipping, irregular, and discontinuous quartz and quartz-carbonate veins and veinlets (Ebert and others, 2000). Quartz vein textures ranges from massive to fine-grained, and comb to bladed. Ore minerals are As sulfosalts (rare), cinnabar (rare to uncommon), stibnite (common), arsenopyrite (very common), and As pyrite (very common). The Donlin Creek deposit is structurally controlled along north-northeast-trending extensional fractures, and the deposit is best developed where mineralizing fluids intersected competent host lithologies such as massive graywacke and porphyry dikes and sills (Ebert and others, 2000). The Donlin Creek deposit contains 127.4 million tonnes grading 2.89 g/t Au or 368.2 Au gold. The deposit may be the largest currently known in Alaska (Bundtzen and others, 2000).

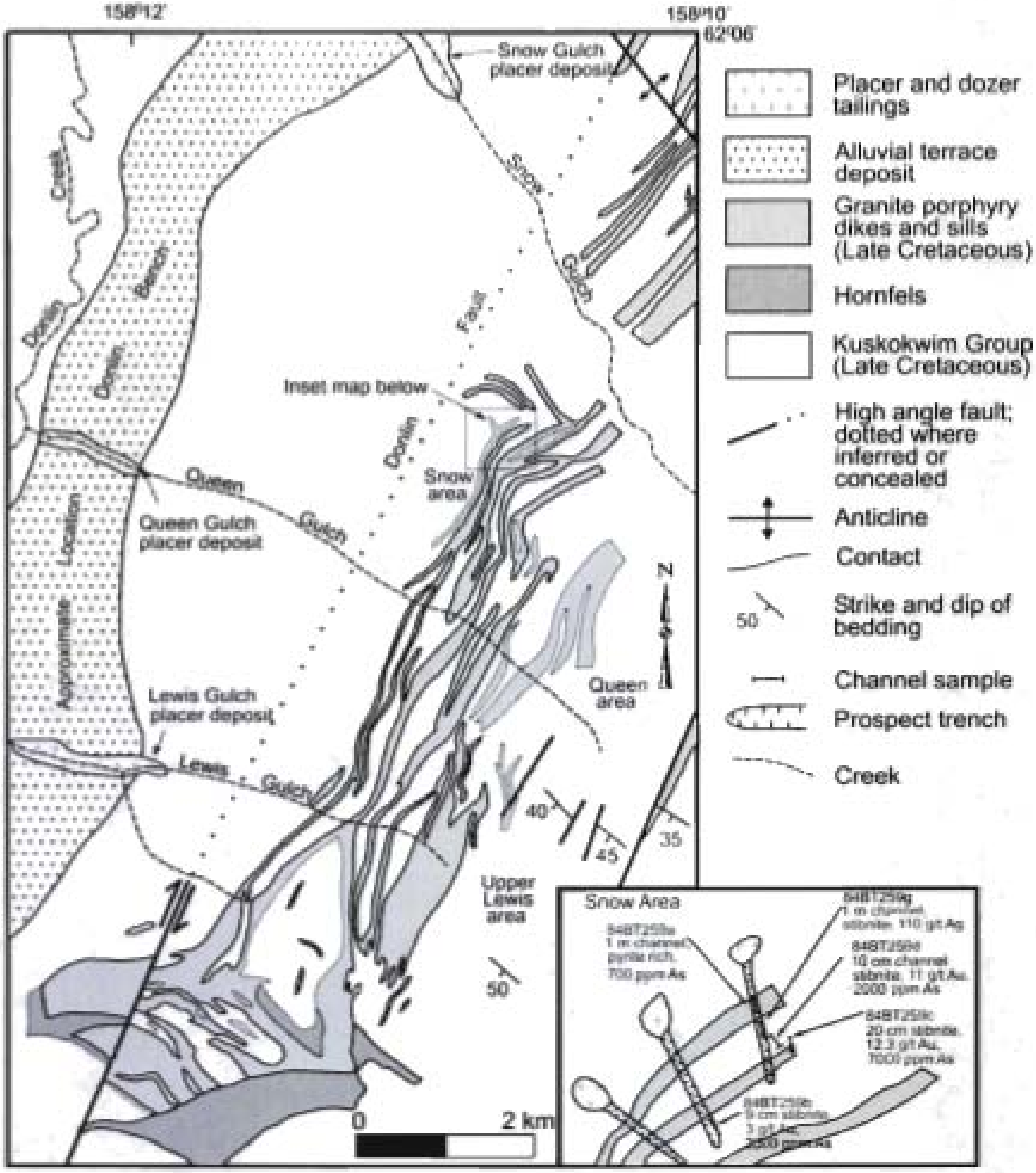


Figure 110. Donlin Creek porphyry Au deposit, Southwestern Kuskokwim Mountains metallogenic belt, Southwestern Alaska. Schematic geologic map of Donlin Creek dike swarm and adjacent units. Adapted from Retherford and McAtee (1994) and Bundtzen and Miller (1997).

Vinasale Granitoid-Related (Porphyry) Au Deposit

The Vinasale Mountain granitoid-related Au (porphyry Au) deposit (fig. 111) (DiMarchi, 1993; Nokleberg and others, 1995a), which lies about 25 km south of McGrath, consists of Au-Ag-Sb-Pb-As sulfide minerals which occur as disseminations, in breccia, and in dolomite veins and segregations. Mafic minerals exhibit silica, sericite, and propylitic replacements. The highest Au concentrations occur in the central zone of the deposit in areas of intense sericite and silica alteration. Over ninety percent of the gold occurs in As and Sb sulfides and sulfosalts. Correlation coefficients are highest between Au and As (0.81). The deposit is hosted in various phases of the Vinasale pluton which consists of a multiphase, 6 km^2 intrusion composed of monzonite, quartz monzonite, and granite porphyry. The pluton intrudes the Late Cretaceous Kuskokwim Group. A K-Ar biotite isotopic age of 69.0 Ma is obtained a quartz monzonite phase of the Vinasale Mountain pluton (Bundtzen, 1986). Based on about 11,260 m of drilling, a central zone of the Vinasale Deposit contains reserves of about 10.3 million tonnes grading 2.40 g/t Au (24,540 kg of gold resource) and with minor Ag and Sb, or about (Bundtzen and Miller, 1997). Recent industry exploration, including soil surveys and geophysical and drilling programs (DiMarchi, 1993) indicate that the Vinasale Mountain as one of the most important lode gold deposits in the Kuskokwim Mineral Belt.

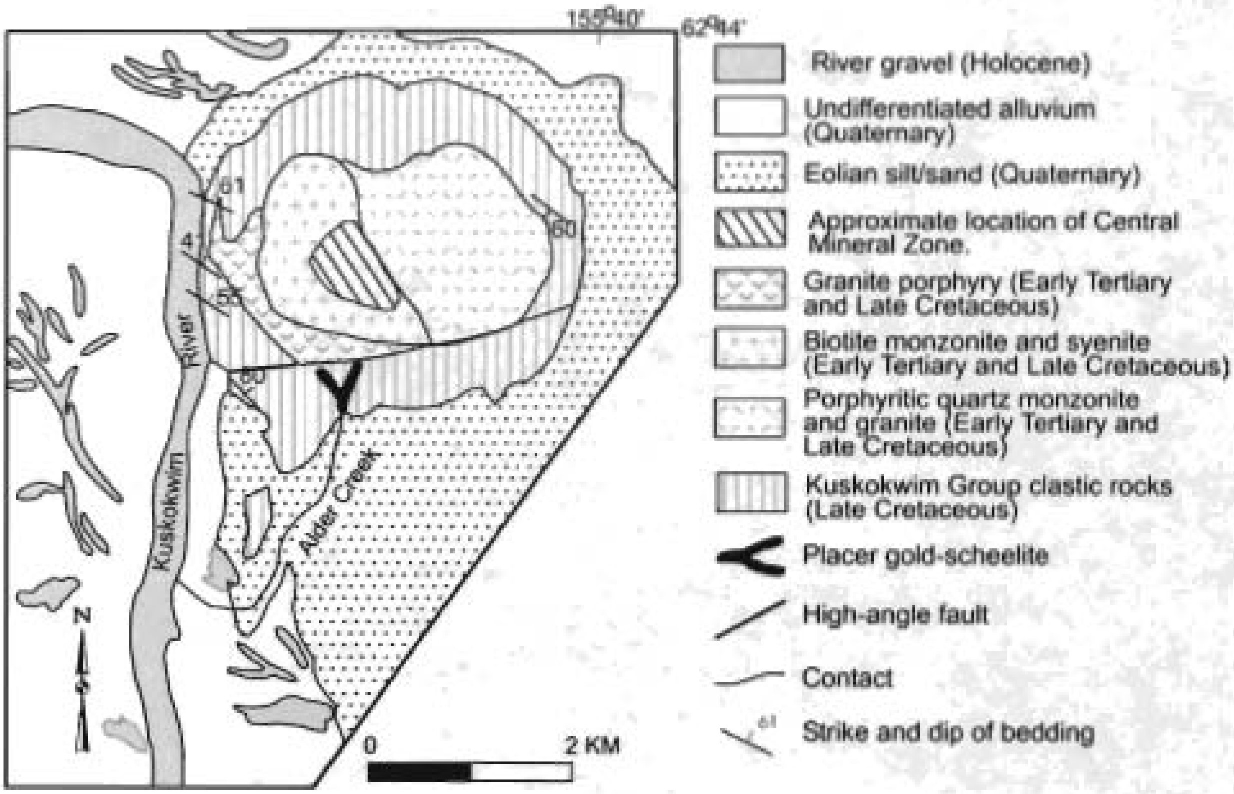


Figure 111. Vinasale Mountain granitoid-related (porphyry) Au deposit, Kuskokwim Mountains metallogenic belt, Southwestern Alaska. Schematic geologic map showing location of Central Mineral Zone. Adapted from Bundtzen (1986), DiMarchi (1993), and Bundtzen and Miller (1997).

Marshall District of Granitoid-Related Au Deposits, West-Central Alaska

A suite of granitoid-related Au deposits of the Marshall district occur at the Arnold prospect near the head of Willow Creek in southwestern Alaska (Bundtzen and Miller, 1997). The deposits consist of quartz-carbonate veins which occur in, or near sheared Late Cretaceous or early Tertiary alaskite sills which intrude the Koyukuk island-arc terrane (Nokleberg and others, 1994c, 1997c). The significant deposits and prospects include the Arnold, Kako, and Stuyahok gold prospects.

The Arnold prospect consists of an approximate east-west-trending suite of low sulfide polymetallic veins which contain gold in quartz and carbonate gangue. The sulfide minerals, which comprise less than one percent of the deposit, are disseminated chalcopyrite, molybdenite, galena, and tetrahedrite. The vein system occurs in, or near sheared alaskite sills. A distinctive albite rhyolite dike or sill parallels the main vein system. The sills intrude Neocomian (early Early Cretaceous) greenstone derived from tholeiite metabasalt and metaandesite. The deposit extends along strike for least 400 meters and ranges from 0.5 to 2 m thick. Abundant carbonate alteration occurs adjacent to the main polymetallic veins. Mo averages about 80 ppm in the veins, Mo anomalies occur in soils. Grab samples of rocks contain up to 97 g/t and 100 g/t Ag.

Other significant gold-polymetallic mineralization in the Marshall district include important lode and associated placer gold occurrences at Kako Creek and Stuyahok, about 55 km and 75 km east of the Arnold prospect, respectively (Miller and others, 1998). Both of the latter prospects resemble the Donlin Creek deposit described above, and are spatially related to small, Late Cretaceous sills and dikes which intrude the Koyukuk terrane.

Au-Ag-Hb-Sb Epithermal Deposits, Kuskokwim Mineral Belt

Epithermal systems of the Kuskokwim Mineral Belt are subdivided into three major types (Bundtzen and Miller, 1997; Gray and others, 1997): (1) structurally controlled (Au)-Hg-Sb deposits related to altered olivine basalt dikes; (2) low temperature Ay-Sb-Hg minerals in shear zones in high level portions of intrusions; and (3) chalcedony breccias hosted in subaerial volcanic piles, including stockwork veins adjacent to volcanic calderas. Although generally poorly classified, the three epithermal deposit types probably correspond to deposit models the hot springs Au-Ag, Creede epithermal, and Sado epithermal deposit models of Cox and Singer (1986).

The structurally controlled Au-Sb-Hg deposits (type 1) are part of a well-studied Hg belt (Sainsbury and MacKevett, 1965) which extends nearly 500 km from the Red Top mine near Bristol Bay to Mount Joaquin near McGrath. The principle type 1 deposit is the Red Devil Hg-Sb mine near Sleetmute which produced more than 85 percent of the 1.5 million kg of past Hg production from the Kuskokwim Mineral Belt, and was the largest mercury mine in Alaska. At Red Devil, high-angle structures cut flysch of the Cretaceous Kuskokwim Group and altered mafic dikes. The fluids tht deposited cinnabar and stibnite utilized faulted mafic dikes as structural conduits; however no clear link exists between dikes and the deposit. Bundtzen and Miller (1997), Gray and others (1997), and Miller and others (1989) all report which fluid inclusion data from type 1 epithermal deposits in the Kuskokwim Mineral Belt which indicate shallow depths of ore deposition at less than 1,500 bars pressure, and less than 200 C. Gray and others (1997) report radiometric ages ranging from 72.5 to 76 Ma for several deposits. Type 2 Au-Sb-Hg vein deposits include the Dishna River Au-Sb prospect and Glenn and Minnie Gulch prospects, which cut high level plutonic rocks in the Flat area (Bundtzen and others, 1992; Bundtzen and Miller, 1997).

During 1998-1999, an important new epithermal Au-Ag deposit (type 3 above) was discovered at the Kaiyah prospect about 125 km southwest of McGrath (Bundtzen and others, 2000). The deposit occurs about 2 km from a curvilinear, faulted contact between the Early Cretaceous flysch of the Yukon-Koyukuk basin and andesite tuff, welded tuff, and rhyodacite domes of the Late Cretaceous and early Tertiary Poison Creek caldera. The volcanic rocks have isotopic ages of 42.5 and 65.2 Ma, and the caldera covers 75 km^2 (Bundtzen and Miller, 1997). The deposit occurs in a 4 by 2.5 km altered area which contains abundant silica alteration, and extensive alunite, jarosite, and sericite alterations. Individual Au-Ag veins average 30 m thick and extend about 450 m along strike. Anomalous elements are Sb, Hg, As, Te, Pb, Cu, and Bi. Geological and geochemical data suggest that the Kaiyah deposit is a high sulfidation epithermal Au-Ag deposit with a Ag:Au ratio of about 40:1. Grades range up to 10.8 g/t Au gold and 465 g/t Ag (Bundtzen and others, 2000).

Other Significant Deposits in the Kuskokwim Mineral Belt

The high grade Au-Bi-Cu skarns at Nixon Fork (fig. 112), 45 km, northeast of McGrath, have been developed and mined since the 1920s. The ore deposits occur in irregular, and rich, pipe-like, garnet-epidote-magnetite-gold-copper-skarns which rim a monzonite stock that has a K-Ar isotopic age of 68 Ma. The intrusion cuts Ordovician limestone of the Novi Mountain Formation (Patton and others, 1994). From 1920 to 1999 Nixon Fork Mining Company and previous operators produced 6,210 kg Au, and byproduct Bi and Cu from about 128,300 tonnes of ore (Bundtzen and others, 2000).

East-Central Alaska Metallogenic Belt of Granitic Magmatism Deposits (Younger, Late Cretaceous and Early Tertiary Part; Belt ECA) East-Central Alaska and Northern Canadian Cordillera

This major, long, extensive, and complex metallogenic belt of Late Cretaceous and early Tertiary granitic-magmatism-related deposits (belt ECA) (fig. 103; tables 3, 4) occurs in east-central Alaska and the western Yukon Territory (Nokleberg and others, 1995a). The significant deposits are mainly various W skarn, porphyry Cu-Mo deposits, polymetallic vein, Sn greisen and vein, and Sb-Au vein deposits in the northern and eastern Yukon-Tanana terrane (table 4). Described below are the major Casino and Taurus porphyry Cu-Mo deposits, and the Road Metal tourmaline-topaz-quartz sulfide greisen deposit.

The East-Central Alaska part of the belt contains a variety granitic magmatism deposits which are hosted in Late Cretaceous and sparse early Tertiary granitoids which intrude the northern and eastern Yukon-Tanana terrane (Table 4). Major deposits are: (1) a W skarn deposit at Salcha River (possibly mid-Cretaceous); (2) porphyry Cu-Mo deposits at Mosquito, Asarco, Taurus, and Casino; (3) a Sn greisen deposit at Ketchem Dome; (4) Sn greisen and Sn vein deposits at Ketchen Dome and Lime Peak; and (5) a felsic-plutonic U deposit at Roy Creek (former Mount Prindle). For deposits in groups (1) to (4), the host rock of the Yukon-Tanna terrane consists of metamorphosed and penetratively deformed, middle Paleozoic and older, quartz-metasedimentary, sparse metavolcanic, and rare middle Paleozoic metagranitoid rocks (Foster and others, 1987). For the deposits in group (5), the granitoid rocks hosting the felsic-plutonic U deposits intrude a sequence of weakly deformed, quartz-rich sandstone, grit, shale, and slate, containing probable Early Cambrian fossils, which form part of the Wickersham passive continental margin terrane (Jones and others, 1987). Yukon Territory part of the belt contains porphyry Cu-Mo deposits in the Carmacks area.

Casino Porphyry Cu-Mo-Au Deposit

The large Casino (Patton Hill) porphyry Cu-Mo-Au deposit in the Carmacks area, Yukon Territory, is hosted in a breccia pipe and associated porphyritic dacite and granite of the Casino Intrusive Complex which has a K-Ar isotopic age 71.3 Ma, which intrudes the Early Jurassic Klotassin batholith. The deposit occurs in the center of the complex and consists of a central, conical breccia pipe, fine-grained quartz monzonite, intrusion breccia, and plagioclase porphyry intrusions (EMR Canada, 1989; Mining Review, 1992; Sinclair, 1986; Northern Miner, December 6,1993; Bower and others, 1995). An innermost zone of potassic alteration is associated with hypogene sulfides, and contains superimposed phyllic and pyrite alteration, and weakly-developed, peripheral propylitic alteration. Supergene minerals are chalcocite, digenite, and covellite which occur as replacements of hypogene sulfides. A 70-m-thick, Au-bearing leached cap overlies a well developed supergene enrichment blanket. Estimated reserves are: (1) for a combined Au-oxide zone in the leached cap and an copper-oxide supergene zone, 28 million tonnes grading 0.68 g/t Au, 0.11% Cu, and 0.024% Mo; (2) for a sulfide supergene zone, 86 million tonnes grading 0.41 g/t Au, 0.43% Cu, and

0.031% Mo; and (3) for a hypogene zone, 445 million tonnes grading 0.27 g/t Au, 0.23% Cu, and 0.024% Mo (Godwin, 1976; Bower and others, 1995).

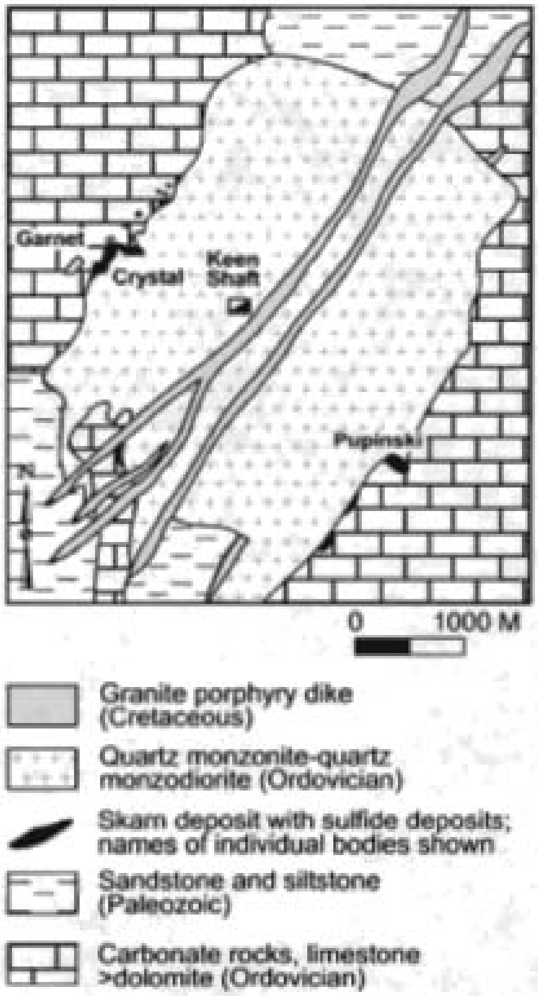


Figure 112. Nixon Fork Cu-Au skarn deposit, adjacent prospects, and surrounding area, Kuskokwim Mountains metallogenic belt, Southwestern Alaska. Schematic geologic map. Porphyry dikes, alteration, and main stock all yield identical K-Ar ages of 69 Ma. Modified from Cutler (1994) and Newberry and others (1997).

Taurus Porphyry Copper-Molybdenum Deposit

The Taurus porphyry Cu-Mo deposit (E.R. Chipp, written commun., 1984; Leriche, 1995) occurs in the eastern part of the Yukon-Tanana Upland in east-central Alaska, and consists of chalcopyrite, molybdenite, and pyrite that occur as disseminations and in veinlets composed of quartz-orthoclase-sericite, quartz-magnetite-anhydrite, quartz-sericite-pyrite-clay-fluorite, and quartz-orthoclase-biotite. The disseminations and veinlets occur in at least three areas in a zone of hypabyssal plutons about 13 km long and 1.6 km wide. The plutons consist of early Tertiary granite porphyry, granodiorite, and quartz latite porphyry (57 Ma, T.K. Bundtzen, written commun., 1994) which intrude middle Paleozoic or older quartz-muscovite schist of the Yukon-Tanana terrane. The core of the pluton exhibits potassic alteration whereas sericitic alteration occurs in the periphery and adjacent wall rocks. The sequence of alteration, from oldest to youngest, is hydrothermal potassic, propylitic, phyllic, and sericitic. Magnetite-rich cores of the potassic-altered granite porphyries contain sparse sulfides. Higher concentrations of Cu and Mo sulfides occur in the periphery along with phyllic alteration. Tourmaline, fluorite, and replacement of chalcopyrite by chalcocite occur locally. Numerous faults and shears occur in the deposit. The deposit contains a resource of 23 million tonnes grading 0.3% Cu and 0.039% Mo (Leriche, 1995).

Road Metal Tourmaline-Topaz-Quartz-Sulfide Greisen Deposit

The Road Metal deposit displays the classic features of a tourmaline-topaz-quartz sulfide greisen deposit (Bundtzen, Schaefer, and Dashevsky, 2003). The deposit occurs adjacent to the Alaska Highway in East-Central Alaska. $^{40}Ar/^{39}Ar$ isotopic ages of 68-70 Ma are obtained from hydrothermal sericite in veins. The Road Metal deposit consists of structurally controlled, sulfide-rich, tourmaline-muscovite greisen, semi-massive sulfide replacement veins, massive white mica alteration zones, and smokey-quartz-rich, potassic alteration zones that hosted in granite and quartz monzonite with a K-Ar isotopic age of 95 Ma. However, sulfide-rich quartz monzonite and white mica alteration minerals in greisen yield $^{40}Ar/^{39}Ar$ isotopic ages ranging from 7067 Ma. Sulfide and sulfosalt minerals in drill core include kobellite, boulangerite, owyheeite, galena, chalcopyrite, pyrite, and tetrahedrite. The sulfide greisens strike northeast, dip vertically, range from 40-50 meters wide, and extend for about 1,400 meters along strike. More than twenty diamond drill holes totaling about 5,300 meters of drilling completed and significant mineralization occurs in about half of the drill holes. Up to 85.8 g/t Au, 4,634 g/t Ag, 6.00% Sb, 2.42% Bi, and 3.83% Cu occur in 1.5-meter-long drill intercepts. No resource or reserve estimates are yet established. A preliminary quartz fluid inclusion study in mineralized greisen indicates primary fluid inclusions have homogenization temperatures from 322-381° C. and contain 16.0 to 18.2 weight percent NaCl (Cameron Rombach and John Mair, University of Western Australia, written commun., 2001). Secondary inclusions have homogenization temperatures ranging from 277-430° C and contain 23.1 to 29.9 weight percent NaCl. These results are consistent with formation in a relatively high temperature saline greisen or a porphyry Cu-Au system at pressures of 1-3 kilobars.

The Road Metal deposit shares some features with other granitoid-related deposits in the East-Central Alaska metallogenic belt (younger part) in the Yukon-Tanana Upland, including high Au and Ag, elevated Bi, major oxide chemistry of host intrusive rocks, and regional geologic setting. A high Bi:Au ratio of about 250:1, high Ag:Au ratio of about 40:1, elevated Sn and W, and intrusive and deposit isotopic ages of 67-70 Ma, collectively suggest that the Road Metal deposit is comparable with deposits hosted in the Carmacks Plutonic Suite in the western Yukon Territory, with isotopic ages of 75-55 Ma, and also with other deposits in the East-Central Alaska metallogenic belt, including the Casino, Taurus, and Mount Nansen porphyry Cu-Mo deposits. If the 400 km of right-lateral strike-slip along the Denali fault is restored, the area hosting the Road Metal deposit may link up with the Southern Alaska Metallogenic Belt (described below), which is near Chulitna and which contains both Au-polymetallic greisen and porphyry deposits as Golden Zone.

Plutonic Rocks Hosting East-Central Alaska Metallogenic Belt

The East-Central Alaska metallogenic belt (younger part) is hosted in Late Cretaceous (with isotopic ages of about 94 to 70 Ma), and in early Tertiary granitoid rocks (with isotopic ages of about 74 to 55 Ma) which are the younger part of the Yukon-Tanana igneous belt (Miller, 1994; Moll-Stalcup, 1994) and the correlative Carmacks Plutonic Suite (Mortensen and others, 1994). In East-Central Alaska, these granitoids intrude the Yukon-Tanana Upland which is underlain by the large Yukon-Tanana terrane, and a collage of smaller, continental-margin terranes, including the Wickershim and Manley terranes (Nokleberg and others, 1994c, 1997). In East-Central Alaska, most of the Late Cretaceous granitoids are calc-alkalic and intermediate in composition, and chemical data indicate which some of the plutons formed from magmas contaminated by continental crust in areas underlain by the continental-margin Yukon-Tanana terrane (Foster and others, 1987; Miller, 1994). The younger, dominantly early Tertiary granitoids generally exhibit high initial Sr ratios and are interpreted as forming from a mixture of mantle-derived magma and continental crust (Foster and others, 1987; Miller, 1994).

The Late Cretaceous granitoid plutonic rocks which host the lode deposits in the western Yukon Territory (Carmacks area) consist of calc-alkaline granodiorite and quartz monzonite plutons of the Carmacks Plutonic Suite which intrude the Yukon-Tanana and locally the Stikinia terranes (fig. 103) (Mortensen and others, 1994).

Origin of and Tectonic Setting for East-Central Alaska Metallogenic Belt (Younger Late Cretaceous and Early Tertiary Part)

The younger, Late Cretaceous and early Tertiary Yukon-Tanana igneous belt, and the Carmacks Plutonic Suite are herein interpreted as part of the subduction-related Kluane arc which occurred along the Late Cretaceous and early Tertiary continental margin of southern and southeastern Alaska (Plafker and others, 1989; Moll-Stalcup, 1994; Nokleberg and others, 1994b, 1997a, 2000). In Alaska, the other major parts of the Kluane arc (Moll-Stalcup, 1994) are the Kuskokwim Mountains sedimentary, volcanic, and plutonic belt, the Alaska Range-Talkeetna volcanic-plutonic belt, and the Yukon-Kanuti igneous belt. The Kluane arc is interpreted as forming immediately after the accretion of Wrangellia superterrane in the mid-Cretaceous, and was substantially dismembered by major dextral-slip faulting in the Cenozoic (Plafker and others, 1989; Nokleberg and others, 1994b, 2000). The Kluane arc is tectonically linked to the Late Cretaceous part of the Chugach accretionary-wedge terrane (Valdez Group and equivalent units) and to the early Tertiary part of the Prince William accretionary-wedge terrane (Orca Group and equivalent units; Plafker and others, 1989; Plafker and Berg, 1994; Nokleberg and others, 1997e, 2000).

Southern Alaska Metallogenic Belt of Granitic Magmatism Deposits (Belt SA) Central and Northern Part of Southern Alaska

The major Southern Alaska metallogenic belt contains a wide variety of felsic-magmatism-related deposits (fig. 103; tables 3, 4) and occurs in the central and northern parts of Southern Alaska (Nokleberg and others, 1995a). The metallogenic belt is hosted in the Late Cretaceous to early Tertiary Alaska Range-Talkeetna Mountains volcanic-plutonic belt (Nokleberg and others, 1994c, 1997c). The granitoid rocks in this igneous belt range in age from Latest Cretaceous to early Tertiary; the largest events occurred in the early Tertiary (Moll-Stalcup, 1994). The significant deposits in the belt are (table 4) (Nokleberg and others, 1997a, b, 1998): a porphyry Cu deposit at Kijik River in the Bristol Bay District; a porphyry Cu-Au deposit at Pebble Copper in western-southern Alaska; and polymetallic vein, Au-Ag breccia pipe, or porphyry Cu-Au deposit at the Golden Zone in the Chulitna district (Nokleberg and others, 1993). Other deposits in the belt are: Ag-Pb-Au (Cu) skarn deposits at Bowser, Sheep Creek, Tin Creek, and Rat Fork Creek in the Farewell District; various Au-Ag polymetallic vein, porphyry Cu, and porphyry Cu-Mo deposits at Nim, Nimbus, Ready Cash, and Silver King in the Chulitna district and at Treasure Creek; various polymetallic vein and porphyry Cu deposits at Bonanza Hills, Nabesna Glacier, and Partin Creek; a porphyry Mo deposit at Miss Molly (Hayes Glacier); a Cu-Au skarn deposit at Zackly in the Valdez Creek district (fig. 113; table 4); a Sn greisen and Sn vein deposits at Boulder Creek (Purkeypile), Coal Creek, Ohio Creek, and Sleitat (fig. 114; table 4); and a carbonate-hosted Hg(?) deposit at White Mountains.

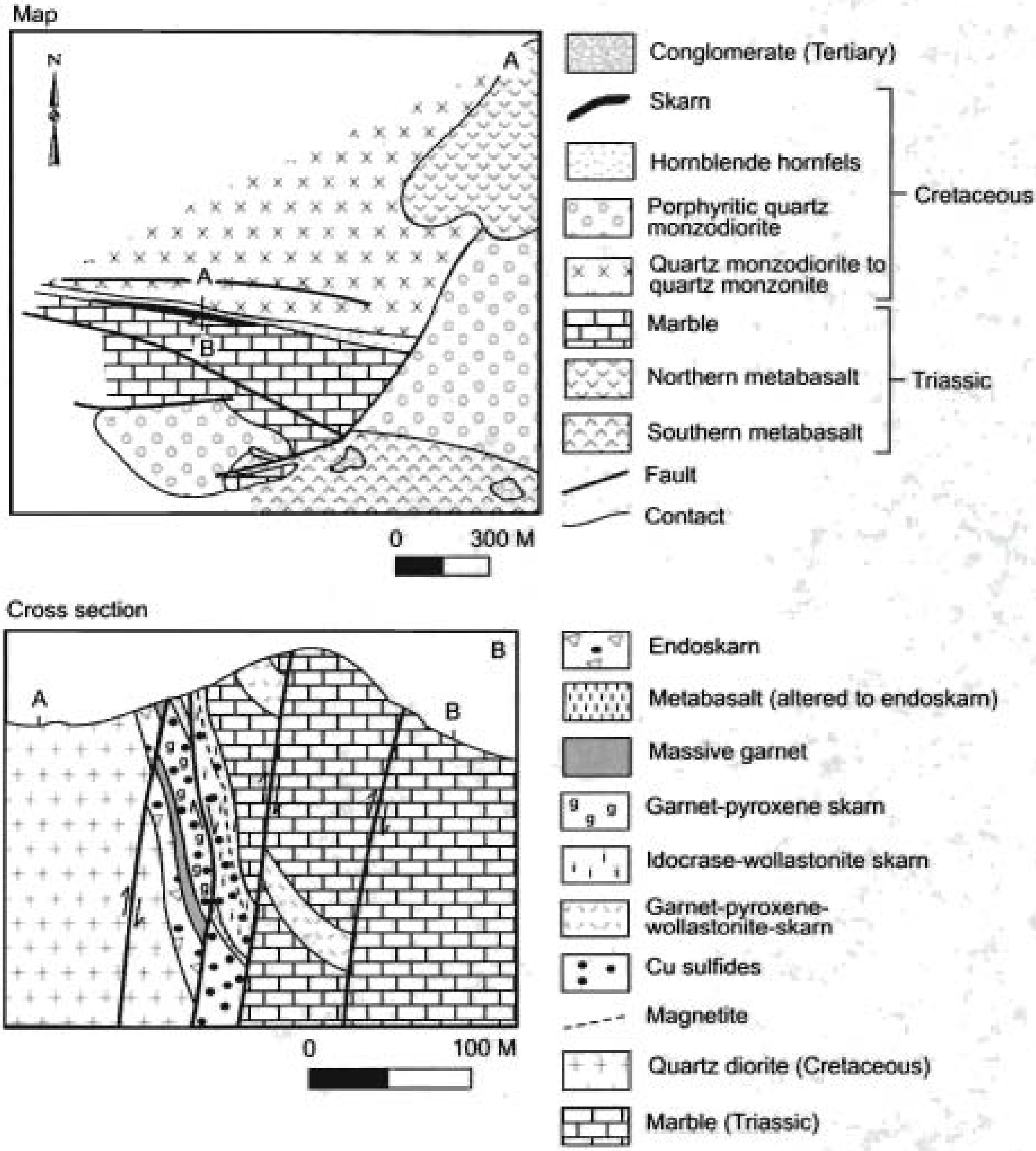


Figure 113. Zackly Cu-Au skarn deposit, Southern Alaska metallogenic belt, Southern Alaska. Schematic geologic map and cross section. Adapted from Nokleberg and others (1986), and Newberry and others (1997).

Tin Creek Cu-Pb-Zn Skarn Deposit

The Tin Creek Cu-Pb-Zn skarn deposit (fig. 115) (Szumigala, 1987; Newberry and others, 1997a) consists of pyroxene-rich skarn with abundant sphalerite and minor chalcopyrite, and garnet skarn with chalcopyrite and minor sphalerite; and locally abundant epidote and amphibole. The pyroxene skarn is distal, and the garnet skarn is proximal to an extensive Tertiary dacite to andesite poprhyry dike swarm that intrudes polydeformed, middle Paleozoic contact metamorphosed, clastic and carbonate rock. The skarn forms small, discontinuous bodies up to 3 m wide along dikes, as manto replacement in marble, and as irregular bodies along along thrust and high-angle faults. The skarns are zoned, with garnet-chalcopyrite-rich skarn proximal to the dike swarm center, and pyroxene-sphalerite-rich skarn distal to the dike swarm. Garnet-rich skarn grades 0.5-1% Cu and 1-2 oz/t Ag, and negligible Zn and Pb. Pyroxene-rich skarn generally contains 5-20% Zn, 0.1-3% Pb, 0.5-2% Cu, and 2-9 oz/t Ag. In a single outcrop, skarn pyroxene becomes more Fe-rich, and sulfides increase towards marble. Sulfide veins occur locally in dikes and wall rocks. Many dikes are lacking associated skarn, and many dikes possess skarn only along one contact.The deposit has a resource of an estimated 230,000 tonnes with 16% combined Pb and Zn.

Kijik River Porphyry Cu Deposit

The Kijik River porphyry Cu deposit consists of a large area of low-grade, disseminated chalcopyrite, pyrite, and minor molybdenite which occur in and adjacent to an early Tertiary dacite porphyry (Eakins and others, 1978; Nelson and others, 1985; T.K. Bundtzen, written commun., 1984). The deposit contains a distinctive orange gossan which extends over a 3 km^2 area. The gossan contains an extensive stockwork, and zones of sericite and silicic alteration and sulfides. The stockwork varies from weak to intense, consists mainly of quartz and sulfide minerals, and is developed both in the dacite porphyry and in overlying volcanic rocks. Extensive propylitic and silicic alteration occurs in the dacite porphyry. The deposit contains a possible resource of 90 million tonnes and some samples containing up to 0.25% Cu and 0.17% Mo (T.K. Bundtzen, written commun., 1984).

Golden Zone Deposit

The Golden Zone deposit exhibits features common to polymetallic vein, Au-Ag breccia pipe, and porphyry Cu deposits. The sulfide mineralogy consists of auriferous arsenopyrite and minor chalcopyrite, sphalerite, and pyrite in a quartz gangue which fills open spaces in a breccia pipe (Hawley and Clark, 1974; Swainbank and others, 1978; C.C. Hawley, written commun., 1985, 1990). The breccia pipe occurs in the highly-fractured central part of an Late Cretaceous early Tertiary quartz diorite porphyry. The ore zone is about 125 m in diameter. At the surface, high-grade mineralization occurs in a breccia pipe which is approximately 75 m wide. Abundant polymetallic veins occur adjacent to the porphyry. The breccia pipe contains an estimated 8.9 million tonnes grading 3.2 g/t Au and minor Cu and Ag. The deposit contains an inferred reserve of 1.6 million tonnes grading 5.2 g/t Au, and 0.5% Cu. An old mine at the deposit produced 50 kg Au, 267 kg Ag, and 19 tonnes Cu. The diorite porphyry has been dated at 68 Ma (Swainbank and others, 1978) and intrudes Permian to Jurassic sedimentary rocks of the Chulitna (ophiolite) terrane, a fault-bounded fragment within the highly-deformed Kahiltna overlap assemblage.

Nabesna Glacier polymetallic vein(?) deposit

The Nabesna Glacier polymetallic vein(?) deposit (Richter, 1975) occurs in three contiguous areas which contain: (1) quartz veins and veinlets containing pyrite and minor chalcopyrite and sphalerite; (2) a zone of disseminated malachite and azurite; and (3) a zone of intense alteration and breccia cemented by quartz, pyrite, chalcopyrite, and galena. The deposit occurs in late Paleozoic metavolcanic porphyry and metabasalt flows of the Tetelna Volcanics and may be related to nearby Late Cretaceous and early Tertiary granitoid plutons and dikes.

Sn and Mo Lode Deposits Hosted by Granitoid plutons of McKinley Sequence

A distinctive group of Sn-greisen, polymetallic vein, and porphyry Mo deposits occur in part of the southern Alaska metallogenic belt at Boulder Creek, Ohio Creek, Coal Creek, and Treasure Creek (Nokleberg and others, 1987, 1988, 1993). These and other lesser deposits occur in or near the early Tertiary McKinley sequence of granite and granodiorite plutons, which exhibit a narrow age range of 55 to 60 Ma (Reed and Lanphere, 1973; Lanphere and Reed, 1985). Many of the McKinley sequence plutons are peraluminous granites having high initial Sr ratios, suggesting incorporation of large amounts of crustal material (Reed and Lanphere, 1973; Lanphere and Reed, 1985). The plutons of the McKinley sequence intrude the the Wrangellia sequence of the Wrangellia supterterrane and the Kahiltna overlap assemblage (Jones and others, 1987). Lanphere and Reed (1985) interpreted these granitoid rocks as forming during early Tertiary collision of the Wrangellia composite terrane with various parts of the passive continental-margin Central composite terrane to the north. However, because more recent tectonic analyses suggest this collision occurred in the mid-Cretaceous (Nokleberg and others, 1985, 1994d; Plafker and others, 1989b; Plafker and Berg, 1994)., the McKinley sequence granitoid plutons are herein interpreted as forming during the crustal contamination of magmas from early Tertiary subduction along the southern margin of Alaska.

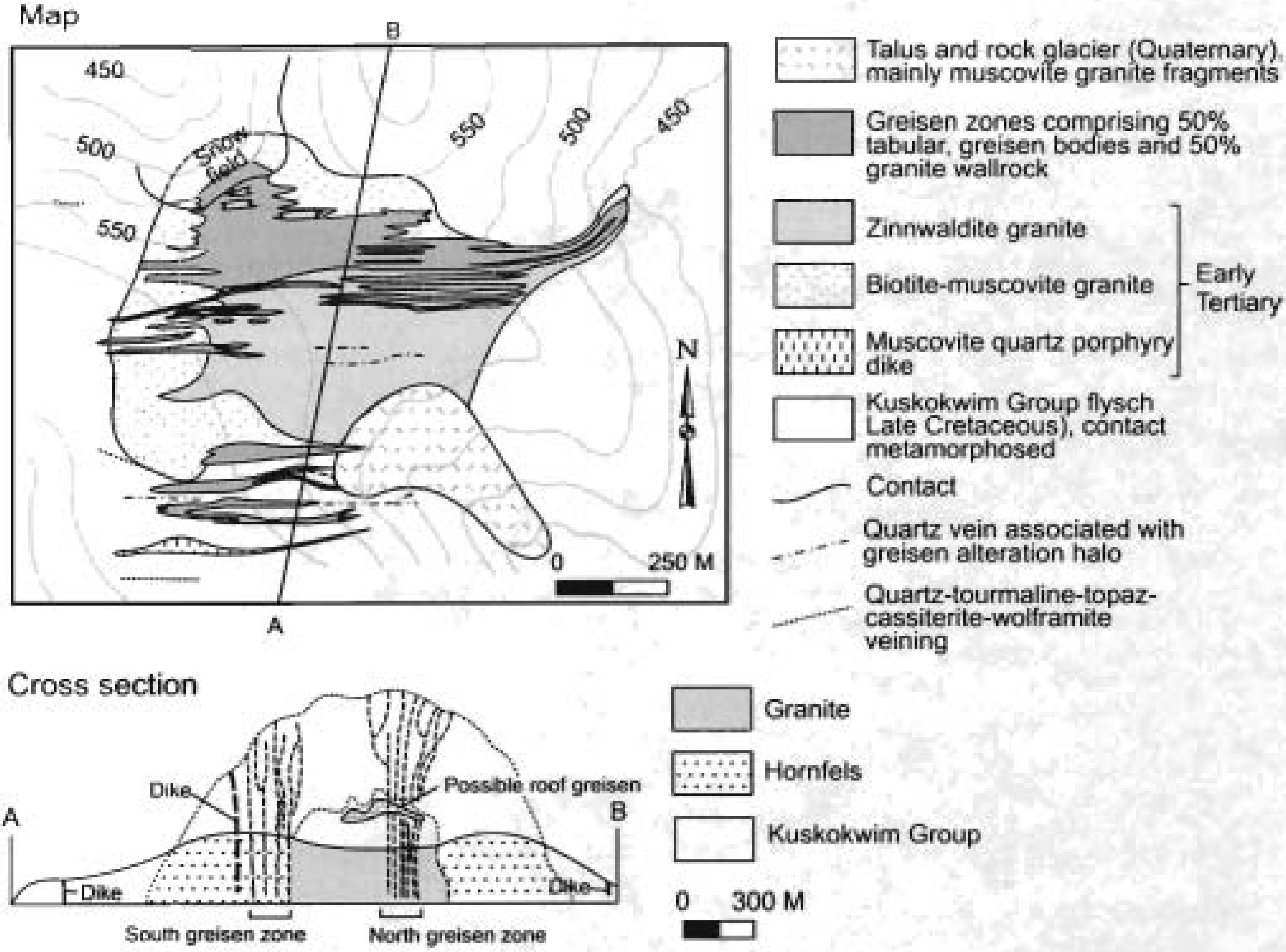


Figure 114. Sleitat Sn greisen and skarn deposit, Kuskokwim Mountains metallogenic belt, Southwestern Alaska. Schematic geologic map and cross section. Adapted from Burleigh (1991) and Hudson and Reed (1997).

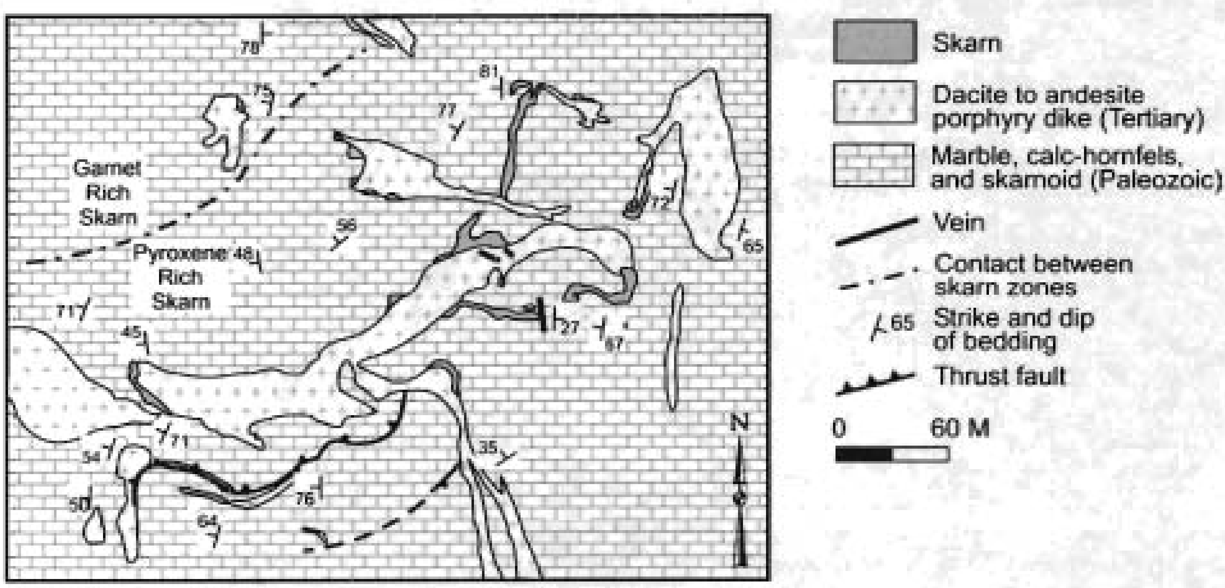


Figure 115. Tin Creek Cu-Pb-Zn skarn deposit, Southern Alaska metallogenic belt, Southern Alaska. Schematic geologic map showing distribution of Zn-Pb skarn along dikes, bedding planes, and faults. Modified from Szumigala (1987) and Newberry and others (1997).

Alaska Range-Talkeetna Mountains Igneous Belt

The Alaska Range-Talkeetna Mountains igneous belt, which hosts the southern Alaska metallogenic belt, extends for about 700 km in the western and central parts of southern Alaska (fig. 103). The igneous belt (unit at, fig 103) consists chiefly of (Moll-Stalcup, 1994; Moll-Stalcup and others, 1994): (1) large and small volcanic fields which are composed of rhyolite, dacite, and andesite flows, pyroclastic rocks, and interlayered basalt and andesite flows of 50- to 75-Ma age; and (2) numerous related diorite, quartz diorite, tonalite, granodiorite, and granite and locally monzonite and syenite plutons. The latter constitute the plutonic part of the Late Cretaceous to early Tertiary part of the Aleutian-Alaska Range and Talkeetna Mountains batholith. The igneous belt occurs mostly south of the Denali Fault, and is partly coeval with the Kuskokwim Mountains igneous belt to the northwest (Moll-Stalcup, 1994). The Alaska Range-Talkeetna Mountains igneous belt overlies various terranes in southern Alaska, including the Wrangellia superterrane, and the Kahiltna overlap assemblage (Jones and others, 1987; Nokleberg and others, 1994c, 1997c).

In the Farewell District, the granitoid rocks and adjacent areas range in age from 52 to 60 Ma (Szumigala, 1987; Bundtzen and others, 1988; Gilbert and others, 1990; Solie and others, 1991; Nokleberg and others, 1993). In the Chulitna District, the granitoid rocks which are associated with deposits (Golden Zone, Nim, Nimbus, Silver King), and in the Valdez Creek district (Zackly deposit) the associated granitoid rocks range in age from 65 to 68 Ma (Swainbank and others, 1978; Newberry and others, 1997). The low temperature Pb-Zn skarns at Tin Creek and Sheep Creek replace and alter granodiorite dikes with isotopic ages of 25-30 Ma. Geochemical and isotopic data indicate that the Alaska Range-Talkeetna Mountains igneous belt has low TiO_2, moderate K_2O, no Fe-enrichment, a calc-alkalic compositional trend, and low initial Sr ratios (Szumigala, 1987; Moll-Stalcup, 1994).

Origin of and Tectonic Setting for Southern Alaska Metallogenic Belt

The Southern Alaska metallogenic belt is hosted by the Alaska Range-Talkeetna Mountains igneous belt which is interpreted as central part of the extensive, subduction-related Kluane igneous arc which formed along the Late Cretaceous and early Tertiary continental margin of southern and southeastern Alaska (Moll and Patton, 1982; Bundtzen and Gilbert; 1983; Swanson and others, 1987; Plafker and others, 1989; Szumigala, 1993; Miller and Bundtzen, 1994; Moll-Stalcup, 1994; Bundtzen and Miller, 1997). Supporting data for this interpretation include (Moll Stalcup, 1994; Moll-Stalcup and others, 1994): (1) the calcic nature of igneous rocks; (2) low initial Sr ratios; low TiO_2 and moderate K_2O values; and (3) the occurrence of the Alaska Range-Talkeetna Mountains igneous belt along the southern margin of southern Alaska, a few kilometers north of major, coeval subduction-zone and accretionary-wedge complexes to the south which are thrust northward, under the Alaska Range-Talkeetna Mountains igneous belt to the north.

Metallogenic Belts Formed During Early Tertiary Oblique Subduction of Kula-Farallon Oceanic Ridge Under Margin of Southern and Southeastern Alaska

Maclaren Metallogenic Belt of Au Quartz Vein Deposits (Belt MC) Northern Part of Eastern-Southern Alaska

The Maclaren metallogenic belt of Au quartz vein deposits occurs in the Maclaren continental-margin arc terrane in the central Alaska Range in the northern part of eastern-southern Alaska (fig. 103; tables 3, 4) (Nokleberg and others, 1997b, 1998; Goldfarb and others, 1997, 1998). The metallogenic belt is hosted in the Maclaren Glacier metamorphic belt which is probably derived from Late Jurassic(?) flysch composed chiefly of argillite and metagraywacke (Nokleberg and others, 1985, 1994d). The significant deposits are at Timberline Creek and Lucky Hill.

Lucky Hill and Timberline Creek Au Quartz Vein Deposits

The Lucky Hill and Timberline Creek Au quartz vein deposits (Smith, 1981; Adams and others, 1992; Goldfarb and others, 1997) consist of free gold and minor pyrite, pyrrhotite, arsenopyrite, galena, and sphalerite in sheeted quartz veins which strike east-northeast and dip steeply to the northwest. The veins occur in semischist of the Maclaren Glacier metamorphic belt at Lucky Hill and in granodiorite at Timberline Creek. A distinctive, yellowish, ankerite-carbonate assemblage also occurs in some veins. Incremental Ar isotopic ages on primary micas indicate an emplacement age of 90 to 100 Ma, whereas the age of vein formation is 57 to 63 Ma. The latter ages are the same as determined for biotite-blocking temperature in the Maclaren Glacier metamorphic belt. The deposits contain an estimated 348,000 tonnes, averaging 7.1 g/t Au. One of Alaska's largest placer Au mines at Valdez Creek occurs downstream from the Lucky Hill and Timberline Creek deposits.

Origin of and Tectonic Controls for Maclaren Metallogenic Belt

The Maclaren Glacier metamorphic belt, which hosts the Maclaren metallogenic belt of Au quartz vein deposits, and part of the Maclaren terrane, displays classic prograde, Barrovian-type metamorphism of which the lower, greenschist facies portions are judged as highly favorable for Au-quartz vein deposits. ^{40}Ar-^{39}Ar ages of metamorphic minerals in auriferous quartz veins which occur in the lower greenschist facies and have isotopic ages rangeing from about 58 to 62 Ma (early Tertiary) (Adams and others, 1992). These ages are interpreted to indicate that Au mineralization occurred in the early Tertiary during oblique subduction of Kula-Farallon oceanic ridge under margin of southern Alaska (Bradley and others, 1993; Haeussler and Nelson, 1993; Haeussler and others, 1995; Goldfarb and others, 1995; 1997; Goldfarb, 1997)..

The Maclaren terrane is interpreted as a displaced continental-margin arc fragment which was tectonically separated from the Kluane schist and the Ruby Range batholith that both occur on the northeast side of the Denali fault some 400 km to the southeast in the Yukon Territory (Nokleberg and others, 1985, 1994d, 2000; Plafker and others, 1989). Similar major Au quartz vein deposits occur in the Juneau metallogenic belt of southeastern Alaska (described herein) (Nokleberg and others, 1985, 1993, 1994d).

Talkeetna Mountains Metallogenic Belt of Au Quartz Vein Deposits (Belt TM) Northern Part of Southern Alaska

The Talkeetna Mountains metallogenic belt of Au quartz vein deposits occurs in the Talkeetna Mountains in the northern part of southern Alaska (fig. 103; tables 3, 4) (Nokleberg and others, 1997b, 1998). The metallogenic belt is hosted in the Late Triassic(?) and Early Jurassic Talkeetna Formation where intruded Jurassic and Cretaceous granitoid rocks that were deformed and metamorphosed to lower greenschist facies during the early Tertiary (Nokleberg and others, 1994c, 1997c). The significant deposit is the Independence mine in the Willow Creek District. Other deposits in the district include those at Gold Bullion, Gold Cord, Lucky Shot, and Thope

Independence Au Quartz Vein Deposit

The Independence Au quartz vein deposit, which occurs in the Willow Creek district in the Talkeetna Mountains (Ray, 1954; Madden-McGuire and others, 1989), consists of quartz veins containing a few percent or less pyrite, chalcopyrite, magnetite, and gold, and minor arsenopyrite, sphalerite, tetrahedrite, Au-tellurides, and galena. The veins average 0.3 to 1 m thick, but some range up to 2 m thick. The veins occupy east-northeast and north-south-striking shear zones up to 7 m wide. Considerable alteration of wall rocks occurs marked by formation of sericite, pyrite, carbonate, and chlorite in parallel bands. The veins occur in zones in and along the southern margin of Jurassic quartz diorite, and younger Cretaceous and early Tertiary granitoid rocks of the Talkeetna Mountains batholith, and also locally in mica schist. The Willow Creek district consists of several mines and many prospects, most in an area about 12.8 km long and 6.2 km wide along southern portion of the Talkeetna Mountains batholith. The mine at the deposit contains several thousand meters of underground workings and produced about 18,400 kg Au from 1909 to 1950. Ore grade ranged from about 17 to 69 g/t Au.

Origin of and Tectonic Controls for Talkeetna Mountains Metallogenic Belt

Hydrothermal micas from the Gold Bullion and Lucky Shot mines in the Willow Creek district exhibit K-Ar isotopic ages of 66 and 57 Ma, respectively (Madden-McGuire and others, 1989). These ages are interpreted to indicate that gold mineralization in the Talkeetna Mountains metallogenic belt occurred in the Late Cretaceous or early Tertiary. Three different tectonic events might be the cause of mineralization: (1) Late Cretaceous and early Tertiary underthrusting of the Chugach and Prince William accretionary-wedge terranes along the Contact fault in southern Alaska; (2)as favored herein, early Tertiary underthrusting of the spreading Kula Ridge under the southern margin of coastal Alaska (Plafker and others, 1989); and (or; 3) early Tertiary dextral-slip faulting along on the Castle Mountain fault system.

Chugach Mountains Metallogenic Belt of Au Quartz Vein Deposits (Belt CM) Southern Alaska

The Chugach Mountains metallogenic belt of Au quartz vein deposits (fig. 103; tables 3, 4) occurs on Kodiak Island, the southeastern Kenai Peninsula, and in the central and eastern Chugach Mountains in southern Alaska. The Au quartz vein deposits occur mainly in the Late Cretaceous flysch of the Valdez Group and Kodiak Formation where these units were metamorphosed to greenschist facies (Goldfarb and others, 1986, 1997, 1998; Nokleberg and others, 1994c, 1997c, 1989b). To a lesser extent, the belt also occurs: (1) in the northern margin of the early Tertiary Orca Group of the Prince William terrane where locally metamorphosed to lower greenschist facies; (2) in metasedimentary rock of the Orca Group within a few kilometers of granitoid plutons; (3) along the southern margin of the Late Triassic through mid-Cretaceous McHugh Complex on the Kenai Peninsula;

and (4) in Eocene and Oligocene granitoid plutons intruding the Valdez and Orca Groups. The deposits in this belt are of small tonnage but locally high grade. For this widespread group of mines and deposits, a unique mineral deposit model for Chugach-type low-sulfide Au quartz veins has been developed by Bliss (1992). The significant deposits are at Cliff, Alaska Oracle, Chalet Mountain, Crown Point, Kilpatrick, Gold King, Granite, Jewel, Kenai-Alaska, Lucky Strike (Palmer Creek), Mineral King (Herman and Eaton), Monarch, and Ramsey-Rutherford (table 4) (Nokleberg and others 1997a, b, 1998). Substantial Au production occurred in this district until the early 1940's; recent exploratory work has been conducted at the Cliff Mine near Valdez, the largest of the many known deposits.

Cliff Au Quartz Vein Deposit

The Cliff Au quartz vein deposit (Johnson, 1915; Pickthorn, 1982; Jansons and others, 1984) consists of quartz veins, up to 3 meters thick and 515 meters long and contain gold, pyrite, galena, sphalerite, arsenopyrite, and stibnite. The veins are hosted in metagraywacke and minor phyllite of the Late Cretaceous Valdez Group. The veins occur in a complicated system of intersecting faults. Sulfide minerals compose about 3 to 5% percent of the ore. The mine contains a few thousand meters of underground workings. Production occurred mainly from 1906 to 1940. The average grade ranged from 34 to 69 g/t Au, and the mine at the deposit produced about 1,610 kg Au from about 25,000 tonnes of ore.

Origin of and Tectonic Controls for Chugach Mountains Metallogenic Belt

The Au quartz veins generally occur in the younger of two generations of quartz fissure veins (Richter, 1963; Goldfarb and others, 1986, 1997, 1998; Nokleberg and others, 1989b). The older and mostly barren veins are approximately parallel to the regional schistosity and to axial planes of minor and major folds. Their strike varies from northwest in the east to northeast in the west. The younger Au veins generally occur in a set of tensional cross joints or fractures, and are normal to the older, barren quartz veins. Both sets of quartz veins generally dip steeply to vertically. Hydrothermal muscovite from Au-bearing veins has been dated at 53 Ma in the Port Valdez district (Winkler and others, 1981b), at 52 Ma in the Hope-Sunrise district (Mitchell and others, 1981), and at 57 Ma in the Nuka Bay district (Borden and others, 1992).

These field relations and isotopic ages are interpreted as indicating that the deposits formed during early Tertiary regional metamorphism and anatectic granite plutonism. Regional tectonic and isotopic studies suggest that the Au veins formed in the Orca and Valdez Groups in response to subduction of the spreading Kula-Farallon Ridge beneath the southern Alaska continental margin (Plafker and others, 1989; Bradley and others, 1993; Haeussler and Nelson, 1993; Haeussler and others, 1995; Goldfarb and others, 1995; 1997; Goldfarb, 1997).

Baranof Metallogenic Belt of Au Quartz Vein Deposits Southeastern Alaska (Belt BN)

The Baranof metallogenic belt of Au quartz vein deposits occurs in Southeastern Alaska and consists of a 250-km-long belt hosted in the Chugach subduction-zone terrane in southern and southeastern Alaska (fig. 103; tables 3, 4) (Brew, 1993; Monger and Nokleberg, 1996; Goldfarb and others, 1997, 1998). The significant deposit in the belt are Apex and El Nido, Chichagoff, Cobol, Hirst-Chichagof, and Reid Inlet (Nokleberg and others 1997a, b, 1998). The principal deposits, at Chichagoff and Hirst-Chichagof are quartz-sulfide veins controlled by faults in metagraywacke and argillite of the Cretaceous Sitka Graywacke of the Valdez Group (Reed and Coats, 1941; Nokleberg and others, 1994a). The Bauer, Silver Bay, Cache, and Lucky Chance mines of the Sitka district have similar graywacke-hosted quartz-pyrite-pyrrhotite-arsenopyrite veins (Berg and Cobb, 1967). Located near the northern end of Chichagof Island, are the Apex-El Nido and Goldwin fissure quartz-sulfide vein mines that are hosted in Tertiary diorite plutons and amphibolite (Reed and Coats, 1941).

Chichagoff and Hirst-Chichagof Au Quartz Vein Deposit

The Chichagoff and Hirst-Chichagof Au quartz vein deposit consists of tabular to lenticular quartz veins which are a few meters thick, extend a few hundred meters along strike, and range up to a few thousand meters depth along plunge. The veins are mainly ribbon quartz containing minor pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, and some scheelite and tetrahedrite locally (Berg, 1984; Bundtzen, Green, Deager, and Daniels, 1987; Brew and others, 1991). Ore shoots occur mainly in shear and gouge zones along the Hirst and Chichagof faults, especially along undulations in fault planes. The deposit is hosted in metagraywacke and argillite of the Cretaceous Sitka Graywacke. The mine produced about 24.6 million g Au, 1.24 million g Ag, and minor Pb and Cu from 700,000 tonnes of ore. Average grade is 7.2 g/t Au and 2.0 g/t Ag. Reserves are 91,000 tonnes of ore grading 41.2 g/t Au in several ore bodies.

Apex and El Nido Au Quartz Vein Deposit

The Apex and El Nido Au quartz vein deposit consists of quartz fissure veins up to 2 m thick and stockworks containing sparse pyrite, arsenopyrite, chalcopyrite, galena, sphalerite, tetrahedrite, and gold (Still and Weir, 1981; Johnson and others, 1981). The mine at the deposit produced an estimated 622,000 g Au, and 93,300 g Ag The host rocks are an altered Mesozoic diorite pluton and an amphibolite mass within the pluton. The pluton intrudes late Paleozoic low-grade pelitic and intermediate volcanic rocks. Minor sulfides occur in the altered diorite wall rocks. The deposit also contains disseminations, veinlets, and small masses of scheelite. The vein system is symmetrical around a vertical fault which bisects the deposit.

Origin of and Tectonic Controls for Baranof Metallogenic Belt

The Au quartz vein deposits of the Baranof metallogenic belt occur mainly in the Late Cretaceous flysch of the Sitka Graywacke (part of the Valdez Group) where these units are metamorphosed to greenschist facies. The Au-quartz vein deposits also occur in early Tertiary granitoid plutons (with isotopic ages of about 51 to 52 Ma) which intrude the Chugach terrane; hydrothermal muscovite from Au-bearing veins has been dated at about 52 Ma (Taylor and others, 1994). As described above for the origin of the Chugach Mountains metallogenic belt, theAu quartz veins of the Baranof metallogenic belt are interpreted as forming in response to subduction of the spreading Kula-Farallon Ridge beneath the southern Alaska continental margin (Plafker and others, 1989; Bradley and others, 1993; Haeussler and Nelson, 1993; Haeussler and others, 1995; Goldfarb and others, 1995; 1997; Goldfarb, 1997).

Juneau Metallogenic Belt of Au Quartz Vein Deposits (Belt JU) Southeastern Alaska

The Juneau metallogenic belt (also referred to as the Juneau gold belt) of Au quartz vein deposits (fig. 103; tables 3, 4) (Twenhofel and others, 1949; Twenhofel, 1952; Goldfarb and others, 1997, 1998) occurs in the Coast Mountains of Southeastern Alaska. The belt, which was first defined by Spencer (1906) and redefined by Brew (1993), occurs in two areas. The northern part of the belt contains significant deposits at Alaska Juneau, Jualin, Riverside, Sumdum, and Treadwell. The southern part of the belt contains smaller deposits.The belt occurs along strike for about 250 km and is hosted in the Yukon-Tanana and Stikinia terranes, the Gravina-Nutzotin Gambier overlap assemblage, and younger, early Tertiary granitoid plutonic rocks. The significant deposits in the belt are at Alaska-Juneau, Gold Standard (Helm Bay), Goldstream, Jualin, Kensington, Riverside, Sea Level, Sumdum Chief, and Treadwell (table 4) (Nokleberg and others 1997a, b, 1998). Most of the deposits occur in the western, greenschist facies part of a belt of inverted, regional-grade metamorphic that occurs to the west of, and underneath of a extensive, foliated tonalite sill which intruded along the western edge of the Yukon-Tanana terrane and the Wrangellia superterrane (Brew, 1994; Gehrels and Berg, 1994).

Alaska-Juneau Au Quartz Vein Deposit

The Au-quartz vein deposit consists of a network of lenticular quartz veins a few centimeters to 1 m thick that contain sparse scattered masses of gold, pyrite, pyrrhotite, arsenopyrite, galena, with minor sphalerite, chalcopyrite, and silver (Goldfarb and others, 1986, 1988, 1991, 1997; Newberry and Brew, 1987, 1988; Light and others, 1989; Brew and others, 1991; Miller and others, 1992). The Alaska-Juneau mine produced 108 t Au, 59 t Ag, and 21,800 t Cu from 80.3 million tonnes of ore mined between 1893 and 1944. Reserves of 61.6 million tonnes grading 1.8 g/t Au remain (Alaska Mineral Industry, 1993, p.13).The vein lode system is about 5.6 km long and 600 m wide. The deposit consists of a series of parallel quartz stringers that are hosted in several units in: (1) phyllite and schist near the contact between the Late Triassic Perseverance Slate; (2) amphibolite derived from late(?) Mesozoic (meta)gabbro dikes and sills; and (3) the informally named Gastineau volcanics of Permian and (or) Late Triassic age. Most of ore occurs in quartz veins; some in adjacent altered metamorphic rocks.

Jualin Au Quartz Vein Deposit

The Jualin Au-quartz vein deposit consists of four or five major quartz fissure veins and pipe-like stockworks which contain minor gold, and considerable pyrite, chalcopyrite, galena, minor sphalerite, and secondary copper minerals (Bundtzen and others, 1990; Goldfarb and others, 1991, 1997; Brew and others, 1991; Swainbank and others, 1991). Pyrite is the dominant sulfide. Gold associated with pyrite occurs as minute blebs in goethite rims and fracture fillings in corroded crystals. The gangue consists of quartz and lesser ankerite, chlorite, and sericite. The mine produced about 1.5 million g Au, and reserves are estimated at 907,000 tonnes of ore grading 10.5 g/t Au. The age of mineralization is interpreted as 55 Ma. The deposit contains more than 5,500 m of horizontal workings.The deposit is hosted in Cretaceous quartz diorite which exhibits proximal ankerite, quartz, and sericite alteration adjacent to veins, and more widespread propylitic alteration. The quartz diorite intrudes Late Triassic greenstone, graywacke, and argillite of Alexander sequence of the Wrangellia superterrane.

Riverside Au Quartz Vein Deposit

The Riverside Au quartz vein deposit consists primarily of disseminated galena, pyrite, tetrahedrite, pyrrhotite, chalcopyrite, sphalerite, gold, and scheelite in two large quartz veins, but in the Lindeberg lode, part of the deposit is a combined quartz vein and epigenetic replacement deposit (Byers and Sainsbury, 1956; Smith, 1977). The mine at the deposit produced about

27,200 tonnes, yielding 93,300 g Au, 3.1 million g Ag, 45,400 kg Cu, 113,500 kg Pb, 9,080 kg Zn, and 3,500 units (318,000 kg) WO_3. The veins occur in a shear zone, schist inclusion, and mylonitic gneiss derived from the Triassic Texas Creek Granodiorite of the informally named Coast plutonic-metamorphic complex of Brew and Ford (1984).

Sumdum Chief Au Quartz Vein Deposit

The Sumdum Chief Au quartz vein deposit consists of two quartz-calcite fissure veins that contain gold, auriferous pyrite, galena, sphalerite, chalcopyrite, and arsenopyrite (Brew and Grybeck, 1984; Kimball and others, 1984; Goldfarb and others, 1988, 1991, 1997). Gold is unevenly distributed and occurs mainly in pockets where small veins intersect the main veins. Mining produced about 750,000 g each of Ag and Au from ore that averaged about 13.7 g/t Au. The veins, up to 6 m thick, occur in upper Paleozoic(?) or Mesozoic graphitic slate and marble of the informally named Coast plutonic-metamorphic complex of Brew and Ford (1984).

Treadwell Au Quartz Vein Deposit

The large Treadwell Au quartz vein deposit consists of disseminated sulfides in quartz and quartz-calcite vein systems in shattered albite sills and dikes. The veins contain sparse gold, pyrite, magnetite, molybdenite, chalcopyrite, galena, sphalerite, and tetrahedrite. The best ore grade is associated with abundant quartz and calcite veinlets (Light and others, 1989; Goldfarb and others, 1991, 1997). Mining produced about 90.1 million gm Au from 25 million tonnes of ore. The albite sills and dikes are Eocene and intrude Jurassic(?) and Early Cretaceous(?) slate and greenstone derived from basaltic tuff or agglomerate (part of the Treadwell Slate in the Gravina-Nutzotin belt). Some ore forms a zone at least 1,100 m long in slate inclusions and in adjacent wall rock. The deposit was mined from above sea level to 790 m beneath sea level in Gastineau Channel from 1885 to 1922 when most workings flooded during a catastrophic influx of sea water.

Origin of and Tectonic Controls for Juneau Metallogenic Belt

The Juneau metallogenic belt is hosted in a wide variety of metamorphosed sedimentary, volcanic, and plutonic rocks which occur adjacent to a complex series of faults between the Alexander and Wrangellia sequences of the Wrangellia superterrane (Nokleberg and others, 2000), the Gravina sequence (Gravina-Nutzotin-Gambier overlap assemblage), and in syn- to post-accretionary granitoid plutonic rocks, including the foliated tonalite sill of Southeastern Alaska (Brew and Ford, 1984). Late Paleozoic and early Mesozoic metasedimentary and metavolcanic rocks host the Jualin (Berg, 1984) and Kensington (Bundtzen and others, 1988) deposits in the Berner Bay district, and the Sumdum Chief (Kimball and others, 1984) and Sea Level deposits. Flysch of the Gravina-Gambier overlap assemblage hosts the Treadwell group of quartz-sulfide-gold deposits, across the Gastineau Channel from the Alaska-Juneau mine (Spencer, 1905), and the Gold Standard and Goldstream deposits. Hydrothermal muscovite from Au-bearing veins from the Alaska-Juneau mine has been dated at about 54 to 57 Ma (Haeussler and others, 1995; Goldfarb and others, 1997). As described above for the origin of the Chugach Mountains, Baranof, and Maclaren metallogenic belts, the Au quartz veins of the Juneau metallogenic belt are interpreted as forming in response to subduction of the spreading Kula-Farallon Ridge beneath the southern Alaska continental margin (Plafker and others, 1989; Bradley and others, 1993; Haeussler and Nelson, 1993; Haeussler and others, 1995; Goldfarb and others, 1995; 1997; Goldfarb, 1997).

Metallogenic Belts Formed During Early Tertiary Spreading Along Kula-Farallon Oceanic Ridge, Southern and Southeastern Alaska

Prince William Sound Metallogenic Belt of Besshi and Cyprus Massive Sulfide Deposits (Belt PW) Eastern-Southern Alaska

The Prince William Sound metallogenic belt of Besshi and Cyprus massive sulfide deposits (fig. 103; tables 3, 4) occurs in the Prince William Sound district along the eastern and northern margins in eastern-southern Alaska. The metallogenic belt is hosted in the southern margin of the Chugach and the Prince William accretionary wedge-turbidite terranes (Jones and others, 1987; Nokleberg and others, 1994c, 1997c). The significant deposits in the belt are (table 4) (Crowe and others, 1992; Newberry and others, 1997; Nokleberg and others 1997a, b, 1998): Besshi massive sulfide deposits at Beatson (Latouche), Ellamar, Fidalgo-Alaska, Midas, and Schlosser, and Cyprus massive sulfide deposits at Copper Bullion (Rua Cove), Knight Island (Pandora), Standard Copper, and Threeman. Many of these deposits were producing mines in the early part of the 20th century.

Beatson (Latouche) and Ellamar Besshi Massive Sulfide Deposits

The Beatson (Latouche), and, Ellamar Besshi massive sulfide deposits (Johnson, 1915; Tysdal, 1978; Jansons and others, 1984; Crowe and others, 1992) consist of massive sulfide lenses and disseminations of mainly pyrite and pyrrhotite, and minor chalcopyrite, cubanite, sphalerite, galena, Ag-bearing minerals, and gold. Gangue minerals are quartz, sericite, and ankerite. The deposits occur in graywacke and argillite of the Paleocene and Eocene Orca Group. The deposits range up to 120 m thick and 300 long along strike. The Latouche and Beatson deposits produced more than 84 million kg Cu from 4.5 million tonnes of ore. The average ore grade was about 1.7% Cu, and 9.3 g/t Ag. The Ellamar deposit produced 7.2 million kg Cu, 1,596 kg Au, and 5,960 kg Ag from 273,760 tonnes of ore. The deposit at Beatson (Latouche) was developed and produced mainly from about 1903 to 1934, and the Ellamar deposit was mined from 1897 to 1934.

Midas Besshi Massive Sulfide Deposit

The Midas deposit consists of disseminated to massive chalcopyrite, pyrite, pyrrhotite, sphalerite, and minor galena in a folded, lens-shaped body (Moffit and Fellows, 1950; Rose, 1965; Jansons and others, 1984; Crowe and others, 1992). The sulfides occur in highly deformed phyllite and metagraywacke of the Late Cretaceous Valdez Group in the southern Chugach accretionary wedge-turbidite terrane. Mafic metavolcanic rocks crop out in the footwall within a few hundred meters of the ore body. On the basis of whole rock REE analyses, the mafic volcanic rocks in the southern Chugach terrane are interpreted by Lull and Plafker (1990) as forming in a short-lived island-arc environment.

Copper Bullion (Rua Cove) Cyprus Massive Sulfide Deposit

The Copper Bullion (Rua Cove) Cyprus massive sulfide deposit (fig. 116) (Koski and others, 1985; Crowe and others, 1992) is a lens-shaped massive body of pyrrhotite with minor chalcopyrite and sphalerite which is hosted in sheared pillow basalt of the lower Tertiary Orca Group of the Prince William terrane. The lens is about 200 m long and is locally interlayered with pillow basalt and hyaloclastite that occur stratigraphically above sheeted dikes. The sulfides include pyrite, phrrhotite, chalcopyrite, sphalerite, cubanite, galena, and marcasite. The gangue assemblage consists of abundant quartz and chlorite, which occur as fine disseminations with massive sulfides, and in pervasive and massive zones in the stockwork zone where fine-grained talc also occurs. The deposit contains a well-preserved feeder zone that underlies the massive sulfide lens is dominanted by pyrrhotite and chalcopyrite. The deposit contains reserves of 990,000 tonnes grading 1.25% Cu, and <0.005 oz/t Au, and <0.1 oz/t Ag.

Origin of and Tectonic Controls for Prince William Sound Metallogenic Belt

The deposits in the Prince William Sound metallogenic belt, except for the Midas deposit, are hosted in the early Tertiary (Paleocene and Eocene) Orca Group which constitutes most of the Prince William terrane and consists of a deformed, thick assemblage of Paleocene and Eocene(?) graywacke, argillite, minor conglomerate, pillow basalt, basaltic tuff, sills, and dikes (Winkler and Plafker, 1981; Jones and others, 1987; Nokleberg and others, 1994c, 1997c; Newberry and others, 1997). On Resurrection Peninsula and on Knight Island, the terrane contains a local ophiolitic rock which is interpreted as slabs of oceanic basement formed during early Tertiary sea-floor spreading along the Kula-Farallon oceanic ridge (Nokleberg and others, 2000). In the upper part of the ophiolite, the mafic volcanic rock of the Prince William terrane was immediately succeeded by a flood of sediment derived from uplift and erosion of the Coast Mountains (Plafker and others, 1989; Plafker and Berg, 1994; Nokleberg and others, 2000). Consequently, the Prince William Sound metallogenic belt is interpreted as forming in a sea-floor spreading tectonic environment. The Cyprus massive sulfide deposits are interpreted as forming during rifting without abundant covering by clastic debris whereas the Besshi deposits are interpreted as forming during sedimentation of clastic debris onto an active oceanic rift.

Yakobi Metallogenic Belt of Gabbroic Ni-Cu Deposits (Belt YK) Southeastern Alaska

The Yakobi metallogenic belt of gabbroic Ni-Cu deposits (fig. 103; tables 3, 4) occurs in Southeastern Alaska and is hosted in Tertiary mafic and ultramafic stocks of the La Perouse Plutonic Suite, which intrudes metagraywacke, clastic rocks, and greenstone of the Cretaceous Sitka Graywacke and the Kelp Bay Group. Both units are part of the Chugach accretionary wedge and subduction-zone terrane (Woodsworth and others, 1991; Brew, 1993; Nokleberg and others, 2000). The principal deposits are at Bohemia Basin (Yakobi Island), Brady Glacier, and Mirror Harbor (table 4) (Nokleberg and others 1997a, b, 1998). At the north end of the belt is the Mount Fairweather Cu-Ni-Co-Pt prospect which consists of mafic-ultramafic float on the southwest flank of the mountain (Plafker and MacKevett, 1970).

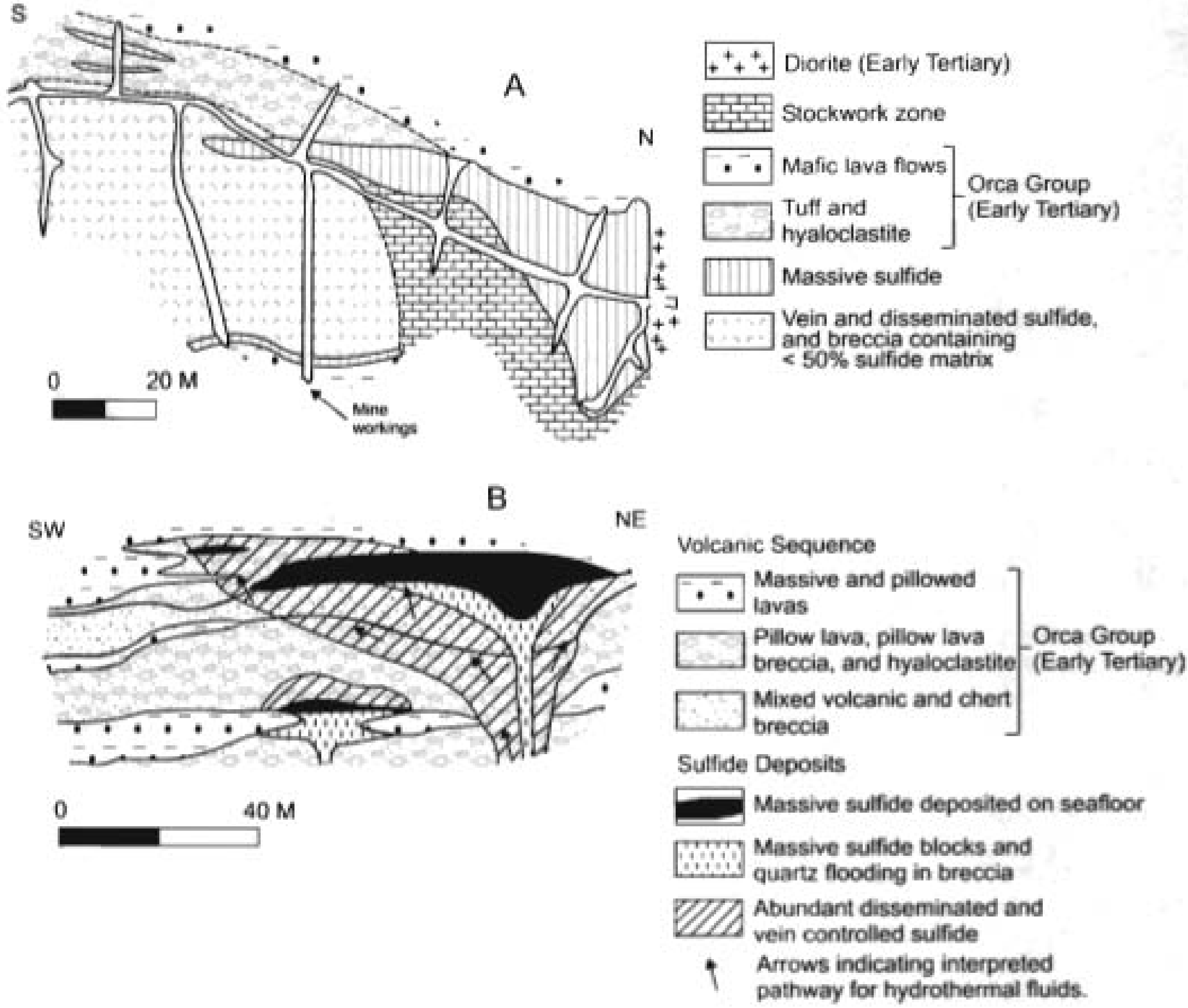


Figure 116. Copper Bullion (Rua Cove) Cyprus massive sulfide deposit, Prince William Sound metallogenic belt, Southern Alaska. A. Schematic geologic map of 370 level. B. Interpretive model. Modified from Koski and others (1985) and Crowe and others (1992).

Bohemia Basin Gabbroic Ni-Cu Deposit

The Bohemia Basin gabbroic Ni-Cu deposit consists of magmatic sulfide segregations, chiefly consisting of pyrrhotite, pentlandite, and chalcopyrite (Himmelberg and others, 1987, Still, 1988; Brew and others, 1991; Berg, 1984; Foley and others, 1997). Estimated resources are19 million tonnes grading 0.33% Ni, 0.21% Cu, and 0.01% Co. The deposit occurs in a trough-like body, about 45 m thick, near the base of a basin-shaped, composite norite of a Tertiary lopolith. The norite, which locally grades into gabbro and diorite, intrudes metagraywacke, phyllite, and greenschist of the Cretaceous and Cretaceous(?) Kelp Bay Group of the Chugach terrane.

Brady Glacier Gabbroic Ni-Cu Deposit

The Brady Glacier gabbroic Ni-Cu deposit (fig. 117) consists of disseminated and lensoid pyrrhotite, pentlandite, and chalcopyrite, with rare pyrite. The sulfide minerals occur near the base of a large, layered Tertiary lopolith which consists mainly of gabbro and sparse peridotite, all part of the La Perouse layered gabbro (Czamanske and Calk, 1981; Himmelberg and Loney, 1981; Foley and others, 1997). The gabbro intrudes metagraywacke and phyllite of the Cretaceous Sitka Graywacke which is part of the Chugach terrane. The mafic and ultramafic rocks locally contain up to 10% disseminated sulfides. Estimated resources are 82 to 91 million tonnes grading 0.53% Ni, 0.33% Cu, 0.03% Co, and minor PGE. Grab samples contain from 0.18 to 1.30 g/t PGE. The deposit occurs almost entirely beneath Brady Glacier, but exposed in small nunataks. Considerable drilling and exploration occurred in the 1970's. Exploration stopped short of development. The deposit is now part of the Wrangell-St. Elias National Park.

Origin of and Tectonic Controls for Yakobi Metallogenic Belt

The gabbroic Ni-Cu deposits and host mafic and ultramafic rocks in the Yakobi metallogenic belt formed during intrusion into the Oligocene La Perouse Plutonic Suite into highly-deformed and low-grade, regionally metamorphosed rocks of the Chugach accretionary wedge and subduction-zone terrane (Woodsworth and others, 1991; Brew, 1993, 1994; Moll-Stalcup and others, 1994). Intrusion occurred in the early Tertiary after cessation of accretion and subduction of the Chugach terrane in the earliest Tertiary. The early Tertiary La Perouse Plutonic Suite is interpreted as forming during final spreading along the Kula-Farallon oceanic ridge during ridge subduction at about 50 to 60 Ma along the margin of southern and Southeastern Alaska (Bradley and others, 1993; Kusky and others, 1997). The early Tertiary subduction of the spreading oceanic ridge, locally partly preserved in ophiolites in the Prince William terrane (Lytwyn and others, 1997; Kusky and Young, 2000, in press), is interpreted as causing: (1) a regional metamorphic welt and formation of anatectic granites (Plafker and others, 1989b; 1994); (2) rapid change in component of strike-slip movements along the subduction zone bordering the early Tertiary continental margin (Bradley and others, 1993); and (3) intrusion of the early Tertiary granitic and mafic-ultramafic plutonic rock of the Sanak-Baranof plutonic belt (Hudson, 1979; Moll-Stalcup and others, 1994) in Southern and Southeastern Alaska. The intrusions are interpreted as forming in a near-trench environment during subduction of the Kula-Farallon oceanic ridge (Bradley and others, 1993; Kusky and others, 1997). Because of temporal and spatial proximity to subduction of the Kula-Farallon oceanic ridge along the margin of Southeastern Alaska from about 50 to 60 Ma, the Oligocene La Perouse Plutonic Suite and associated gabbroic Ni-Cu deposits of the Yakobi metallogenic belt are interpreted as forming either: (1) during the last gasp of oceanic ridge mafic plutonism (this article); or (2) possibly slightly later in association with strike-slip dismemberment of a continental-margin arc (Goldfarb and others, 1997, 1998; Goldfarb, 1997).

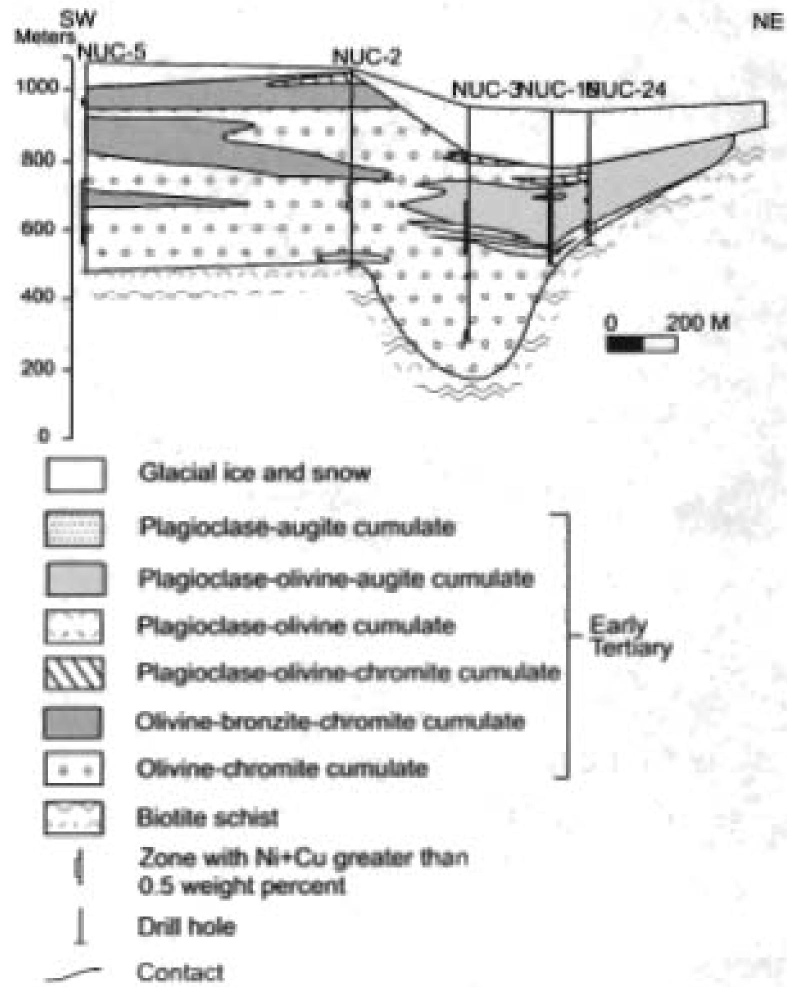


Figure 117. Brady Glacier gabbroic Ni-Cu deposit, Yakobi metallogenic belt, Southeastern Alaska. Schematic southwest-northeast cross section. Adapted from Himmelberg and Loney (1981).

Metallogenic Belts Formed in Late Cretaceous and Early Tertiary Coast Continental-Margin Arc, Southeastern Alaska, and Southern Canadian Cordillera

An extensive suite of Late Cretaceous and early Tertiary metallogenic belts hosting granitic-magmatism related deposits occur in Southeastern Alaska and the southern Canadian Cordillera (fig. 103; tables 3, 4). These belts are hosted mainly in the the Coast-North Cascade plutonic belt and correlative units. In alphabetical order, these metallogenic belts are the Bulkey, Carmacks, Catfish, Central-Southeastern Alaska, Fish Lake-Bralorne, Gambier, and Surprise Lake belts. The host Coast-North Cascade plutonic belt consists chiefly of quartz diorite, granodiorite, and locally more mafic or felsic plutons (Rubin and others, 1991; Gehrels and others, 1990; Wheeler and McFeeley, 1991; van der Heyden, 1992; Woodsworth and others, 1992; Journeay and Friedman, 1993). The Early Late Cretaceous through early Tertiary intrusions are interpreted as forming sequentially during contraction, local(?) dextral transpression, and transtension, and accompanied by regional metamorphism (Rubin and others, 1991; Journeay and Friedman, 1993). The Coast-North Cascade plutonic belt constitutes part of a laterally-extensive, Andean-type Coast continental-margin arc which overlaps the Wrangellia superterrane, and previously-accreted, more inboard terranes in Southern Alaska and coastal Canadian Cordillera (fig. 103) (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). The Early Late Cretaceous through early Tertiary intrusions were emplaced concurrently with structures formed sequentially, first during contraction, and subsequently during local(?) dextral transpression and associated regional metamorphism (Woodsworth and others, 1977; Leitch and others, 1989; Rubin and others, 1991; Journeay and Friedman, 1993; Schiarizza and others, 1997). The plutonic belt and associated metallogenic belts of granitic-magmatism deposits are interpreting as forming immediately after the mid-Cretaceous accretion of the Wrangellia superterrane, and the subsequent oceanward stepping of subduction and continental margin magmatism (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996).

Surprise Lake Metallogenic Belt of Porphyry Mo-W-Cu, and Au-Ag Polymetallic Vein Deposits (Belt SL) Northern British Columbia

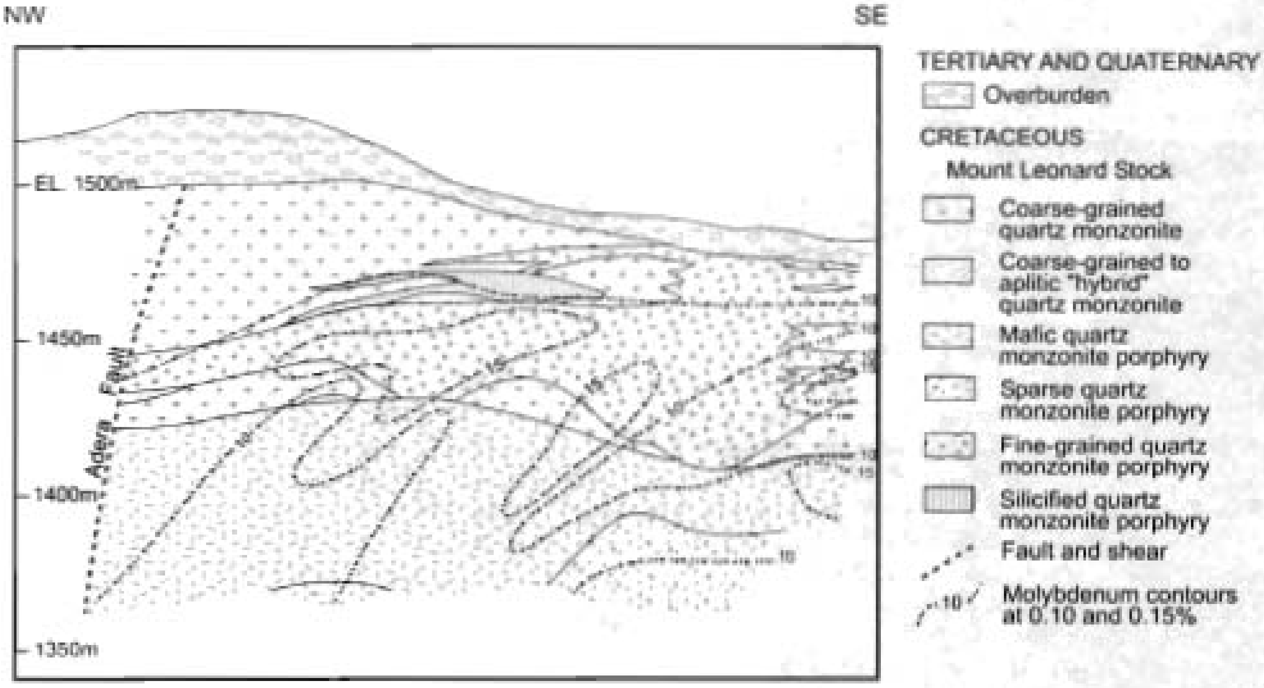
The Surprise Lake metallogenic belt of porphyry Mo-W-Cu, and Au-Ag polymetallic vein deposits (fig. 103; tables 3, 4) occurs in northern British Columbia and is hosted in the northwest-trending Surprise Lake Plutonic Suite. The significant deposit in the belt are (table 4) (Nøkleberg and others 1997a, b, 1998): porphyry Mo deposits at Adanac-Adera (Ruby Creek), Mount Ogden, Red Mountain (Bug, Fox, Boswell R.), and S.Q.E. (Storie, Casmo); a porphyry Cu-Mo deposit at Sutlahine River Area (Thorn, Kay); porphyry Mo and W- and Mo skarn deposits at Mt. Haskin West (Joem, Rain, Moly Zone), and Windy (Balsam, Star, Kuhn, Dead Goat); and Au-Ag polymetallic vein deposits at Engineer Mine, Montana Mountain, Venus, and Wheaton River.

Adanac-Adera Porphyry Mo Deposit

The Adanac-Adera porphyry Mo deposit (fig. 118) consists of molybdenite with accessory pyrite, fluorite, chalcopyrite, scheelite, and wolframite, along with minor arsenopyrite which occur in a quartz-vein stockwork. Estimate reserves are 152 million tonnes grading 0.063% MoS_2 at a cutoff grade of 0.04% Mo (EMR Canada, 1989; Dawson and others, 1991; Mining Review, 1992; Pinsent and Christopher, 1995; MINFILE, 2002). The deposit is hosted by a quartz monzonite stock which is part of the Late Cretaceous Surprise Lake Batholith (Pinsent and Christopher, 1995). The deposit exhibits silicic and potassic alteration which occur as envelopes, up to several centimetres thick, around quartz veins. Minor uranium occurs in the deposit. The Surprise Lake Batholith exhibits a K-Ar isotopic age of 70.6 ± 3.8 Ma as an average of six dates. This value represents a cooling age and differs significantly from a U-Pb zircon age of 83.8 ± 5 Ma (Mihalynuk and others, 1992). Associated W-, Cu-, and Sn-greisen vein, and W and Sn (Cu, Pb, Zn) skarns occur along contacts between the stock with limestone of Cache Creek Assemblage (Ray and others, 1992).

Mount Ogden Porphyry Mo Deposit

The Mount Ogden porphyry Mo deposit consists of molybdenite in an alaskite and quartz monzonite stock which intrudes amphibolite-grade, Permian and Triassic limestone, and clastic sedimentary and volcanic rocks of the Stikinia terrane (EMR Canada, 1989; MINFILE, 2002). Molybdenite occurs mainly in the alaskite as platy crystals in veins, in veinlets, as rosettes in vuggy quartz, and as interstitial grains. Some molybdenite veins range up to 10 cm wide and occur over 30 meters. Alteration consists of quartz-sericite, with fluorite, biotite, minor pyrite and sphalerite. Estimated reserves are 218 million tonnes grading 0.30% MoS_2. The country rocks locally contain skarns with disseminated pyrite, pyrrhotite, magnetite, and traces of sphalerite and scheelite.



118. Adanac-Adera porphyry Mo deposit, Surprise Lake metallogenic belt, Canadian Cordillera. Generalized cross section through high-grade zone. Adapted from Pinsent and Christopher (1995).

Red Mountain Porphyry Mo Deposit

The Red Mountain porphyry Mo deposit consists of disseminated molybdenite which occurs in a quartz stockwork (EMR Canada, 1989; Dawson, and others, 1991; Yukon Minfile, 1992; Sinclair, 1986). Estimated reserves are 187 million tonnes grading 0.167% MoS2 (with a 0.1% cut-off), and 21.3 million tonnes grading 0.293% MoS_2 with a 0.25% cut-off. The deposit occurs in an altered Late Cretaceous quartz monzonite stock of the Surprise Lake Suite, with a K-Ar isotopic age of 87.3 Ma, and in adjacent contact-metamorphosed argillite of the early Paleozoic Nasina Assemblage of the Yukon-Tanana terrane. The stock is complex, exhibits a classical alteration pattern, and is intruded by barren quartz diorite.

Surprise Lake Polymetallic and Epithermal Au-Ag Veins.

Ag-Pb polymetallic vein deposits are associated with an Late Cretaceous pluton at Boswell River, Yukon Territory (Lees, 1936), and near the Red Mountain porphyry Mo deposit. Several Au-Ag polymetallic vein mines at Venus, Montana Mountain, and Wheaton River are hosted in or near the Late Cretaceous Carcross pluton which occurs south of Whitehorse, Yukon Territory (Hart, 1994). Au veins at the Engineer Mine, southwest of Atlin, B.C., are probably related to Eocene magmatism which formed both the volcanic rocks and late stocks (Mihalynuk, 1990). The deposit at the Engineer Mine are cut by the major Lewellyn Fault. The Au epithermal veins at the Engineer mine are transitional between mesothermal and epithermal, low-sulphidaiton type.

Origin of and Tectonic Controls for Surprise Lake Metallogenic Belt

The Surprise Lake metallogenic belt is associated with the Surprise Lake Plutonic Suite which consists of stocks and batholiths, comprising mainly felsic, high-level, Si- and lithophile element-rich rocks, and has K-Ar isotopic ages of 84 Ma (Woodsworth and others, 1991). Plutons in the suite intrude the Cassiar, Stikine, Yukon-Tanana, and Cache Creek terranes. The major plutonic units are the Surprise Lake batholith, near Atlin, B.C., and the Needlepoint Pluton, near Cassiar, B.C. (Woodsworth and others, 1991). The Surprise Lake Plutonic Suite is part of the extensive Late Cretaceous and early Tertiary Coast-North Cascade plutonic belt which occurs along the western and central parts of the Canadian Cordillera and into East-Central Alaska (fig. 103) (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). Probable coeval, extrusive equivalents for the Surprise Lake Plutonic suite are the Windy-Table Volcanics to the east and west (Mihalynuk, 1999; Mihalynuk and others, 1992), and the Carmacks Assemblage to the north (Grond and others, 1984) and unnamned tuffaceous units in the Sustut Basin to the south (Woodsworth and others, 1991). The Coast-North Cascade plutonic belt forms the major part of the Coast continental-margin arc in the region.

Central-Southeastern Alaska Metallogenic Belt of Porphyry Mo and Cu Deposits (Belt CSE) Southeastern Alaska

The Central-Southeastern Alaska metallogenic belt of porphyry Mo and Cu deposits (fig. 103; tables 3, 4) occurs along the western coast of Southeastern Alaska and is hosted in (Nokleberg and others, 1995a): (1) a belt of late Oligocene and younger Cenozoic granitoid stocks of the Glacier Bay magmatic belt; and (2) the Tkope-Portland Peninsula volcanic-plutonic belt. These igneous belts intrude the Wrangellia superterrane in Southeastern Alaska, and are part of the more extensive Late Cretaceous and early Tertiary Coast-North Cascade plutonic belt. This belt extends along the western and central parts of the Canadian Cordillera for several thousand km (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). The significant deposits in the Central-Southeastern Alaska metallogenic belt are porphyry Cu-Mo deposits at Margerie Glacier, Nunatak, and Quartz Hill, a porphyry Mo deposit at Burroughs Bay, and a Fe skarn deposit at North Bradfield Canal (table 4) (Nokleberg and others 1997a, b, 1998).

Margerie Glacier Porphyry Cu Deposit

The Margerie Glacier porphyry Cu deposit (MacKevett and others, 1971; Brew and others, 1978; Berg and others, 1981; Berg, 1984) consists of chalcopyrite, pyrite, arsenopyrite, sphalerite, molybdenite, and minor scheelite in shear-zone-hosted quartz veins, as massive sulfide veins, and as disseminations in a propylitically altered, Tertiary(?) porphyritic granite stock and adjacent hornfels. The granite stock is part of the Glacier Bay belt of middle Tertiary granitoid rocks which have isotopic ages of about 25 to 30 Ma (Brew 1994). The stock intruded Permian(?) metamorphosed pelitic and volcanic rocks, and sparse marble of the Alexander sequence of the Wrangellia superterrane. The deposit contains estimated resources of 145 million tonnes grading 0.02% Cu, 0.27 g/t Au, and 4.5 g/t Ag (MacKevett and others, 1971; Brew and others, 1978). Parts of the deposit are higher grade.

Nunatak Porphyry Cu-Mo Deposit

The Nunatak porphyry Cu-Mo deposit (MacKevett and others, 1971; Brew and others, 1978; Berg and others, 1981; Berg, 1984) occurs in northern southeastern Alaska, and consists of numerous, closely spaced molybdenite-bearing quartz veins and stockwork, and minor disseminated molybdenite in hornfels, skarn, and a mineralized fault zone around a Tertiary granite porphyry stock. The granite porphyry stock has not yet been isotopically dated, but is part of the Glacier Bay magmatic belt of middle Tertiary granitoid rocks which range in age from about 25 to 30 Ma (Brew and Morrell, 1983; Brew, 1988). Disseminated sulfides within the granite porphyry stock consist of varying amounts of pyrite, pyrrhotite, chalcopyrite, and sparse tetrahedrite, and bornite. The most mineralized part of the stockwork contains a resource of 2.03 million tonnes grading 0.067% Mo and 0.16% Cu; the less mineralized part of the stockwork contains 117.5 million tonnes grading 0.026% Mo and 0.18% Cu (MacKevett and others, 1971; Brew and others, 1978). Similar tonnage and grade material may exist below sea level. The granite porphyry stock intrudes tightly folded Paleozoic metasedimentary rocks of the Alexander sequence of the Wrangellia superterrane.

Quartz Hill Porphyry Mo Deposit

The Quartz Hill porphyry Mo deposit (fig. 119), which contains one of the world's largest concentrations of molybdenum (Hudson and others, 1979; P.R. Smith and J.E. Stephens, written commun., 1985; Wolfe, 1995; Ashleman and others, 1997) occurs in the southern part of eastern-southeastern Alaska. The deposit consists of a flat-lying, tabular stockwork of molybdenite-bearing, randomly oriented quartz veins and fractures, and also disseminated molybdenite, all of which are distributed throughout the multiply-altered hypabyssal Quartz Hill composite quartz monzonite stock which crops out over an area of several square kilometers. The Quartz Hill stock is roughly ovoid in outcrop, is approximately 5 km long by 3 km wide (Brew and Ford, 1984a, b), and is part of the Tkope-Portland Peninsula volcanic-plutonic belt. The stock is cut by a progressively younger sequence of plugs and dikes consisting of porphyritic quartz latite, igneous breccia, quartz monzonite, quartz feldspar porphyry, and latite which are abundant in the core of the Quartz Hill stock. A K-Ar isotopic age of about 27 Ma was obtain for the stock (Ashleman and others, 1997). The host rocks are paragneiss and plutonic rocks of the Coast Plutonic Complex. The deposit contains estimated reserves of 1,600 million tonnes grading 0.127% MoS_2, at an 0.08% MoS_2 cut-off, and an estimated 210 million tonnes grading 0.22% MoS_2 (Wolfe, 1995).

Origin of and Tectonic Controls for Central-Southeastern Alaska Metallogenic Belt

The Glacier Bay magmatic belt and the Tkope-Portland Peninsula volcanic-plutonic belt, which constitute some of the youngest, extensive igneous units in southeastern Alaska (Brew and others, 1992, 1993), hosts the Central-Southeastern Alaska metallogenic belt.The Oligocene Glacier Bay magmatic belt, which hosts the Margerie Glacier porphyry Cu and polymetallic vein deposit, and the Nunatak porphyry Cu-Mo deposit, consists of calc-alkalic, biotite granite and alkali granite plutons which are dominantly unfoliated, metaluminous, and moderately peraluminous. K-Ar isotopic ages rangefrom 31 to 42 Ma. The Tkope-Portland Peninsula volcanic-plutonic belt of Oligocene age hosts the Quartz Hill porphyry molybdenum deposit (Brew and Morrell, 1983; Brew, 1988). The Tkope-Portland Peninsula volcanic-plutonic belt consists of calc-alkalic and alkalic, locally

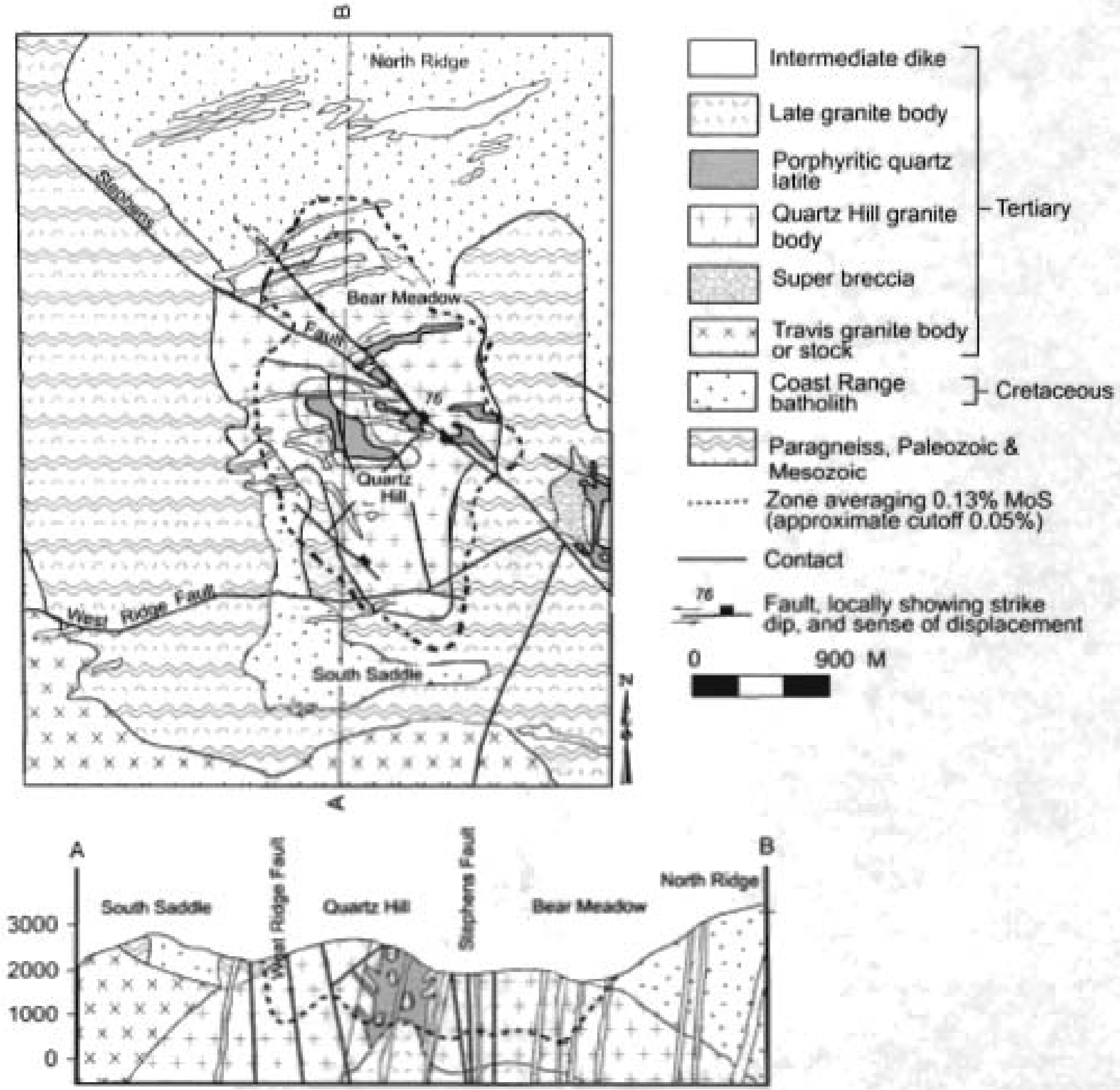


Figure 119. Quartz Hill porphyry Mo deposit, Central-Southeastern Alaska metallogenic belt, Southeastern Alaska. Adapted from and Nokleberg and others (1995).

peraluminous, hornblende-biotite granite and granite porphyry, and lesser syenite and gabbro (Brew, 1988). K-Ar, Rb-Sr, and fission track isotopic ages range from 19 to 35 Ma. The belt exhibits strongly fractionated REE patterns, large Europium anomalies, and initial Sr ratios of 0.747 to 0.705 (Arth and others, 1986).

The Glacier Bay magmatic and Tkope-Portland Peninsula volcanic-plutonic belts are part of the extensive Late Cretaceous and early Tertiary Coast-North Cascade plutonic belt which extends the length of the Canadian Cordillera and into East-Central Alaska (fig. 103) (Rubin and others, 1991; Gehrels and others, 1990; Wheeler and McFeeley, 1991; van der Heyden, 1992; Woodsworth and others, 1992; Journeay and Friedman, 1993). The Coast-North Cascade plutonic belt forms the major part of the Coast continental-margin arc in the region.

Bulkley Metallogenic Belt of Porphyry Cu-Mo and Polymetallic Vein Deposits (Belt BK) Central British Columbia

The Bulkley metallogenic belt of porphyry Cu-Mo and polymetallic vein deposits (fig. 103; tables 3, 4) occurs in central British Columbia and is hosted in a belt of small stocks and batholiths of the Late Cretaceous Bulkley Plutonic Suite which are exposed along the uplift of the Skeena Arch in the central part of the Stikinia terrane (Carter, 1982; Mihalynuk, 1992; Mihalynuk and others, 1999). This suite is part of the extensive Late Cretaceous and early Tertiary Coast-North Cascade plutonic belt which occurs along the western and central parts of the Canadian Cordillera for several thousand km (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). The significant porphyry Cu-Mo deposits of the Bulkley metallogenic belt are associated with generally small, calc-alkaline plutons of the Bulkley Plutonic Suite and consist mainly of biotite and hornblende granodiorite and quartz diorite which were emplaced at high levels along high-angle faults within an extensional stress field (Dawson and others, 1991). Most of the plutons hosting this metallogenic belt are too small to depict on figure 103. The significant deposits in the belt are (table 4) (Nokleberg and others 1997a, b, 1998): porphyry Cu-Mo and Mo deposits at Glacier Gulch (Hudson Bay Mountain), Huckleberry, and Poplar; and polymetallic vein deposits at Red Rose, Capoose Lake, and Nadina (Silver Queen).

Glacier Gulch (Hudson Bay Mountain)
Porphyry Mo (W, Cu) Deposit

The Glacier Gulch (Hudson Bay Mountain) porphyry Mo (W, Cu) deposit occurs at Hudson Bay Mountain, Smithers, B.C., and consists of molybdenite and minor scheelite which occur in stockwork and quartz vein swarms formed during two periods of mineralization. The deposits are related to the intrusion of a sheet-like granodiorite body and a later quartz-porphyry plug, into rocks of the Hazelton Group of the Stikinia terrane (Bright and Jonson, 1976; EMR Canada, 1989; Atkinson, 1995; MINFILE, 2002). Most intense quartz-molybdenite-scheelite vein mineralization is related to a crudely layered granodiorite sheet. An estimated resource of 100 million tonnes grading 0.297% MoS_2 and 0.06% WO_3 is defined by surface drilling and underground exploration (Kirkham, 1967; Bright and Jonson, 1976). Hydrothermal alteration patterns are irregularly developed.

Huckleberry Porphyry Cu-Mo (Au-Ag) Deposit

The Huckleberry porphyry Cu-Mo (Au-Ag) deposit (fig. 120) consists of chalcopyrite and minor molybdenite which occur in a stockwork in contact-metamorphosed and altered Jurassic Hazelton Group tuffs at a contact with a Late Cretaceous granodiorite porphyry stock of the Burkley Plutonic Suite (Sutherland Brown, 1969; Carter, 1970; MacIntyre, 1984; EMR Canada, 1989; Mining Review, 1992; Society of Exploration Geologists Newsletter, no. 20, January, 1995, p. 26; Jackson and others, 1995; MINFILE, 2002). Magnetite occasionally accompanies chalcopyrite. Potassic, phyllic, and propylitic alteration haloes surround the stock. The stockwork consists of quartz and chalcopyrite, and lesser pyrite, molybdenite which are cut by younger anhydrite veinlets. Associated with the stockwork is biotite and albite alteration. Estimated, pre-production reserves, at cut-off grade of 0.30% Cu, for the Main Zone, are 53.7 million tonnes grading 0.445% Cu, 0.013% Mo, and 0.06 g/t Au, and for the East Zone, are 108.4 million tonnes grading 0.484% Cu, 0.014% Mo, and 0.055 g/t Au (Jackson and Illerbrun, 1995).

Poplar Porphyry Cu-Mo (Ag) Deposit

The Poplar porphyry Cu-Mo (Ag) prospect occurs 40 km to the north of the Huckleberry deposit and consists of disseminated chalcopyrite and pyrite which occur in a Late Cretaceous biotite-monzonite porphyry stock (Mesard and others, 1979; EMR Canada, 1989; House and Ainsworth, 1995). Quartz-chalcopyrite-molybdenite veins are associated with gypsum gangue. The porphyry stock intrudes volcaniclastic and epiclastic rocks of the Hazelton Group in the Stikinia terrane. Estimated resources are 144.1 million tonnes grading 0.368% Cu, 0.10% MoS_2, and 2.8 g/t Ag (Mesard and others, 1979).

Red Rose W-Au-Cu-Ag Polymetallic Vein Deposit

The Red Rose W-Au-Cu-Ag polymetallic vein deposit occurs near Hazelton, B.C. and consists of scheelite, ferberite, chalcopyrite, molybdenite and uraninite which occur in a sheared quartz vein (EMR Canada, 1989; Dawson and others, 1991). The sheared quartz vein cuts one of three northeast-trending diorite dikes which intrude contact metamorphosed argillite and siltstone of the Red Rose Formation, near the contact with porphyritic granodiorite of the Cretaceous Rocher Deboule stock. Estimated reserves are 20,000 tonnes grading 5% WO_3 have been identified (Mulligan, 1984).

Capoose Lake Ag-Au Polymetallic Vein Deposit

The Capoose Lake Ag-Au polymetallic vein prospect occurs 110 km southeast of Burns Lake in central British Columbia, and consists of Ag- and Au-bearing disseminations and veinlets of galena, pyrite, pyrrhotite, chalcopyrite, arsenopyrite, and sphalerite which are hosted in contact-metamorphosed volcanic rocks of the Hazelton Group. The disseminations and veinlets which occur both as replacements of garnet in the contact-metamorphosed host volcanic rocks, and as fillings in structurally-controlled fracture zones, are related to rhyolite sills which are coeval with, and probably satellitic to the adjacent Late Cretaceous Capoose batholith. Estimated resources are 28.3 million tonnes grading 36 g/t Ag and 0.91 g/t Au (Andrew and Godwin, 1987; Andrew, 1988).

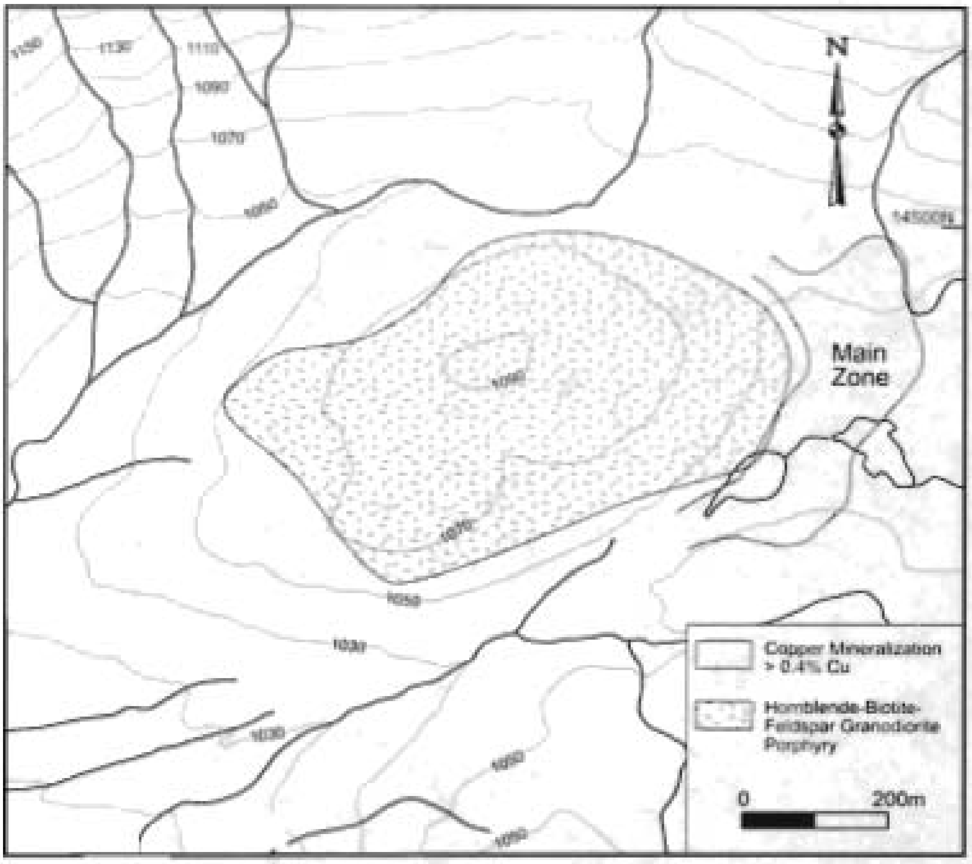


Figure 120. Huckleberry porphyry Cu-Mo deposit, Bulkley metallogenic belt, Canadian Cordillera. Schematic map showing main ore body. Adapted from Jackson and Illerbrun (1995).

Nadina (Silver Queen) Ag Polymetallic Vein Deposit

The Nadina (Silver Queen) Ag polymetallic vein deposit consists of sphalerite, galena, and chalcopyrite which occur in a gangue of quartz, rhodochrosite, chalcedony, and barite which are hosted in Late Cretaceous andesite and altered fragmental volcanic rocks (EMR Canada, 1989; Leitch and others, 1990; Dawson and others, 1991). Estimated reserves are 1.72 million tonnes grading 6.19% Zn, 328 g/t Ag, and 2.7 g/t Au. The deposit age is bracketed by microdiorite (with an isotopic age of 75.0±1.0 Ma) (MINFILE, 2002), and by younger felsite dikes and sills which are part of the Eocene Goosly Lake Intrusions.

Origin of and Tectonic Controls for Bulkey Metallogenic Belt

The Late Cretaceous Bulkley Plutonic Suite is coeval with the Surprise Lake and Carmacks Plutonic Suites, and with the volcanic rocks of the Carmacks Assemblage which all occur in the northern part of the Stikinia terrane (Woodsworth and others, 1991). Together, these plutonic rocks form part of the extensive Late Cretaceous and early Tertiary Coast-North Cascade plutonic belt that constitutes the major part of the Coast continental-margin arc mainly in the western Canadian Cordillera (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). Local Late Cretaceous volcanic units interpreted to be comagmatic with the Bulkley Plutonic Suite include the Brian Boru (Sutherland Brown, 1960) and Tip Top Hill (Woodsworth and others, 1991) volcanic rocks of the Kagalka Group (MacIntyre, 1985).

Fish Lake-Bralorne Metallogenic Belt of Porphyry Cu-Mo, Porphyry Cu-Au, Au Quartz Vein, Au-Ag Polymetallic Vein, and Related Deposit Types (Belt FLB) Southwestern British Columbia

The Fish Lake-Bralorne metallogenic belt of porphyry Cu-Mo, Au quartz vein, and Au-Ag polymetallic vein deposits (fig. 103; tables 3, 4) occur along the northeastern margin of the Coast Plutonic Complex in southwestern British Columbia. The belt contains the Bralorne district which contains a group of major Au mines. The Bralorne-and Pioneer Au deposits occur in Permian and Triassic diorite, gabbro, and greenstone, part of an ophiolite assemblage, which occurs along a shear zone along the complex tectonic boundary between Bridge River and Cadwallader terranes. The Congress polymetallic vein and Minto Ag-Au stibnite vein deposits in the Bridge River mining camp are related to stocks and dikes of the early Tertiary Bendor suite with isotopic ages of 70 to 65 Ma (Leitch and others, 1989; Church, 1995). These deposits occur to the northeast of the Bralorne district. Several other Sb-Au polymetallic vein deposits occur in the mining camp and are associated with the Late Cretaceous and early Tertiary Bendor pluton, Robson stock, and related intrusions (Leitch and others, 1989). Also occurring in the belt are porphyry Cu deposits, as at Empress, which locally grade to high-sulphidation epithermal vein systems in the easternmost partr of the Coast Plutonic Complex, directly on strike from the coeval Bralorne deposit (McMillan, 1983). The belt also includes porphyry Mo and Cu-Mo occurrences which are associated with Eocene stocks which occur along major dextral strike-slip faults.

The porphyry Cu-Mo and related deposits in the metallogenic belt are associated with Late Cretaceous porphyry dikes and stocks which are coeval with the adjacent eastern margin of the Coast Plutonic Complex and intrude metasedimentary rocks of the Methow terrane (Leitch and others, 1989). These granitoid rocks are part of the extensive Late Cretaceous and early Tertiary Coast-North Cascade plutonic belt which occurs along the western and central parts of the Canadian Cordillera for several thousand km (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). The significant deposits in the belt are (table 4) (Nokleberg and others 1997a, b, 1998): porphyry Cu-Mo deposits at Fish Lake, Giant Copper (Canam, A.M.), and Poison Mountain (Copper Giant); and Au quartz vein deposits at Bralorne, Pioneer (Bridge River area), and Carolin. The Maggie (Bonaparte River) deposit occurs along the margin of the belt.

Bralorne and Pioneer Au Quartz Vein Deposits

The Bralorne and Pioneer mines of the Bralorne district, and the smaller Wayside and BRX mines, are typically large, continuous, mesothermal Au-quartz-sulfide veins which range from 1 to 2 m wide, and consist commonly of quartz, calcite, free gold, arsenopyrite, pyrite, and lesser sphalerite, galena, scheelite, chalcopyrite and molybdenite (Leitch and others, 1989). The veins are lenticular and plunge steeply within a steeply-dipping major shear zone named the Cadwallader Break. The deposits have major metals of Au-W-Mo-As and Au/Ag ratios of 2 to 5. A district-wide mineral zoning varies from high-temperature Au-As-W-Mo through intermediate Sb-Ag-Au-As, to low-temperature Sb-Hg vein assemblages (Woodsworth and others, 1977). The southwest to northeast zonation is interpreted as forming in the thermal aureole of Late Cretaceous to early Tertiary plutons of the Coast Plutonic Complex. The Bralorne deposit is associated with Late Cretaceous (86-91 Ma) porphyry dikes. The Bralorne-Pioneer district mines produced 129.96 tonnes Au between 1899 and 1978 from 7.319 million tonnes ore (Dawson and others, 1991). Proven and probable reserves for Bralorne in 1991 were 965,000 tonnes grading 9.3 g/t Au (MINFILE, 2002).

Fish Lake Porphyry Cu-Au (Ag-Mo-Zn) Deposit

The Fish Lake porphyry Cu-Au (Ag-Mo-Zn) deposit consists of pyrite and chalcopyrite with minor molybdenite, bornite, sphalerite and tetrahedrite which occur in stockwork veins (EMR Canada, 1989; McMillan, 1991; Taseko Mines Ltd., news release, May 4, 1993; Caira and others, 1995; MINFILE, 2002). The deposit is hosted mainly in: (1) contact metamorphosed Early Cretaceous(?) andesite flows and volcaniclastic rocks which occur in an embayment in a porphyritic quartz diorite stock; (2) an associated, east-west-elongated complex of subparallel quartz-feldspar porphyry dikes; and (3) disseminations in a Late Cretaceous quartz-diorite porphyry and in adjacent contact-metamorphosed Early Cretaceous sedimentary and volcanic rocks (McMillan, 1991; Taseko Mines Ltd., news release, May 4, 1993). The quartz diorite stock exhibits a U-Pb zircon isotopic age of about 80 Ma (Schiarizza and Riddell, 1997), and the biotite hornfels exhibits a K-Ar whole-rock isotopic age of 77.2 Ma (Wolfhard, 1976). The principal orebody is ovoid shaped with dimensions of 1500 m by 800 m and a maximum depth of 880 m. Estimated resource are 1,148 million tonnes grading 0.22% Cu and 0.41 g/t Au (Wolfhard, 1976; McMillan, 1991; Caira and others, 1995).

Maggie Porphyry Cu-Mo Deposit

The Maggie (Bonaparte River) porphyry Cu-Mo deposit consists of chalcopyrite and molybdenite occurring in fine disseminations in quartz veins and in host rock, and in narrow veinlets in or bordering quartz and calcite veins. The deposit is hosted by the early Tertiary Maggie quartz monzonite stock, with a K-Ar isotopic age of 61 Ma, which intrudes metasedimentary and metavolcanic rocks of Cache Creek terrane (Miller, 1976). The stock occurs several tens of kilometers east of other plutons in the Fish Lake-Bralorne metallogenic belt. Chalcopyrite and molybdenite occur in quartz veins and are disseminated in the stock. High Cu and Mo grades occur in overlapping potassic and phyllic alteration, and lower Cu and Mo grades occur in phyllic and argillic alteration. Estimated resources are 181 million tonnes grading 0.28% Cu and 0.029% MoS_2 (Miller, 1976).

Poison Mountain Porphyry Cu-Mo (Ag-Au) Deposit.

The Poison Mountain Cu-Mo (Ag-Au) porphyry deposit consists of pyrite, chalcopyrite, molybdenite, and bornite which occur in veinlets, fracture fillings and disseminations (Brown, 1995; MINFILE, 2002). The deposit is concentrated at the contacts between a quartz diorite porphyry stock and dikes, with isotopic ages of 59 Ma, and contact-metamorphosed Early Cretaceous graywacke of the Jackass Mountain Group which is part of the Methow terrane. The deposit is surrounded by concentric zones of potassic, phyllic, and propylitic alteration. Concentric zones of copper sulfide and minor oxide minerals surround a barren granodiorite core. Estimated reserves, at 0.15% Cu cut-off, are: (1) in the oxide zone, 40.2 million tonnes grading 0.228% Cu (s), 0.15% Cu (ox), 0.127 g/t Au, and 0.007% Mo; and (2) in the sulfide zone, 768.3 million tonnes grading 0.232 Cu, 0.122 g/t Au, and 0.007% Mo (Brown, 1995; Seraphim and Rainboth, 1976; McMillan, 1991). The stock and associated dikes exhibit K-Ar isotopic ages which range from a hornblende age of 61.4 for biotite-altered quartze diorite, to a biotite-hornblende age of 55.5 Ma for contact-metamorphosed sedimentary rock in the outer part of the deposit (Brown, 1995). The deposit occurs 75 km southeast of Fish Lake.

Origin of and Tectonic Controls for Fish Lake-Bralorne Metallogenic Belt

The Fish Lake-Bralorne metallogenic belt is defined by the distribution of a suite of small, Late Cretaceous to Eocene, quartz monzonite and quartz diorite stocks which are part of the Coast Plutonic Complex but occur east of the main part of the batholith. The plutons are essentially coeval with plutons marking the eastern edge of the Coast suite, and probably represent the eastern limit of Late Cretaceous-Eocene magmatism in the southern part of the continental-margin arc. The Coast Plutonic Complex is part of the Coast-North Cascade plutonic belt.

Three major pulses of mineralization are interpreted for the Fish Lake-Bralorne belt (Schiarizza and others, 1997): (1) The older, Late Cretacous deposits in the belt are interpreted as forming along early Late Cretaceous reverse to sinistral faults which are interpreted as forming during the last part of contractual deformation which was associated with subduction; (2) The younger, latest Cretaceous to Paleocene deposits in the belt occur along dextral-slip faults, such as the Castle Pass fault and may in part be controlled by an extensional bend in the fault system (Schiarizza and others, 1997). And (3) the still younger, porphyry occurrences and associated polymetallic vein deposits are associated with Middle Eocene granodiorite plutons which occur along dextral fault systems.

Tyaughton-Yalakom Metallogenic Belt of W-Sb Polymetallic Vein and Hg-Sb Vein Deposits (Belt TY) Southern British Columbia

The Tyaughton-Yalakom metallogenic belt of W-Sb polymetallic vein and Hg-Sb vein deposits occurs in southern British Columbia and consists of several belts of scheelite-stibnite and cinnabar-stibnite veins which occur along major faults in the Methow and Cadwalleder terranes in southwestern British Columbia (fig. 103; tables 3, 4) (Nokleberg and others, 1997b, 1998). The significant deposits are at Tungsten Queen, Tungsten King, Silverquick, Manitou, Eagle, and Red Eagle.

The Tungsten Queen and Tungsten King W-Sb polymetallic vein deposits consist of banded, chalcedony-quartz-stibnite-scheelite veins which occur in pervasively silica-carbonate-altered ultramafic rocks (Schiarrizza and others, 1989). The Tungsten Queen deposit is hosted by listwanite-altered ultramafic rock along branched fractures in the Relay Creek-Marshall Creek fault system (Schiarrizza and others, 1990). The spatially-separated Silverquick, Manitou, and other similar Hg-Sb vein prospects consist of cinnabar which occurs as fracture-coatings and disseminations in both the Bridge River Greenstone and a Cretaceous conglomerate. These deposits may be a later overprint (Schiarrizza and others, 1989).

The Eagle and Red Eagle prospects consist of cinnabar-carbonate veins which occur in subsidiary shears in the Bridge River Greenstone, adjacent to the Bridge River-Yalakom fault system (Schiarrizza and others, 1990). The Hg-Sb vein deposits of the Tyaughton-Yalakom metallogenic belt are clearly associated with the Eocene dextral-slip faults of the Talakom, Relay Creek, and Fortress Ridge fault systems (Schiarrizza and others, 1989, 1990). The W-Sb occurrences also occur along the Relay Creek fault may be related to probable latest Cretaceous to Eocene dikes.

The vein deposits of the Tyaughton-Yalakom metallogenic belt are herein interpreted as forming during intrusion of the younger part of the Coast-North Cascade plutonic belt. The Tyaughton-Yalakom metallogenic belt is related to Fish Lake-Bralorne metallogenic belt of granitic-magmatism-related deposits.

Gambier Metallogenic Belt of Porphyry Cu-Mo and Zn-Pb-Cu Skarn Deposits (Belt GB) Southern British Columbia

The Gambier metallogenic belt of porphyry Cu-Mo and Zn-Pb-Cu skarn deposits (fig. 103; tables 3, 4) occurs in southern British Columbia and is associated with a linear belt of early Tertiary plutons which are part the southwestern Coast Plutonic Complex. The discordant felsic stocks intrude older, larger, concordant and more mafic plutons, and metamorphic pendants, of the Coast Plutonic Complex. These granitoid rocks are part of the extensive Late Cretaceous and early Tertiary Coast-North Cascade plutonic belt which occurs along the western and central parts of the Canadian Cordillera for several thousand km (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). The significant deposits in the belt are porphyry Cu-Mo deposits at Gambier Island, Hi-Mars (Lewis Lake), and O.K.., and a Zn-Pb skarn deposit is at Lynn Creek (table 4) (Nokleberg and others 1997a, b, 1998).

Gambier Island Porphyry Cu-Mo Deposit

The Gambier Island porphyry Cu-Mo (Zn-Pb) deposit consists of pyrite, chalcopyrite, and molybdenite which occur as disseminations, fracture fillings and veinlets (EMR Canada, 1989; Mining Review, 1990; Fox and others, 1995; MINFILE, 2002).

Both sulfide-bearing and sulfide-free quartz veins occur in the deposit. The deposit forms a broad arcuate zone 1200 m long by 200 m wide in an elliptical-shaped, early Tertiary quartz porphyry stock of the Coast Plutonic Complex and adjacent volcanic rocks. Estimated resources are 114 million tonnes grading 0.29% Cu and 0.018% MoS_2 (MINFILE, 2002). The quartz porphyry stock intrudes volcanic rocks of the Cretaceous Gambier Group which is part of the Gravina-Gambier overlap assemblage.

Hi-Mars Porphyry Cu-Mo Deposit

The Hi-Mars porphyry Cu-Mo deposit consists of a widespread occurrence of chalcopyrite and molybdenite which occur as disseminations and fracture fillings in a small Cu-Mo (Au-Ag) porphyry deposit which is part of the Coast Plutonic Complex (British Columbia Department of Mines and Petroleum Resources, 1972, Geology, Exploration, and Mining, p. 272; George Cross Newsletter no. 49, March 10, 1978). The deposit, which occurs 7 km northeast of Powell River, contains an inferred resource of 82 million tonnes grading 0.3% Cu (George Cross Newsletter No. 49, March 10, 1978); this resource may be for several zones in the deposit. The deposit probably is similar in age and genesis to the adjacent O.K. deposit.

O.K. Porphyry Cu-Mo Deposit

The O.K. porphyry Cu-Mo deposit consists of a stockwork with chalcopyrite, molybdenite and pyrite with minor sphalerite and bornite which occur in fractures, as quartz stringers, irregular veinlets, blebs and as disseminations (Meyer and others, 1976; EMR Canada, 1989; Mining Review, 1992; MINFILE, 2002). The deposit is mainly enclosed in a composite, narrow, northwest-trending, elliptical granodiorite pluton which contains a narrowm leucogranite porphyry dike along the exis of the pluton. Although both intrusions contain a quartz vein stockwork, most of the Cu-Mo sulfides occur in the granodiorite within a few hundred meters of the contact with the leucocratic porpohyry dike. The plutonic rocks are part of the Coast Plutonic Complex (Woodsworth and others, 1991). The age of the granitoids range in the Coast Plutonic Complex range from Jurassic to Tertiary. The deposit age is interpreted as Late Cretaceous. The deposit contains a resource of 104.9 million tonnes grading 0.46% Cu and 0.028% MoS_2 (Meyer and others, 1976; MINFILE, 2002).

Lynn Creek Zn-Pb Skarn Deposit

The Lynn Creek Zn-Pb skarn deposit consists of sphalerite, galena, pyrrhotite, chalcopyrite and pyrite in quartz veins and calc-silicate skarn. The deposit is hosted in shear zones in a roof pendant of Jurassic to Cretaceous metasedimentary and metavolcanic rocks of the Cretaceous Gambier Group. The plutonic rocks are part of the Coast Plutonic Complex. Poorly-estimated reserves are 272,000 tonnes grading 9% Zn with variable Ag (MINFILE, 2002). Local high-grade zones contain up to 68.6 g/t Ag and up to 20% Zn. The deposit age interpreted as Late Cretaceous to early Tertiary.

Origin of and Tectonic Controls for Gambier Metallogenic Belt

The Gambier metallogenic belt is defined by the distribution of a suite of small, early Tertiary granitoid bodies which constitute the younger part of the Coast Plutonic Complex which is part of the Coast-North Cascade plutonic belt which forms a major granitoid plutonic belt of Late Cretaceous and early Tertiary age which extends the length of the Canadian Cordillera and into East-Central Alaska (fig. 103). The belt consists chiefly of quartz diorite, granodiorite, and locally more mafic or felsic plutons (Rubin and others, 1991; Gehrels and others, 1990; Wheeler and McFeeley, 1991; van der Heyden, 1992; Woodsworth and others, 1992; Journeay and Friedman, 1993).

Catface Metallogenic Belt of Porphyry Cu-Mo-Au and Au-Ag Polymetallic Vein Deposits (Belt CF) Vancouver Island

The Catface metallogenic belt of porphyry Cu-Mo-Au and Au-Ag polymetallic vein deposits (fig. 103; tables 3, 4) occurs on Vancouver Island in the southern Canadian Cordillera and is associated with the middle to late Eocene Catface plutonic suite which consists of numerous, small irregular stocks, dikes and sills (Carson, 1973) which form a broad belt extending from near Nanaimo west to Ucluelet and north to Zeballos on Vancouver Island. The suite is part of the extensive Late Cretaceous and early Tertiary Coast-North Cascade plutonic belt which occurs along the western and central parts of the Canadian Cordillera for several thousand km (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). The significant deposits in the belt are at Catface, Domineer-Lakeview, and Privateer (table 4) (Nokleberg and others 1997a, b, 1998).

Porphyry Cu-Mo and Polymetallic Vein Deposits

The Catface porphyry Cu (Au-Mo) deposit consists of chalcopyrite, bornite, chalcocite, pyrite, pyrrhotite and molybdenite which occur in a stockwork of fractures and quartz veinlets (Dawson and others, 1991; Mining Review, 1992; Enns and McDougall, 1995; MINFILE, 2002). The stockwork is accompanied by biotite alteration. Estimated resources for the Cliff

Zone are 188 million tonnes grading 0.42% Cu, 0.014% Mo, and 308 million tonnes grading 0.37% Cu, 0.12% Mo; potential for additional resources exists at depth (McDougall, 1976; Enns and McDougall, 1995).The deposit is hosted in an apophysis of Eocene porphyritic quartz diorite of the Catface plutonic suite and has a K-Ar isotope age of 48 Ma. The diorite intrudes relatively older quartz monzonite and metabasalt of the Late Triassic Karmutsen Formation of Wrangellia.

The Domineer-Lakeview Au-Ag polymetallic vein zone occurs at Mount Washington, near Comox, and consists of a silicified vein-shear zone which cuts basaltic volcanic rocks of the Late Triassic Karmutsen Formation sedimentary rocks of the Late Cretaceous Nanaimo Group, and sills of the Catface Plutonic Suite. The Au-Ag polymetallic vein zone is interpreted as a shallow-dipping, post intrusion body. The shear zone is intensely altered to kaolinite and contains tabular zones which are silicified and cut by Au veins with quartz, pyrite, and arsenopyrite. The deposit is associated with a small, previously-producing porphyry Cu-Mo deposit, and several mineralized breccia pipes. Estimated reserves are 550,298 tonnes grading 6.75 g/t Au and 32.2 g/t Ag (Muller and Carson, 1969; MINFILE, 2002).

The Privateer Au polymetallic vein deposit consists of a set of thin, ribbon quartz veins which cut contact-metamorphosed volcanic rocks of the Middle Jurassic Bonanza Group, as well as the Zeballos stock of the Catface Plutonic Suite. The Privateer is the largest and most productive of a group of small mines in and adjacent to the stock. The major ore minerals are abundant pyrite and arsenopyrite, sphalerite, less abundant chalcopyrite, galena, and pyrrhotite, and rare free gold. Estimated production is 280,000 tonnes of ore containing 18.8 g/t Au along with Ag, Pb, and Zn (Stevenson, 1950; Dawson and others, 1991).

Origin of and Tectonic Controls for Catface Metallogenic Belt

The Middle to Late Eocene intrusions of the Catface Plutonic Suite are mainly calc-alkaline, tonalite and quartz diorite and minor granodiorite and granite, and commonly porphyritic. The plutons are roughly synchronous with Paleogene plutons in the southern Coast and Intermontane belts, were emplaced at high levels as indicated by associated breccias and diatremes, and intrude rocks as young as the Late Cretaceous Nanaimo Group (Woodsworth and others, 1991). The Catface Plutonic Suite is the southern part of the extensive Late Cretaceous and early Tertiary Coast-North Cascade plutonic belt which formed a major continental-margin arc in mainly the western Canadian Cordillera (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996).

Metallogenic Belts Formed in Backarc Part of Early Tertiary Coast Continental-Margin Arc, Southern Canadian Cordillera

The Skeena (SK) and Nelson (NS) constitute two major metallogenic belts of granitic-magmatism-related deposits occur in the southern Canadian Cordillera (fig. 103; tables 3, 4) that are interpreted as forming during granitic plutonism occurring during back arc extension or transtension in an region continentward of the subduction-related Coast continental-margin arc. These two early Tertiary two metallogenic belts represent the last stage of magmatism in the Coast-North Cascade plutonic belt that comprises most of the Coast continental-margin arc. This period of regional extension or transtension in the southern Canadian Cordillera is interpreted as the result of either: (1) a change from transpression to transtension at about 55 Ma caused by a change of obliquity of convergence of the oceanic plate (Parrish and others, 1988); or (2) alternatively, but likely, collapse of overthickened thrust units (Monger and Nokleberg, 1996; Nokleberg and others, 2000). This origin is analogous to the occurrence of back-arc magmatism forming the Columbia River basalt to the rear of the Cascade arc in the Miocene (Wells and Heller, 1988; England and Wells, 1991; Nokleberg and others, 2000).

Skeena Metallogenic Belt of Porphyry Cu-Mo, Porphyry Mo; Ag Polymetallic Vein and Au-Ag Epithermal Vein Deposits (Belt SK) Central British Columbia

The Skeena metallogenic belt of porphyry Cu-Mo; porphyry Mo; Ag polymetallic vein, and Au-Ag epithermal vein deposits occurs in central British Columbia (fig. 103; tables 3, 4), and is associated with several early Tertiary plutonic suites in the Intermontane Belt in west-central British Columbia, including the Nanika, Babine, Quanchus and Goosly (Woodsworth and others, 1991; Carter, 1982). Coeval and spatially related volcanic rocks support the interpretation which many of the plutons represent the roots of volcanic centres. The host plutonic rocks are the younger part of the Coast-North Cascade plutonic belt and the related early Tertiary Kamloops magmatic belt (Plafker and others, 1989; Nokleberg and others, 1994c, 1997c). The significant deposits in the belt are (table 4) (Nokleberg and others 1997a, b, 1998): porphyry Mo deposits at Ajax, Bell Moly (Alice Arm), Kitsault (BC Moly), Lucky Ship, Mount Thomlinson, Redbird, Roundy Creek, Serb Creek; porphyry Cu-Mo deposits at Berg, Big Onion, Dorothy, and Nanika (DW, New Nanik); polymetallic and Ag polymetallic vein deposits at Capoose Lake, Equity Silver (Sam Goosly), Nadina (Silver Queen), and Prosperity-Porter Idaho; and porphyry Cu-Au (Mo) deposits at Bell Copper (Newman), Granisle, and Morrison. However the age of the Equity Silver (Sam Goosly) deposit is unresolved.

Porphyry Mo and Cu-Mo Deposits Associated with Nanika Intrusions of Nanika Plutonic Suite

The Eocene Nanika Plutonic Suite, which forms the most widespread suite of post-accretionary granitoid plutons intruding the Stikinia terrane, include the Nanika Intrusions south of Bowser Basin (Carter, 1982), and the Alice Arm Intrusions west of the basin (Woodsworth and others, 1991). The small, multi-stage, calc-alkaline granitic to granodiorite stocks, dikes and sills, which were intruded along steeply-dipping faults, are interpreted to be the roots of deeply-eroded volcanic centers, perhaps of the Hazelton Group (MacIntyre, 1985). Several major porphyry deposits associated with Nanika Intrusions occur northeast of Hazelton, B.C. The largest of these deposits are at Berg, Mount Thomlinson, and Redbird. Other significant deposits in the Huston district are at Lucky Ship porphyry Mo and Nanika Mountain porphyry Cu (Mo) deposits. The Serb Creek porphyry Mo and the Big Onion porphyry Cu-Mo deposits (Wojdak and Stock, 1995) occur east and west of Smithers, respectively

Berg Porphyry Cu-Mo (Pb-Zn-Ag-Au) Deposit

The Berg porphyry Cu-Mo (Pb-Zn-Ag-Au) deposit consists of chalcopyrite, molybdenite and pyrite with minor sphalerite, galena, and arsenopyrite (Panteleyev, 1981; EMR Canada, 1989; Dawson and others 1991). Estimated reserves are 238 million tonnes grading 0.39% Cu, 0.05% MoS2, 2.84 g Ag. The deposit occurs within a fine-grained stockwork of quartz veinlets which are distributed in a broad asymmetrical zone around a semicircular quartz-monzonite porphyry stock of the Eocene Nanika Suite, and within the peripheral, contact-metamorphosed volcanic rocks of the Hazelton Group. The most intense Mo concentrations occur in the stock whereas the most intense Cu concentrations occur 60 meter beyond the contact. A pyrite halo occurs from 300 to 600 meters from the contact. Also occurring is extensive oxidation, leaching, and secondary enrichment.

Mount Thomlinson Porphyry Mo Deposit

The Mount Thomlinson porphyry Mo deposit consists of molybdenite, chalcopyrite, along with minor magnetite and scheelite which occur in a stockwork of quartz veinlets near the northwest contact of a circular, Eocene quartz monzonite porphyry stock which intrudes argillaceous Jurassic sedimentary rocks (Carter, 1982; EMR Canada, 1989). Estimated reserves are 40.8 million tonnes grading 0.12% MoS_2. The deposit occurs predominantly within intrusive rocks along the northwest contact. The host sedimentary rocks are deformed and metamorphosed into biotite, muscovite, cordierite, and andalusite-bearing schists.

Redbird Porphyry Mo Deposit

The Redbird porphyry Mo deposit consists of molybdenite and pyrite which occur in a stockwork of quartz veinlets within peripheral, concentric alteration zones of a quartz-monzonite porphyry stock of the Eocene Nanika Suite which intrudes Middle Jurassic pyroclastic rocks of the Hazelton Group (EMR Canada, 1989; Dawson and others, 1991). Estimated reserves are 63.5 million tonnes grading 0.17% MoS_2.The stock is dominantly one phase, and hosts a peripheral ring of molybdenum. Also present are potassic (K-feldspar), silica-sericite, and kaolinite alteration are present. The stock has a K-Ar isotopic age of 49.0 Ma.

Porphyry Mo Deposits Associated with Alice Arm Intrusions of Nanika Plutonic Suite

The Alice Arm Intrusions of the Nanika Plutonic Suite, which occur along the eastern margin of the Coast Plutonic Complex, consist of small granite to quartz monzonite porphyry stocks which intrude clastic rocks of the Late Jurassic Bowser Assemblage at the intersections of north-northwest and east-northeast faults (Carter, 1982). The major porphyry deposits are the Ajax porphyry Mo, Bell Moly porphyry Mo-W, and Kitsault (B.C. Moly) porphyry Mo (Ag, Pb, Zn, Cu) deposit.

Ajax Porphyry Mo Deposit

The Ajax porphyry Mo deposit consists of molybdenum in a quartz-vein stockwork which is hosted in an Eocene quartz monzonite porphyry intrusion, and in adjacent, contact-metamorphosed Jurassic argillaceous rocks (Soregaroli and Sutherland Brown, 1976; EMR Canada, 1989; MINFILE, 2002). The deposit occurs in four small, closely-spaced plutons. Estimated reserves are 178.5 million tonnes grading 0.121% MoS_2. Total reserves are 417.3 million tonnes grading 0.09% MoS_2 with a very high stripping ratio. The porphyry intrusion exhibits a K-Ar biotite isotopic age of 54.0 Ma age.

Bell Moly Porphyry Mo-W Deposit

The Bell Moly porphyry Mo-W deposit consists of molybdenite and minor scheelite which occur in a quartz vein stockwork in an Eocene quartz monzonite porphyry and in adjacent biotite hornfels in Jurassic metasedimentary and metavolcanic rocks (Carter, 1982; EMR Canada, 1989). Estimated reserves are 106 million tonnes grading 0.09% MoS_2. The deposit occurs in a crescent-shaped zone around the eastern portion of the stock.

Kitsault (B.C. Moly) Porphyry Mo Deposit

The Kitsault (B.C. Moly) porphyry Mo (Ag-Pb-Zn-Cu) deposit consists of molybdenite in quartz-vein stockworks which are related to an Eocene quartz monzonite and quartz diorite stock which intrudes Late-Jurassic and Early Cretaceous siltstone and graywacke of the Bowser Assemblage (Carter, 1982; Steininger, 1985; EMR Canada, 1989; Hodgson, 1995; MINFILE, 2002). The veinlets are cut by quartz veins, up to 3 meters wide and contain pyrite, galena, sphalerite, scheelite, chalcopyrite, tetrahedrite and pyrrhotite. Molybdenum-bearing rocks form a ring structure around the stock in quartz veinlets. At least five stock phases are recognized. Several stages of ores are associated with intramineral dikes. The porphyry exhibits a K-Ar isotopic age of 53.7 Ma. Estimated combined production and reserves are 113.3 million tonnes grading 0.184% MoS_2. Between 1967 and 1972 production was 9.3 million tonnes grading 0.112% MoS_2. Estimated reserves in 1989 were 104 million tonnes grading 0.19% MoS_2.

Ag Polymetallic Vein Deposits Associated with Goosly Plutonic Suite

The Goosly Plutonic Suite consists of small alkaline gabbro, syenomonzonite, and quartz monzonite stocks which occur near the western end of Francois Lake. The suite intrudes Late Cretaceous volcanic and clastic rocks of the Skeena Assemblage and is associated with subvolcanic to Eocene volcanic centers (Church, 1971). The major Ag polymetallic vein deposits are at Equity Silver (Sam Goosly) and Prosperity-Porter Id.

Equity Silver (Sam Goosly) Ag Polymetallic Vein Deposit

The Equity Silver (Sam Goosly) Ag deposit is an unusual polymetallic stockwork and vein deposit which consists of pyrite, chalcopyrite, pyrrhotite, and tetrahedrite, and minor sphalerite, galena, and silver sulfosalts which are accompanied by argillic alteration (Carter, 1982; Cyr and others, 1984; Northern Miner, March 28,1988; Schroeter and Lane, 1991; Panteleyev, 1995; MINFILE, 2002). The sulfides occur in veins, disseminations, and massive sulfide replacement bodies, ranging up to 120 m thick, which are located in tabular fracture zones roughly parallel to stratigraphy. Estimated combined production and reserves are 32.1 million tonnes grading 71.3 g/t Ag and 3.90 g/t Au. The mine closed in 1984; estimated remaining reserves are 5,915,454 tonnes grading 72.01 g/t Ag, 0.82 g/t Au, and 0.22% Cu. Estimated total Au content of combined production and reserves is 16.9 tonnes. The deposit age is poorly constrained and is younger than the host Late Cretaceous units and older than the Goosly Lake intrusions. The deposit occurs between a granitic stock (with a K-Ar isotopic age of 58 Ma), and a gabbro-monzonite stock (with a K-Ar isotopic age of 48 Ma). The plutonic rocks are part of the Goosly Lake Intrusions and intrude sedimentary and pyroclastic rocks of the Cretaceous Skeena Assemblage. The deposit is interpreted by Panteleyev (1995) as a subvolcanic Cu-Au-Ag deposit which commonly occurs near or above a porphyry Cu hydrothermal system.

Prosperity-Porter Idaho Ag Polymetallic Vein Deposit

The Prosperity-Porter Idaho deposit, an important past silver producer, consists of a set of narrow polymetallic Ag veins hosted in volcanic rocks of the Hazelton Assemblage which is related to the Hyder biotite granodiorite pluton. The pluton is part of an Eocene granitoid suite in the northeastern Coast Plutonic Complex (Woodsworth and others, 1991). From 1922 to 1950 the mine at the deposit produced 2.36 million ounces of Ag. Estimated reserves are 826,277 tonnes grading 669 g/t Ag and 5% Pb+Zn (Schroeter and Lane, 1991). Related silver mines in the Stewart region are those at Idaho and Indian (Alldrick, 1985; Alldrick and others, 1987).

Porphyry Cu-Au-Ag Deposits Associated with Babine Plutonic Suite

The Eocene Babine Plutonic Suite, which consists of distinctive, small, biotite feldspar granodiorite to quartz diorite porphyry stocks and dikes, is associated with several porphyry Cu-Au mines and significant prospects in central British Columbia. The suite consists of a northwest-trending belt of multiple intrusions of stocks, dikes, and breccias which are fault-controlled (Kirkham, 1971), and interpreted as the loci of volcanic centres for equivalent extrusive rocks in the area (Carter, 1982). The major porphyry Cu-Au-Ag deposits are at Bell Copper, Granisle, and Morrison. These deposits exhibit: (a) an annular zoning of sulfide minerals and associated potassic to phyllic to argillic alteration (Carson and Jambor, 1974); and (2) high precious-metal contents which are characteristic of classic (non-plutonic) calc-alkaline porphyry deposits (Sinclair, and others, 1982). Other deposits in the Babine Lake district (Carter and others, 1995) are the Dorothy porphyry Cu-Mo deposit which is hosted in a feldspar porphyry dike, and the Hearne Hill Cu-Au breccia pipe which is associated with a biotite-feldspar porphyry plug (Ogryzlo and others, 1995).

Bell Copper Porphyry Cu-Au (Mo) Deposit

The Bell Copper porphyry Cu-Au (Mo) deposit (fig. 121) consists of chalcopyrite and lesser bornite which occur as disseminations and in quartz lenses and stockwork veinlets. Estimated combined production and reserves are 71.75 million tonnes grading 0.46% Cu, 0.23 g/t Au, 0.48 g/t Ag, and 0.006% Mo (Carson and others, 1976; Noranda Inc., annual report, 1990;

Butrenchuk, 1991; Diron and others, 1995; MINFILE, 2002). The deposit is hosted in biotite-feldspar porphyry of the Eocene Babine Plutonic Suite and the adjacent Jurassic metasedimentary rocks and metavolcanic rocks of the Hazelton Group. A K-Ar biotite isotopic age of 51.0 Ma for the porphyry is interpreted as the age of deposit. The deposit exhibits pervasive potassic (mainly biotite) alteration with a surrounding, concentric halo of chlorite and sericite-carbonate alteration. The alteration coincides with a two-km-wide pyrite halo which surrounds the deposit (Dirom and others, 1995). A supergene chalcocite zone caps the deposit and extends to depths of 50 to 70 meters. Higher Cu grades occur in a 60 to 90 m-thick, flat-lying area which is connected to a central pipe-like zone which is centered on the western contact of the intrusion. Past production was 28.7 million tonnes grading 0.46% Cu.

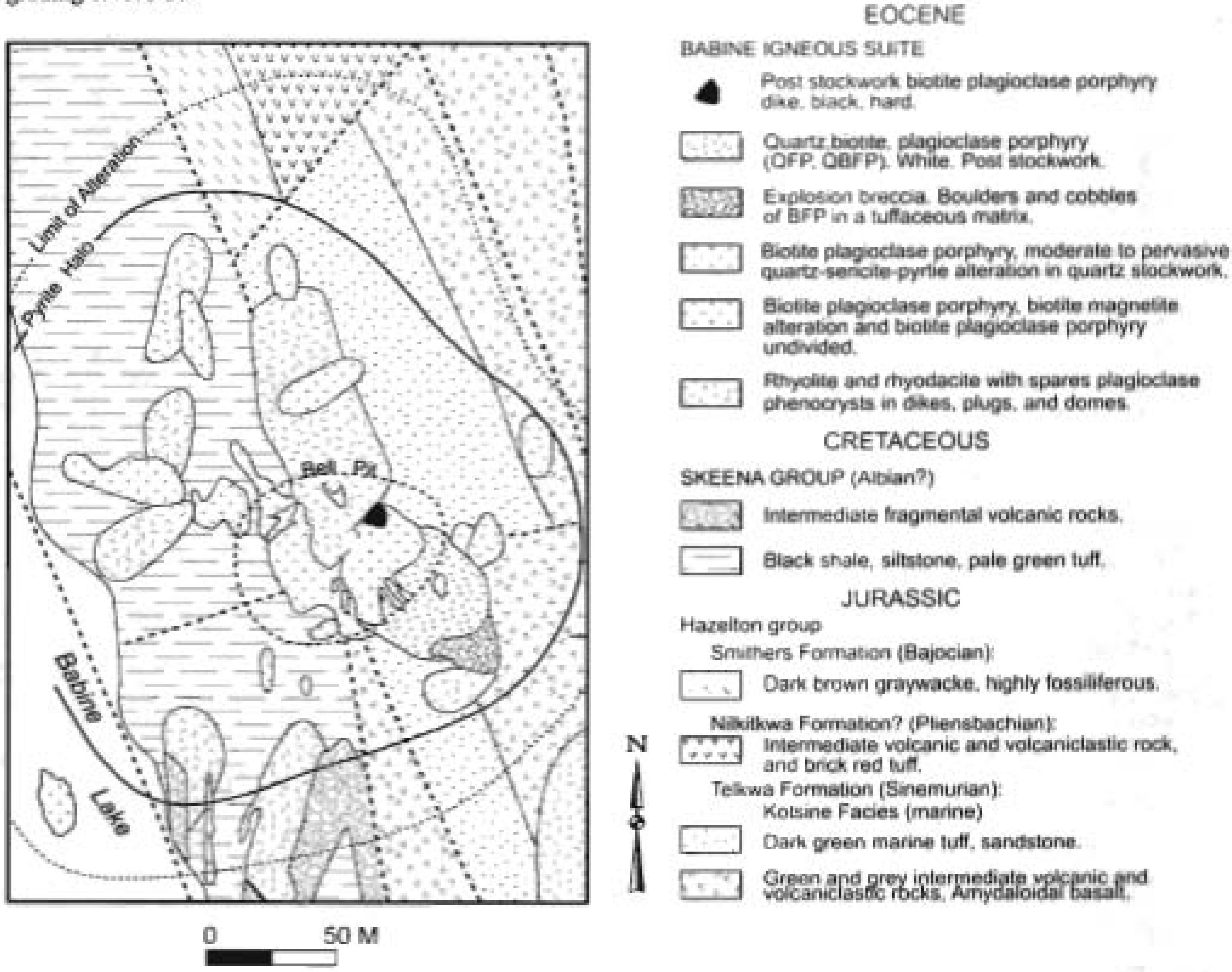


Figure 121. Bell Copper porphyry Cu-Au deposit, Skeena metallogenic belt, Canadian Cordillera. Schematic geologic map of area around open pit and alteration halos. Adapted from Butrenchuk (1991).

Granisle Porphyry Cu-Au (Mo) Deposit

The Granisle porphyry Cu-Au (Mo) deposit consists of chalcopyrite, bornite and pyrite with low grade Au and Ag and local minor molybdenite which occur in quartz-filled fractures (Carson and Jambor, 1974; Fahrni and others, 1976; EMR Canada, 1989; Dawson and others, 1991; Dirom and others, 1995). The deposit is associated with Eocene Babine porphyry intrusions (with K-Ar isotopic ages of 51.2 Ma) which intrude volcanic and sedimentary rocks of the Early Jurassic Hazelton Group. Combined estimated production and reserves re 66.2 million tonnes grading 0.42% Cu, 0.12 g/t Au, 1.12 g/t Ag, and 0.009 g/t Mo. The deposit is centered on the contact between biotite-feldspar porphyry and an earlier quartz diorite phase. A central potassic alteration zone is successively rimmed by a quartz-sericite-carbonate-pyrite alteration zone and by a chlorite-carbonate-epidote alteration zone (Dirom and others, 1995).

Morrison Porphyry Cu-Au (Mo) Deposit

The Morrison Porphyry Cu-Au (Mo) deposit consists of chalcopyrite and pyrite which occur in a stockwork of veinlets and fractures, and as disseminations (Carter, 1982; EMR Canada, 1989; Ogryzlo and others, 1995). Estimated resources are 86 million tonnes grading 0.42% Cu, 0.34 g/t Au, 3.4 g/t Ag, and 0.017% Mo. The deposit is hosted in biotite-hornblende-plagioclase porphyry of the Eocene Babine Suite and in adjacent Jurassic sedimentary rocks. The porphyry, sedimentary rocks, and deposit are displaced by a fault.

Au-Ag Epithermal Vein Deposits Associated with Quanchus Plutonic Suite

The Quanchus Plutonic Suite forms an arcuate chain of large stocks in west-central British Columbia. The plutons in the suite are similar in composition to plutons in the Nanika suite to the west, but contain more hornblende and biotite; in addition, the suite contains only minor porphyry Cu-Mo prospects (Woodsworth and others, 1991). Comagmatic with the plutons of the Quanchus suite are uplifted and eroded felsic volcanic centers in the Eocene Ootsa Lake Group in the Fawnie Range. The significant Au-Ag epithermal vein prospects are: (1) the Holy Cross and Uduk Lake deposits (Lane and Schroeter, 1995); (2) the Wolf prospect which is related to resurgent doming and felsic intrusion within a caldera (Andrew and others, 1986); (3) the Clisbako prospect which is hosted in felsic volcanics of the Eocene Clisbako formation, and is one of several similar deposits in a caldera with a diameter of 40 km (Metcalfe and Hickson, 1995); and (4) the Blackdome mine which occurs in an Eocene andesite-rhyolite-volcaniclastic sequence, which is coeval with the Ootsa Lake and Clisbako Volcanics to the north, and is controlled by doming and normal faulting (Vivian and others, 1987).

Origin of and Tectonic Controls for Skeena Metallogenic Belt

The Skeena metallogenic belt of porphyry Cu-Mo; porphyry Mo; Ag polymetallic vein, and Au-Ag epithermal vein deposits occurs in central British Columbia (fig. 103) and is associated with several early Tertiary plutonic suites in the Intermontane Belt in west-central British Columbia. The plutonic suites, which consist of the Nanika, Babine, Quanchus, and Goosly Suites (Woodsworth and others, 1991; Carter, 1982), are coeval and spatially related to suprajacent volcanic rocks, indicating that the plutons were the roots of former volcanic centers. The plutonic suites are commonly controlled by high-angle faults which caused uplift and block-faulting in the Stikinia terrane. The plutonic suites and coeval volcanic units form part of an extensive continental-margin arc in the Canadian Cordillera which consisted of the early Tertiary Kamloops magmatic belt (Plafker and others, 1989; Nokleberg and others, 1994c, 1997c) and the Late Cretaceous and early Tertiary Coast-North Cascade plutonic belt (Nokleberg and others, 1994c, 1997c). These volcanic-plutonic suites in the southern Intermontane Belt are interpreted as high-level products of deep-seated plutonism and metamorphism in the Coast Belt to the west which formed in a transpressive orogen related to an extensional stress field (Woodsworth and others, 1991).

Nelson Metallogenic Belt of Ag Polymetallic Vein, Ag-Pb-Zn Manto, Au-Ag Epithermal Vein, Porphyry Mo, Paleoplacer U. and Related Deposits (Belt NS) Southern British Columbia

The Nelson metallogenic belt of Ag polymetallic vein; Ag-Pb-Zn manto; Au-Ag epithermal vein, porphyry Mo, paleoplacer U and related deposits (fig. 103; tables 3, 4) occurs in southern British Columbia. The belt contains significant Au-Ag polymetallic vein and manto deposits which occur in two settings. Some deposits occur to the east, in or near the Middle Jurassic Nelson Batholith which is part of the Nelson plutonic suite (Woodsworth and others, 1991). The significant deposits in the belt are (table 4) (Nokleberg and others 1997a, b, 1998): Au-Ag and Ag polymetallic vein deposits at Ainsworth District, Highland Bell (Beaverdell), Millie Mack, and Silverton District (Sandon, Silver Ridge), a porphyry Mo deposit at Carmi Moly; a Zn-Pb-Ag skarn and manto deposit at Riondel (Blue Bell); and a paleoplacer U deposit at Lassie Lake area (Blizzard).

Bluebell (Riondel) Zn-Pb-Ag Skarn and Manto Deposit

The Bluebell (Riondel) Zn-Pb-Ag skarn and manto deposit (fig. 122) consists of sphalerite, galena, pyrrhotite, pyrite, arsenopyrite, chalcopyrite and knebelite which occur in replacement bodies and in veins controlled by bedding, fractures and open anticlinal culminations (Hoy, 1980, 1982a; Nelson, 1991; Beaudoin and others, 1992). The manto and vein deposits occur along bedding or fractures, and in pre-deformational breccias, and anticlinal culminations in Early Cambrian limestone of the Badshot Formation, and in quartz-mica schist of the Mohican Formation. A distinctive skarn mineral assemblage includes prograde knebelite (Fe-Mn olivine) and retrograde minnesotaite (Fe talc), Fe-, Mn-, and Mg-carbonate, chlorite, calcite, and quartz. A K-Ar isotopic age of 59 Ma for vein muscovite which cuts a gabbro dyke indicates an Eocene age of mineralization for the Riondel deposit and possibly for the district (Beaudoin and others, 1992). The mine at the deposit attained the largest production from a Canadian Zn-Pb-Ag skarn mine. Between 1895 and 1971 estimated production was 4.82 million tonnes of ore, and estimated reserves are 0.35 million tonnes grading 6.3% Zn, 5.2% Pb, and 45 g/t Ag.

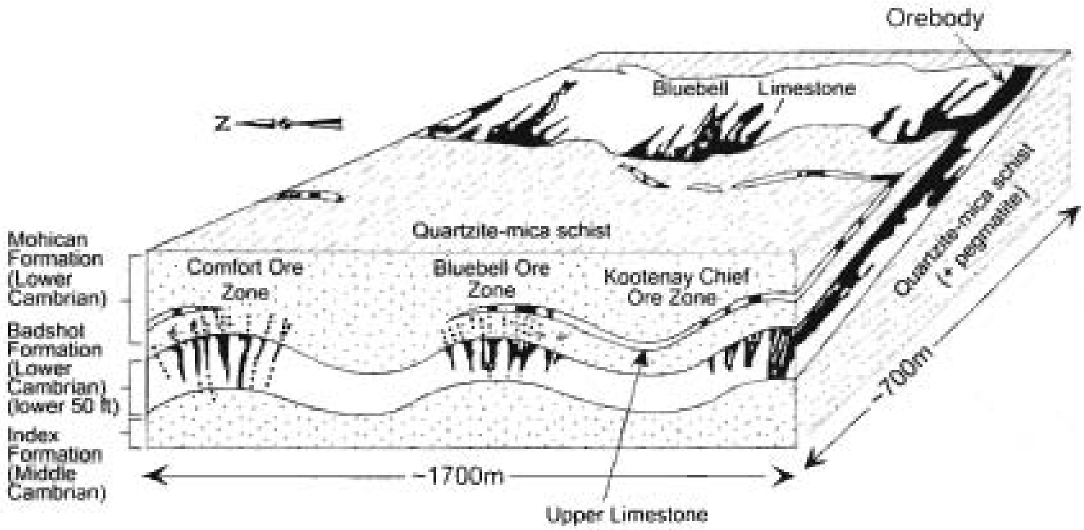


Figure 122. Bluebell (Riondel) Zn-Pb-Ag skarn and manto deposit, Nelson metallogenic belt, Canadian Cordillera. Schematic block diagram. Host Bluebell limestone occupies western limb of a north-trending antiform. Adapted from Hoy (1980) and Dawson (1996a).

Highland Bell (Beaverdell) Ag-Polymetallic Vein Deposit

The Highland Bell (Beaverdell) Ag-polymetallic vein deposit consists of sphalerite, pyrite, galena, arsenopyrite, chalcopyrite and minor pyrargarite in quartz-calcite veins which occur along a northeast-trending, 3 km by 800 meter belt on the west slope of Mt. Wallace (Watson and others, 1982; MINFILE, 2002). The deposit was notably rich in Ag, and the mine at the deposit had the longest continuous operating life of any mine in British Columbia. Between 1901 and 1992, estimated production was 941,644 tonnes grading 1,060 g/t Ag, 1.14% Pb, and 1.37% Zn. The majority of the production (1,166 tonnes of Ag) was from the upper and lower Lass vein systems which occur in Jurassic granodiorite and adjacent turbiditic clastic and pyroclastic rocks of the Permian Wallace Formation. However, the Highland Bell deposit is interpreted as forming during intrusion of the Eocene quartz monzonitic Beaverdell stock which has a K-Ar isotopic age of 50 Ma (Christopher, 1975; Watson and others, 1982).

Carmi Moly Porphyry Mo-Cu (U-F) Deposit

The Carmi Moly porphyry Mo-Cu (U-F) deposit consists of molybdenite and chalcopyrite which are disseminated in brecciated Early Jurassic granodiorite which has been intruded by a alkalic to calc-alkalic Eocene quartz monzonite porphyry Beaverdell stock with a K-Ar isotopic age of 50 Ma (Eocene), which also contains part of the deposit (Dawson and others, 1991; MINFILE, 2002). The deposit occurs in a 2-km-diameter annular-shaped pyrite zone. The stock is part of the Coryell Plutonic Suite. Estimated reserves are 44.5 million tonnes grading 0.13% Mo.

Lassie Lake and Hydraulic Lake Paleoplacer U deposits

Lassie Lake and Hydraulic Lake paleoplacer U deposits consists of autunite and saleeite which occur in paleostream channels in Paleogene continental sedimentary rocks or basins which overly quartz monzonite of Cretaceous Valhalla pluton which is part of the alkaline Coryell Plutonic Suite and calc-alkalic plutons of the Okanagan composite batholith underlie the paleoplacer U deposits. (Sawyer and others, 1981; MINFILE, 2002). Secondary U minerals, autunite and saleeite, derived from underlying uraniferous quartz monzonite of the Cretaceous Valhalla pluton, are concentrated in early Tertiary paleochannel sediments where oxidation was retarded by a capping of plateau basalt of the Pliocene Chilcotin Group. Estimated reserves are 2.1 million tonnes containing 4000 tonnes of U and grading 0.227% U_3O_8 (Bell, 1991; Sawyer and others, 1981). The uranium minerals occur in oxidized facies of coarse-grained fluvial sedimentary rocks and in disseminated organic material in reduced, fine-grained sedimentary rocks.

Origin of and Tectonic Controls for Nelson Metallogenic Belt

The Nelson metallogenic belt contains a wide variety of Ag polymetallic vein; Ag-Pb-Zn manto; Au-Ag epithermal vein, porphyry Mo, paleoplacer U, and related deposits (tables 3, 4). Some deposits occur to the east, in or near the Middle Jurassic Nelson Batholith which is part of the Nelson plutonic suite (Woodsworth and others, 1991). Other deposits occur to the west in the Okanagan Valley in, or near the Eocene alkaline Coryell Plutonic Suite which is interpreted as forming during regional extension. The Coryell Suite is interpreted as the rear or back-arc part of the Coast-North Cascade plutonic belt. The vein and manto deposits which occur in, or around the Middle Jurassic Nelson Batholith, including those in the Silverton, Ainsworth, Slocan, and Sandon districts, were originally interpreted as forming during the Middle Jurassic intrusion of the batholith and associated granitoid dikes (Cairnes, 1934; Hedley 1947, 1952). However, recent isotopic studies suggest: (1) an Eocene age for mineralization for deposits in the district (Beaudoin and others, 1992), including the large Bluebell (Riondel) skarn and manto; and (2) that the deposits formed during intrusion of (Eocene) mafic and lamprophyric dikes.

To the west in the Okanagan Valley several other Au-Ag epithermal vein deposits are hosted by Eocene trachyte volcanic rocks of the Marron Formation which is genetically related to the alkalic Coryell Plutonic Suite (Woodsworth and others, 1991; Church, 1973). The Au-Ag epithermal vein deposits include the Vault (Panteleyev, 1991) and Dusty Mac (Zhang and others, 1989) deposits. The igneous rocks and associated deposits are interpreted as forming during Eocene regional extension associated with the low-angle Okanagan shear zone (Tempelman-Kluit and Parkinson, 1986; Parrish and others, 1991).

Early to Middle Tertiary Metallogenic Belts 52 to 23 Ma; Figures 102, 103)

Overview

The major early Tertiary metallogenic belts in the Russian Far East and the Canadian Cordillera are summarized in table 3 and portrayed on figures 102 and 103. The major belts are as follows. (1) In the Russian Southeast, the Central Sakhalin (CS) belt, which contains Au quartz vein and talc deposits, is hosted in deformed units of the Aniva subduction zone terrane, and is interpreted as forming in collisional event during the early Tertiary(?) accretion of outboard terranes to the east. (2) On the southern Kamchatka Peninsula in the Russian Northeast, the Sredinny metallogenic belt of Au quartz vein and metamorphic REE vein(?) deposits is hosted in the Sredinny-Kamchatka terrane and is interpreted as forming during accretion of the outboard outboard Olyutorka arc and generation of hydrothermal fluids. (3) Also on the southern Kamchatka Peninsula in the Russian Northeast, the Kvinumsky metallogenic belt of hornblende peridotite Cu-Ni and gabbroic Ni-Cu deposits, is hosted in cortlandite-norite-diorite intrusions which intrude the older metamorphic and granitoid rocks of the Sredinny-Kamchatka metamorphic terrane. The belt is interpreted as forming during backarc intrusion related to subduction beneath the Kamchatka Peninsula part of Northeast Asia continental margin arc. (4) In the Russian Northeast, the Central Koryak (CKY) belt, which contains granitic-magmatism-related deposits, is hosted in the Kamchatkak-Koryak volcanic-plutonic belt, and is interpreted as forming along a transform continental-margin arc. (5) In the Russian Northeast, the Olyutor (OT) belt, which contains granitic-magmatism-related and clastic sediment-hosted Hg deposits, is hosted in the East Kamchatka volcanic and sedimentary basin, and is interpreted as forming during subduction-related granitic plutonism that formed the Kamchatka Peninsula part of Northeast Asia continental margin. (6) In the central Canadian Cordillera, the Pinchi Lake belt, which contains Hg epithermal vein, Sb-Au vein, silica-carbonate Hg deposits hosted in, or near shear zones, is interpreted as forming during transcurrent faulting along Cascade volcanic-plutonic belt. And (7) in the southern Canadian Cordillera, the Owl Creek (OC) belt, which also contains granitic-magmatism-related deposits, is hosted in the Cascade volcanic-plutonic belt and is interpreted as forming during subduction-related granitic plutonism which formed the Cascade continental margin arc. In the below descriptions of metallogenic belts, a few of the noteable or signficant lode deposits (table 4) are described for each belt.

Metallogenic-Tectonic Model for Early to Middle Tertiary (52 to23 Ma; Figure 123)

During the early to middle Tertiary (middle Eocene to the early Miocene - 42 to 23 Ma), the major metallogenic-tectonic events were (fig. 123; table 3): (1) accretion of the Olyutorka island arc; (2) continuation of a series of continental-margin arcs, associated metallogenic belts, and companion subduction-zone assemblages around the Circum-North Pacific; (3) continuation of sea-floor spreading in the Arctic and eastern Pacific Oceans; (4) establishment of a new continental margin in the northern and eastern parts of the Circum-North Pacific as the result of the disappearance of the Kula Ocean plate and inception of subduction of the leading edge of the Pacific Ocean plate; (5) continuation of dextral transpression between the Pacific Ocean plate (PAC) and the North American continental margin in the eastern part of the Circum-North Pacific; and (6) a change to orthogonal transpression between the Pacific Ocean plate and the Southern Alaska continental margin because of counterclockwise rotation of Western Alaska.

At about 50 Ma (Vogt and others, 1979), the Gakkel Ridge (GK; northern extension of the Atlantic mid-Ocean Ridge) was initiated and sea-floor spreading extended into the Eurasia Basin (eb) in the Arctic ocean, thereby resulting in the North American–Eurasia plate boundary in the Russian Northeast. The exact location of the Euler pole changed throughout the Cenozoic, thereby resulting in regional changes in the stress regime (Savostin and others, 1984; Harbert and others, 1990). Analysis of marine magnetic anomalies in the Eurasia Basin suggests that the region underwent extension from about 56 to 36 Ma (Savostin and Drachev, 1988a, b; Harbert and others, 1990; Fujita and others, 1997).

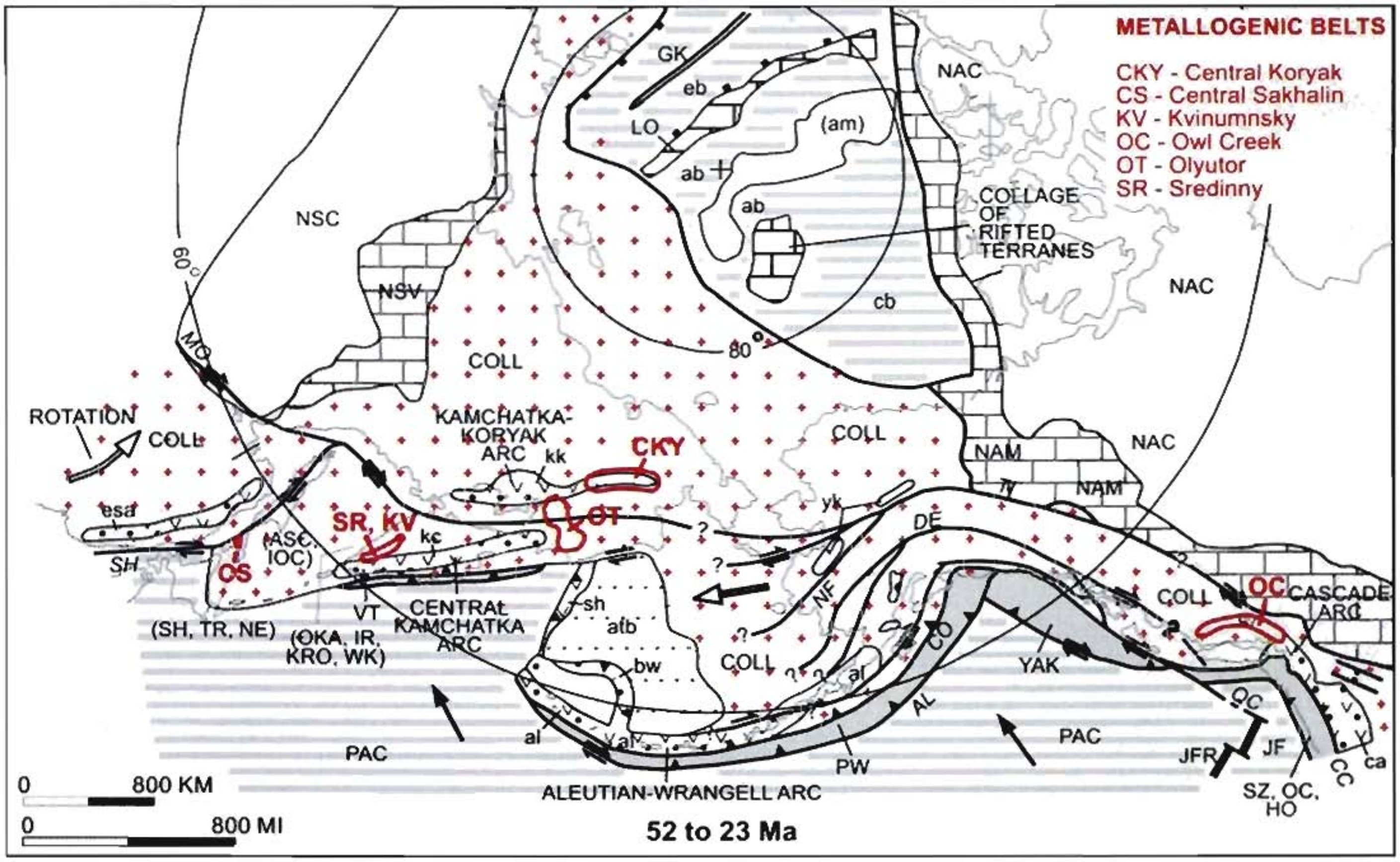


Figure 123. Early to middle Tertiary (Middle Eocene through early Miocene - 52 to 23 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

Specific Events for Early to Middle Tertiary

(1) The younger, bimodal volcanic and plutonic rocks of the youngest part of East-Sikhote Alin volcanic-plutonic belt (es), mainly basalt, rhyolite, and associated granitic plutonic rocks, are herein interpreted as forming in a dextral-transpression tectonic regime. During dextral-transpression, the the Central Sakhalin (CS) metallogenic belt of Au quartz vein and talc deposits formed in the Aniva subduction zone terrane during associated hydrothermal activity.

(2) In the early Eocene, at about 50 Ma (Heiphitz and others, 1994; Brandon and others, 1997, 1998; Garver and others, 1998; Solo'ev and others, 1998; Konstantinovskaya, 1999), the Olyutorka island arc accreted against the West Kamchatka accretionary-wedge terrane (WK; fig. 123) along the Vatyn thrust of Brandon and others (1997, 1998) which is interpreted as a low-angle, seaward-dipping zone of obduction (Brandon and others, 1997, 1998; Ramthun and others, 1997). Alternatively, Geist and others (1994) suggested that the Olyutorka arc and its companion subduction zone formed near the margin of Northeast Asia. During accretion of the Olyutorka arc was formation of the Sredinny metallogenic belt (SR) of Au quartz vein and = metamorphic REE vein(?) deposits.

(3) In the area of the central and southern Russian Far East, tectonic wedging occurred because of the accretion of the India plate against the Eurasia plate (Worall and others, 1996). The tectonic wedging resulted in sinistral displacement along the reactivated Mongol-Okhotsk fault (*MO*) and dextral displacement along the Sakhalin-Hokkaido fault (*SH*) parallel to the margin of the Russian Far East. A complex array of normal faults, en-echelon folds, and thrusts is interpreted as forming within and adjacent to the tectonic wedge (Worall and others, 1996). The relation of sinistral movement along the reactivated Mongol-Okhotsk fault and dextral movement along the Denali (DE), Tintina (TI), and related faults to the east in mainland Alaska in unclear.

(4) The bimodal volcanic and plutonic rocks of the Kamchatka-Koryak volcanic-plutonic belt (kk) are herein interpreted as forming in a sinistral tectonic regime. The Kamchatka-Koryak volcanic-plutonic belt constitutes the Cetnral Kamchatka arc. Forming in the volcanic-plutonic belt was the Central Koryak (CKY) metallogenic belt which contains granitic-magmatism-

related deposits. Forming in the backarc part of the arc was the Kvinumsky (KV) metallogenic belt of hornblende peridotite and gabbroic Cu-Ni deposits.

(5) Rifting commenced at about 50 Ma along the Gakkel Ridge (GK; northern extension of the mid-Atlantic ridge) and extended into the Russian Northeast (Fujita and others, 1997). The rifting is interpreted as causing eruption of basalts in the Chersky Range at about 37 Ma (Fujita and others, 1997). The Lomonosov Ridge terrane (LO) is interpreted as forming during the rifting of passive continental margin units now preserved in the Barents Sea region (out of field of fig. 123) (Zonenshain and others, 1990). Sedimentation continued in the large Amerasia (ab), Canada (cb) and Eurasia (eb) Basins.

(6) A short-lived period of marine arc volcanism formed the Bowers (bw) and Shirshov (sh) Ridges In the Bering Sea. The arc formed on the rear edge of the previously accreted Aleutia terrane (al), a fragment of the Kula Ocean plate (Scholl and others, 1992, 1994) The Bowers Ridge volcanic belt consists chiefly of intermediate- composition volcanic rocks, mainly altered andesite, breccia, volcaniclastic sedimentary rocks, and lesser diatomaceous siltstone (Cooper and others, 1992; Scholl and others, 1992). Analysis of sparse dredge samples and DSDP drill cores suggests a Miocene age for the volcanic rocks. The presence of a trench filled with as much as 12 km of sedimentary rocks located at the base of the northern and eastern slopes of Bowers Ridge suggests that the unit formed in an early Tertiary arc-trench system which faced toward the northeast. The Shirshov Ridge volcanic belt consists chiefly of two assemblages. (1) A relatively older oceanic assemblage is composed of amphibolite, gabbro, diabase, basalt, and chert. Chert contains Late Cretaceous (Campanian to Maastrichtian) to early Paleogene microfauna. (2) A relatively younger volcanic-arc assemblage is composed of altered andesite, volcaniclastic sedimentary rocks, and shale of Miocene and younger age (Baranov and others, 1991; Scholl and others, 1992). Alternatively, the Bowers and Shirshov Ridges may be the northward extension of the Olyutorka-Kamchatka island arc (OKA; Brandon and others, 1997, 1998). Also in the Bering Sea, a thick sedimentary prism started to form in the Aleutian-Bowers sedimentary basin (atb) which overlies the Aleutia terrane (Plafker and Berg, 1994; Scholl and others, 1992, 1994).

(7) Tectonic escape (crustal extrusion) of terranes continued to occur along major dextral-slip faults, including the Denali (*DE*), Nixon Fork (*NF*), Kaltag (*KA*), and companion faults in the area of the Western Alaska the Bering Sea (Scholl and others, 1992, 1994). Dextral-wrench basins continued to form in association with the major dextral-slip faults and were rapidly filled with continental sediments. Coincident with crustal extrusion was counterclockwise oroclinal bending of Alaska which perhaps resulted from compression between Eurasia and North America (Scholl and others, 1992, 1994; Plafker and Berg, 1994). To the east, in the area of Southern Alaska, displacement continued along major dextral-slip faults, including the Denali, Nixon Fork, and Kaltag faults. These and similar dextral-slip faults probably extended into the area of the Bering Sea.

(8) The Pacific Ocean plate (PAC) moved towards North America as a result of sea-floor spreading along the Juan de Fuca oceanic ridge. Along the Aleutian megathrust (*AL*), plate convergence continued to vary from oblique-orthogonal in the east to oblique in the west. Oblique-transpressive displacement occurred between the Pacific Ocean plate (PAC) and the southern Canadian Cordillera.

(9) As a result of trapping of part of the Kula Ocean plate (underlying the Aleutian-Bowers basin), and step-out of subduction, the western part of Aleutian-Wrangell arc (al) was initiated at about 40 Ma. This major Andean-type arc overlapped the previously accreted Kula Ocean plate and initially extended for a distance of about 3,000 km along the Bering Straits and Southern Alaska. Associated with the arc was subduction of part of the Pacific Ocean plate (PAC) to form the Prince William (PW) and Yakutat (YA) terranes along Aleutian megathrust (*AL*).

(10) At about 25 to 30 Ma, a major tectonic change occurred in the Southern Canadian Cordillera with tectonic overriding of the northern segment of the Juan de Fuca oceanic ridge (JFR) and resultant establishment of dextral-slip along the Queen Charlotte fault (*QC*). This tectonic change ended subduction of the Farallon Ocean plate (FAR) and started northward migration and subduction of the Yakutat terrane (YAK), resulting in the beginning of volcanism in the Wrangellia volcanic field (wr) in the eastern part of the Aleutian-Wrangell arc (fig. 123). Total movement of the Yakutat terrane is estimated at about 600 km (Plafker and Berg, 1994; Plafker and others, 1994). Movement ceased along major dextral-slip faults in interior Canadian Cordillera, including the Tintina (*TI*) and Fraser Creek-Straight Creek (*FS*) faults. Between latitudes 51° and 60°, the Queen Charlotte transform fault separated the Cascade arc and the Aleutian-Wrangell arc. This fault forms the North American plate margin between Vancouver Island, Canada, and northern Southeastern Alaska.

(11) Offshore of the southern Canadian Cordillera, sea-floor spreading occurred along the Juan de Fuca oceanic ridge (JFR). To the east, subduction of the Juan de Fuca plate (JF) resulted in initiation of the Cascade continental-margin arc (ca). Part of the subducting plate is preserved in the Siletzia (SZ), Olympic Core (OC), and Hoh (HO) terranes along branches of the Cascadia megathrust (*CC*). Forming along transcurrent faults along the extension of the Cascade arc was the Pinchi Creek (PC) metallogenic belt of Hg epithermal vein, Sb-Au vein, silica-carbonate Hg deposits. Also forming in the Cascade arc was the Owl Creek (OC) metallogenic belt, which also contains granitic-magmatism-related deposits and is interpreted as forming during subduction-related granitic plutonism.

Metallogenic Belts Formed in Tertiary Collision of Outboard Terranes, Russian Southeast

Central Sakhalin Metallogenic Belt of Au Quartz Vein and Talc Deposits (Belt CS) Sakhalin Island, Southeastern Part of Russian Far East

The Central Sakhalin metallogenic belt of Au quartz vein and talc deposits occurs in the Aniva subduction-zone terrane in the central part of Sakhalin Island (fig. 102; tables 3, 4) (Nokleberg and others, 1997b, 1998). The major deposit at Langeriiskoe consists of Au-bearing quartz-sulfide veins in lenticular bodies of fractured and faulted Permian-Triassic spilite and graywacke, Jurassic-Early Cretaceous slate, and Cenozoic volcanic rocks and chert (Khanchuk and others, 1988; Bekhtold and Semenov, 1990). The Au-bearing quartz-sulfide veins are interpreted as forming during metamorphism associated with middle or late Tertiary folding and faulting. Also in the metallogenic belt are talc deposits, formed by hydrothermal alteration of ultramafic intrusive rocks which are also of economic interest.

The host Aniva terrane is composed of intensely deformed and metamorphosed sedimentary and volcanic rocks which locally display Late Cretaceous to Paleogene transitional glaucophane-greenschist facies metamorphism. The Aniva terrane is interpreted as a subduction zone unit which was tectonically linked to the Cretaceous East Sikhote-Alin volcanic-plutonic belt (Nokleberg and others, 1994c, 1997c). The Central Sakhalin belt of Au quartz vein and talc deposits hosted in the Aniva terrane are herein interpreted as possibly forming in a collisional environment during the early Tertiary(?) accretion of outboard terranes to the east.

Sredinny Metallogenic Belt of Au Quartz Vein and Metamorphic REE Vein(?) Deposits (Belt SR) Southern Kamchatka Peninsula

The Sredinny metallogenic belt of Au quartz vein deposits and a single metamorphic REE vein(?) deposit occurs in the southern part of the Kamchatka Peninsula in the zoned metamorphic complexes of the Sredinny-Kamchatka terrane (fig. 102; tables 3, 4) (Nokleberg and others, 1997b, 1998). The Au quartz vein deposits occur mainly in metasandstone and metasiltstone. The major Au quartz vein deposit is at Tumannoe and a single metamorphic REE vein(?) deposit is at Anomalnoe.

Tumannoe Au quartz vein deposit

The Tumannoe Au quartz vein deposit (D.A. Babushkin and others, written commun., 1986) occurs in quartz phyllite which is interbedded with late Paleozoic metasandstone and metasiltstone. The major ore minerals are gold, arsenopyrite, and pyrite, with rare chalcopyrite and magnetite. The mineralized zones vary from 30 to 115 m long and 20 to 50 m thick and occur in stockworks with gold, arsenopyrite, and pyrite. The deposit consists of a stockwork which is probably remobilized from black shale. This and associated deposits are small, but are sources for placers on the western coast of Kamchatka Peninsula. The average grade of the Tumannoe deposit is 0.4-2.2 g/t Au and 3 g/t Ag.

Anomalnoe Metamorphic REE Vein(?) Deposit

The small metamorphic REE vein(?)deposit at Anomalnoe (D.A. Babushkin and others, written commun., 1986) consists of an altered vein of K-feldspar and albite which is hosted in Proterozoic(?) schist. The vein is longer than 1 km and varies from 1 to 12.5 m wide. The principal economic minerals are columbite and tantalite which contain Ta and Ni. Accessory minerals are ilmenite-rutile and rare epidote. A K-Ar isotopic feldspar age for the veins is 170 Ma.

Origin of and Tectonic Controls for Sredinny Metallogenic Belt

The Sredinny metallogenic belt is hosted by the by the Sredinnyi-Kamchatka metamorphic terrane which consists of several metamorphic sequences (Nokleberg and others, 1994c, 1997c). The belt is herein interpreted as forming during accretion of the outboard Olyutorka island arc and generation of hydrothermal fluids. A K-Ar isotopic age of about 40 Ma for the Tumannoe deposit is herein interpreted as a minimum time for accretion of the Olyutorka arc. The K-Ar isotopic age of 170 Ma for the REE vein(?)deposit at Anomalnoe is uncertain.

Metallogenic Belts Formed in Tertiary Backarc Rifting and Continental-Margin Transform, and Transcurrent Faulting, Russian Southeast

Kvinumsky Metallogenic Belt of Hornblende Peridotite and Gabbroic Cu-Ni Deposits (Belt KV) Southern Kamchatka Peninsula

The Kvinumsky metallogenic belt of hornblende peridotite and gabbroic Cu-Ni deposits occurs in the southern Kamchatka Peninsula and is associated with early Tertiary intrusive rock (fig. 102; tables 3, 4) (Bundtzen and others, 2003a, b). The major Cu-Ni deposits, at Shanuch, Kvinum, and Kuvalorog, are associated with cortlandite-norite-diorite intrusions which intrude the older metamorphic and granitoid rocks of the Sredinny-Kamchatka metamorphic terrane (Nokleberg and others, 1997b, 1998, 2000). An incremental $^{40}Ar/^{39}Ar$ isotopic age for the host intrusive rock ranges from 60-40 Ma (Bundtzen and others, 2003a, b). The deposits generally consists of pentlandite, Zn-bearing chrome spinel, pyrrhotite, chalcopyrite, and bornite which occur in veinlets and as disseminations in hornblendite-peridotite-norite-diorite intrusions. The deposits are small and the sulfides occur mainly as disseminations in gabbro (Shcheka and Chubarov, 1984). Ni is less than 1.0%, and Cu is less than 1.0%. The sulfide disseminations contain up to 1 g/t Au and up to 6 g/t Pt. The region containing these deposits is inaccessible and poorly explored. The Kvinumsky metallogenic belt of hornblende peridotite and gabbroic Cu-Ni deposits is herein interpreted as forming during backarc intrusion related to subduction beneath the Kamchatka Peninsula part of Central Kamchatka continental margin arc.

Central Koryak Metallogenic Belt of Igneous Arc Deposits (Belt CKY) East-Central Part of Russian Northeast

The Central Koryak metallogenic belt of igneous-arc-related deposits (fig. 102; tables 3, 4) occurs in the Koryak Highlands in the east-central part of the Russian Northeast. The belt extends from the Penzhina Inlet to the Anadyr Bay for about 1,000 km and is composed mainly of Sn polymetallic, Au-Ag epithermal, Hg-Sb vein, and porphyry Mo-Cu deposits. The significant deposits in the belt are (table 4) (Nokleberg and others 1997a, b, 1998): Sn polymetallic vein deposits at Ainatvetkin, Berezovaya, Khrustal (Khrustalnoe), Parkhonai, Reznikov, and Unnei; Au-Ag epithermal vein deposits at Ametistovoe, Ivolga, Orlovka, and Sprut; volcanic-hosted Hg deposits at Agranai and Lamut; clastic sediment-hosted Hg or hot-spring Hg? deposits at Krassnaya Gorka, Lyapganai, and Neptun; silica-carbonate Hg deposits at Pervenets and Tamvatney; and porphyry Cu-Mo deposits at Kuibiveen, Lalankytap, and Rzhavy.

The metallogenic belt is hosted in or near the calc-alkaline magmatic rocks of the western part of the Kamchatka-Koryak volcanic belt (fig. 102) (Pozdeev, 1986, 1990; Filatova, 1988; Nokleberg and others, 1994c, 1997c). Various, isolated ring, volcanic-plutonic, and volcanic structures host about a third of the metallogenic belt. The Kamchatka-Koryak volcanic belt unconformably overlie nappes and thrust slices of previous-accreted flysch, island arc, and ophiolite terranes. The Sn polymetallic and Au-Ag epithermal vein deposits occur mainly along the southern flank of the metallogenic belt in a region underlain by a thick crust composed of a granitic and metamorphic rocks up to 40 km thick. The northern part of the belt consists of the Parkhonai district which contains Sn, Au-Ag, Sb, and Hg polymetallic vein, and clastic-sediment-hosted Hg deposits. The Central Koryak metallogenic belt also has potential for undiscovered Sn lode deposits.

Sn polymetallic Deposits

The Sn polymetallic vein deposits are hosted by metasedimentary rocks, silicic and intermediate volcanic rocks, and granite porphyry and rhyolite stocks and dikes which occur above concealed granitic batholiths (Lashtabeg and others, 1987). The significant Sn polymetallic deposits are at Ainatvetkin, Reznikov, Khrustal, and Unnei. The deposits tend to be enriched in Ag, In, Bi, and sometimes Au.

Ainatvetkin Sn polymetallic Deposit

The Sn polymetallic deposit at Ainatvetkin (Lugov and others, 1974; Lugov, ed., 1986) consists of cassiterite-bearing sulfide-chlorite-quartz veins and fracture zones which are up to a few hundred m long and range 1.0 to 6.0 m thick. The ore minerals are cassiterite, magnetite, pyrrhotite, chalcopyrite, galena, sphalerite, arsenopyrite, wolframite, scheelite, pyrite, stannite, canfieldite, pyrargyrite, gold, and native copper. The cassiterite-chlorite-quartz veins and fracture zones contain up to 10 % sulfide minerals. Most economically important are brecciated zones with fragments of metasomatically altered rocks and quartz-chlorite cement with sulfides. The deposit is hosted in complexly-folded Late Cretaceous (Santonian through Campanian) sandstone and shale which is overlain by Late Eocene and Oligocene rhyolite, rhyodacite, rhyodacite tuff, and ignimbrite. The Late Cretaceous clastic rocks are cut by numerous late Paleogene stocks, dikes, and hypabyssal granitoids. The deposit is of medium size and averages 0.6 % Sn.

Ag-Au and Au-Ag Epithermal Vein Deposits

Various Ag-Au and Au-Ag epithermal vein deposits also occur in the Central Koryak metallogenic belt, as at Ametistovoe, Ivolga, and Sprut, are related to intermediate composition subvolcanic complexes (Khvorostov and Zaitsev, 1983). These epithermal deposits are vertically and lateral zoned with respect to the Sn and Sn-Ag deposits.

Ametistovoe Au-Ag Epithermal Vein Deposit

The Ametistovoe Au-Ag epithermal vein deposit (fig. 124) (Khvorostov, 1983; V.P. Khvorostov, written commun., 1986; Benevolskyi and others, 1992) contains two types of ore bodies: (1) ore pipes with small subparallel veins and veinlets; and (2) steeply dipping veins and zones. The veins are hundreds of meters long and several meters thick; the zones are several tens of meters thick. The veins are composed of quartz, kaolinite-quartz, and sulfide-quartz types. The main ore minerals are gold, argentite, and küstelite. Subordinate minerals are stephanite, stibiopearceite, aguilarite, pyrargyrite, miargyrite, freibergite, naumannite, and native silver. Pyrite, galena, sphalerite, and chalcopyrite are widespread and comprise up to 20 to 30 percent of some veins. The gangue minerals are quartz, kaolinite, adularia, and chlorite. The Au:Ag ratio averages 1:3. The richest ore bodies

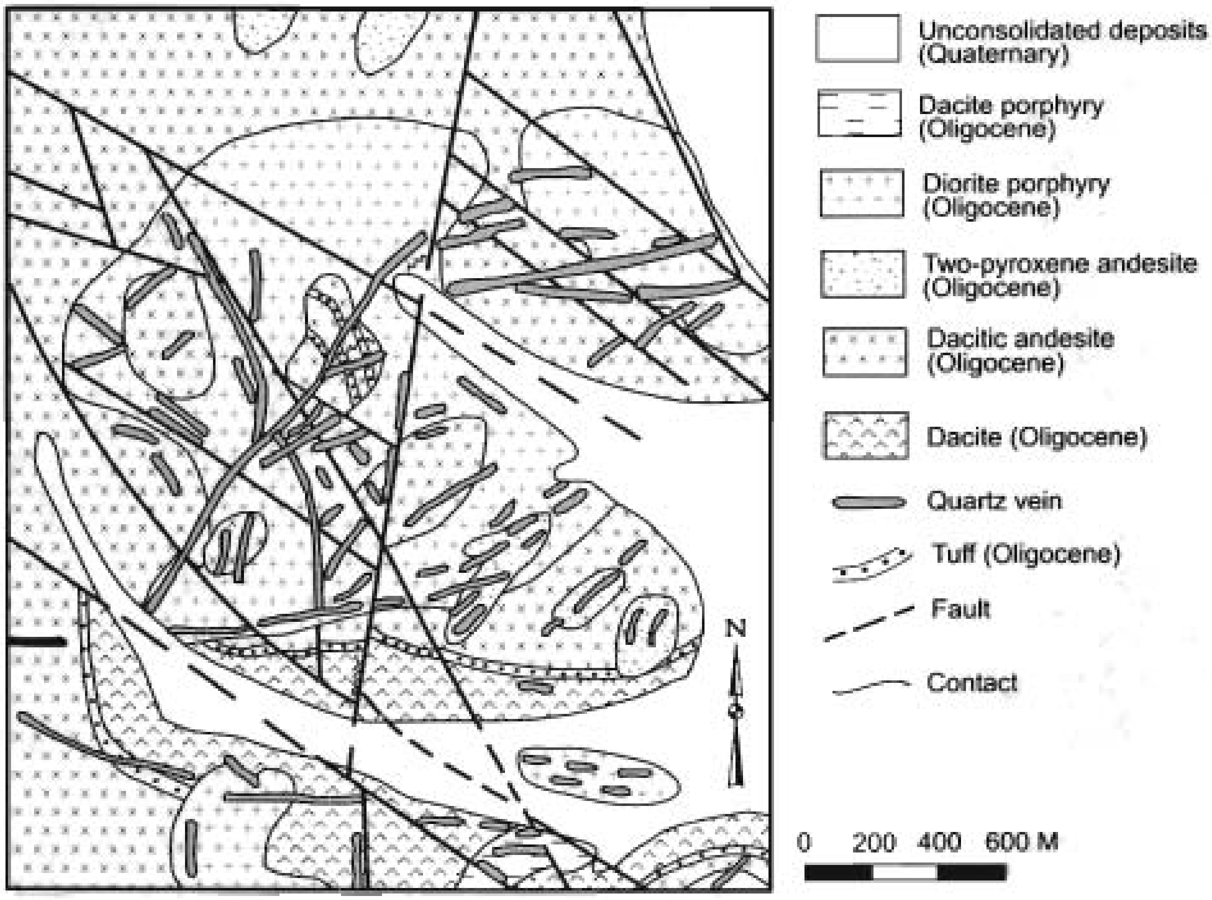


Figure 124. Ametistovoe Au-Ag epithermal vein deposit, Central Koryak metallogenic belt, Russian Northeast. Schematic geologic map. Adapted from Khvorostov (1983).

are confined to altered rocks which contain a alteration of kaolinite, illite, and quartz superimposed on widespread epidote-chlorite-carbonate propylitic alteration. The deposit is centered on a magmatic structure which is about 5 to 6 km deep. The host volcanic rocks are Eocene and Oligocene flows with K-Ar ages of 18-24 Ma which consist mainly of andesite, andesite-basalt, andesite-dacite, and dacite. Associated are local abundant extrusive-vent and hypabyssal rocks of similar compositions. The deposit is controlled by: (1) a northwest- and nearly north-south-trending faults; (2) radial and concentric fractures; and (3) extrusive and hypabyssal bodies. The deposit is large with prove reserves of 96 tonnes Au. The average grade of the Ametistovoe deposit is 16 g/t Au. The area around the Ametistovoe deposit has considerable potential for discovery of additional deposits.

Hg Deposits

Hg deposits occur throughout the Central Koryak metallogenic belt with more abundant deposits in the southern and northern extreme parts of the belt. Extensive mineralized fault zones contain cinnabar, stibnite and realgar which are associated with intermediate-composition, small intrusions and dikes which intrude Late Cretaceous through Paleogene sandstone and shale. Significant clastic sediment-hosted Hg deposits are at Lyapganai, Neptun, and Krassnaya Gorka.

Lyapganai Clastic Sediment-Hosted Hg Deposit

The clastic sediment-hosted Hg deposit at Lyapganai (Tarasenko and Titov, 1970; Babkin, 1975; Vlasov, 1977) consists of a mineralized fracture zone in Late Cretaceous sandstone and mudstone. The fracture zone is cemented by quartz and dolomite with subordinate kaolinite and calcite. Disseminated cinnabar occurs in the vein or coats breccia clasts as thin rims. Stibnite and pyrite are minor. The ore minerals range from disseminated to massive and occur in breccia, veinlets, and banded disseminations. The ore bodies vary in size from 0.1 to 4.2 m in width by 110 m to 420 m in length. The most promising ore bodies occur in faults which trend northeast, parallel to major fold axes. The Lyapganai deposit is similar to many other clastic sediment-hosted Hg deposits in the Koryak upland. The deposit is of medium size and contains an estimated 1,400 tonnes of ore grading from 0.5 to 2.4% Hg.

Both volcanic-hosted Hg and Sn deposits occur in a major, northwest-trending transverse lineament along the northeastern flank of the belt. The host rocks are rhyolite, andesite, basalt, clastic, and siliceous-volcanogenic rocks and ophiolite allochthons. The significant deposits are the volcanic-hosted Hg deposit at Lamut, and a major silica-carbonate Hg and W deposit at Tamvatney. Some Hg deposits are similar to hot-spring Hg deposits.

Lamut Volcanic-Hosted Hg Deposit

The small volcanic-hosted Hg Lamut deposit (Babkin, Drabkin, and Kim, 1967; Rozenblyum, Zincevich, and Nevretdinov, 1975) consists of lenticular occurrences and masses of quartz, opal, chalcedony, dolomite, dickite, and cinnabar. Subordinate ore minerals are metacinnabar, realgar, stibnite, and pyrite. The deposit occurs in intensely silicified, kaolinized, carbonatized, and chloritized late Paleogene rhyolite, and less commonly in basalt and tuff. The deposit occurs along northeast-trending fracture zones.

Tamvatney Silica-Carbonate Hg Deposit

The major Tamvatney silica-carbonate Hg deposit (Rozenblum and others, 1973; Babkin, 1975; Voevodin and others 1979, 1980) consists of cinnabar, tungstenite, wolframite, and Fe and As sulfides which occur in altered serpentinite, serpentinized peridotite, conglomerate, and coarse-grained sandstone, and argillite. The serpentinite is deformed into mylonite and displays carbonate, silica, and argillic alteration. The main ore minerals are cinnabar, tungstenite, wolframite, huebnerite, scheelite, marcasite and pyrite. Minor minerals are metacinnabar, stibnite, realgar, orpiment, arsenopyrite, sphalerite, chalcopyrite, millerite, bravoite, chalcocite, pyrrhotite, and hematite. Relic ilmenite, chromite, magnetite, niccolite, and pentlandite occur in serpentinite and silica-carbonate alteration. The vein gangue minerals mainly quartz, chalcedony, magnesite, dolomite, kaolinite, dickite associated with peculiar hard and liquid bitumens, and native sulfur. The middle part of the deposit consists of stockworks, masses of ore minerals, veins, and a dense network of sulfide veinlets. The zone of mineralization extends for about 20 km with an average thickness of about 20 to 30 m. The deposit occurs along the northern tectonic contact of the Tamvatney lherzolite ophiolite body which structurally overlays a clastic rocks of Early Cretaceous (Aptian and Albian) and Oligocene-Miocene age. The ultramafic rocks are intruded by Early Cretaceous gabbronorite, Late Cretaceous plagiogranite, and Neogene andesite and basalt. The age of the deposits is interpreted as Early Pleistocene. The deposit is large with estimated reserves of 30,000 tonnes Hg in ore which averages 0.81% Hg.

Porphyry Mo-Cu Deposits

Au-bearing, porphyry Mo-Cu occurrences, such as at Kuibiveen, and numerous hydrothermal vein deposits, containing Au, Ag, Cu, Mo, Pb, and Zn, also occur in the Central Koryak metallogenic belt. These deposits formed at varying temperatures, represent a variety of mineral deposit types. The significant deposit is at Kuibiveen.

Kuibiveen Porphyry Mo Deposit

The porphyry Mo deposit at Kuibiveen consists of quartz-tourmaline breccias, altered rocks, veins, and zones of linear and stockwork quartz-sulfide veinlets which occur in a nearly east-west-trending zone which is about 25 km long and about 4 km wide (Zakharov and V.P. Vasilenko, written commun., 1977; I.S. Rozenblyum, written commun., 1991). The deposits consists of disseminated molybdenite, arsenopyrite, chalcopyrite, galena, and native gold which occur in zones from tens of meters up to hundreds of meters thick. The deposit occurs in a Neogene complex of small intrusions and dikes of intermediate and felsic composition. The deposit occurs along a fault which thrusts Late Cretaceous siliceous sedimentary rocks over Oligocene and Miocene sandstone and conglomerate. The deposit is of small to medium size.

Origin of and Tectonic Controls for Central Koryak Metallogenic Belt

The Kamchatka-Koryak volcanic belt, which hosts the Central Koryak metallogenic belt, is composed of lesser Late Cretaceous and mainly of Paleocene, Eocene, and Miocene age. The belt extends for 800 km parallel to, but mainly east of the northern part of the Okhotsk-Chukotka volcanic-plutonic belt (fig. 102) (Nokleberg and others, 1994c, 1997c). The belt occurs in discontinuous and isolated volcanic fields and consists of gently dipping nonmarine volcanic rocks of various compositions, and sandstone, gritstone, and conglomerate with flora. The lower part of the volcanic belt consists of mafic volcanic rocks, mainly Maastrichtian-Danian tholeiitic basalt, along with abundant Paleocene to Eocene alkali basalt, and associated minor diorite, monzonite, gabbro, granodiorite, and granite which yield K-Ar ages of 56-73 Ma. The upper part of the volcanic belt consists of calc-alkaline dacite, rhyolite, andesite, and basalt with late Eocene and early Miocene flora and K-Ar ages, and is associated with subvolcanic bodies and dikes of rhyolite, granodiorite, and diorite. The Kamchatka-Koryak volcanic belt is interpreted as a major, mainly early Tertiary arc which formed along a continental margin-parallel transform fault. (Khanchuk and Ivanov, 1999a, b).

Metallogenic Belts Formed in Tertiary Continental-Margin Arcs, Kamchatka Peninsula, and Southern Canadian Cordillera

Olyutor Metallogenic Belt of Igneous-Arc-Related Deposits (Belt OT) Kamchatka Peninsula

The Olyutor metallogenic belt of igneous-arc-related deposits (fig. 102; tables 3, 4) occurs in northern Kamchatka. The metallogenic belt extends for more than 600 km along the Bering Sea coast and is hosted in the East and Central Kamchatka volcanic belts (Nokleberg and others, 1994c, 1997c). The little studied Olyutor metallogenic belt contains a variety of Au-Ag epithermal vein, Sn polymetallic vein, clastic sediment-hosted Hg, and porphyry Mo-Cu deposits (table 4). Several mineable Hg, Au, Mo, Cu, Pb and Zn deposits occur in many, slightly-eroded volcanic structures (Tarasenko and Titov, 1969). Numerous, poorly explored, porphyry Cu-Mo, Au-Ag epithermal vein, sulfur-sulfide, and Sn polymetallic vein deposits occur along the southern flank of the belt, and a zone of Hg-Sb and Hg-As deposits extends for more than 100 km along the Olyutor Bay coast. The deposits in the Olyutor belt are hosted mainly in Tertiary sedimentary, volcanic, and hypabyssal intrusive rocks. The Hg-Sb-As deposits also occur in Neogene extrusive rocks, and in serpentinite melange zones. The porphyry Mo-Cu deposits occur in Tertiary diorite and granodiorite porphyry stocks and associated dikes which intrude Late Cretaceous and early Paleogene tuffaceous and clastic rocks. The porphyry Mo-Cu deposits extend more than 100 km in the northern part of the belt, with intrusions apparently occurring along major faults. The significant deposits in the Olyutor metallogenic belt are the Olyutor clastic sediment-hosted Hg deposit, the Lalankytap porphyry Mo-Cu deposit, and the Maletoivayam sulfur-sulfide deposit (Nokleberg and others 1997a, b, 1998)..

Olyutor Clastic Sediment-Hosted Hg Deposit

The Olyutor clastic sediment-hosted Hg deposit (Babkin, 1975; Vlasov, 1977) consists of veins and veinlets which occur in steeply-dipping fracture zones. The fracture zones radiate from a large northeast-trending fault which cuts Paleogene and Neogene volcaniclastic rocks which are deformed into small linear folds. Individual ore bodies extend along strike from tens of meters to 600 m. The veins have numerous apophyses typically containing mineralized breccia which often grade into zones of veinlets. The most productive ore bodies occur in tuff. The main ore minerals are cinnabar accompanied by stibnite and sometimes realgar. The ore also contains quartz cement and quartz-kaolinite breccia fragments. The main gangue minerals are quartz and kaolinite, and less commonly dolomite. Wall rock alteration includes weak silicification, kaolinization, and carbonatization. The deposit is large and contains an estimated 700 tonnes Hg averaging 1.4% Hg, and up to 0.4% Sb and 4 g/t Au.

Lalankytap Porphyry Mo-Cu Deposit

The Lalankytap porphyry Mo-Cu deposit (Brazhnik and Kolyasnikov, 1989; Brazhnik and Morozov, 1989) consists of an oval stockwork about 1.2 by 0.6 km in area which contains randomly oriented quartz veinlets with irregularly disseminated pyrite, molybdenite, and chalcopyrite; and minor pyrrhotite, sphalerite, galena, magnetite, martite, rutile, anatase, and sphene. The ore minerals occur both in the veinlets and in disseminations. Cu- and Mo-minerals are related to a zone of quartz-biotite-sericite-pyrite alteration which occurs in a Paleogene quartz diorite and monzodiorite pluton and in adjacent, intruded Late Cretaceous flysch. The pluton is bounded by a nearly east-west zone of pyritized altered rocks more than 11 km long and from 1 to 4 km wide. The deposit is of small to medium size. Small amounts of gold occur in goethite-cemented, Quaternary alluvial conglomerate near the deposit.

Maletoivayam Sulfur-Sulfide Deposit

The Maletoivayam sulfur-sulfide deposit (Vlasov, 1971, 1976, 1977) occurs at the southern end of the Olyutorka volcanic belt, in the Miocene Korfovsky Formation. Two occurrences, lower and upper, are separated by a 10-50 m thick bed of kaolinite-montmorillonite and quartz-kaolinite rocks. Both occurrences are dip at 5-10° with respect to bedding orientation in the host rocks. The upper ore body can be traced for 1800 m along strike, is 80 to 700 m wide, and 3 to 115 m thick. The ore is disseminated in sulfide-sulfur-alunite silicified rock and in sulfuric silicified rock, which contains most of major native sulfur tonnage. The sulfide-sulfur-alunite silicified rock contains 18% S, 30-40% alunite, and 10% Fe sulfides. The ore contains up to 30% native sulfur. Native sulfur of 96-99% purity is separated using thermal reduction. About 60% potassium sulfate is also separated. The deposit is large and contains up to 30% S.

Origin of and Tectonic Controls for Olyutor Metallogenic Belt

The East Kamchatka volcanic belt which hosts the northern part of the Olyutor metallogenic belt consists chiefly of a major chain of modern volcanoes of Pliocene and younger age (Nokleberg and others, 1994c, 1997c). The main lithologies are basalt, andesite-basalt, rare dacite, and tuff. The belt is the northward continuation of modern Kuril volcanic arc which started to form in the Neogene.

The Central Kamchatka volcanic belt which hosts the central and southern parts of the Olyutor metallogenic belt extends for 1,500 km longitudinally the Kamchatka Peninsula (Sredinny Range). The volcanic belt contains the modern-day Kamchatka volcanic arc. The belt consists chiefly of thick, gently dipping andesite, dacite, and rhyolite strata interlayered with sandstone, siltstone, and conglomerate, and widespread large ignimbrite fields (Nokleberg and others, 1994c). The belt ranges from Oligocene to Holocene age. Shallow-marine deposits predominate in the lower part and nonmarine deposits predominate in the upper part. Formation of the belt culminated with eruptions of Pliocene to Quaternary plateau basalts which are associated with stratovolcanoes (Filatova, 1988). A minimal crustal thickness of 27 to 33 km occurs in the region. The Central Kamchatka volcanic belt is tectonically linked to the Kuril-Kamchatka accretionary wedge and subduction zone terrane and to the Cenozoic subduction of the Pacific Plate along the Kuril-Kamchatka megathrust (Nokleberg and others, 2000).

Pinchi Lake Metallogenic Belt of Hg Epithermal Vein, Sb-Au Vein, and Silica-Carbonate Hg Deposits (Belt PC) Central British Columbia

The Pinchi metallogenic belt of Hg epithermal vein, Sb-Au vein, and silica-carbonate Hg deposits occurs in central British Columbia (fig. 103; tables 3, 4) (Nokleberg and others, 1997b, 1998). The belt is 100 km long, contains 12 or more Hg mines and prospects, and occurs along the faulted eastern boundary of Cache Creek terrane with the Stikinia terrane. Although no known Eocene or Oligocene intrusions exist, the mercury mineralization is interpreted as early Tertiary in age. The significant deposits are at Pinchi Lake.

Pinchi Lake Silica-Carbonate Hg Deposits

The Pinchi Lake and smaller Bralorne Takla silica-carbonate Hg deposits (Armstrong, 1949; Dawson and others, 1991) consist of cinnabar which occurs in a stockwork of thin quartz veins, replacements, lodes and breccia fillings. The deposit is hosted in marine limestone and carbonatized ultramafic rocks which occur in shears along the Pinchi Fault which separates the Mississippian to Triassic Cache Creek terrane from the Late Triassic and Early Jurassic Quesnellia island-arc terrane. The host ultramafic rocks, chert, argillite, and greenstone of the Cache Creek ophiolite are intensely altered along the fault zones to an assemblage of Fe-Mg carbonates, quartz, mariposite and talc. Mineralization postdated both the Late Triassic blueschists and Late Cretaceous-early Tertiary conglomerates. Between 1942 to 1975, estimated production was 6000 tonnes of Hg. Estimated reserves are 1.1 million tonnes grading 0.32% Hg.

Pinchi Lake District of Sb-Au Vein Deposits

The Sb-Au vein deposits in the Pinchi Lake district occur in the same geological settings as which of the silica-carbonate Hg deposits. Both types of deposits exhibit the same, distinctive, green, silica-carbonate-mariposite or listwanite alteration assemblage. The Snowbird Au-Sb prospect at Stuart Lake consists of quartz-stibnite veins in a shear zone of silica-carbonate minerals. The shear zone occurs in sedimentary rocks of the Cache Creek terrane. Inferred reserves are 227,000 tonnes grading 6.86 g/t Au (Madu and others, 1990). The Lust Dust Au-Ag-Zn-Sb deposit consists of veins and replacements composed of quartz-stibnite-boulangerite-sphalerite-pyrite. The veins and replacements occur in a shear zone in folded sedimentary rocks of the Cache Creek terrane (Armstrong, 1949). The Indata Lake Au-Ag prospect is composed of quartz-pyrite-arsenopyrite-chalcopyrite-stibnite veins which occur in sheared and brecciated volcanic rocks of the Takla Assemblage and limestone of the Cache Creek terrane (Eastfield Resources Ltd., News Releases of October, 28, November 4, December 1, 1987). The deposit and sheared rocks occur along a splay of the Pinchi Fault.

Origin of and Tectonic Controls for Pinchi Lake Metallogenic Belt

The deposits in the Pinchi metallogenic belt postdate the host bedrock units, both the Late Triassic blueschist of the Cache Creek terrane and overlying Late Cretaceous and early Tertiary conglomerate (Paterson, 1977). The deposits occur in shears along the Pinchi Fault which separates the Mississippian to Triassic Cache Creek terrane from the Late Triassic Quesnellia island-arc terrane. The fault is interpreted as providing a zone of permeability for mercury-bearing hydrothermal solutions (Dawson and others, 1991). Reactivation and shearing along the fault, and formation of the deposits may have occurred during a period of uplift, magmatism, and transcurrent faulting in the Eocene and Oligocene (Gabrielse, 1985), possibly related to the Cascade volcanic-plutonic belt to the south. No known Eocene or Oligocene intrusions exist in the region.

Owl Creek Metallogenic Belt of Porphyry Cu-Mo, Porphyry Mo, and Au Polymetallic Vein Deposits (Belt OC) Southern British Columbia

The Owl Creek metallogenic belt of porphyry Cu-Mo, porphyry Mo and Au polymetallic vein deposits (fig. 103; tables 3, 4) occurs in southern British Columbia and is associated with a belt of late Tertiary plutons which extends from northern Washington into the Coast Plutonic Complex. The plutons are mostly small, circular quartz monzonite to dioirite plugs which intrude major, northwest-trending shear zones. These granitoid rocks are part of the middle Tertiary to Recent Cascade continental-margin arc which occurs in the USA Pacific Northwest and southern British Columbia (Nokleberg and others, 1994c, 1997c; Monger and Nokleberg, 1996). The significant deposits in the belt are the Owl Creek district porpbyry Cu-Mo deposits, and the Clear Creek (Gem) porphyry Mo deposit (table 4) (Nokleberg and others 1997a, b, 1998). The deposits in the Owl Creek metallogenic belt are hosted in or near: (1) calc-alkaline, high-level plutons of the Chilliwack suite which is part Chilliwack Batholith on the British Columbia-Washington border; and (2) the Doctor's Point pluton on Harrison Lake which is coeval and probably cogenetic with the Pemberton belt of late Tertiary volcanic rocks (Souther, 1991; Woodsworth and others, 1991). The significant deposits are at: Clear Creek (Gem), Owl Creek district, and Salal Creek. Lesser deposits occur at Harrison Gold (Abo) and Doctor's Point. These mesothermal Au polymetallic vein deposits are intimately associated with 25-Ma quartz diorite intrusions, and either consist of veins in hornfels adjacent to the stiock, as at Doctor's Point, or as vein stockworks within the quartz diorite pluton, as at Harrison Gold (Ray, 1991). The veins contain quartz, pyrrhotite, and pyrite, and minor chalcopyrite, molybdenite, scheelite, and rare bismuth telluride minerals (Dawson and others, 1991). Also occurring in the metallogenic belt are Au polymetallic vein deposits at Boundary Red Mountain and Lone Jack mines which are located along the western part of the Chilliwack Batholith in Washington (Ray, 1986).

Clear Creek (Gem) Porphyry Mo Deposit

The Clear Creek (Gem) porphyry Mo deposit consists of an arcuate zone of molybdenite with minor pyrite and sphalerite which occur in quartz and calcite veins and as fracture filling (EMR Canada, 1989; MINFILE, 2002). Estimated reserves are 15.9 million tonnes grading 0.07% Mo (MINFILE, 2002). The deposit occurs in an arcuate zone around the northeast margin of an Oligocene quartz monzonite stock, named the Gem Stock, with a K-Ar isotopic age of 35 Ma. The stock intrudes quartz diorite and granodiorite of the mid-Cretaceous Spuzzum pluton, and schist and gneiss of the Cretaceous Settler Schist.

Owl Creek Porphyry Cu-Mo District

The Owl Creek porphyry Cu-Mo district consists of veins and disseminations of chalcopyrite, molybdenite, and pyrite with minor bornite which occur as blebs, disseminations and fracture fillings (Mahoney, 1977; EMR Canada, 1989; MINFILE, 2002). Estimated resources are 10 to 20 million tonnes grading 0.3 to 0.4% Cu and 0.03% MoS_2 (MINFILE, 2002).The deposit is hosted in probable mid-Tertiary quartz diorite and feldspar porphyry of the Coast Plutonic Complex, and in propylitic- and argillic-altered and volcanic rocks of the Late Triassic Cadwallader Group (Mahoney, 1977).

Salal Creek Porphyry Mo Deposit

The Salal Creek porphyry Mo deposit occurs along the contact between a fine-grained granite core and a medium-grained granodiorite margin of a pluton dated which has a K-Ar isotopic age of 8 Ma (Stephens, 1972). The deposit exhibits in a typical ring or circular pattern. To the north is the Franklin Glacier porphyry Cu-Mo prospect which has a K-Ar isotopic age of 7 Ma (Dawson and others, 1991).

Origin of and Tectonic Controls for Owl Creek Metallogenic Belt

The Owl Creek metallogenic belt of porphyry Cu-Mo, porphyry Mo and Au polymetallic vein deposits is hosted in a belt of late Tertiary plutons which approximately coincide with the Pemberton belt of late Tertiary and Quaternary volcanic rocks (Woodsworth and others, 1991; Souther, 1991). K-Ar ages of the pluton rocks progressively decrease northward, from between 35 and 16 Ma in the south, to about 7 Ma in the north. These relatively young plutonic rocks and associated volcanic rocks are part of the Cascade volcanic-plutonic belt of the U.S.A. Pacific Northwest and southern British Columbia (Nokleberg and others, 1994c, 1997c, 2000).

In the Canadian Cordillera, the Cascade volcanic-plutonic belt consists of Pleistocene and Holocene basalt, andesite, and dacite eruptive centers, and late Eocene(?), Oligocene, and Miocene plutons (Chilliwack and Mount Barr batholiths). In U.S.A. Pacific Northwest, the belt consists of volcanic rocks of stratovolcanoes, mostly andesite but ranging from basalt to rhyolite. The belt includes interbedded fluvial and lacustrine deposits and minor tonalite to granodiorite plutons. In Washington, parts of belt are included in the Ohanapecosh, the Fifes Peak, and the Northcraft Formations (Vance and others, 1987; Smith, 1993). The youngest active volcanoes in the belt are Mount Jefferson, Mount Hood, Mount Adams, Mount St. Helens, and Mount Rainier.

The Cascade volcanic plutonic belt and corresponding Cascade continental-margin arc is interpreted as forming in response to subduction of the Juan de Fuca Plate (Wells and Heller, 1988; England and Wells, 1991; Monger and Nokleberg, 1996; Nokleberg and others, 2000). Remnants of the subducting plate are preserved in the Siletzia, Olympic Core, and Hoh terranes along branches of the Cascadia megathrust.

Middle Tertiary Metallogenic Belts (20 to 10 Ma) (Figures 125, 126)

Overview

The major middle Tertiary metallogenic belts in the Russian Far East and the Canadian Cordillera are summarized in table 3 and portrayed on figures 125 and 126. The major belts are as follows. (1) In the Russian Northeast, the Central Kamchatka (CK) belt, which contains granitic-magmatism-related deposits, and the East Kamchatka (EK) belt, which contains Au-Ag epithermal vein deposits, are hosted in the Central Kamchatka volcanic and sedimentary basin, and are interpreted as forming during subduction-related granitic plutonism which formed the Kamchatka Peninsula part of Northeast Asia continental margin arc. (3) In Southern Alaska, the Alaska Peninsula and Aleutian Islands (AP) belt, which also contains granitic-magmatism-related deposits, is hosted in the Aleutian volcanic belt and is interpreted as forming during subduction-related granitic plutonism which formed the Aleutian continental margin arc. And (3) in the southern Canadian Cordillera, continuing on from the early Tertiary was the Owl Creek (OC) belt, which contains granitic-magmatism-related deposits and is hosted in the Cascade volcanic-plutonic belt, is interpreted during subduction-related granitic plutonism which formed the Cascade continental margin arc. In the below descriptions of metallogenic belts, a few of the noteable or signficant lode deposits (table 4) are described for each belt.

Metallogenic-Tectonic Model for Middle Tertiary (20 to10 Ma; fig. 127)

During the middle Tertiary (Miocene - 20 to 10 Ma), the major metallogenic-tectonic events were (fig. 127; table 3): (1) continuation of a series of continental- margin arcs, associated metallogenic belts, and companion subduction-zone assemblages around the Circum-North Pacific; (2) back-arc spreading behind the major arcs; (3) opening of major sedimentary basins behind major arcs; (4) in the eastern part of the Circum-North Pacific, a continuation of dextral transpression between the Pacific Ocean plate and the Canadian Cordillera margin, and a continuation of orthogonal transpression between the Pacific plate and the Southern Alaska continental margin; and (5) continued sea-floor spreading in the Arctic and eastern Pacific Oceans.

Specific Events for Middle Tertiary

(1) After accretion of various terranes in the early Eocene and outward stepping of subduction, the Northeast Asia arc commenced activity. Parts of this arc are preserved in the East Japan volcanic-plutonic belt (ej), Kuril volcanic arc (ku), and the various parts of the Kamchatka arc consisting of the Central Kamchatka volcanic belt (kc), Central Kamchatka volcanic and sedimentary basin (ck), and West Kamchatka sedimentary basin (wk). To the northeast, the Okhotsk-Chukotka arc ceased activity. These two major Andean-type arcs overlapped previously accreted adjacent terranes in both the Russian Southeast and to the south and extended for a distance of about 3,000 km. Associated with these arcs was subduction of part of the Pacific Ocean plate (PAC) along the Kuril-Kamchatka megathrust (*KK*) to form the Kuril-Kamchatka (KUK) subduction-zone terrane. Intra-arc faulting resulted in tectonic doubling of the Kamchatka-Koryak (kk) arc which started to become extinct as the Central Kamchatka arc (kc) enlarged. Forming in the Kamchatka part of the Northeast Asia arc was the Central Kamchatka (CK) metallogenic belt, which contains granitic-magmatism-related deposits, and is hosted in the Central Kamchatka volcanic and sedimentary basin.

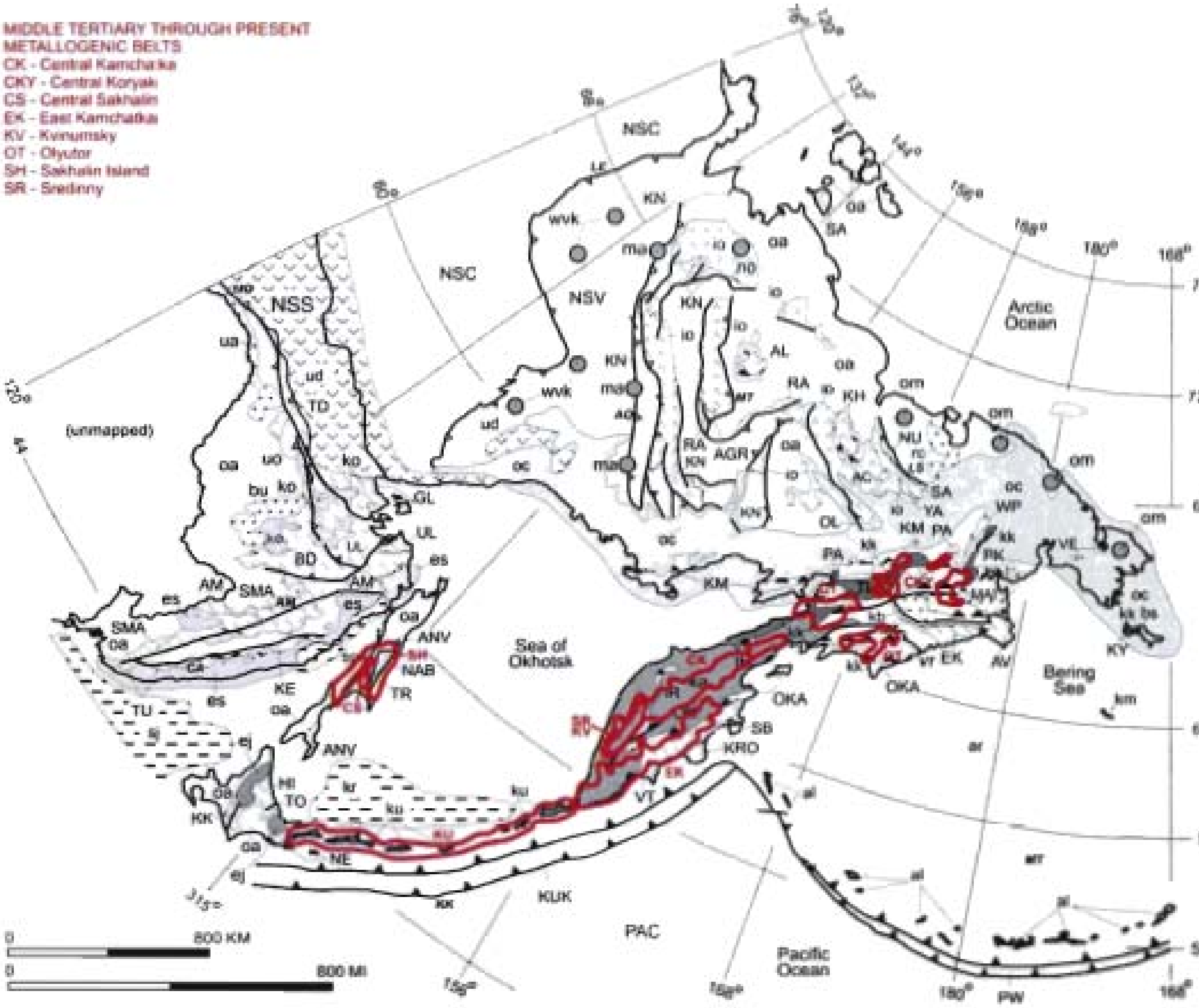


Figure 125. Generalized map of major Tertiary through Present metallogenic belts, overlap assemblages, and tectonically-linked subduction-zone or accretionary-wedge terranes for Russian Far East, northern Japan, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 59 for explanation.

(2) Regional extension associated with back-arc spreading behind the northern Japan part of the Northeast Asia arc (East Japan volcanic-plutonic belt, ej), resulted in marine eruption of the Sea of Japan back-arc unit (sj) which consists of mainly tholeiitic basalt and associated rocks.

(3) In the Sea of Okhotsk, back-arc spreading occurred behind the Kuril Island and Kamchatka Peninsular part of the Northeast Asia arc (B.A. Natal'in in Nokleberg and others, 1994a), resulting in marine and continental eruption of tholeiitic to alkalic basalt and associated rocks forming Sakhalin-Primorye volcanic belt (sp). This regional extension is also interpreted as the result of seaward rotation of the Kamchatka Peninsula, and in formation of major units within the Sea of Okhotsk (as discussed by B.A. Natal'in in Nokleberg and others, 1994a). Back-arc spreading may have occurred simultaneously with trench roll-back and migration of the Northeast Asia arc into the Pacific Ocean plate.

(4) In the Arctic Ocean, rifting continued along the Gakkel Ridge (GK) along with continued sedimentation in the Amerasia basin (as). Analysis of marine magnetic anomalies in the Eurasia Basin suggests this region underwent compression from about 36-5 Ma (Savostin and Drachev, 1988a, b; Harbert and others, 1990; Fujita and others, 1997). Geologic mapping reveals which late Miocene thrust faults and companion folds, which were associated with regional compression, occurred along the Myatisk and companion faults in the Mona and Chersky Ranges as described by Gaiduk and others (1989, 1993). Fault displacements are about 15 to 20 km.

(5) A major orthogonal junction formed between the western end of Aleutian-Wrangell arc (al) and Central Kamchatka arc (kc). The western terminus of the Aleutian-Wrangell arc is interpreted as having been obducted onto the Kamchatka Peninsula, thereby forming the Kamchatskiy Mys oceanic terrane (too small to depict on fig. 127), which is interpreted as the oceanic base of the ancestral Aleutian-Wrangell arc, and the Stolbovskoy island-arc terrane (also too small to depict on fig. 127), which is interpreted as the older, western part of the arc (Geist and others, 1988, 1994).

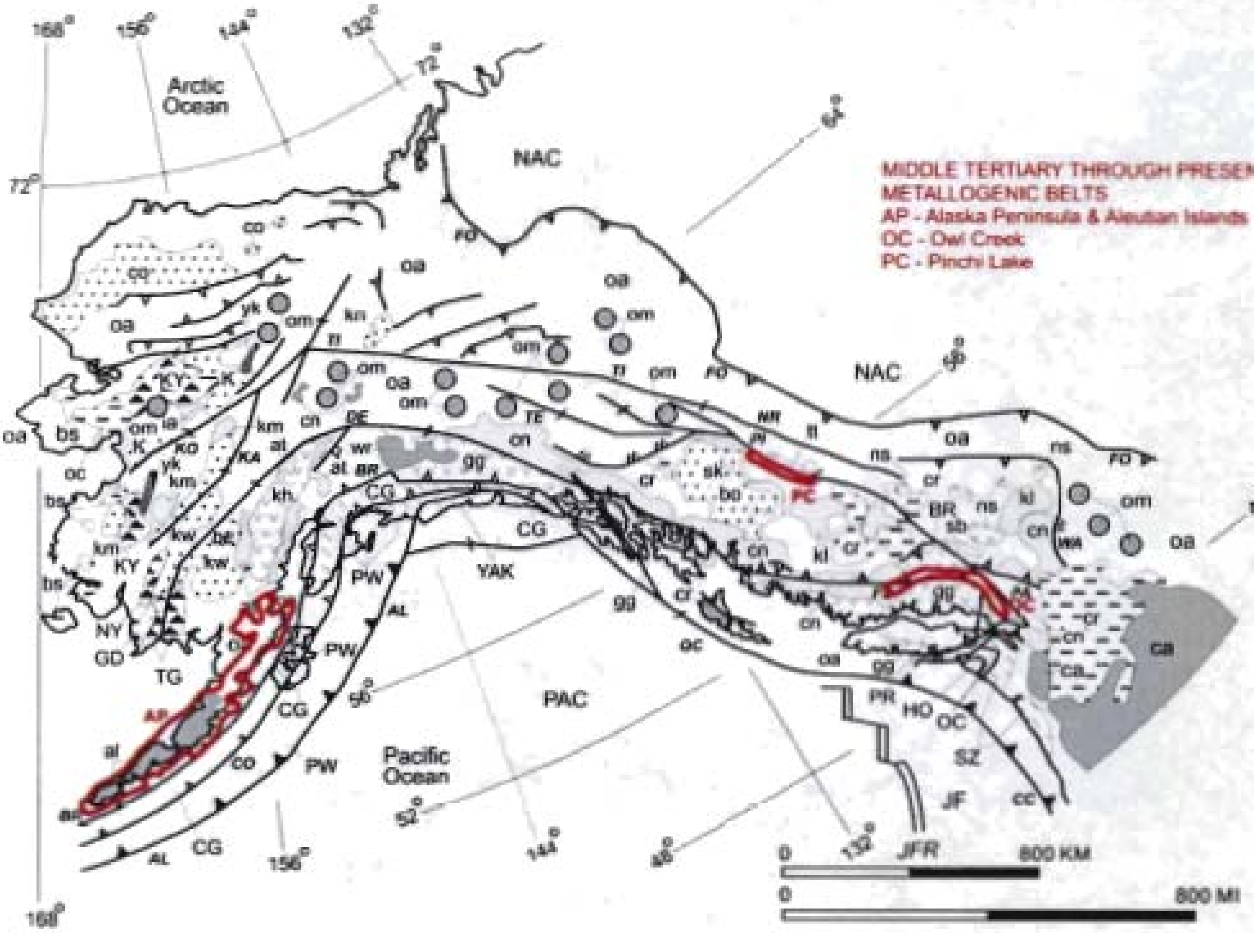


Figure 126. Generalized map of major middle Tertiary through Present metallogenic belts, overlap assemblages, and tectonically-linked subduction-zone or accretionary-wedge terranes for Alaska, Canadian Cordillera, and adjacent offshore areas. Refer to text for description of metallogenic belts. Adapted from Nokleberg and others (1997b, 1998). Refer to figure 60 for explanation.

(6) In the early to middle Miocene, a short episode (approximately 22 to 10 Ma) of sea-floor spreading along the Komandorsky Ridge (KOM) formed a small pair of oceanic plates which exhibit magnetic anomalies 5 and 6. The spreading occurred after the marine-arc volcanism in this area which formed the Bowers (bw) and Shirshov (sh) Ridges in the middle Eocene and early Miocene.

(7) Intense tectonic disruption occurred in the western part of Aleutian-Wrangell arc, along the western Aleutian megathrust (*AL*), as a result of the transform coupling between the Pacific and North American plates (Geist and others, 1988). A complex array of strike-slip, extension, and rotation structures formed in this area (Scholl and others, 1992, 1994; Vallier and others, 1994). In the area of the Bering Sea, a thick sedimentary prism continued to form in the Aleutian-Bowers basin (atb) which overlies a fragment of accreted Kula Ocean plate (Plafker and Berg, 1994; Scholl and others, 1992, 1994).

(8) Tectonic escape (crustal extrusion) of terranes continued to occur along major dextral-slip faults, including the Denali (*DE*), Iditarod-Nixon Fork (*NF*), Kaltag (*KA*), and companion faults (Scholl and others, 1992, 1994). Dextral-wrench basins continued to form in association with the dextral-slip faults and were rapidly filled with continental sediments. Dextral displacement continued farther east along major dextral-slip faults such as the Denali (*DF*), Iditarod-Nixon Fork (*NF*), and Kaltag (*KA*) faults. Estimates of total Cenozoic displacements along the Denali and Tintina faults are between 400 and 500 km each (Nokleberg and others, 1985; Plafker and Berg, 1994; Monger and Nokleberg, 1996). These and companion dextral-slip faults probably extended into the area of the Bering Sea.

(9) The Pacific Ocean plate (PAC) continued to move northwestward. Along the Aleutian megathrust (*AL*) plate convergence continued to vary from oblique-orthogonal in the east to oblique to transform in the west.

(10) The Aleutian-Wrangell continental-margin arc was associated with mainly oblique subduction of the northern edge of Pacific Ocean plate (PAC) along the Aleutian megathrust (*AL*) to form the Prince William terrane (PW). During northward migration, the Yakutat terrane (YA) started to underthrust the Prince William terrane along the eastern part of the Aleutian megathrust. Forming in the Aleutian-Wrangell continental-margin arc in Southern Alaska was the Alaska Peninsula and Aleutian Islands (AP) metallogenic belt which contains granitic-magmatism-related deposits and is hosted in the Aleutian volcanic belt.

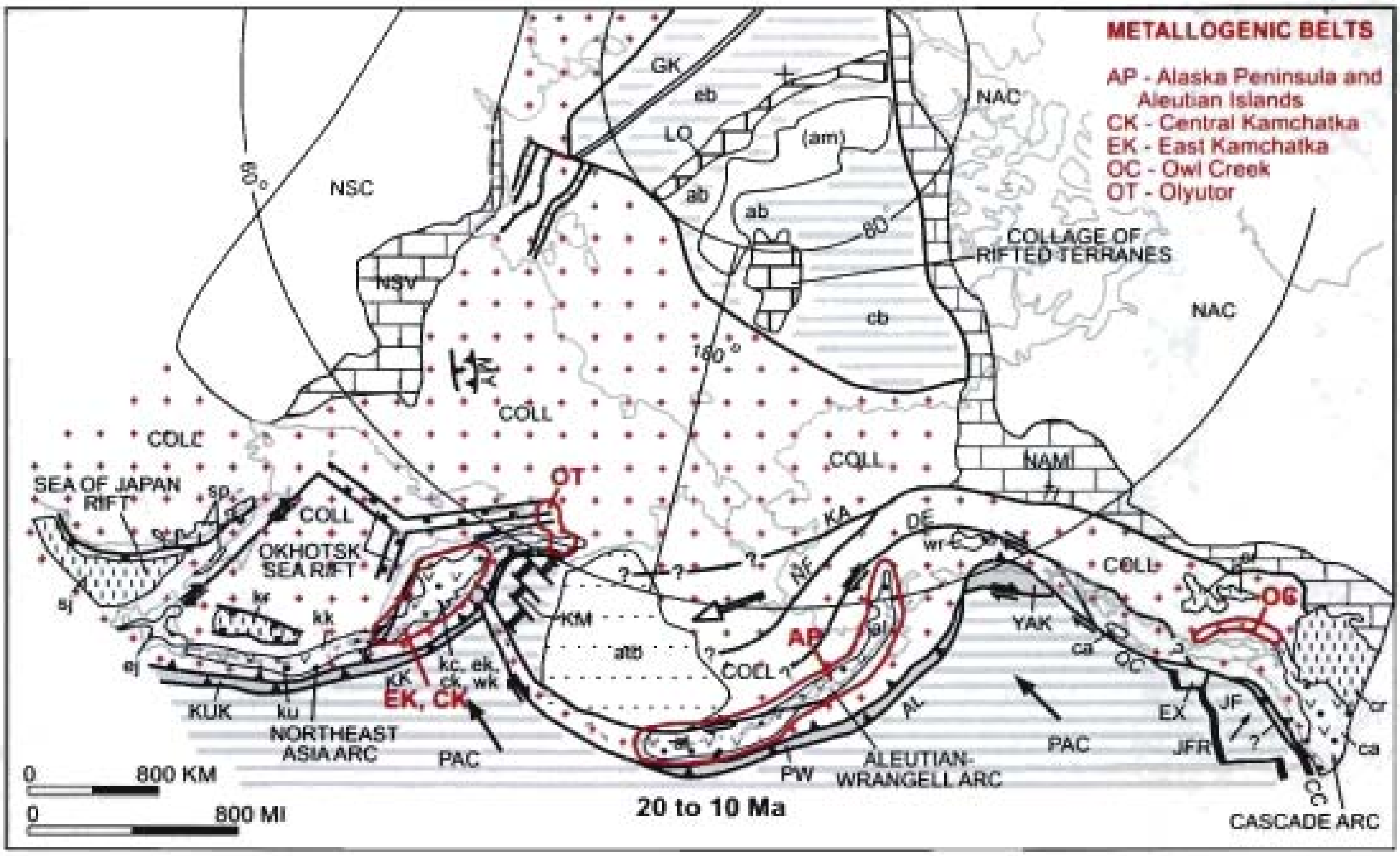


Figure 127. Middle Tertiary (Miocene - 20 to 10 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

(11) Offshore of the southern Canadian Cordillera, sea-floor spreading continued along the Juan de Fuca Oceanic ridge (JFF). Northward movement of the Pacific Ocean plate (PAC) and associated transform displacement on the Queen Charlotte transform fault (*QC*) resulted in continued northward migration and subduction of the Yakutat terrane (YA) beneath the continental margin of Southern Alaska.

(12) To the south, the Cascade continental-margin arc continued activity. Associated with this arc was continued subduction of part of the Juan de Fuca plate (JF) along the ancestor of the modern Cascadia megathrust (*CC*). Regional extension, associated with back-arc spreading the behind Cascade arc (ca), resulting in continental eruption of the Columbia River basalt (cr; Wells and Heller, 1988; England and Wells, 1991). Continuing on from the early Tertiary in the Cascade arc was the was the Owl Creek (OC) metallogenic belt, which contains granitic-magmatism-related deposits, and is interpreted during subduction-related granitic plutonism.

Metallogenic Belts Formed in Tertiary Continental-Margin Arcs, Kamchatka Peninsula, Southern Alaska, and Southern Canadian Cordillera

East Kamchatka Metallogenic Belt of Au-Ag Epithermal Deposits (Belt EK) Eastern and Southern Kamchatka Peninsula

The East Kamchatka metallogenic belt of Au-Ag epithermal deposits (fig. 125; tables 3, 4) occurs in the eastern and southern parts of the Kamchatka Peninsula. The deposits are hosted in the East-Kamchatka volcanic belt which overlies late Mesozoic and Cenozoic island-arc and terranes of accretionary-wedge terranes (Pozdeev, 1990). The Au-Ag epithermal deposits, most of which are economic or are potentially economic, are associated mainly with Miocene volcanoes, hypabyssal bodies, and small intrusions. The significant deposits in the belt are at Asachinskoe, Kitkhoi, Kumroch, Mutnovskoe, and Rodnikovoe (table 4) (Nokleberg and others 1997a, b, 1998).

The Au-Ag epithermal vein deposits in the East Kamchatka metallogenic belt are interpreted as forming in two stages (Petrenko, 1999). (1) In the early Miocene, Au-Ag (± Zn, Pb) epithermal vein and stockwork deposits, as at Mutnovskoe, Kumroch, and Kitkhoi, formed during eruptions of intermediate and felsic volcanic rocks and during formation of small diorite-granodiorite intrusions (Lattanzi and others, 1995). The major metals are Au, Pb, and Zn, along with Ag and sulfosalts. And (2) in the late Miocene, Au quartz-adularia epithermal vein deposits, as at Rodnikovoe and Asacha deposits, formed in andesite-basaltic piles associated with hypabyssal bodies, and in mafic, intermediate, and felsic dikes. The deposits are sulfide poor and are associated with propyllitic alteration. Some of the deposits may be Pliocene; however, K-Ar isotopic studies of stockworks, dikes, and adularia-quartz veins yield ages of 12 to 5 Ma, indicating a Miocene age. The association of sulfide-rich and sulfide-poor epithermal deposits in the East Kamchatka metallogenic belt suggests diverse volcanic processes (Pozdeev, 1990; Lattanzi and others, 1995). A recent study by Takahashi and others (2002) presents a 4-fold classification of epithermal Au-Ag mineralization in Kamchatka: (1) Late Cretaceous Okhotsk-Chukotka Belt (Sergeevka deposit); (2) the middle Tertiary Koryak-Western Kamchatka Belt (including the Ametistovoe deposit with a K-Ar isotopic age of 41.4 Ma); (3) the late Tertiary Central Kamchatka belt (including the Zolotoy deposit with a K-Ar isotopic age of 17.1 Ma, and the Aginskaya deposit with a K-Ar isotopic age of 6.9 Ma); and (4) the Eastern Kamchatka belt (including the Asachinskoye, Mutnovskoe, Rodnikovoe, and Porozhistovoe deposits with K-Ar isotopic ages 0.9-7.4 Ma). An overview of the major Au-Ag epithermal vein deposits of the Kamchatka was published by Petrenko (1999).

AsachinskoeAu-Ag Epithermal Vein Deposit

The AsachinskoeAu Au-Ag epithermal vein deposit (Shchepot'ev, 1989; I.D. Petrenko, written commun., 1991; A.I. Pozdeev, written commun., 1991; Petrenko, 1999;Okrugin and others, 2002) consists of a zone of quartz-adularia veins that occur along a north-south trending, strike-slip fault. Veins split and pinch out in tuff and andesitic lava. Ore body is a nearly flat-lying band, gently dipping to the south, and conformable to the hypabyssal host rocks. Ore exhibits colloform-banded structure. Ore minerals comprise less than 1% of the veins. Ore mineral assemblages are: gold-hydromica, gold-naumanite-polybasite, and gold-adularia-quartz. Major ore minerals are pyrite, gold, selenium polybasite, and naumanite. Deposit occurs in center of a hypabyssal dacite dome at the intersection of three large linear faults. Deposit associated with hypabyssal volcanic rocks that are inferred in cross-section. A K-Ar isotopic age for the deposit is 4 Ma (Takahashi and others, 2001). The deposit is medium size with up to 20 g/t Au and 40-50 g/t Ag. Estimated reserve are 1.56 million tonnes averaging 35 g/t Au and 62 g/t Ag.

Mutnovskoe Au-Ag Epithermal Vein Deposit

The Mutnovskoe Au-Ag epithermal vein deposit (Shchepot'ev, 1989; I.D. Petrenko, written commun., 1991; Lattanzi and others, 1995; Petrenko, 1999;Okrugin and others, 2002) deposit occurs in the central part of a paleovolcano composed of Oligocene-Miocene mafic- and intermediate-composition volcanic rocks. Plutonic rocks consist of Miocene diorite intrusions and numerous dikes of varied composition. Major ore zone consists of a thick vein and some apophyses with zones of quartz veinlets between them. Drilling indicates which ore extends to a depth of 500 m below the surface. In heavily weathered zones, generally at the southern flank of the deposit, quartz veins contain from 10-18% sulfides. On the less weathered northern flank, the deposit is sulfide-poor and contains 0.2-2% base metals. The major ore assemblages are gold- tennantite-tetrahedrite, gold-argentite-pearsite, and chlorite-galena-sphalerite. Canfieldite, as well as the telluride minerals, hessite and altaite, also occur. The deposit is vertically zoned, with gold, tennantite, and tetrahedrite occurring in the upper part of the veins, and chalcopyrite, galena, sphalerite occurring in the lower part of the veins. The K-Ar age of mineralization for the north flank of the Mutnovskoe deposit is 3.3 Ma and 1.1 Ma for the south flank of the deposit (Takahashi and others, 2001). The deposit is of medium size. Average grades range up to 3 g/t Au and 10 g/t Ag. Proven reserves are to the North, 1.8 million tonnes of ore averaging 16 g/t Au and 315 g/t Ag, and to the South, 5.2 million tonnes of ore averaging 12.4 g/t Au, 1300 g/t Ag, and 69,000 tonnes combined Pb and Zn. The deposit contains an estimated resource of about 20 tonnes Au.

Rodnikovoe Au Quartz-Adularia Epithermal Vein Deposit

The Rodnikovoe Au quartz-adularia epithermal vein deposit (I.D. Shchepot'ev, 1989; D. Petrenko, written commun., 1991; Petrenko, 1999) consists of a major vein and related quartz and quartz-carbonate veins and veinlets which cut the apical part of a gabbro-diorite intrusion. In addition to gold, the veins and veinlets contain goldfieldite, silver sulfosalts, and argentite. Gold fineness is 400 to 600. Alteration includes propylitic (chlorite-carbonate and epidote-chlorite facies), kaolinitic, quartz-hydromica alteration with montmorillonite, and silicic with quartz and pyrite. The altered rocks are laterally zoned. The ore occurs in a complex vein system with several funnel-shaped ore shoots which narrow with depth. The shoots dip 30-50° south. The vertical extent of mineralization is less than 150 m. High Au concentrations (25-30 g/t Au) occur in upper levels of ore bodies. The quartz-adularia veins are Late Miocene with K-Ar ages of approximately 0.9 to 1.1 Ma (Takahashi and others, 2001). The deposit is of medium size. Average grades range up to 11.3 g/t Au and 40-50 g/t Ag. The estimated reserves are 40 tonnes gold and 356 tonnes silver with an average grade of 11.0 g/t Au and 98.0 g/t Ag.

Origin of and Tectonic Controls for East Kamchatka Metallogenic Belt

The Central Kamchatka volcanic belt which hosts the East Kamchatka metallogenic belt consists chiefly of Eocene to Quaternary thick, gently dipping andesite, dacite, and rhyolite strata which are interlayered with sandstone, siltstone, and conglomerate, and widespread large ignimbrite fields. Shallow-marine deposits predominate in the lower part and nonmarine deposits predominate in the upper part. The formation of the belt culminated with eruptions of Pliocene to Quaternary plateau basalts which are associated with large composite cone volcanoes. The volcanic belt is interpreted as a major post-accretionary continental-margin arc which is tectonically linked to the Kuril-Kamchatka accretionary wedge and subduction zone complex (fig. 125) (Nokleberg and others, 1994c, 1997c).

Central Kamchatka Metallogenic Belt of Au-Ag Epithermal and Porphyry Cu-Mo Deposits (Belt CK) Kamchatka Peninsula

The Central Kamchatka metallogenic belt of Au-Ag epithermal vein and porphyry Cu-Mo deposits (fig. 125; tables 3, 4) occurs along the length of the Kamchatka Peninsula. The deposits are hosted in the Central Kamchatka volcanic and sedimentary basin of Oligocene to Holocene age (Nokleberg and others, 1994c, 1997c). The significant deposits in the belt are (table 4) (Nokleberg and others 1997a, b, 1998): Au-Ag epithermal vein deposits at Aginskoe (Aga), Baran'evskoe, Oganchinskoe, Ozernovskoe, Sukharikovskie Grebni, Tutkhlivayam, and Zolotoi; a porphyry Cu-Mo deposit at Krasnogorskoe; and a volcanic-hosted Hg deposit at Chempura.

The Au-Ag epithermal vein deposits are interpreted as forming mainly during two stages in the Miocene. (1) In the early Miocene (22 to 14 Ma), during eruption of mainly felsic volcanic rocks, low sulfide, Au-Ag deposits, as at Ozernovskoe and Tutkhlivayam, with high Te contents, formed during construction of composite cone volcanoes and associated hypabyssal intrusions. At the same time, sulfide Au deposits, as at Olgakanskoe, with high Cu, Pb, and Zn contents, formed in association with intermediate intrusions. However some of these deposits may have formed during the Late Eocene to Oligocene. And (2) in the late Miocene (12 to 5 Ma), in the final stages of Miocene volcanism, andesitic and basaltic alterations. Au (± Ag) epithermal vein deposits formed in association with small hypabyssal bodies and dikes, as at Aginskoe, Sukharikovskie Grebni, and Baran'evskoe deposits and some ore bodies of Tutkhlivayam deposit. These deposits consist mainly of gold and minor sulfide minerals in quartz-adularia veins. In the middle and northern parts of the belt, Hg deposits, as at Chempura, and Au and Au-Ag epithermal vein deposits occur in late Miocene hypabyssal bodies and dikes.

Porphyry Mo, Cu, and Cu-Mo deposits in the southern part of the belt occur in Miocene subalkaline granite porphyry and porphyritic diorite. These granitoid plutons intrude areas underlain by the eastern part of the Sredinny-Kamchatka metamorphic terrane. These deposits, as at Kirganik, Krasnogorskoe, and Malakhitovoe, are small to medium-size, and occur mainly in stockworks and in long fracture zones in both intrusions and adjacent metamorphic rocks. The major ore minerals are pyrite, chalcopyrite, and molybdenite. Molybdenite contains high amounts up to 600 g/t rhenium.

Ozernovskoe Au-Ag Epithermal Vein Deposit

The large Ozernovskoe Au-Ag epithermal vein deposit (Shchepot'ev, 1989) consists of Au-bearing quartz-adularia veins along with Cu-Mo, realgar-orpiment, and Au-Ag deposits. The Au-Ag deposits occurs in veinlets and disseminations and is superimposed on various facies of hydrothermally-altered rocks. Ore formed in fracture-filling veins and veinlets, and as metasomatic replacement of earlier aggregates. At least four stages of mineralization are recognized: (1) gold-goldfieldite-quartz (fineness of 933-938); (2) tellurium-silvanite-goldfieldite-kaolinite-quartz gold 945 fine; (3) gold-hessite-hydromica-quartz (gold 894 fine); and (4) gold-adularia-hydromica-quartz (gold 643 to 679 fine). Host rocks exhibit several types of alteration, mainly propylitization and silicification. Argillite, displaying quartz-sericite, quartz-kaolinite, and quartz-montmorillonite-hydromica facies alteration, occurs in the central part of the ore field, near the main volcanic vent. Altered rocks consist of quartz and pyrite-alunite-kaolinite-quartz assemblages which form linear bodies up to 100 m thick along the fault zones. The largest ore bodies occur in these tabular, altered silicified rocks. The deposit occurs in a weakly-eroded volcano composed of basaltic andesite, andesite, and dacitic pyroclastic rocks and lava. The deposit is large and contain 0.01-0.1% Te and Au in rare high-grade zones, up to 700 g/t Au. Most of the ore is low-grade, ranging from 2-20 g/t Au.

Aginskoe Au-Ag Epithermal Vein Deposit

The Aginskoe Au-Ag epithermal vein deposit (Shchepot'ev,1989) consists dominantly of fine-grained, chalcedony-like quartz, adularia, and hydromica with colloform banding. The ore minerals comprise 0.3 to 1.0% of veins. The major ore minerals are tellurides, including hessite, altaite, calaverite, silvanite, and petzite. A total of 55 ore minerals are identified. Gold fineness ranges from 740 to 990, and the Au/Ag ratio varies from 2:1 to 7:1. Six stages of ore deposition are recognized: (1) quartz-pyrite; (2) gold-adularia-corrensite-quartz with a gold fineness of 924 to 968; (3) gold-adularia-quartz with a gold fineness of 936 to 952 at upper levels, and a gold fineness of 740 to 854 at deeper levels; (4) gold-calaverite-quartz with a gold fineness 940 to 960; (5) gold-hessite-corrensite-quartz with a gold fineness 816 to 880 and (6) quartz-zeolite-calcite. Endogenous zoning is marked by a vertical change of ore composition, texture, and structure. The concentration of tellurides and sulfides increases with depth. The deposit occurs in a volcanic caldera composed of Miocene basaltic andesite and basaltic andesite tuff. Ore occurs in fracture zones and zones of intense jointing. Ore-bearing structures consist of shear and breccia tectonic zones, which include numerous andesitic dikes and veins, lenses, and veinlets of adularia-quartz and quartz-carbonate composition. The main ore-bearing zones are the Aginskaya and Surpriz. In the main ore-bearing zones, short ore bodies merge at depth forming a gently-dipping mineralized band; complicated in the upper part by steeply-dipping ore shoots. Hydrothermal alteration, commonly propylitic, is common. The deposit is of medium size and contains an estimated resource of 30-50 tonnes Au and 70-100 tonnes Ag. The average grade of the Aginskoe deposit is 20 g/t Au. The deposit is currently under development.

Kirganik Porphyry Cu Deposit

The Kirganik porphyry Cu deposit (Vlasov, 1977; A.V. Ignatyev, written commun., 1980) consists of steeply-dipping zones of rocks with biotite-K-feldspar metasomatic alteration. The deposit is 10-15 m thick, up to 1200 m long, and occurs in Late Cretaceous siliceous volcanic rocks. The deposit consists of zones of disseminated and veinlet copper and Au minerals. The ore bodies are generally conformable with the host rocks. The oxidized zone extends deepest in heavily fractured rocks, to a depth of 100 to 120 m, and contains up to 0.8 g/t Au. The richest ore is in biotite-K-feldspar-metasomatically altered rocks. Altered rocks containing both pyroxene and K-feldspar are practically devoid of ore. The ore minerals are pyrite, chalcopyrite, magnetite, bornite, chalcocite, hematite, and gold. The richest Au values occur in rich chalcosite-chalcopyrite-bornite ore with more than 1% Cu. The K-Ar isotopic age of the biotite-K-feldspar-altered rocks which host the ore is 65-75 Ma. The deposit is of medium size. Average grades are 0.1-1% Cu and 0.2 to 0.4 g/t Au in disseminated and veinlet ore, and up to 0.8 g/t Au in oxidized ore.

Origin of and Tectonic Controls for Central Kamchatka Metallogenic Belt

The Central Kamchatka volcanic and sedimentary basin (Nokleberg and others, 1994c, 1997c) which hosts the Central Kamchatka metallogenic belt consists chiefly of late Oligocene to Holecene volcanic and sedimentary rocks in sequences up to 5 km thick. The belt ranges from 20 to 70 km wide and is about 350 km long. The volcanic and sedimentary basin also contains mainly shallow-marine sedimentary rocks up to 6,000 m thick, and widespread tuff, basalt, and basaltic andesite. The basinal units overly deformed Late Cretaceous to early Tertiary sedimentary rocks. The basin is interpreted as a forearc unit of the Central Kamchatka volcanic belt; both are interpreted as parts of the major, post-accretionary, Northeast Asia continental-margin arc in the Russian Far East (Nokleberg and others, 1994c, 1997c).

Alaska Peninsula and Aleutian Islands Metallogenic Belt of Igneous Arc Deposits (Belt AP) Western-Southern Alaska

The major Alaska Peninsula and the Aleutian Islands metallogenic belt of igneous arc deposits (fig. 126; tables 3, 4) occurs in western-southern Alaska (Nokleberg and others, 1995a). The metallogenic belt is hosted in the area underlain or adjacent to the middle and late Tertiary granitic and volcanic rock of the Aleutian arc in the eastern Aleutian Islands and the southwestern Alaska Peninsula (Nokleberg and others, 1994c, 1997c). The arc is composed mainly of middle Tertiary to Holocene andesite to dacite flows and tuff, shallow intrusive rocks, small silicic stocks and sills, and associated sedimentary rocks (Burk, 1965; Wilson, 1985). Underlying parts of the southwestern Alaska Peninsula, almost as far west as Cold Bay, is the mainly Mesozoic bedrock of the Peninsular island-arc terrane.

Numerous epithermal vein, polymetallic vein, and porphyry Cu and Cu-Mo deposits occur in the metallogenic belt. The significant deposits are (table 4) (Nokleberg and others 1997a, b, 1998): epithermal vein deposits at Apollo-Sitka, Aquila, Canoe Bay, Fog Lake (Pond), Kuy, Shumagin, and San Diego Bay; polymetallic vein deposits at Braided Creek, Sedanka (Biorka), Cathedral Creek, and Kilokak Creek; and porphyry Cu and Mo deposits at Bee Creek, Mallard Duck Bay, Mike, Pyramid, Rex, and Sedanka (Biorka). The epithermal and polymetallic vein and porphyry deposits of the Alaska Peninsula and Aleutian Islands belt occur over a distance of over 800 km. This belt is related to the epithermal and hydrothermal 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 continental-margin arcs along the rim of the Circum-Pacific rim.

Pyramid Porphyry Cu Deposit

The Pyramid porphyry Cu deposit (Armstong and others, 1976; Hollister, 1978; Wilson and Cox, 1983; G.L. Anderson, written commun., 1984; R.L. Detterman, oral commun., 1986) occurs in the southwestern Alaska Peninsula and consists of disseminated molybdenite and chalcopyrite(?) in a Fe-stained dacite porphyry stock of late Tertiary age. A zonal alteration pattern is defined by a core of secondary biotite, containing about 3 to 10% magnetite, which grades outward into an envelope of quartz-sericite alteration. Fractures adjacent to the stock are filled with sericite. Local extensive oxidation and supergene enrichment by chalcocite and covellite occur in a blanket as much as 100 m thick. The deposit is centered on a 3 km^2 area within the stock, and contains a resource of 110 million tonnes grading 0.4% Cu, 0.03% Mo, and trace of Au (G.L. Anderson, written commun., 1984). The host stocks and dikes, and several smaller stocks which occur nearby all intrude the fine-grained clastic rocks of the Late Cretaceous Hoodoo Formation, and the Paleocene or Eocene to Oligocene Stepovak(?) or Tolstoi(?) Formation. The sedimentary rocks are contact metamorphosed adjacent to the stocks.

Bee Creek Porphyry Cu Deposit

The Bee Creek porphyry Cu deposit consists of chalcopyrite, pyrite, and traces of molybdenite in contact-metamorphosed Jurassic and Cretaceous sedimentary rocks which are intruded by a small tonalite porphyry stock of Tertiary age (Cox and others, 1981). The deposit, located on the Alaska Peninsula 25 km northeast of Chignik Lagoon, was discovered by Bear Creek Mining Company in cooperation with Bristol Bay Native Corporation in the late 1970's (E.D. Fields, written commun., 1977).The contact-metamorphosed sedimentary rocks and the porphyry stock exhibit strong potassic (biotite) alteration, and quartz grains in the porphyry contain abundant, high-salinity fluid-filled inclusions. The deposit is unexplored on the southwest and northeast sides and probably contains a resource of between 5 and 30 million tonnes with average grade between 0.1 to 0.4 percent Cu. Five drill holes totaling 2,359 m explore the deposit; one hole intercepted 150 m averaging 0.25% Cu.

Aleutian Arc

The Aleutian arc, which hosts the Alaska Peninsula and Aleutian Islands metallogenic belt, is composed of Oligocene (post-30 Ma) 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 graywacke, shale, and lahars (Burk, 1965; Wilson and Cox, 1983; Wilson, 1985; Wilson and others, 1993; Vallier and others, 1994). To the northeast on the Alaska Peninsula, magmatism apparently started in the late Miocene (about 15 Ma). An older Eocene and Oligocene succession of igneous rock that yields K-Ar ages ranging from 40 to 30 Ma, is located in the northeastern Aleutian Islands and is defined as the Meshik arc by Wilson (1985).

Petrologic, chemical, and isotopic characteristics of the Aleutian arc (Miller and Richter, 1994) are as follows. (1) The arc consists predominantly of andesite and low-silica dacite; rhyolite occurs only in a few volcanic centers. (2) The axial part of the central and northeastern parts of the arc is mostly calc-alkalic; SiO_2 contents typically range between 50 to 78 percent. (3) Volcanic centers to the southwest are either tholeiitic or transitional to calc-alkalic. (4) The back arc contains alkalic volcanic rocks which occur in widely separated centers. And (5) initial Sr ratios are relatively low, in the range of 0.70305 to 0.7046.

The lode deposits of Alaska Peninsula and Aleutian Islands metallogenic belt reflect the bedrock underlying the arc. The northeastern part of the arc on the southwestern part of the Alaska Peninsula is underlain by Mesozoic bedrock of the Peninsular terrane, part of the Wrangellia superterrane (Wilson and Cox, 1983; Nokleberg and others, 1994d). On the Alaska Peninsula, the Peninsular terrane consists of a Late Triassic(?) and Early Jurassic sequence of volcaniclastic and volcanic rocks (Talkeetna Formation), the Middle Jurassic part of the Alaska-Aleutian Range batholith (Reed and Lanphere, 1969, 1973), and younger Cretaceous sedimentary rocks. In contrast, to the southwest, the Aleutian arc is interpreted to be underlain by oceanic crust (Wilson and Cox, 1983; Vallier and others, 1994). The Pyramid Bee, Creek, Rex, and Warner Bay porphyry Cu deposits in the central part of the metallogenic belt occupy a transitional zone between the parts of the magmatic arc underlain by oceanic crust to the southwest and by continental crust to the northeast. Some of the deposits to the northeast are Mo-rich and contain anomalous concentrations of Bi, Sn, and W which may be characteristic of continental-margin deposits (Wilson and Cox, 1983). K-Ar isotopic studies indicate a variable time span of up to two million years between igneous activity and mineralization. Isotopic studies also indicate sporadic occurrences of mineralization during a long period of igneous activity (Wilson and Cox, 1983).

Tectonic Setting for Alaska Peninsula and Aleutian Islands Metallogenic Belt

The Aleutian arc, one of the classic igneous continental-margin arcs along the Circum-Pacific rim, occurs structurally above the Aleutian megathrust, an active subduction zone which dips to the northwest and along which the Pacific Plate is being thrust under the southern margin of Alaska (fig. 126). The tectonic setting, and the field, petrologic, chemical, and isotopic data summarized above are used by analogy to infer subduction zone settings for ancient belts of igneous rocks (Vallier and others, 1994) and their associated granitoid-magmatism metallogenic belts (Nokleberg and others, 1993).

Late Tertiary and Quaternary Metallogenic Belts (4 to 0 Ma; Figures 125, 126)

Overview

The major late Tertiary and Quaternary metallogenic belts in the Russian Northeast, Alaska, and the Canadian Cordillera are summarized in table 3 and portrayed on figures 125 and 126. The major belts are as follows.
(1) In the Russian Southeast, the Sakhalin Island (SH) belt, which contains Silica-carbonate, volcanic-hosted Hg deposits, is hosted in shear zones and late Tertiary volcanic rock, and is interpreted as related to backarc spreading behind the Kuril volcanic arc. (2) In the Russian Northeast, the Kuril (KU) belt, which contains granitic-magmatism-related deposits, is hosted in the Kuril volcanic-plutonic belt and is interpreted as forming during subduction-related granitic plutonism which formed the Kuril Island part of Northeast Asia continental margin arc. (3) Also in the same region, several metallogenic belts continued on from the early and middle Tertiary is the Olyutor (OT) metallogenic belt which is hosted in the East Kamchatka volcanic and sedimentary basin. (4) In Southern Alaska, also continuing on from the middle Tertiary, was the Alaska Peninsula and Aleutian Islands (AP) belt, which contains granitic-magmatism-related deposits and which is hosted in the Aleutian volcanic belt. This metallogenic belt is interpreted as forming during subduction-related granitic plutonism which formed the Aleutian continental margin arc. And (5) in the southern Canadian Cordillera, continuing on from the early and middle Tertiary, was the Owl Creek (OC) belt, which contains granitic-magmatism-related deposits and is hosted in the Cascade volcanic-plutonic belt. This metallogenic belt is interpreted during subduction-related granitic plutonism which formed the Cascade continental margin arc. In the below descriptions of metallogenic belts, a few of the noteable or signficant lode deposits are described for each belt.

Metallogenic-Tectonic Model for Late Tertiary and Quaternary (4 to 0 Ma; Figure 128)

During the late Tertiary and Quaternary (Pliocene to the present - 4 to 0 Ma), the major metallogenic-tectonic events were and are (fig. 128; table 3): (1) continuation of a series of continental-margin arcs, associated metallogenic belts, and companion subduction-zone assemblages around the Circum-North Pacific; (2) continuation of opening of major sedimentary basins behind major arcs; (3) in the eastern part of the Circum-North Pacific, a continuation of dextral transpression between the Pacific Ocean plate and the Canadian Cordillera margin; (4) a continuation of oblique-orthogonal transpression between the Pacific plate and the Southern Alaska; and (5) continuation of sea-floor spreading in the Arctic and eastern Pacific Oceans. The modern geodynamic pattern is defined by interaction of the Eurasian, North American, and Pacific Ocean plates (Cook and others, 1986; Parfenov and others, 1989; Fujita and others, 1997). The pole of rotation between the Eurasian and North American plates is located on, or near the south coast of the Laptev sea in the Russian Northeast (Cook and others, 1986; Larson and others, 1997).

Specific Events for Late Tertiary and Quaternary

(1) The Northeast Asia continental-margin arc continues activity. Parts of the arc are in the East Japan volcanic-plutonic belt (ej), the Kuril arc (ku), the Central Kamchatka volcanic and sedimentary basin (kc), and the East Kamchatka volcanic belt (ek). Associated with the arc is subduction of the western edge of the Pacific Ocean plate (PAC) along the Kuril-Kamchatka megathrust (*KK*) to form the Kuril-Kamchatka (KUK) terrane. A major orthogonal junction occurs between the western end of Aleutian-Wrangell arc (al) and Kamchatka arc (kc). Continuing on, or forming anew in the Northeast Asia continental margin arc are: (a) the Sakhalin Island (SH) metallogenic belt which is hosted in shear zones in late Tertiary and older rock, and is interpreted as forming during backarc spreading behind Kuril arc. (b) the Central Kamchatka (CK) metallogenic belt which is hosted in the Central Kamchatka volcanic and sedimentary basin; (c) the East Kamchatka (EK) metallogenic belt which is hosted in the Central Kamchatka volcanic and sedimentary basin; and (d) the Olyutor (OT) metallogenic belt which is hosted in the East Kamchatka volcanic and sedimentary basin. The latter three metallogenic belts contain granitic-magmatism-related deposits and are interpreted as forming during granitic plutonism associated with subduction of the Pacific Plate.

(2) Rifting continues along the Gakkel Ridge (GK; northern extension of mid-Atlantic Ridge) and the extension of the ridge toward the Eurasian plate. The Gakkel Ridge and its extension define the modern boundary between the North American and Eurasian plates. Analysis of sea-floor spreading anomalies in the Eurasia Basin (eb) suggest that the Russian Northeast underwent extension from about 5 to 0.5 Ma (Moma rift episode as discussed by Fujita and others, 1990a, b, 1997; Savostin and Drachev, 1988a, b; Harbert and others, 1990; Fujita and others, 1997). The youngest change, a northward pole shift, occurred at about 0.5 Ma, as indicated by resurgent or continued thrusting (Imaev, 1991). Focal mechanism studies indicate which parts of this region are undergoing compression (Cook and others, 1986; Parfenov and others, 1989; Fujita and others, 1990a, b; Riegel and others,

1993). This compression is relieved by extrusion of the Okhotsk block to the southeast (Riegel and others, 1993) and by uplift and thrusting in the CSB area (Koz'min, 1984; Imaev and others, 1990; Koz'min and others, 1996). Sedimentation continues in the Amerasia basin (ab).

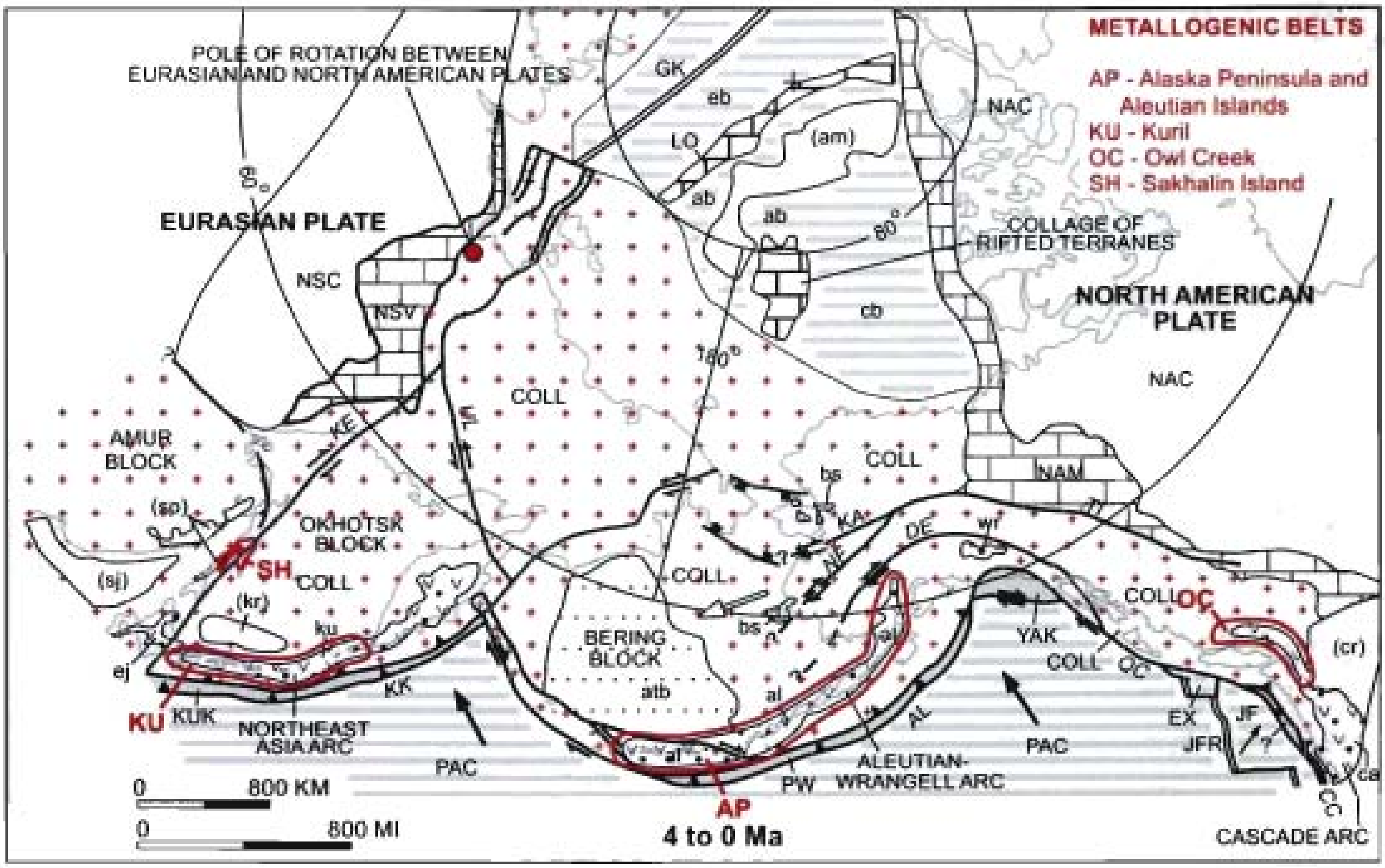


Figure 128. Late Tertiary and Quaternary (Pliocene through present - 4 to 0 Ma) stage of metallogenic-tectonic model. Refer to text for explanation of metallogenic-tectonic events, to tables 3 and 4 for descriptions metallogenic belts and significant deposits, and to figure 18 for explanation of abbreviations, symbols, and patterns. Adapted from Nokleberg and others (1997b, 1998, 2000).

(3) Seismicity defines several new tectonic blocks, including the Amur, Okhotsk, and Bering blocks (Riegel and others, 1993; Fujita and others, 1997; Mackey and others, 1997). Boundaries between blocks are defined by epicenters located by teleseismic and regional networks (Fujita and others, 1997).

(4) Marine and continental eruption of sparse, generally small, highly dispersed flows of Bering Strait alkaline basalt (bs) occurred in the Quaternary and Recent. This volcanism may possibly be related to dextral-wrench faulting and tectonic escape in this region. Rotation of the Bering block created extension on the Seward Peninsula and on Chukotka (Mackey and others, 1997), or the Bering block may have formed as the back-arc with respect to the Aleutian-Wrangell arc.

(5) Tectonic escape (crustal extrusion) of terranes continues along major dextral-slip faults, including the Denali (*DE*), Nixon Fork (*NF*), Kaltag (*KA*), and companion faults (Scholl and others, 1992, 1994) which may extend into the Bering Sea. Dextral-wrench basins continue to form in association with the dextral-slip faults and are still filling with continental sediments. A thick sedimentary prism continues to form in the Aleutian-Bowers basin (atb; Plafker and Berg, 1994). In Interior and Southern Alaska, displacement continues along major dextral-slip faults, such as the Denali (*DE*) fault.

(6) The Pacific Ocean plate (PAC) continues to move northwestward relative to the North American plate. Along the Aleutian megathrust (*AL*), plate convergence continues to vary from orthogonal in the east to oblique to transform in the west.

(7) Intense tectonic disruption continues in the western part of Aleutian-Wrangell arc along the western Aleutian megathrust (*AL*), as a result of the transform coupling between the Pacific Ocean plate (PAC) and the North American plate (Geist and others, 1988; Scholl and others, 1992, 1994). A thick sedimentary prism continues to form in the Aleutian-Bowers basin (atb) which overlies a fragment of accreted Kula Ocean plate (Plafker and Berg, 1994).

(8) Along the margin of Southern Alaska, the eastern part of the Aleutian-Wrangell arc continues activity. Associated with the arc is mainly oblique subduction of the northern edge of Pacific Ocean plate (PAC) along the Aleutian megathrust (*AL*), continuing the formation of the younger part of the Prince William terrane (PW). Continuing in the Aleutian-Wrangell arc is the Alaska Peninsula and Aleutian Islands (AP) metallogenic belt which contains granitic-magmatism-related deposits and is hosted in

the Aleutian volcanic belt. The Yakutat terrane (YA) continues to migrate northwestward and continues to underthrust the Prince William terrane (PW) along the eastern part of the Aleutian megathrust (*AL*).

(9) Sea-floor spreading continues along the Juan de Fuca oceanic ridge (JFR). Northward movement of the Pacific Ocean plate (PAC) continues with transform displacement on the Queen Charlotte transform fault (*QC*).

(10) The Cascade continental-margin arc continues to form. Continuing in the Cascade arc was the Owl Creek (OC) metallogenic belt which is hosted in the Cascade volcanic-plutonic belt. Associated with the Cascade arc is subduction of part of the Juan de Fuca oceanic plate (JF) and formation of a subduction-zone complex along the Cascadia megathrust (*CC*; Goldfinger and others, 1996, 1997; Fleuh and others, 1997).

Metallogenic Belts Formed in Late Tertiary and QuaternaryContinental-Margin Arcs, Kamchatka Peninsula, Southern Alaska, and Southern Canadian Cordillera

Sakhalin Island Metallogenic Belt of Silica-Carbonate or Volcanic-Hosted Hg Deposits (Belt SH) Sakhalin Island, Southeastern Part of Russian Far East

The Sakhalin Island metallogenic belt of silica-carbonate and volcanic-hosted Hg deposits occurs in the central and southern part of Sakhalin Island, in and adjacent to the Aniva, Nabilsky, and West-Sakhalin terranes (fig 125; tables 3, 4) (Nokleberg and others, 1997b, 1998). The Russian name for the silica-carbonate Hg deposit type is listwandite. The silica-carbonate Hg deposits occur along or adjacent to major faults in faulted fragments of Late Cretaceous sedimentary rocks, serpentinized and altered ultramafic rocks, and in post-accretionary Neogene volcanic rocks. The significant deposits along the In' River, and at Inskoe, Svetlovskoe, Ostrinskoe, and Yasnoe consist of cinnabar and native Hg in fracture zones along contacts between gabbroic rocks and serpentinite, or in jasper, basalt, and shale. The Hg minerals either replace quartz and carbonate in listwandite or forms pods. Some of the Hg deposits, as along the In' River, occur in volcanic rocks, but display silica-carbonate alteration. Other deposits, as at Inskoe, are hosted in altered quartzite and Neogene volcanic rock.

The origin of the Hg deposits of the Sakhalin island belt is not clear. Silica-carbonate Hg deposits are classically interpreted as related to thrust faults in or near subduction zones (J.J. Rutuba, *in* Cox and Singer, 1986). However the nearest late Tertiary subduction zone occurred a few hundred km to the east, east of the Kuril arc which has been active since the late Tertiary (Nokleberg and others, 1994c, 1997c). The Hg deposits of the Sakhalin island metallogenic belt may have multiple origins. Some of the silica-carbonate Hg deposits may have formed during late Tertiary back-arc rifting and formation of the Sakhalin-Primorye alkali basalts and related igneous rocks. Some or all of the in the belt deposits may have formed in the back arc portions of the late Tertiary through Holocene Kuril arc (Nokleberg and others, 2000).

Kuril Metallogenic Belt of Au-Ag Epithermal Vein, Cu-Pb-Zn Polymetallic Vein, Sn silica-sulfide vein, Sn Vein, Sulfur-sulfide (volcanic S), Kuroko Massive Sulfide, and Porphyry Mo Deposits (Belt KU) Kuril Islands, East-Central Part of Russian Far East

The Kuril metallogenic belt of Au-Ag epithermal vein, Cu-Pb-Zn polymetallic vein, Sn silica-sulfide vein, sulfur-sulfide (volcanic S), kuroko massive sulfide, and porphyry Mo deposits (fig. 125; tables 3, 4) occurs in the Kuril volcanic arc in the east-central part of the Russian Far East. The belt contains a wide variety of volcanic and hypabyssal-related deposits (table 4) (Nokleberg and others 1997a, b, 1998): sulfur-sulfide (volcanic S) deposits at Ebeko, Golovninskoe, Krishtofovich Volcano, Novoe, Vysokoe, and Zaozernoe; Au-Ag (Zn) epithermal vein deposits at Prasolovskoe, Rifovoe, Semaya River, and Sofya; Cu-Pb-Zn polymetallic vein deposits at Dushnoe, Koshkina, and Tet'yaevskoe; Sn silica-sulfide vein and Sn vein deposits at Rudnikovskoe and Spiridonovskoe; porphyry Mo deposits at the Carpinsky caldera and Reidovskoe; and a kuroko Cu-Pb-Zn deposit at Valentinovskoe. The principal Au-Ag epithermal vein, and polymetallic, Sn, and Sn silica-sulfide vein deposits are interpreted as forming during late Neogene during aerial volcanism (Shcheglov and others, 1984). The small occurrences of kuroko-type massive sulfide deposits are interpreted as forming during early Miocene seafloor volcanism. The volcanic S deposits are interpreted as forming during the construction of Quaternary volcanic cones and fields. The Au-Ag epithermal vein and the volcanic S deposits are of potential economic interest.

Novoe Sulfur-Sulfide (Volcanic S) Deposit

The Novoe sulfur-sulfide (Volcanic S) deposit (Petrachenko, 1967) occurs in a flat-lying sequence, about 500 to 400 m thick, of andesite, andesite-basalt, and related tuff. The sequence crops out in scarps of a 2 km-wide erosional depression. Some ore bodies are controlled by faults. The sulfur ore occurs in hydrothermally altered silicified rock, with opalite, alunite, and kaolinite. All altered rocks in the deposit contain some sulfur, but the higher-grade ores contain opalite, silicified rock, and alunite.

Secondary minerals are barite, gypsum, marcasite, pyrite (up to 15%), and molybdenite. The age of mineralization is Pliocene and Quaternary. The deposit is large. Average grades are up to 20-80% S and up to 0.5% MoS_2. The deposit contains about 5 million tonnes sulfur.

Prasolovskoe Au-Ag Epithermal Vein Deposit

The Prasolovskoe Au-Ag epithermal vein deposit (Danchenko, 1991) consists of ore veins which are mostly steeply-dipping, and range from 2-3 m thick, with a few up to 10 m thick. The veins consist mainly of banded metacolloidal gold, telluride, and quartz veins which contain up to 1-3% ore minerals. The deposit exhibits a vertical succession of assemblages. From bottom to top the assemblages are: gold-cassiterite-quartz; polysulfide-quartz; gold-telluride-quartz; and gold-adularia (carbonate)-quartz. The dominant ore minerals are pyrite, chalcopyrite, bornite, chalcocite, covellite, and sphalerite. Arsenopyrite, molybdenite, cassiterite, galena, argentite, native silver, gold, hessite, naumannite, and goldfieldite are also abundant. Limonite, covellite, malachite, and azurite occur in an oxidized zone. The ore bodies are explored to a depth of over 200 m. An area 1.5 by 0.5 km is propylitically altered and impregnated with pyrite as well as numerous quartz veinlets with epidote, sericite, adularia, chlorite, calcite, and rare barite. Earlier veinlet and disseminated ore is related to Miocene intrusions. The later Au-Ag ore is related to the Pliocene volcano-plutonic complex. The deposit is associated with Pliocene plagiogranite and quartz diorite which intrude early and middle Miocene pyroclastic green tuff deposits. The deposit is of medium size and was mined before the 1990's.

Koshkina Cu-Pb-Zn Polymetallic Vein Deposit

The small Koshkina Cu-Pb-Zn polymetallic vein deposit (Petrachenko, 1978) consists of ore bodies up to 200 m long which occur hydrothermally altered rock types outside a granodiorite and diorite intrusion. The ore bodies consist of areas of closely-spaced sericitized and hydromicatized veins and veinlets with variable composition. Mineral assemblages in veins and veinlets are quartz-tourmaline, quartz-chlorite-sericite, chlorite-carbonate with zeolites, and quartz-chlorite-epidote. The ore minerals are chalcopyrite, cleiophane, galena, stibnite, realgar, orpiment, arsenopyrite, pyrite, marcasite, hematite, and magnetite. Polymetallic and antimony-arsenic ores are spatially separated and various alterations. The mineralogy and metal content of the deposit vary widely. The deposit occurs on the northern part of Shumshu Island and covers an area of approximately 5 km^2. The deposit is hosted in heavily altered early-middle Miocene volcanic rocks which are intruded by numerous extrusive and intrusive rocks, all part of a volcano-plutonic complex. Host rocks are propylitized up to epidote-chlorite facies, and are locally silicified. Propylitized granodiorite and diorite crops out in the middle part of the mineralized area. Alteration was the result of sulfate and halogene-acid hydrothermal solutions. The age of mineralization is late Miocene(?).

Valentinovskoe Kuroko Cu-Pb-Zn Deposit

The Valentinovskoe kuroko Cu-Pb-Zn deposit (Neverov, 1964) consists of two steeply-dipping, thin, lens-like deposits, up to 150 m long. Two ore types exist. (1) The first and most common type consists of massive, fine-grained sphalerite, galena, chalcopyrite, chalcocite, tetrahedrite, melnikovite, barite, gypsum, quartz, chalcedony, chlorite, sericite, and calcite. This ore contains approximately 1% Cu, 1.5-1.7% Pb, and 10-13% Zn. And (2) the second and less common ore type consists of pyrite, sphalerite, and chalcopyrite with galena and other sulfides. This ore contains up to 4% Cu, 10-16% Zn, and 1-1.7% Pb. The deposit occurs in early Miocene rhyolite, dacite, andesite, and andesitic tuff with chert interbeds. The host rocks are propylitized or sericitized and are part of a submarine tuff complex. The deposit is small with average grades of 1% Cu, 1.5-1.7% Pb, and 10-13% Zn in fine-grained ore, and locally up to 4% Cu, 10-16% Zn, and 1-1.7% Pb.

Origin of and Tectonic Controls for Kuril Metallogenic Belt

The Kuril volcanic arc which hosts the Kuril metallogenic belt consists chiefly of tuff, breccia, andesite, basalt, and local hypabyssal and plutonic rocks including gabbro, diorite, and diabase (Nokleberg and others, 1994c). The arc occurs as large Quaternary active volcanoes which are tectonically linked to middle Tertiary through Holocene subduction of the western margin of the Pacific oceanic plate (Nokleberg and others, 1994c, 1997c).

Summary of Metallogenic and Tectonic History

The preceding analysis of the metallogenesis and tectonics of the Russian Far East, Alaska, and the Canadian Cordillera reveals a series of metallogenic belts which formed during a complicated geologic history. The metallogenic belts are hosted in older rock units of tectonostratigraphic terranes, along suture zones between accreted terranes, or in overlap assemblages of continental margin igneous arcs. Metallogenic belts formed before accretion (pre-accretion) are interpreted as forming in the early history of terranes and are inherently linked to the older geology and tectonic history of the host rocks. Accretionary metallogenic belts are interpreted as forming during collision of terranes with continental margins, resulting in varying amounts of regional metamorphism, anatectic granites, and associated lode deposits. Post-accretionary metallogenic belts are interpreted as forming mainly in parts of continental-margin arcs which overlie craton or craton margin terranes.

Pre-Accretionary Metallogenic Belts

Several major and minor metallogenic belts of deposits hosted in mafic and ultramafic rocks occur in the Russian Far East, Alaska, and the Canadian Cordillera. The principal deposits are hornblende peridotite Cu-Ni, anorthosite-hosted apatite Ti-Fe, gabbroic Ni-Cu, hornblende peridotite Cu-Ni, podiform Cr, serpentinite-hosted asbestos, stratiform Zr, zoned mafic-ultramafic Ti, and zoned mafic-ultramafic PGE deposits. These deposits and host rocks are interpreted as forming mainly in oceanic tectonic environments, including basal island arc, ophiolite, oceanic ridge, seamount, and subduction zone environments. A few deposits are interpreted as rarely forming in continental rift environments. Subsequent to formation, most of these ocean-derived metallogenic belts and their host rocks migrated and were accreted to the margin of the North Asian Craton Margin or North American Craton Margin. Several of the metallogenic belts occur in thin, but extensive sheets of obducted ophiolites which were thrust onto the Paleozoic and early Mesozoic continental margin terranes of the Russian Northeast and northern Alaska. In island-arc terranes, these mafic-ultramafic-related deposits occur mainly in deep-level mafic to ultramafic plutons, some of which are concentrically zoned.

Several major pre-accretionary metallogenic belts of stratiform and stratabound massive sulfide and associated deposits occur in Russian Far East, Alaska, and the Canadian Cordillera. The principal deposits types are Austrian Alps W, basaltic Cu, bedded barite, Besshi massive sulfide, carbonate-hosted Hg, carbonate-related Nb, Ta, and REE, Cyprus massive sulfide, ironstone (Superior Fe), Kipushi Cu-Pb-Zn, Korean Pb-Zn, Kuroko massive sulfide, Zn-Pb SEDEX, sandstone-hosted U, sediment-hosted Cu deposits, sedimentary P, volcanogenic Mn and Fe, Southeast Missouri Pb-Zn, shoshonite-hosted Cu, and stratabound Hg and Au. This wide variety of stratiform and stratabound deposits, and associated deposits are formed in a wide variety of tectonic environments, including continental margin, island arc, seamount, ophiolite, and continental rift environments. These and the other deposit types listed above also occur in accreted fragments of continental margin, cratonal, island arc, oceanic, ophiolite, and subduction-zone terranes. Major suites of stratiform and stratabound sulfide deposits also occur in the North Asian Craton Margin (unit NSV, Verkhoyansk fold belt) and in the North American Craton Margin (unit NAC).

Several major and minor pre-accretionary metallogenic belts of felsic-magmatism-related deposits occur in the Russian Far East, Alaska, and the Canadian Cordillera. The principal deposit types are Au-Ag epithermal vein, Cu-Au skarn, felsic plutonic REE, Fe-Au skarn, fluorite greisen, Pb-Zn skarn, polymetallic vein, porphyry Cu, porphyry Cu-Mo, Sn greisen, and Sn vein. These deposits are hosted mainly in continental margin or island arc tectonic environments. Subsequent to formation, most of these metallogenic belts and their host rocks migrated along the margin of, or were accreted to the North Asian Craton Margin or the North American Craton Margin.

Accretionary Metallogenic Belts

Several major and minor accretionary metallogenic belts occur in the Russian Far East, Alaska, and the Canadian Cordillera. The principal deposit types Au polymetallic vein, Au quartz vein, Au skarn, Cu-Ag quartz vein, Cu skarn, granitoid-related Au, Kennecott Cu, porphyry Cu-Mo, Sn quartz vein, Sn greisen, Sn skarn, Sn vein, Sn-W polymetallic vein, talc, W quartz vein, and W skarn. These deposits are generally interpreted as forming from metamorphic-hydrothermal and (or) magmatic-hydrothermal fluids which formed in collisional zones between terranes or between terranes and craton margin units. In some regions, the deposits are interpreted as forming in lower-grade, greenschist-facies extensional zones immediately after the major period of accretion and thrusting. The various felsic-magmatism-related deposits are interpreted as forming during major periods of anatexis which occurred during or immediately after accretion. The accretionary metallogenic belts generally occur along both sides of major fault boundaries between adjacent terranes, or between terranes and craton margins.

Post-Accretionary Metallogenic Belts

Several major and minor metallogenic belts of igneous arc-related deposits, mainly porphyry, polymetallic vein, epithermal, skarn, and related deposits, occur in the Russian Far East, Alaska, and the Canadian Cordillera. The principal deposit types are Au-Ag epithermal vein, B skarn, clastic sediment-hosted Hg, Cu skarn, Cu-Mo skarn, disseminated Au-sulfide, Fe-Au skarn, felsic plutonic U, granitoid-related Au, hot-spring Hg, kuroko massive sulfide, Mo-Cu skarn, Pb-Zn skarn, polymetallic vein, porphyry Au, porphyry Cu, porphyry Cu-Au, porphyry Cu-Mo, porphyry Mo, porphyry Sn, rhyolite-hosted Sn, sandstone U, Sb-Au vein, silica-carbonate Hg, sulfur-sulfide (volcanic S), Sn greisen, Sn quartz vein, Sn silicate-sulfide vein, Sn skarn, volcanic-hosted Hg, and W skarn.

These deposits are mainly hosted in or near granitoid plutonic, hypabyssal siliceous, and volcanic rocks which formed mainly during younger, mainly Cretaceous and Cenozoic continental-margin arc igneous activity. These post-accretionary, igneous arc deposits commonly transect several adjacent terranes and continental margin units. A general geographic and temporal pattern exists in that the older metallogenic belts and associated igneous rock belts, mainly of Cretaceous age, occur inboard, and the younger, Cenozoic belts occurring progressively outboard towards active continental-margins. These metallogenic belts contain a most diverse spectrum of lode deposits, but also have a high potential for discovery of new deposits. Particularly in the

Russian Far East, the metallogeny of post-accretionary, igneous-arc-related deposits depends to a great extent on the lithology and composition of the host rocks of the basement terranes. Throughout the region, in the Russian Far East, Alaska, and the Canadian Cordillera, the Cretaceous and Cenozoic the post-accretionary, igneous-arc-related deposits generally exhibit a general metallogenic zoning typical of continental-margin arcs.

Conclusions

The Phanerozoic metallogenic and tectonic evolution of the Circum-North Pacific can be explained as a succession of arcs and tectonically paired subduction zones which formed along the margins of the Northeast Asian and North American plates above the subducting oceanic lithosphere of mainly the Mongol-Okhotsk, Cache Creek, ancestral Pacific, and Pacific Oceans. In both Northeast Asia and in the North American Cordillera, most of the arcs formed in island arcs near continental margins or along the continental margins. With respect to Northeast Asia and North America, the paleolocations of those arcs, which occur oceanward of coeval accretionary complexes, are highly suspect in the Paleozoic but are successively less so in the Mesozoic.

The complex metallogenesis and tectonics of this region are analyzed by the following steps. (1) The notable or significant lode deposits are described and classified according to defined mineral deposit models. (2) Metallogenic belts are delineated. (3) Tectonic environments for the cratons, craton margins, orogenic collages of terranes, overlap assemblages, and contained metallogenic belts are assigned from regional compilation and synthesis of stratigraphic, structural, metamorphic, and faunal data. The tectonic environments include cratonal, passive continental margin, metamorphosed continental margin, continental-margin arc, island arc, oceanic crust, seamount, ophiolite, accretionary wedge, subduction zone, turbidite basin, and metamorphic. (4) Correlations are made between terranes, fragments of overlap assemblages, and fragments of metallogenic belts. (5) Coeval terranes and their contained metallogenic belts are grouped into a single metallogenic and tectonic origin, for instance, a single island arc or subduction zone. (6) Igneous-arc and subduction-zone terranes, which are interpreted as being tectonically linked, and their contained metallogenic belts, are grouped into coeval, curvilinear arc-subduction-zone-complexes. (7) By use of geologic, faunal, and paleomagnetic data, the original positions of terranes and their metallogenic belts are interpreted. (8) The paths of tectonic migration of terranes and contained metallogenic belts are constructed. (9) The timings and nature of accretions of terranes and contained metallogenic belts are determined from geologic, age, and structural data; (10) The nature of collision-related geologic units and their contained metallogenic belts are determined from geologic data. (11) The nature and timing of post-accretionary overlap assemblages and contained metallogenic belts are determined from geologic and age data.

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TABLE 1. Mineral deposit models for classification of significant lode deposits and for metallogenic analysis of Russian Far East, Alaska, and the Canadian Cordillera.

Deposit Group	Related Deposit Models
Deposits related to marine felsic to mafic extrusive rocks	Kuroko Zn-Pb-Cu massive sulfide (Ag, Au, Cd, Sn, Sb, Bi, barite) Besshi Cu-Zn massive sulfide (Cu, Zn, Ag) Cyprus Cu-Zn-Ag massive sulfide (Au, Pb, Cd, Sn) Volcanogenic Mn Volcanogenic Fe
Deposits related to subaerial extrusive rocks	Au-Ag epithermal vein Volcanic-hosted Hg (Plamennoe type) Hot spring Hg Silica-carbonate Hg Volcanic-hosted Sb (Au, Ag, As) vein Rhyolite-hosted Sn Sulfur-sulfide (S, FeS_2)
Stratiform deposits in fine-grained clastic and siliceous sedimentary rocks	SEDEX Zn-Pb-Ag Bedded barite
Stratabound deposits in coarse clastic sedimentary rocks and subaerial basalts	Sediment-hosted Cu (Kupferschiefer and Redbed) Basaltic Cu (Dzhalkan type) Clastic sediment-hosted Hg (Nikitovka type) Sandstone-hosted U
Deposits in carbonate and chemical-sedimentary rocks	Kipushi Cu-Pb-Zn Southeast Missouri Pb-Zn Korean Pb-Zn massive sulfide Ironstone (Superior Fe) Stratabound W (Austrian Alps-type) Carbonate-hosted Hg (Khaidarkan type) Stratiform Zr (Algama Type) Sedimentary phosphorite
Deposits related to calc-alkaline and alkaline granitic intrusions- veins and replacements	Polymetallic veins Sb-Au veins (simple Sb deposits) Sn quartz veins (Rudny Gory or Replacement Sn) Sn silicate-sulfide veins (Cornish type) Sn polymetallic veins (Southern Bolivian type) Co-arsenide polymetallic veins Carbonatite-related Ta, Nb, REE stockwork and vein
Deposits related to calc-alkaline and alkaline granitic intrusions - skarns and greisens	Cu (±Fe, Au, Ag, Mo) skarn (contact metasomatic) Zn-Pb (±Ag, Cu, W) skarn (contact metasomatic) and associated Manto replacement deposits Au, Co, and As skarn W skarn and greisen Fe (±Au, Cu, W, Sn) skarn Sn greisen and skarn Sn-B (Fe) Skarn (Ludwigtite type) Boron skarn (datolite type) Fluorite greisen
Deposits related to calc-alkaline and alkaline granitic intrusions	Porphyry and Granitic Plutons-Hosted Deposits Porphyry Cu-Mo (Au, Ag) Porphyry Mo (±W, Sn, Bi) Porphyry Sn Granitoid-related Au Felsic plutonic U-REE W vein
Deposits related to mafic and ultramafic rocks	Zoned mafic-ultramafic Cr-PGE (±Cu, Ni, Au, Co, Ti, or Fe) (Alaskan-Uralian PGE) Zoned ultramafic, mafic, felsic, and alkalic PGE-Cr and apatite-Ti

	Anorthosite apatite-Ti-Fe Gabbroic Ni-Cu (PGE) Podiform Cr Hornblende-Peridotite Cu-Ni (PGE) Serpentine-hosted asbestos
Deposits related to regionally metamorphosed rocks	Au quartz vein (includes concordant vein, and shear zone Au) Disseminated Au-sulfide (Maiskoe type) Clastic sediment-hosted Sb-Au Cu-Ag quartz vein (vein Cu) Kennecott Cu

TABLE 2. Summary of correlations and tectonic linkages for the Circum-North Pacific.

Units, correlations, and age	Tectonic environment(s)	Tectonic linkages and comments
CRATONAL, PASSIVE CONTINENTAL-MARGIN AND RELATED TERRANES AND OVERLAP ASSEMBLAGES IN THE RUSSIAN SOUTHEAST		
Kabarga, Sergeevka, Kabarga, and Voznesenka terranes of Khanka superterrane. Late Proterozoic and Paleozoic.	Passive continental margin.	Derived from Gondwanaland supercontinent during Devonian rifting and formation of bimodal volcanic rocks. Contain Late Paleozoic continental-margin arcs.
Argun and Gonzha terranes. Archean and Paleozoic.	Cratonal.	Derived from North Asian Craton during Late Proterozoic rifting. Dismembered parts of the Altaid orogenic system.
Oldoi and Mamyn terranes. Proterozoic to middle Paleozoic.	Passive continental margin.	Derived from North Asian Craton Margin during Late Proterozoic rifting, dismembered part of Altaid orogenic system.
Baladek terrane. Archean, Paleozoic, Early Mesozoic.	Cratonal.	Derived from North Asian Craton during Late Proterozoic rifting.
Ayansk terrane. Paleozoic.	Passive continental margin.	Derived from North Asian Craton Margin during Late Devonian rifting?
Bureya terrane. Early Paleozoic and older.	Continental-margin arc.	Rifted fragment of North China Craton. Dismembered part of Manchurid orogenic system.
LAOELIN-GRODEKOVO ISLAND ARC IN THE RUSSIAN SOUTHEAST		
Laoelin-Grodekovsk terrane, various back-arc units within Khanka superterrane, and Chongjin terrane (Japan). Permian.	Island arc.	Formed adjacent to Khanka superterrane.
Spassk terrane of Khanka superterrane. Early and middle Paleozoic.	Accretionary wedge.	Linked to Laoelin-Grodekovo terrane.

Units, correlations, and age	Tectonic environment(s)	Tectonic linkages and comments
CRATONAL AND PASSIVE AND METAMORPHOSED CONTINENTAL-MARGIN TERRANES IN THE RUSSIAN NORTHEAST, ALASKA, AND CANADIAN CORDILLERA		
Chukotka terrane, Arctic Alaska superterrane, Cassiar terrane. Proterozoic, Paleozoic, and early Mesozoic.	Passive continental margin.	Dismembered parts of North American Craton Margin.
Seward terrane (both sides of Bering Straits) Coldfoot, and Ruby terranes. Early and middle Paleozoic (mainly).	Metamorphosed continental margin.	Highly metamorphosed and deformed fragments of North American Craton Margin. Contain Late Devonian and Early Mississippian continental-margin arc rocks.
Yukon-Tanana and Kootenay terranes. Paleozoic.	Metamorphosed continental margin.	Highly metamorphosed and deformed rifted fragments of North American Craton Margin. Contain Late Devonian and Early Mississippian continental-margin arc rocks.
Dillinger, Kula-Nera, Nixon Fork, Prikolyma, Omulevka, Mystic, and Viliga terranes. Paleozoic and early Mesozoic.	Passive continental margin.	Dismembered fragments of North Asian Craton Margin (Verkhoyansk fold and thrust belt). Late Devonian and Early Mississippian rifting.
Kilbuck-Idono, Okhotsk, and Omolon terranes. Late Archean, Proterozoic, and early Paleozoic.	Cratonal.	Dismembered fragment of North Asian Craton. Late Devonian and Early Mississippian rifting.

TABLE 2. Summary of correlations and tectonic linkages for the Circum-North Pacific – Continued.

Unit(s) and Correlations. Age	**Tectonic Environment(s)**	**Tectonic Linkages. Comments**
MAINLY TRIASSIC TO MID-CRETACEOUS ISLAND-ARC AND CONTINENTAL-MARGIN-ARC TERRANES AND OVERLAP ASSEMBLAGES, AND LINKED SUBDUCTION-ZONE TERRANES		
Monakin Continental-margin Arc		
Monakin volcanic-pluotnic belt, granitic plutonic rocks of Korea, and volcanic-plutonic belt of Southeast China. Jurassic.	Igneous overlap assemblage.	Discontinuous parts of Great Hinggan arc.
Badzhal, Khabarovsk, and Samarka terranes. (Also Taukha, and Oshima terranes) Paleozoic to Cretaceous.	Accretionary wedge.	Linked to Monakin continental-margin arc. Also linked to Umlekan arc (below). Remnants of subduction of Ancestral Pacific Ocean plate. Taukha, and Oshima terranes linked to coeval granitic plutonic rocks of Korea and volcanic-plutonic belt of southeast China.
Umlekan Continental-Margin Arc		
Umlekan-Ogodzhin volcanic-plutonic belt. Jurassic and Early Cretaceous	Igneous overlap assemblage.	Northern extension of Monakin arc.
Badzhal, Khabarovsk (older Jurassic part), and Samarka terranes. Paleozoic to Cretaceous.	Accretionary wedge.	Linked to Umelkan arc and to Monakin arc (above). Remnants of subduction of Ancestral Pacific Ocean plate.
Khingan continental-margin arc		
Khingan-Okhotsk volcanic-plutonic belt. Early and mid-Cretaceous.	Continental-margin arc.	Formed after collision of Anui microcontinent with Samarka terrane
Amur River, Khabarovsk, and Kiselevka-Manoma terranes. Jurassic and Early Cretaceous.	Accretionary wedge.	Linked to Khingan continental-margin arc. Remnants of oblique subduction of Ancestral Pacific Ocean plate.
Kema Continental-Margin Arc		
Kema terrane, and Early to mid-Cretaceous volcanic rocks of Hokkaido Island. Mid Cretaceous.	Igneous overlap assemblage.	Transpressive continental-margin arc analogus to Tertiary margin of California.
Aniva and Kamuikotan terranes. Cretaceous.	Transpressional subduction zone.	Linked to Kema arc. Remnants of subduction of Ancestral Pacific Ocean plate.
Uda Continental-Margin Arc		
Uda volcanic-plutonic belt, Uniya-Bom turbidite-basin terrane, Umlekan-Ogodzhin volcanic-plutonic belt, and Upper Amur sedimentary assemblage. Late Jurassic and Early Cretaceous.	Igneous overlap assemblage.	Deposited on and adjacent to, and intruded into the North Asian Craton and Stanovoy block of the North Asian Craton.
Turkuringra- Dzhagdi, Galam, and Ulban terranes. Jurassic and Cretaceous.	Subduction zone or accretionary wedge.	Linked to Uda arc. Remnants of subduction of Mongol-Okhotsk Ocean plate.
Kony-Murgal Island Arc		
Kony-Murgal terrane. Late Triassic to Early Cretaceous.	Continental-margin and island arc.	
Talovskiy and Penzhina-Anadyr terranes. Mainly Jurassic and Early Cretaceous.	Subduction zone and accretionary wedge.	Linked to Kony-Murgal arc. Remnants of subduction of Ancestral Pacific Ocean plate.
Pekul'ney island arc		
West Pekul'ney terrane. Late Triassic to Early Cretaceous.	Island arc.	
Pekul'ney terrane. Mainly Jurassic and Early Cretaceous.	Subduction zone.	Linked to Pekul'ney arc. Remnants of subduction of Ancestral Pacific Ocean plate.

TABLE 2. Summary of correlations and tectonic linkages for the Circum-North Pacific – Continued.

Unit(s) and Correlations. Age	Tectonic Environment(s)	Tectonic Linkages. Comments
	Mainitskiy Island Arc	
Mainitskiy terrane. Late Jurassic to mid-Cretaceous.	Island arc.	Axial part of arc.
Alkatvaam. Late Triassic to Paleocene.	Accretionary wedge.	Linked to Mainitskiy arc. Remnants of subduction of Ancestral Pacific Ocean plate.
Uyandina island arc		
Uyandina-Yasachnaya volcanic belt. Late Jurassic.	Island arc.	Axial part of arc.
Garbyn'ya, Debin, and Chursky Range ophiolites. Unknown.	Ophiolite.	Linked to Uyandina arc. Remnants of subduction of Oimyakon Ocean plate.
	Oloy and Svyatov Nos Continental-Margin Arcs	
Oloy and and Svyatov Nos Arcs volcanic belts. Late Jurassic.	Continental-margin arc.	Axial part of arc.
South Anyui terrane. Late Jurassic and Early Cretaceous.	Subduction zone.	Linked to Oloy and Svyatov Nos arcs. Remnants of subduction of South Anyui Ocean plate.
	Alazeya Island Arc	
Alazeya, Khetachan, and Oloy terranes. Late Paleozoic to Early Jurassic.	Island arc.	Axial part of arc.
Aluchin terrane. Late Paleozoic to Early Jurassic.	Subduction zone	Linked to Alazeya arc. Remnant of subduction of Ancestral Pacific Ocean plate.
	Nutesyn Continental-Margin Arc	
Nutesyn terranes. Mainly Late Jurassic to Early Cretaceous.	Continental-margin arc	Axial part of arc.
Velmay terrane. Upper Triassic.	Subduction zone.	Linked to Nutesyn arc. Remnant of subduction of Angayucham Ocean plate.
	Koyukuk Island Arc	
Koyukuk, Nyac, and Togiak terranes. Mainly Late Jurassic to Early Cretaceous.	Island arc.	Axial part of arc.
Angayucham and Goodnews terranes. Devonian to Early Jurassic.	Subduction zone.	Linked to Koyukuk arc. Remnant of subduction of Angayucham Ocean plate.
	Gravina Island Arc	
Kahiltna sedimentary and volcanic assemblage; Gravina-Nutzotin-Gambier volcanic-plutonic-sedimentary belt; Cadwaller, Methow, Izee, and Wallowa island-arc and turbidite-basin terranes; Spences Bridge volcanic-plutonic belt; Tahtsa-Three Sisters-Francois Lake magmatic assemblage. Juassic to mid-Cretaceous with minor Triassic units.	Island arc and turbidite basin.	Axial part of arc.
Chugach (younger part, Valdez Group), Pacific Rim, Bridge River, and Baker terranes. Jurassic to Late Cretaceous.	Accretionary wedge and subduction zone.	Linked to Gravina arc. Remnants of subduction of Cache Creek Ocean plate.

TABLE 2. Summary of correlations and tectonic linkages for the Circum-North Pacific – Continued.

Unit(s) and Correlations. Age	Tectonic Environment(s)	Tectonic Linkages. Comments
Talkeetna-Bonanza Island Arc		
Peninsular sequence of Wrangellia supterterrane (Talkeetna Formation) in Alaska; Bonanza Formation and Cadwallader island arc and Methow turbidite-basin terranes in Canadian Cordillera. Late Triassic and Early Jurassic.	Island arc.	Axial part of arc.
Chugach (older part, blueschist and McHugh Complex), Bridge River, and Baker terranes. Paleozoic, Triassic, and Early Jurassic.	Accretionary wedge and subduction zone.	Linked to Talkeetna and Bonanza arcs. Remnants of subduction of Cache Creek and Farallon Ocean plates.
Stikinia-Quesnellia Island Arc		
Stikinia and Quesnellia terranes. Permian to Early Jurassic.	Island arc.	Axial part of arc.
Cache Creek, Slide Mountain, and Seventymile terranes. Paleozoic and Mesozoic.	Subduction zone and accretionary wedge.	Linked to Stikinia-Quesnellia arc. Remnants of subduction of Cache Creek Ocean plate.
MAINLY LATE CRETACEOUS AND EARLY CENOZOIC CONTINENTAL-MARGIN ARCS, ISLAND ARCS, AND LINKED SUBDUCTION ZONES		
East Sikhote-Alin Continental-Margin Arc (Late Cretaceous)		
East Sikhote-Alin volcanic-plutonic belt, Sorachi-Yezo, West Sakhalin terrane. Cretaceous and early Tertiary.	Igneous overlap assemblage.	Axial part of arc.
Hidaka accretionary-wedge, younger part of the Aniva, Nabilsky, and Tokoro terranes. Permian to Cretaceous.	Accretionary wedge and subduction zone.	Linked to East Sikhote-Alin arc. Remnants of subduction of Ancestral Pacific Ocean plate.
Okhotsk-Chukotka Continental-Margin Arc		
Okhotsk-Chukotka volcanic-plutonic belt and Penzhina sedimentary basin. Cretaceous and early Tertiary.	Igneous overlap assemblage.	Axial part of arc.
West-Kamchatka, Ekonay, and Yanranay terranes. Upper Paleozoic, Jurassic and Early Cretaceous.	Accretionary wedge.	Linked to Okhotsk-Chukotka arc. Remnants of subduction of Ancestral Pacific Ocean plate.
Olyutorka Island Arc		
Olyutorka-Kamchatka, Iruneiskiy, Kronotskiy, Shmidt, Terpeniya, and Nemuro terranes. Late Cretaceous and Early Tertiary.	Island arc.	Axial part of arc.
Vetlovskiy terrane. Late Cretaceous and early Tertiary.	Accretionary wedge.	Linked to Olyutorka arc. Remnants of subduction of Ancestral Pacific Ocean plate.
Kluane and Coast North Cascade Continental-Margin Arcs		
Kuskokwim Mountains sedimentary, volcanic, and plutonic belt, Alaska Range-Talkeetna Mountains volcanic-plutonic belt, Coast-North Cascade plutonic belt, and Kamloops magmatic belt. Late Cretaceous and early Tertiary.	Igneous overlap assemblage.	Axial part of arc.
Chugach terrane (the Late Cretaceous Valdez Group), older part of the Prince William terrane, and Pacific Rim terrane. Late Cretaceous and early Tertiary.	Accretionary wedge and subduction zone.	Linked to Kluane and Coast North Cascade arcs. Remnants of subduction of ancestral Pacific Ocean plate.

TABLE 2. Summary of correlations and tectonic linkages for the Circum-North Pacific – Continued.

Unit(s) and Correlations. Age	Tectonic Environment(s)	Tectonic Linkages. Comments
MIDDLE AND LATE CENOZOIC CONTINENTAL-MARGIN ARCS AND LINKED SUBDUCTION ZONES		
Northeast Asia Continental-Margin Arc		
East Japan volcanic-plutonic belt, Central Kamchatka volcanic belt, Central Kamchatka volcanic and sedimentary basin, East Kamchatka volcanic belt, Eastern Sakhalin sedimentary basin, and the West Kamchatka sedimentary basin. Early Eocene to Miocene to present.	Igneous overlap assemblages.	Axial part of arc.
Kuril-Kamchatka terrane. Miocene to present.	Accretionary wedge and subduction zone.	Linked to Northeast Asia arc. Remnant of subduction of Pacific Ocean plate.
Sea of Japan unit, Sakhalin-Primorye volcanic belt, and Kuril unit. Oligocene to Miocene.	Back-arc units.	Linked to Northeast Asia arc.
Aleutian-Wrangell Continental-Margin Arc		
Aleutian volcanic belt, and Wrangell volcanic field. Early Eocene to Miocene to present.	Igneous overlap assemblages.	Axial part of arc.
Attu Island part of Prince William terrane and Yakutat terrane. Early Tertiary to present.	Accretionary wedge.	Linked to Aleutian-Wrangell arc. Remnants of subduction of ancestral Pacific Ocean plate.
Cascade Continental-Margin Arc		
Cascade volcanic-plutonic belt. Eocene to present.	Igneous overlap assemblage.	Axial part of arc.
Siletzia, Olympic Core, and Hoh terranes, and modern-day subduction zone. Eocene to present.	Subduction zone and accretionary wedge.	Linked to Cascade arc. Remnants of subduction of Juan de Fuca plate.
Columbia River Basalt Group. Miocene.	Back-arc unit.	Linked to Cascade arc.

TABLE 3. Tectonic environment of Proterozoic and Phanerozoic metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera. Refer to Figures 2-18 for location of metallogenic belts. For each time interval (time-stage) in the metallogenic-tectonic model, the metallogenic belts are listed in a clockwise order, according to similar tectonic environments, starting with the area of the Russian Southeast and ending with the area of the southern Canadian Cordillera. [Environment refers to metallogenic-tectonic environment of host rocks as defined and described here. Time scale is from Palmer (1983). Metallogenic belts are defined and adapted from Nokleberg and others (1997a, b, 1998b) and as modified herein. Abbreviations given for metallogenic belts as depicted on generalized maps of metallogenic belts and host rocks (figures 2-18) and on metallogenic-tectonic model for Devonian through Present (Figures 19-32).]

PROTEROZOIC METALLOGENIC BELTS (2500 TO 570 Ma) (Figures 2, 3)			
Metallogenic Belt (Abbreviation)	**Major Mineral Deposits Types. (Significant Mineral Deposits)**	**Environment. Host Unit.**	**Tectonic Event. Comments**
Metallogenic Belts Formed During Proterozoic Rifting of North Asian Craton or Craton Margin			
Oroek (OK)	Ironstone (Superior Fe), sediment-hosted Cu.	Passive continental margin. Prikolyma terrane.	Sedimentation along Proterozoic passive continental margin (ironstone deposits). Mesoproterozoic to Neoproterozoic incipient rifting of passive continental margin (sediment-hosted Cu deposits).
Lantarsky-Dzhugdzhur (LD)	Anorthosite Apatite-Ti-Fe. (Bogidenskoe, Gayumskoe, Maimakanskoe, Dzhaninskoe) Gabbroic Cu-Ni-Co-PGE (Avlandzhinsky, Kontaktovy, Nyandomi Ozerny, Odorin)	Gabbro and anorthosite plutons, and alkali granites intruding North Asian Craton.	Mesoproterozoic rifting of passive continental margin of North Asian Craton and intrusion of gabbro and anorthosite plutons, relatively younger, Rapakivi-type alkalic granite.
Ulkan (UL)	Felsic Plutonic REE and related deposits. (Albititovoe, Burgundiy, Gurjanouskoe, Krasnogorskoe, Mezhdurechnoe, Nygvagan, Ulkanskoe, Uzhnoe, Zapadnoe)	REE granite, alkalic dikes, and altered basalt in or near Paleoproterozoic Ulkan volcano-tectonic basin overlying older units of North Asian Craton.	Possible formed during Mesoproterozoic rifting?
Bilyakchan (BI)	Sediment-hosted Cu and basalt Cu.	Passive continental margin. Verkhoyansk fold belt, North Asian Craton Margin.	Sedimentation along Proterozoic passive continental margin (ironstone deposits). Neoproterozoic incipient rifting of passive continental margin.
Omolon (OM)	Ironstone (Superior Fe). (Verkhny-Omolon))	Marine sedimentation. Omolon terrane.	Sedimentation along Paleoproterozoic passive continental margin. Terrane interpreted as a rifted fragment of North Asian Craton.
Kilbuck (KI)	Ironstone (Superior Fe). (Canyon Creek)	Marine sedimentation. Kilbuck terrane (pre-rifting).	Sedimentation along Paleoproterozoic passive continental margin. Rifted fragment of North Asian Craton.
Metallogenic Belts Formed During Proterozoic Sedimentation, Rifting, and Hydrothermal Activity Along North American Craton or Craton Margin			
Sinuk River (SR)	Stratiform massive sulfide-barite. (Aurora Creek, Nelson, Rocky Mountain Creek, Quarry) Stratabound Fe and Mn (American, Bear, Cub, Monarch)	Marine volcanism. Seward terrane.	Interpreted as forming during marine volcanogenic rifting(?) of the North American Continental Margin.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Gillespie (GE)	SEDEX Zn-Cu-Pb-Au-Ag. (Blende, Hart River)	Mafic plutons intruding North American Craton Margin.	Intrusion of gabbro and diorite sills during rifting of Paleoproterozoic passive continental margin?
Wernecke (WR)	U-Cu-Fe (Au-Co) vein and breccia (Igor)	Hydrothermal replacement? North American Craton Margin.	Hydrothermal activity along Paleoproterozoic passive continental margin.
Rapitan (RA)	Iron formation. (Crest Iron)	Marine sedimentation. North American Craton Margin.	Marine exhalation along Mesoproterozoic North American Craton Margin.
Metallogenic Belts Formed During Proterozoic Rifting of North American Craton or Craton Margin			
Redstone (RD)	Sediment-hosted Cu-Ag. (Coates Lake)	Rifted continental margin. North American Craton Margin.	Incipient rifting of Paleoproterozoic North American Craton Margin.
Churchill (CH)	Cu vein (Churchill (Davis Keays))	Rifted continental margin. North American Craton Margin.	Mesoproterozoic rifting of Proterozoic North American Craton Margin.
Monashee (MO)	SEDEX Zn-Pb-Ag. (Big Ledge and Ruddock Creek)	Rifted craton. Fragment of North American Craton.	Paleoproterozoic rifting of North American Craton.
Purcell (PR)	SEDEX Zn-Pb-Ag. (Sullivan, Moyie, Vine)	Rifted continental margin. North American Craton Margin.	Incipient rifting of Proterozoic North American Craton Margin
Clark Range (CR)	Sediment-hosted Cu-Ag deposits	Rifted continental margin. North American Craton Margin.	Mesoproterozoic rifting of Proterozoic North American Craton Margin.
CAMBRIAN THROUGH SILURIAN METALLOGENIC BELTS (570 to 408 Ma) (Figures 2, 3)			
Metallogenic Belts Formed During Early Paleozoic Marine Sedimentation in Rifted Fragments of Gondwandaland Supercontinent			
Voznesenka (VZ)	Korean Pb-Zn (Chernyshevskoe)	Marine sedimentation. Khanka superterrane.	Rifting of early Paleozoic (Cambrian) continental margin. Rifted fragment of Gondwandaland supercontinent.
Kabarga (KA)	Ironstone (Superior Fe) (Ussuri)	Marine sedimentation. Khanka superterrane.	Sedimentation along early Paleozoic (Cambrian) continental margin. Rifted fragment of Gondwandaland supercontinent.
Metallogenic Belts Formed During Early Paleozoic Sedimentation or Marine Volcanism in Manchurid and Altaid Orogenic Systems			
South Khingan (SK)	Ironstone (Superior Fe). (South Khingan, Kimkanskoe)	Marine sedimentation. Bureya superterrane.	Sedimentation along early Paleozoic passive continental margin. Part of Manchurid orogenic system.
Gar (GA)	Volcanogenic Fe, Cu massive sulfide, stratiform Zn-Pb. (Gar, Kamenushinskoe, Chagoyan)	Continental-margin arc. Khingan terrane.	Subduction-related volcanism associated with early Paleozoic (Cambrian) continental-margin arc. Part of Altaid orogenic system.
Metallogenic Belts Formed During Early Paleozoic Sea-Floor Spreading, Regional Metamorphism, or During Subduction-Related Volcanism in Russian Far East Terranes			
Galam (GL)	Volcanogenic Fe and Mn; sedimentary P. (Gerbikanskoe)	Ocean floor volcanism. Galam accretionary-wedge terrane.	Sea-floor spreading in early Paleozoic (Cambrian) forming part of ancestral Pacific Ocean.
Omulevka River (OR)	Austrian Alps W, Kipushi Cu-Pb-Zn. (Omulev, Vesnovka)	Passive continental margin. Omulevka terrane (pre-rifting).	Regional metamorphism associated with Late Silurian accretion of Rassokha oceanic crust terrane to Omulevka continental margin terrane.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Rassokha (RA)	Basaltic Cu, sediment-hosted Cu. (Agyndja), porphyry Cu.	Distal passive continental margin. Rassokha terrane.	Subduction-related volcanism associated with incipient continental-margin arc. Possible precursor to Late Devonian Kedon arc?
Metallogenic Belts Formed During Early Paleozoic Rifting of Continental Margins or in Continental-Margin Arc Terranes			
Dzhardzhan River (DZR)	Southeast Missouri Pb-Zn, sediment-hosted Cu; sandstone-hosted U. (Manganiler, Aga-Kukan, Kyongdyoi)	Rifted continental margin. North Asian Craton Margin.	Incipient rifting of early Paleozoic (Cambrian) continental-margin. Some deposits may have formed during late Paleozoic rifting.
Anvil (AN)	SEDEX Zn-Pb-Ag. (Faro, Vangorda, Grum, Swim, DY)	Rifted continental margin. North American Craton Margin.	Incipient rifting of early Paleozoic (Cambrian) North American Continental-Margin.
Howards Pass (HP)	SEDEX Zn-Pb. (XY, Anniv, OP)	Rifted continental margin. North American Craton Margin.	Incipient rifting of early Paleozoic (Silurian) North American Continental-Margin.
Kootenay (KO)	SEDEX Zn-Pb. (Reeves-MacDonald, HB, Duncan Lake, Mastadon))	Rifted continental margin. Kootenay terrane.	Rifting of early Paleozoic (Cambrian) North American Continental-Margin.
Prince of Wales Island (PW)	Porphyry Cu-Mo, polymetallic vein. (McLean Arm, Kassan Peninsula) Zone mafic-ultramafic Cu-Au-PGE. (Salt Chuck)	Continental-margin arc. Alexander sequence, Wrangellia superterrane.	Subduction-related granitic plutonism associated with an Ordovician-Silurian continental-margin arc.
MIDDLE AND LATE DEVONIAN METALLOGENIC BELTS (387 to 360 Ma) (Figures 4, 5)			
Metallogenic Belt Formed During Collision			
Yaroslavka (YA)	F & Sn greisen. (Voznesenka II, Yaroslavkoe)	Anatectic plutonism. Khanka superterrane (pre-rifting).	Granitic plutonism associated with collision of Voznesenka and Kabarga terranes of the Khanka superterrane in early Paleozoic (Devonian).
Metallogenic Belts Formed in a Middle Paleozoic Continental Arc Along North Asian and North American Craton Margins			
Kedon (KE)	Au-Ag epithermal vein, porphyry Mo, Fe skarn. (Kubaka, Olcha, Zet)	Continental-margin arc. Omolon terrane.	Subduction-related volcanism associated with Paleozoic (Devonian) continental-margin arc. Belt continued into Mississippian.
Eastern Seward Peninsula (ES)	Kuroko massive sulfide. (Kiwalik Mountain)	Continental-margin arc. Seward terrane.	Subduction-related volcanism associated with submerged continental-margin arc. Arc and metallogenic belt extended into Mississippian. Arc formation succeeded by continental-margin rifting.
Arctic (AT) (Includes Ambler district)	Kuroko massive sulfide and Kipushi massive sulfide. (Arctic, Ruby Creek, Sun, Smucker)	Continental-margin arc. Coldfoot terrane.	Subduction-related volcanism associated with submerged continental-margin arc. Arc and metallogenic belt extended into Mississippian. Arc formation succeeded by continental-margin rifting.
Brooks Range (BR)	Porphyry Cu, Cu-Pb skarn, polymetallic vein. (Victor, Esotuk Glacier, Romanzof Mountains)	Continental-margin arc. Arctic Alaska superterrane.	Subduction-related granitic plutonism that formed a mainly Late Devonian continental-margin arc.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Alaska Range and Yukon-Tanana Upland (AKY)	Kuroko massive sulfide. (WTF, Red Mountain, Sheep Creek, Liberty Bell, Anderson Mountain, Miyaoka, Hayes Glacier, McGinnis Glacier, Delta district)	Continental-margin arc. Yukon-Tanana terrane.	Subduction-related volcanism associated with Late Devonian and Mississippian submerged continental-margin arc. Arc and metallogenic belt extended into early Mississippian. Arc formation succeeded by continental-margin rifting.
Dawson (DA)	Volcanogenic Pb-Zn-Cu Massive sulfide, SEDEX Pb-Cu-Zn-Ba (Lucky Joe, Mickey, Lone Star)	Continental-margin arc. Yukon-Tanana terrane.	Subduction-related volcanism associated with Late Devonian and Mississippian submerged continental-margin arc. Arc and metallogenic belt extended into early Mississippian. Arc formation succeeded by continental-margin rifting.
Frances Lake (FR)	Kuroko massive sulfide. (Kudz Ze Kayah, Wolverine-Lynx)	Continental-margin arc. Yukon-Tanana terrane.	Subduction-related volcanism associated with submerged continental-margin arc. Arc and metallogenic belt extended into early Mississippian. Arc formation succeeded by continental-margin rifting.
Tracy (TR)	Kuroko massive sulfide. (Ecstall, Alamo, Sweetheart Ridge, Sumdum, & others)	Continental-margin arc. Yukon-Tanana terrane (pre-rift).	Subduction-related volcanism associated with submerged continental-margin arc.
Mount Sicker (MS)	Kuroko volcanogenic massive sulfide. (Mount Sicker (Lenora-Tyee, Twin J, Lara, Copper Canyon); Myra Falls (Lynx, Myra, Price, HW))	Island arc. Wrangellia superterrane.	Subduction-related volcanism associated with island arc.
Kootenay-Shuswap (KS)	Kuroko, Besshi, and Cyprus massive sulfide. (Shuswap, Goldstream, Harper Creek, Chu Chua, Adams, Liard, & others)	Back-arc part of continental-margin arc. Kootenay terrane (pre-rifting)	Subduction-related volcanism associated with submerged continental-margin arc. Belt extended into early Mississippian. Arc formation succeeded by continental-margin rifting.
Metallogenic Belts Formed During Middle Paleozoic Rifting of North Asian Craton Margin			
Khamna River (KR)	Carbonatite-related Nb, Ta, REE. (Khamna, Gornoe Ozero)	Rifted passive continental margin. North Asian Craton Margin.	Rifting of middle Paleozoic (Devonian) continental-margin. Hosted in Late Devonian alkalic granitic rocks and carbonatites.
Sette-Daban (SD)	Southeast Missouri Pb-Zn, sediment-hosted Cu. (Sardana, Urui, Kupandzha)	Rifted passive continental margin. North Asian Craton Margin.	Rifting of middle Paleozoic (Late Devonian to Early Mississippian) continental-margin. Belt continued into Early Mississippian.
Selennyakh River (SEL)	Southeast Missouri Pb-Zn, stratabound Hg. (Gal-Khaya, Kondakovskoe)	Rifted passive continental margin. Omulevka terrane.	Rifting of middle Paleozoic (Late Devonian to Early Mississippian) continental-margin. Belt continued into Early Mississippian.
Tommot River (TO)	Carbonatite-related Nb, Ta, and REE (Tommot)	Rifted passive continental margin. Omulevka terrane.	Rifting of middle Paleozoic (Late Devonian to Early Mississippian) continental-margin. Belt continued into Early Mississippian.
Urultun & Sudar Rivers (URS)	Southeast Missouri Pb-Zn, carbonate-hosted Hg. (Urultun, Uochat)	Rifted passive continental margin. Omulevka terrane.	Rifting of middle Paleozoic (Late Devonian to Early Mississippian) continental-margin. Belt continued into Early Mississippian.
Yarkhodon (YR)	Southeast Missouri Pb-Zn (Slezovka, Gornoe)	Rifted passive continental margin. Prikolyma terrane.	Rifting of middle Paleozoic (Late Devonian to Early Mississippian) continental-margin. Belt continued into Early Mississippian.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Berezovka River (BE)	Kuroko massive sulfide and sulfide vein. (Berezovskoe)	Rifted passive continental margin. Berezovka terrane.	Rifting of middle Paleozoic (Late Devonian to Mississippian) continental-margin. Belt continued into Permian(?).
Metallogenic Belts Formed During Middle Paleozoic Rifting of North American Craton Margin or in Low-Temperature Brines Along Craton Margin			
Mystic (MY)	SEDEX massive bedded barite, Southeast Missouri Pb-Zn. (Gagaryah, Reef Ridge)	Rifted passive continental margin. North Asian Craton Margin.	Rifting of middle Paleozoic (Late Devonian to Early Mississippian) continental-margin. Belt continued into Early Mississippian.
Northern Cordillera (NCO)	Southeast Missouri Zn-Pb. (Gayna River, Goz Creek, Godlin Lakes)	Rifted continental margin. North American Craton Margin.	Incipient rifting of Late Proterozoic to middle Paleozoic (Devonian-Mississippian) North American Continental Margin. Belt extended from Late Proterozoic to Devonian(?).
Dempster (DE)	SEDEX Ba, Ni-Zn-PGE-Au SEDEX, Kuroko Zn-Pb-Cu massive sulfide. (Rein, Marg, Nick)	Rifted continental margin. North American Craton Margin.	Rifting of middle Paleozoic (Late Devonian to Early Mississippian) North American Continental Margin.
Macmillan Pass (MP)	Sedimentary-Exhalative Zn-Pb-Ag. (Tom, Jason, Main)	Rifted continental margin. North American Craton Margin.	Rifting of middle Paleozoic (Late Devonian to Early Mississippian) North American Continental Margin.
Finlayson Lake (FL)	Sedimentary-Exhalative Zn-Pb-Ag. (Maxi, Matt Berry, Finlayson Lake)	Rifted continental margin. North American Craton Margin.	Incipient rifting of middle Paleozoic (Late Devonian to Early-Mississippian) North American Continental Margin.
Liard (LI)	Southeast Missouri(?) Ba-F (Leguil Creek, Lower Liard)	Rifted continental margin. North American Craton Margin.	Rifting of middle Paleozoic (Late Devonian to Early Mississippian) North American continental-margin.
Gataga (GA)	Sedimentary-Exhalative Zn-Pb-Ag. (Cirque, Driftpile Creek, Gataga)	Rifted continental margin. North American Craton Margin.	Incipient rifting of middle Paleozoic (Late Devonian to Early Mississippian) North American continental-margin.
Robb Lake (RL)	Southeast Missouri Zn-Pb. (Robb Lake)	Rifted continental margin. North American Craton Margin.	Rifting of middle Paleozoic (Late Devonian to Early Mississippian) North American Continental Margin.
Southern Rocky Mountains (SRM)	Chemical-sedimentary gypsum (Windemere Creek, Marysville, Mount Brussilof, Parson, Brocso)	Rifted continental margin. North American Craton Margin.	Incipient rifting of middle Paleozoic (Devonian) North American Continental Margin. Belt extended into Late Proterozoic with formation of sedimentary Mg and Ba vein deposits.
Ingenika (IN)	Southeast Missouri Zn-Pb-Ag. Monarch (Susie, Beveley and Regent)	Passive continental margin. Cassiar terrane.	Deposition by low-temperature brines which may have originated within an adjacent shale basin.
Cathedral (CA)	Southeast Missouri Zn-Pb-Ag. Monarch (Kicking Horse)	Passive continental margin. North American Craton Margin.	Deposition by low-temperature brines which may have originated within an adjacent shale basin.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
MISSISSIPPIAN METALLOGENIC BELTS (360 to 320 Ma) (Figures 4, 5)			
Continuing Metallogenic Belts			
Metallogenic Belt Formed During Mississippian-Pennsylvanian Back-Arc Spreading Along North American Craton Margin			
Northwestern Brooks Range (NBR)	SEDEX Zn-Pb. (Lik, Red Dog Creek) Kuroko massive sulfide. (Drenchwater Creek) Bedded barite, sulfide vein.	Incipient rift(?) along continental margin arc. Arctic Alaska superterrane.	Subduction-related volcanism associated with Mississippian-Pennsylvanian, back-arc spreading that was possibly associated with a short-lived continental-margin arc
Selennyakh River (SEL)			Belt started in Devonian.
Sette-Daban (SD)			Belt started in Devonian.
Urultun & Sudar Rivers (URS)			Belt started in Devonian.
Kedon (KE)			Belt started in Devonian.
Northern Cordillera (NCO)			Belt started in Devonian.
Dempster (DE)			Belt started in Devonian.
Macmillan Pass (MP)			Belt started in Devonian.
Finlayson Lake			Belt started in Devonian.
Gataga (GA)			Belt started in Devonian.
PENNSYLVANIAN METALLOGENIC BELTS (320 to 286 Ma) (Figures 6, 7)			
Metallogenic Belt Formed During Mississippian-Pennsylvanian Back-Arc Spreading Along North American Craton Margin			
Northwestern Brooks Range (NBR)			Belt started in Mississippian.
Metallogenic Belt Formed in Late Paleozoic Island Arc Terrane in the Russian Southeast			
Laoelin-Grodekovsk (LG)	Porphyry Cu-Mo, Au-Ag epithermal vein. (Baikal, Komissarovskoe)	Island arc. Laoelin-Grodekovsk terrane.	Subduction-related granitic plutonism that formed the Laoelin-Grodekovsk island arc, part of Khanka superterrane, a rifted fragment of Gondwandaland supercontinent. Not depicted on metallogenic model because of formation beyond map area.
Metallogenic Belts Formed In Late Paleozoic Oceanic Lithosphere Preserved in Subduction Zones Terranes in Russian Northeast			
Aluchin (AC)	Podiform Cr. (Teleneut)	Back-arc rifting? Aluchin subduction zone terrane	Oceanic lithosphere preserved in Aluchin subuction zone that was tectonically linked to Alazeya island arc.
Ust-Belaya (UB)	Podiform Cr. (Ulst-Belaya)	Oceanic ridge. Penzhina Anadyr subduction zone terrane.	Oceanic lithosphere preserved in Penzhina Anadyr subuction zone that was tectonically linked to Koni-Murgal continental margin and island arc.
Metallogenic Belts Formed in Late Paleozoic Skolai Island Arc in Wrangellia Superterrane			
Alaska Range-Wrangell Mountains (ARW)	Cu skarn, porphyry Cu, polymetallic vein. (Rainy Creek, Rainbow Mountain, Chistochina)	Island arc. Wrangellia sequence, Wrangellia superterrane.	Subduction-related granitic plutonism in Skolai island arc developed along margin of Wrangellia superterrane.
Ketchikan (KK)	Kuroko massive sulfide (Moth Bay)	Island arc. Wrangellia sequence, Wrangellia superterrane.	Subduction-related granitic plutonism in Skolai island arc developed along margin of Wrangellia superterrane

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
LATE TRIASSIC METALLOGENIC BELTS (Carnian through Norian - 230 to 208 Ma) (Figure 7)			
Metallogenic Belt Formed During Early Mesozoic Rifting? in Alaskan Passive Continental-Margin Terranes			
Farewell (FW)	Gabbroic Ni-Cu-PGE. (Farewell district)	Rifting? Dillinger terrane.	Incipient rifting of Dillinger and adjacent passive continental margin terranes?
Metallogenic Belts Formed in Middle Mesozoic Talkeetna-Bonzana Island Arc in Wrangellia Superterrane			
Kodiak Island and Border Ranges (KOD)	Podiform Cr. (Halibut Bay, Claim Point, Red Mountain, Bernard Mountain, Dust Mountain)	Island arc. Border Ranges mafic-ultramafic assemblage	Subduction-related intrusion of mafic-ultramafic plutons into basal part of Talkeetna-Bonzana island arc in Wrangellia superterrane. Metallogenic belt extended into Early and Middle Jurassic.
Eastern Alaska Range (EAR) (equivalent to Kluane-Nikolai belt)	Gabbroic Ni-Cu. (Fish Lake, Wellgreen) Besshi massive sulfide (Denali) Strataform gypsum (Bullion Creek)	Back-arc rifting? Nikolai Greenstone, Wrangellia sequence, Wrangellia superterrane	Back-arc rifting associated with Talkeetna part of Talkeetna-Bonanza island arc in Wrangellia superterrane. Alternative interpretation of hot spot (oceanic plume).
Alexander (AX)	Cyprus massive sulfide, Kuroko massive sulfide, bedded barite. (Windy Craggy, Greens Creek, Castle Island, Kupreanof Island, Haines)	Back-arc? Nikolai Greenstone and equivalent units, Wrangellia sequence, Wrangellia super terrane.	Back-arc rifting associated with Bonanza part of the Talkeetna-Bonanza island arc in Wrangellia superterrane. Alternative interpretation of hot spot (oceanic plume).
Metallogenic Belts Formed in Middle Mesozoic in Stikinia-Quesnellia Island Arc			
Galore Creek (GL)	Porphyry Cu-Au. (Galore Creek, Red Chris)	Island arc. Stikinia & Quesnellia terranes.	Subduction-related granitic plutonism that formed the Stikinia-Quesnellia island arc. Belt continued into Early Jurassic.
Sustut (SU)	Basaltic Cu (Susut)	Island arc. Stikinia terrane.	Formation in the upper oxidized parts of the Stikinia-Quesnellia island arc volcanic pile during shallow burial metamorphism and diagenesis.
Copper Mountain (North) (CMN)	Porphyry Cu-Au, porphyry Cu-Mo. (Lorraine, Mount Mulligan)	Island arc. Stikinia & Quesnellia terranes.	Subduction-related granitic plutonism that formed the Quesnellia island arc. Belt continued into Early Jurassic.
Copper Mountain (South) (CMS)	Porphyry Cu-Au. (Copper Mountain, Ingerbelle, Iron Mask, Mount Polley)	Island arc. Quesnellia terrane.	Subduction-related granitic plutonism that formed the Quesnellia island arc. Belt continued into Early Jurassic..
Guichon (GU)	Porphyry Cu-Mo-Au, Au skarn. (Highland Valley district, Brenda, Gibraltar, Craigmont, Hedley)	Island arc. Quesnellia terrane.	Subduction-related granitic plutonism that formed the Quesnellia island arc. Belt continued into Early Jurassic.
Texas Creek (TC)	Porphyry Cu-Mo-Au, polymetallic vein. (Schaft Creek, Kerr, Sulphurets, Snip, Red Mountain, & others)	Island arc. Stikinia terrane.	Subduction-related granitic plutonism that formed the Stikinia island arc. Belt continued into Early Jurassic.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
EARLY JURASSIC METALLOGENIC BELTS (Hettangian through Pleinsbachian - 208 to 193 Ma) (Figure 8)			
Metallogenic Belts Formed in Middle Mesozoic in Talkeetna-Bonzana Island Arc in Wrangellia Superterrane			
Alaska Peninsula (AP)	Cu & Fe skarn. (Crevice Creek, Glacier Fork, Kasna Creek, Magnetite Island)	Island arc. Granitic plutons Peninsular sequence, Wrangellia superterrane.	Subduction-related granitic plutonism that formed the Talkeetna part of the Talkeetna-Bonanza island arc in Wrangellia superterrane. Metallogenic belt may have extended into Middle Jurassic.
Talkeetna Mountains-Alaska Range (TM)	Kuroko massive sulfide. (Johnson River)	Island arc. Talkeetna Formation, Peninsular sequence, Wrangellia superterrane.	Subduction-related marine volcanism associated with Talkeetna part of Talkeetna- Bonanza island arc in Wrangellia superterrane.
Island Porphyry (IP)	Porphyry Cu-Mo, Cu skarn, Fe skarn. (Island Copper, Tasu, Jedway, Burnaby Iron)	Island arc. Wrangellia superterrane.	Subduction-related granitic plutonism that formed the Bonanza part of the Talkeetna-Bonanza island arc in Wrangellia superterrane. Belt continued into early Late Jurassic.
Metallogenic Belts Formed During Middle Mesozoic in Stikinia Island Arc			
Klotassin (KL)	Porphyry Cu-Au-Ag. (Minto Creek, Williams Creek)	Island arc. Stikinia and Yukon-Tanana terranes.	Subduction-related granitic plutonism that formed the Stikinia island arc.
Toodoggone (TO)	Au-Ag epithermal vein and porphyry Cu-Au. (Lawyers, Chappelle, AI, Kemess)	Island arc. Stikinia terrane.	Subduction-related granitic plutonism that formed the Stikinia island arc.
Coast Mountains (CM)	Kuroko massive sulfide, Besshi massive sulfide) (Eskay Creek, Dolly Varden, North Star, Granduc, Anyox)	Island arc. Stikinia terrane	Subduction-related, back-arc volcanism associated with Stikinia island arc. Three periods of deposit formation, middle and late Paleozoic, Late Triassic, and Early Jurassic.
Continuing Metallogenic Belts			
Texas Creek (TC)			Belt started in Late Triassic.
Galore (GL)			Belt started in Late Triassic.
Copper Mountain (North) (CMN)			Belt started in Late Triassic.
Copper Mountain (South) (CMS)			Belt started in Late Triassic.
Guichon (GU)			Belt started in Late Triassic.
MIDDLE JURASSIC METALLOGENIC BELTS (Toarcian through Callovian - 193 to 163 Ma) (Figure 8)			
Continuing Metallogenic Belts			
Talkeetna Mountains (TM)			Belt started in Early Jurassic.
Alaska Peninsula (AP)			Belt started in Early Jurassic.
Island Porphyry (IP)			Belt started in Early Jurassic.
Klotassin (KL)			Belt started in Early Jurassic.
Texas Creek (TC)			Belt started in Late Triassic.
Galore (GL)			Belt started in Late Triassic.
Toodoggone (TO)			Belt started in Early Jurassic
Coast Mountains (CM)			Belt started in Early Jurassic
Copper Mountain (North) (CMN)			Belt started in Late Triassic.
Copper Mountain (South) (CMS)			Belt started in Late Triassic.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Guichon (GU)			Belt started in Late Triassic.
LATE JURASSIC METALLOGENIC BELTS (Oxfordian through Kimmerigian - 163 to 144 Ma) (Figures 9, 10)			
Metallogenic Belts Formed Along Late Mesozoic Continental-Margin Transform Fault in Russian Southest			
Ariadny (AR)	Zoned mafic-ultramafic Ti. (Katenskoe, Ariadnoe, Koksharovskoe)	Transform margin. Zoned mafic-ultramafic plutons intruding Samarka terrane.	Transform-margin-related intrusion of mafic-ultramafic plutons along major continental-margin transform faults that formed after accretion of Samarka subduction zone terrane. Belt may have extended into Early Cretaceous.
Metallogenic Belts Formed in Late Mesozoic Continental Margin and Island Arc Systems in Russian Far East			
North Bureya (NB)	Au-Ag epithermal vein and granitoid-related Au deposits. (Pokrovskoe, Pioneer)	Continental-margin arc. Umlekan-Ogodzhin volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the Umlekan continental-margin arc.
Chersky-Argatass Ranges (CAR)	kuroko massive sulfide. (Khotoidokh)	Island arc. Indigirka-Oloy volcanic-plutonic assemblage.	Subduction-related volcanism associated with Uyandina island arc. Belt extended into Middle Jurassic.
Yasachnaya River (YS)	Pb-Zn skarn, porphyry Cu. (Kunarev, Terrassnoe, Datsytovoe)	Island arc. Uyandin-Yassachny volcanic-plutonic belt.	Subduction-related volcanism associated with Uyandina island arc.
Oloy (OL)	Porphyry Cu-Mo, Au-Ag epithermal vein. (Peschanka, Vesennee)	Island arc. Oloy volcanic belt.	Subduction-related granitic plutonism that formed the Oloy island arc. Belt extended into Early Cretaceous.
Pekulney (PK)	Basaltic Cu. (Skalistaya)	Oceanic crust. Pekul'ney subduction-zone terrane.	Primitive island arc and neighboring sea-floor environment.
Tamvatney-Mainits (TAM)	Podiform Cr. (Krassnaya Gora)	Island arc. Zoned mafic-ultramafic plutons in Mainitskiy terrane.	Subduction-related intrusion of mafic-ultramafic plutons into basal part of Mainitskiy island arc. Mafic-ultramafic rocks hosting deposits form part of structurally-complex ophiolite at base of Mainitskiy island arc terrane. Belt extended into Early Cretaceous
Mainits (MA)	Kuroko massive sulfide. (Ugryumoe)	Island arc. Mainitskiy terrane.	Massive sulfide deposition associated with Mainitskiy island arc. Belt extended into Early Cretaceous.
Svyatoy-Nos (SVN)	Au-Ag epithermal vein. (Polevaya)	Island arc. Svyatoy-Nos volcanic belt.	Subduction-related granitic plutonism that formed the Svyatoy-Nos island arc.
Kuyul (KUY)	Podiform Cr-PGE. (Talov, Tikhorechen)	Island arc. Talovskiy terrane.	Subduction-related intrusion of mafic-ultramafic plutons into basal part of Kony-Murgal island arc.
Metallogenic Belts Formed in Late Mesozoic Koyukuk and Togiak Island Arc Systems in Western and Southwestern Alaska			
Eastern Seward Peninsula and Marshall (ESM)	Podiform Cr; serpentinite-hosted asbestos. (No significant deposits)	Island arc. Thrust slices of mafic-ultramafic rocks, upper Angayucham terrane.	Subduction-related intrusion of mafic-ultramafic plutons into basal part of Koyukuk island arc. Mafic-ultramafic rocks hosting deposits form upper, thrust-slice part of Angayucham subduction zone terrane.
Kobuk (KB)	Podiform Cr; serpentinite-hosted asbestos. (Iyikrok Mountain, Avan, Misheguk Mountain, Siniktanneyak Mountain)	Island arc. Thrust slices of mafic-ultramafic rocks, upper Angayucham terrane.	Subduction-related intrusion of mafic-ultramafic plutons into basal part of Koyukuk island arc. Mafic-ultramafic rocks hosting deposits form upper, thrust-slice part of Angayucham subduction zone terrane.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Southwestern Alaska (SWA)	Zoned mafic-ultramafic PGE. (Kemuk Mountain, Red Mountain)	Island arc. Goodnews terrane.	Subduction-related intrusion of mafic-ultramafic plutons into basal part of Togiak island arc. Mafic-ultramafic rocks hosting deposits occur in tectonically linked Goodnews subduction zone terrane.
Yukon-River (YR)	Podiform Cr. (Caribou Mountain, Lower Kanuti River, Holonada)	Island arc. Thrust slices of mafic-ultramafic rocks, upper Angayucham terrane.	Subduction-related intrusion of mafic-ultramafic plutons into basal part of Koyukuk island arc. Mafic-ultramafic rocks hosting deposits form upper, thrust-slice part of Angayucham subduction zone terrane.
Metallogenic Belts Formed in Late Mesozoic Gravina Island Arc in Southern and Southeastern Alaska, and Canadian Cordillera			
Eastern-Southern Alaska (ESA)	Porphyry Cu, porphyry Cu-Mo. (Pebble Copper, Orange Hill, Bond Creek)	Island arc. Gravina-Nutzotin-Gambier belt, Wrangellia sequence, Wrangellia superterrane.	Subduction-related granitic plutonism that formed the Gravina island arc on the Wrangellia superterrane. Belt continued into Early Cretaceous.
Klukwan-Duke (KL)	Zoned mafic-ultramafic Ti-Cr-PGE. (Union Bay, Klukwan, Haines)	Island arc. Gravina-Nutzotin-Gambier belt, Wrangellia sequence, Wrangellia superterrane.	Subduction-related mafic-ultramafic plutonism associated with basal part of Gravina island arc on the Wrangellia superterrane. Belt continued into Early Cretaceous.
Metallogenic Belts Formed in Late Mesozoic Collision and Overthrusting in Eastern Alaska and Canadian Cordillera			
Fortymile (FM)	Serpentinite-Hosted Asbestos. (Slate Creek, Clinton Creek)	Collisional. Alteration of ultramafic rock, Seventymile terrane.	Regional metamorphism occurring during obduction and overthrusting of oceanic lithosphere of Seventymile terrane onto the North American Craton Margin.
Cassiar (CS)	Serpentine-hosted asbestos. Cassiar (McDame)	Collisional. Alteration of ultramafic rock, Slide Mountain terrane.	Regional metamorphism occurring during obduction and overthrusting of oceanic lithosphere of Slide Mountain onto the North American Craton Margin.
Francois Lake (FL)	Porphyry Mo. (Endako)	Collisional. Francois Lake plutonic suite.	Anatectic granitic plutonism associated with obduction of Stikinia-Quesnellia island arc and associated subduction zone complexes onto the North American Craton Margin.
Cariboo (CB)	Au quartz vein. (Cariboo Gold Quartz, Frasergold)	Collisional. Veins in Downey Creek Formation of Kootenay terrane.	Regional metamorphism occurring during obduction and overthrusting of Kootenay, Stikinia-Quesnellia arc island and associated subduction zone complexes onto the North American Craton Margin. Belt continued into Early Cretaceous.
Rossland (RL)	Au-Ag polymetallic vein. (Rossland, Sheep Creek, Ymir Erie Creek).	Collisional. Veins in Nelson plutonic suite.	Anatectic granitic plutonism associated with obduction of Stikinia-Quesnellia island arc and associated subduction zone complexes onto the North American Craton Margin.
Continuing Metallogenic Belt			
Island Porphyry (IP)			Belt started in Early Jurassic and ceased in early Late Jurassic.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
EARLY CRETACEOUS METALLOGENIC BELTS (Neocomian - 144 to 120 Ma) (Figures 11, 12)			
Metallogenic Belts Formed Along Late Mesozoic Continental-Margin Transform Faults in Russian Southeast			
Samarka (SA)	W skarn, porphyry Cu-Mo. (Vostok-2, Benevskoe, Khvoshchovoe, Kafen, Malakhitovoe)	Transform continental-margin. Samarka accretionary-wedge terrane.	Anatectic granitic plutonism occurring during subduction of Kula oceanic ridge along the transform continental margin of the Russian Southeast. Belt continued into late Early Cretaceous.
Algama (AL)	Stratiform Zr. (Algaminskoe)	Transform-margin. Alkalic igneous rock intruding Stanovoy block of North Asian Craton.	Intrusion of alkali igneous rock associated with mafic-ultramafic plutons that intruded along major continental-margin transform faults during subduction of terranes along Mongol-Okhotsk fault system.
Kondyor (KO)	Zoned mafic-ultramafic Cr-PGE. (Kondyor)	Transform-margin. Zoned mafic-ultramafic intrusions intruding Stanovoy block of North Asian Craton.	Intrusion of mafic-ultramafic plutons along major continental-margin transform faults during subduction of terranes along Mongol-Okhotsk fault system.
Metallogenic Belts Formed During Late Mesozoic Closure of Mongol-Okhotsk Ocean in Russian Southeast			
Selemdzha-Kerbi (SK)	Au quartz vein and granitoid-related Au. (Tokur, Petrovsko-Eleninsky)	Collisional. Veins and plutons intruding Tukuringra-Dzhagi and Galan terranes.	Anatectic granitic plutonism associated with collision Bureya and Khanka continental-margin arc superterranes with the North Asian Craton and closure of the Mongol-Okhotsk Ocean. Belt extended into Late Jurassic.
Stanovoy (ST)	Granitioid-related Au, Au-Ag epithermal vein, Au quartz vein. (Kirovskoe)	Transform-margin. Zoned mafic-ultramafic intrusions intruding Stanovoy block of North Asian Craton..	Anatectic granitic plutonism and regional metamorphism associated with accretion of Bureya superterrane to North Asian Craton and closing of Mongol-Okhotsk Ocean. Belt extended into Early Cretaceous.
Metallogenic Belts Formed During Late Mesozoic Accretion of Kolyma-Omolon Superterrane in Russian Northeast			
Kular (KU)	Au quartz vein, granitoid-related Au, Sn quartz vein. (Burguat, Solur, Novoe)	Collisional. Veins and plutons in Northern part, Verkhoyansk granite belt.	Anatectic granitic plutonism and regional metamorphism associated with accretion of Kolyma-Omolon superterrane to North Asian Craton Margin. Belt continued into late Early Cretaceous (Albian).
Allakh-Yun (AY)	Au quartz vein, granitoid-related Au, W-Sn quartz vein. (Bular, Yur, Nezhdanin, Levo-Dybin)	Collisional. Verkhoyansk granite belt.	Regional metamorphism and anatectic granitic plutonism associated with accretion of Kolyma-Omolon superterrane to North Asian Craton Margin. Belt continued into Early Cretaceous.
Yana-Polousnen (YP)	Granitoid-related Au, Sn quartz vein, & others. (Polyarnoe, Deputatskoe, Kandidatskoe, Chistoe, Ilin-Tas)	Collisional. Plutons and veins in Northern part, Verkhoyansk granite belt.	Anatectic granitic plutonism and regional metamorphism associated with late stage of accretion of Kolyma-Omolon superterrane to North Asian Craton Margin. Belt continued into early Late Cretaceous.
Darpir (DP)	Sn skarn, Sn greisen, granitoid-related Au, porphyry Cu. (Titovskoe, Chepak, Bastion)	Collisional. Main part, Verkhoyansk granite belt.	Anatectic granitic plutonism associated with accretion of Kolyma-Omolon superterrane to North Asian Craton Margin.
Tompon (TO)	Cu, W, Sn skarn, Sn quartz vein. (Khunkhada, Agylki, Erikag)	Collisional. Skarns and veins adjacent to Main part, Verkhoyansk granite belt.	Anatectic granitic plutonism associated with accretion of Kolyma-Omolon superterrane to North Asian Craton Margin.
Shamanikha (SH)	Au quartz vein, Cu-Ag quartz vein. (Glukhariny, Opyt)	Collisional. Veins in Prikolyma terrane.	Regional metamorphism associated with accretion of Kolyma-Omolon superterrane to North Asian Craton Margin.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Verkhoyansk (VK)	Au quartz vein, Au-Sn polymetallic vein. (Nikolaevskoe, Otkyrtoe, Chochimbal, Imtandzha)	Collisional. Skarns and veins adjacent to Main part, Verkhoyansk granite belt.	Regional metamorphism and anatectic granitic plutonism associated with accretion of Kolyma-Omolon superterrane to North Asian Craton Margin. Belt continued into Early Cretaceous.
Yana-Kolyma (YA)	Au quartz vein, Sn vein, granitoid-related Au. (Natalka, Svetloe, Kholodnoe, Zhdannoe, Utin, Alyaskitovoe,)	Collisional. Veins and plutons in or adjacent to Main part, Verkhoyansk granite belt.	Regional metamorphism and anatectic granitic plutonism associated with early stage of accretion of Kolyma-Omolon superterrane to North Asian Craton Margin.
Metallogenic Belts Formed During Late Mesozoic Island Arcs, Russian Northeast, Southeastern Alaska, and Southern Canadian Cordillera			
Left Omolon (LO)	Porphyry Mo-Cu, Mo-Cu skarn. (Bebekan, Medgora)	Island arc. Oloy-Svyatoy Nos volcanic belt.	Subduction-related granitic plutonism that formed the Oloy arc island arc.
Western-Southeastern Alaska (WSE)	Porphyry Mo, Cu-Ag skarn, felsic plutonic U. (Baker Island, Jumba, Magnetite Cliff, Bokan Mountain)	Island arc. Granitic rocks intruding Gravina-Nutzotin-Gambier belt, Wrangellia sequence, Wrangellia superterrane.	Subduction-related granitic plutonism that formed the Gravina arc. Metallogenic belt and host granitic suite formed during final accretion of Wrangellia superterrane.
Britannia	Kuroko massive sulfide (Britannia, Maggie, Northair, Nifty)	Island arc. Gravina-Nutzotin-Gambier belt, Wrangellia sequence, Wrangellia superterrane.	Subduction-related granitic plutonism that formed the Gravina island arc on the Wrangellia superterrane.
Continuing Metallogenic Belts			
Oloy (OL)			Belt started in Late Jurassic.
Mainits (MA)			Belt started in Late Jurassic.
Tamvatney-Mainits (TAM)			Belt started in Late Jurassic.
Cariboo (CB)			Belt started in Middle Jurassic.
LATE EARLY CRETACEOUS METALLOGENIC BELTS (Cenomanian through Albian - 119 to 100 Ma) (Figures 11, 12)			
Metallogenic Belt Formed in Late Mesozoic Continental-Margin Arc, Russian Southeast			
Badzhal-Ezop-Khingan (BZ-KH)	Sn greisen, skarn, and vein. (Solnechnoe, Prvourmiiskoe, Ezop, Khingan)	Continental-margin arc. Khingan-Okhotsk volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the Khingan continental-margin arc. Belt extended into Early Cretaceous.
Metallogenic Belts Formed in Late Mesozoic Collision and Accretion of Island Arcs, and Transform Continetnal-Margin Faulting, Russian Northwest, Western and Northern Alaska, and Northern Canadian Cordillera			
Anadyr River (AD)	Au quartz vein. (Vaegi, Nutekin)	Collison or Extensional. Veins in Mainitskiy, West Pekulney, or Penzhina-Anadyr terranes.	Regional metamorphism and generation of hydrothermal fluids associated with accretion and collision of Mainitskiy island arc onto North Asian Craton margin.
Nome (NO)	Au quartz vein. (Rock Creek, Big Hurrah, Mt. Distan)	Extensional. Veins in Seward terrane.	Regional metamorphism associated with extension that occurred after overthrusting of Angayucham subduction zone terrane.
Southern Brooks Range (SBR) (Includes Chandalar district)	Au quartz vein. (Mikado)	Extensional. Veins in Coldfoot terrane, and in Hammond terrane of Arctic Alaska superterrane.	Regional metamorphism associated with extension that occurred after overthrusting of Angayucham subduction zone terrane.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Fish River (FR)	Sedimentary P and Fe. (Rio Alto, Fish River)	Strike-slip fault. North American Craton Margin	Late Mesozoic, dextral movement along the Kaltag-Porcupine fault system.
Metallogenic Belts Formed in Late Mesozoic Collision and Accretion of Wrangellia Superterrane, and Generation of Omineca-Selwyn Plutonic Belt, Canadian Cordillera			
Selwyn (SW)	W-Cu skarn, Zn-Pb-Ag skarn, Zn-Pb-Ag manto. (Canada tungsten, Macmillan Pass, Sa Dena Hes, Quartz Lake, Prairie Creek)	Collisional. Cassiar plutonic suite, Omineca-Selwyn plutonic belt.	Probable anatectic granitic plutonism (Omineca-Selwyn plutonic belt) associated with final accretion of Wrangellia superterrane to North American continental margin.
Tombstone (TS) (extension of Tintina gold belt in Alaska)	Ag polymetallic vein, Au-Sb vein, W-Sn-Au skarn. (Ken Hill-Galena Hill district, Brewery Creek, Ray Gulch, Eagle)	Collisional Veins and granitic plutons of Omineca-Selwyn plutonic belt.	Regional metamorphism and anatectic granitic plutonism (Omineca-Selwyn plutonic belt) associated with final accretion of Wrangellia superterrane to North American continental margin.
Cassiar (CA)	Porphyry Mo, W skarn, Zn-Pb-Ag manto, Sn skarn, Au skarn. (Logtung, Risby, Midway Manto)	Collisional. Cassiar plutonic suite, Omineca-Selwyn plutonic belt.	Probable anatectic granitic plutonism (Omineca-Selwyn plutonic belt) associated with final accretion of Wrangellia superterrane to North American continental margin.
Whitehorse (WH)	Cu-Fe skarn, porphyry Cu-Au-Ag, Au-Ag polymetallic vein. (Whitehorse Copper Belt, Hopkins, Sekulmun, Mount Nansen)	Collisional. Whitehorse plutonic suite, Omineca-Selwyn plutonic belt.	Probable anatectic granitic plutonism (Omineca-Selwyn plutonic belt) associated with final accretion of Wrangellia superterrane to North American continental margin.
Bayonne (BA)	Porphyry Mo, Cu-Mo skarn. (Boss Mountain, Trout Lake, Red Mountain Moly, Emerald-Invincible, Dodger, and others)	Collisional. Bayonne plutonic suite, Omineca-Selwyn plutonic belt.	Probable anatectic granitic plutonism (Omineca-Selwyn plutonic belt) associated with final accretion of Wrangellia superterrane to North American continental margin.
Continuing Metallogenic Belts			
Samarka (SA)			Metallogenic belt started in Early Cretaceous (Neocomian).
Kular (KU)			Belt started in Early Cretaceous (Neocomian).
Mainits (MA)			Belt started in Late Jurassic.
Tamvatney-Mainits (TAM)			Belt started in Late Jurassic.
EARLY LATE CRETACEOUS METALLOGENIC BELTS (Cenomanian through Santonian - 100 to 84 Ma) (Figures 13, 14)			
Metallogenic Belt Formed in Late Mesozoic Part of East Sikhote-Aline Continental-Margin Arc, Russian Southeast			
Sergeevka (SG)	Granitoid-related Au. (Askold, Progress)	Continental-margin arc. East Sikhote-Aline volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the East Sikhote-Aline continental margin arc.
Taukha (TK)	B skarn, Pb-Zn skarn. (Dalnegorsk, Nikolaevskoe, Partizanskoe, Krasnogorskoe)	Continental-margin arc. East Sikhote-Aline volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the East Sikhote-Aline continental margin arc.
Kema (KM)	Au-Ag epithermal vein, porphyry Cu-Mo. (Glinyanoe, Sukhoi Creek, Tayozhnoe Verkhnezolotoe)	Continental-margin arc. East Sikhote-Aline volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the East Sikhote-Aline continental margin arc.
Luzhkinsky (LZ)	Sn polymetallic vein, Sn silica-sulfide vein, porphyry Sn. (Tigrinoe , Zimnee, Arsenyevskoe, Yantarnoe)	Continental-margin arc. East Sikhote-Aline volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the back arc part of East Sikhote-Aline continental margin arc.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Lower Amur (LA)	Au-Ag epithermal vein, porphyry Cu, Sn Greisen. (Mnogovershinnoe, Belaya Gora)	Continental-margin arc. East Sikhote-Aline volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the East Sikhote-Aline continental margin arc.
Metallogenic Belt Formed in Late Mesozoic Oceanic Crust and Island Arc Terranes, Russian Southeast			
Aniva-Nabil (ANN)	Volcanogenic Mn and Fe (Bereznyakovskoe and Lyukamskoe); Cyprus Cu massive sulfide (Novikovskoe and Rys'e)	Oceanic crust and island arc rocks. Aniva and Nabilskiy terranes.	Formation in oceanic crustal and island arc assemblages that were subsequently tectonically incorporated into the Aniva and Nabilsky terranes accretionary wedge and subduction zone terranes.
Metallogenic Belts Formed in Late Mesozoic and Early Cenozoic Olyutorka Island Arc, Russian Northeast			
Koryak Highlands (KH)	Zoned mafic-ultramafic PGE; Cu massive sulfide. (Snezhnoe)	Island arc. Olyutorka-Kamchatka terrane.	Subduction-related intrusion of mafic-ultramafic plutons into Olyutorka island arc. Belt continued into Late Cretaceous and possibly into early Tertiary.
Vatyn (VT)	Volcanogenic Mn & Fe. (Itchayvayam)	Island arc. Olyutorka-Kamchatka terrane.	Sea floor sedimentation associated with Olyutorka island arc. Belt continued into Late Cretaceous and possibly into early Tertiary.
Metallogenic Belts Formed in Late Mesozoic Part of Okhotsk-Chukotka Continental-Margin Arc, Russian Northeast			
Dogdo-Erikit zone (EADE), Eastern Asia-Arctic Metallogenic Belt	Au-Ag epithermal vein, Sn polymetallic vein, volcanic-hosted Hg. (Kysylga, Solkuchan, Dodgo)	Continental-margin arc. Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the Okhotsk-Chukotka continental-margin arc. Hosted in orthogonal branch of Okhotsk-Chukotka volcanic-plutonic belt. Zone part of Eastern Asia metallogenic belt.
Okhotsk zone (EAOH), Eastern Asia-Arctic Metallogenic Belt	Au-Ag epithermal vein. (Karamken, Julietta, Agat)	Continental-margin arc. Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the back-arc part of Okhotsk-Chukotka continental-margin arc. Belt continued into Late Cretaceous. Zone part of Eastern Asia metallogenic belt.
Koni-Yablon zone (EAKY), Eastern Asia-Arctic Metallogenic Belt	Porphyry Cu-Mo, Cu-Mo skarn. (Nakhtandjin, Osennee, Lora, Etandzha)	Continental-margin arc. Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the Okhotsk-Chukotka continental-margin arc. Axial part Okhotsk-Chukotka volcanic-plutonic belt. Zone part of Eastern Asia metallogenic belt.
Korkodon-Nayakhan zone (EAKN), Eastern Asia-Arctic Metallogenic Belt	Porphyry Mo, granitoid-related Au. (Orlinoe, Khetagchan)	Continental-margin arc. Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related volcanism associated with Okhotsk-Chukotka continental-margin arc. Orthogonal branch of Okhotsk-Chukotka volcanic-plutonic belt. Zone part of Eastern Asia metallogenic belt.
Verkhne-Kolyma zone (EAVK), Eastern Asia-Arctic Metallogenic Belt	Sn-Ag polymetallic vein, Rhyolite-hosted Sn, granitoid-related Au. (Tigrets-Industriya, Kandychan, Butugychag)	Continental-margin arc. Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related volcanism associated with Okhotsk-Chukotka continental-margin arc. Orthogonal branch of Okhotsk-Chukotka volcanic-plutonic belt. Belt continued into Late Cretaceous. Zone part of Eastern Asia metallogenic belt.
Vostochno-Verkhoyansk zone, (EAVV), Eastern Asia-Arctic Metallogenic Belt	Ag polymetallic vein, clastic sediment-hosted Hg. (Mangazeika, Menkeche)	Continental-margin arc. Back arc part of Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related magmatism associated with back-arc part of Okhotsk-Chukotka continental margin arc. Belt continued into Late Cretaceous. Zone part of Eastern Asia metallogenic belt.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Adycha-Taryn (EAAT) zone, Eastern Asia-Arctic Metallogenic Belt	Clastic-sediment-hosted Sb-Au, Au-Ag epithermal vein, Ag-Sb polymetallic vein. (Ak-Altyn)	Continental-margin arc. Transverse extension of Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related magmatism associated with back-arc part of Okhotsk-Chukotka continental margin arc. Belt continued into Late Cretaceous. Zone part of Eastern Asia metallogenic belt.
Omsukchan zone (EAOM), Eastern Asia-Arctic Metallogenic Belt	Au-Ag epithermal vein, Sn polymetallic vein, silicate-sulfide, porphyry Sn, porphyry Cu-Mo, & others. (Nevskoe, Mechta, Dukat).	Continental-margin arc. Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the back-arc part of Okhotsk-Chukotka continental-margin arc. Orthogonal branch of Okhotsk-Chukotka volcanic-plutonic belt. Zone part of Eastern Asia metallogenic belt.
Chokurdak zone (EACD), Eastern Asia-Arctic Metallogenic Belt	Sn polymetallic vein, Sn greisen. (Deputatskoe, Churpuunaya)	Island arc. Svyatoy-Nos volcanic belt.	Subduction-related granitic plutonism that formed the back-arc part of Okhotsk-Chukotka continental-margin arc.
Chaun zone (EACN), Eastern Asia-Arctic Metallogenic Belt	Sn polymetallic vein, Sn greisen, Sn skarn, Sn porphyry, granitoid-related Au. (Valkumei, Chechekuyum, Kanelyveen, Iultin, Svetloe)	Continental-margin arc. Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the Okhotsk-Chukotka continental-margin arc. Correlated with Seward Peninsula metallogenic belt. Belt continued into Late Cretaceous. Zone part of Eastern Asia metallogenic belt.
Metallogenic Belt Formed During Late Mesozoic Collision and Accretion of Chukotka Superterrane, Russian Northeast			
Chukotka (CH)	Au quartz vein, Sn polymetallic vein. (Karalveem, Ozernoe)	Collisional. Veins and granitic plutons in Chukotka terrane.	Regional metamorphism and anatectic granitic plutonism associated with accretion of rifted Chukotka passive continental-margin terrane to Northeast Asia.
Metallogenic Belts Formed in Late Mesozoic Collision and Accretion of Wrangellia Superterrane, Southern Alaska			
East-Central Alaska (older part) (ECA) (includes major part of Tintina gold belt)	Granitoid-related Au, polymetallic vein, porphyry Cu, Sb-Au vein. (Democrat, Fort Knox, Pogo, Kantishna district, Manley-Livengood area)	Collisional Veins and granitic plutons in interior Alaska.	Regional metamorphism and anatectic granitic plutonism mainly in Yukon-Tanana terrane associated with final accretion of Wrangellia superterrane to North American continental margin. Belt started in late Early Cretaceous.
Yukon-Tanana Upland (YT)	Au-quartz vein. (Purdy)	Collisional. Veins in Yukon-Tanana terrane.	Regional metamorphism and anatectic granitic plutonism mainly in Yukon-Tanana terrane associated with final accretion of Wrangellia superterrane to North American continental margin.
Wrangell Mountains (WR)	Cu-Ag quartz vein, Kennecott Cu (Kathleen-Margaret, Kennecott)	Collisional. Veins and replacements in Late Triassic Nikolai Greenstone and Nizina Limestone, Wrangellia sequence, Wrangellia superterrane.	Regional metamorphism and vein emplacement associated with accretion of Wrangellia superterrane to southern Alaska.
Continuing Metallogenic Belts			
Badzhal-Ezop-Khingan (BZ-KH)			Belt started in late-early Cretaceous.
Selwyn (SW)			Belt started in late Early Cretaceous.
Cassiar (CA)			Belt started in late Early Cretaceous.
Whitehorse (WH)			Belt started in late Early Cretaceous.
Bayonne (BA)			Belt started in late Early Cretaceous.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
LATE CRETACEOUS AND EARLY TERTIARY METALLOGENIC BELTS (Campanian through early Eocene - 84 to 52 Ma) (Figures 15, 16)			
Continuing Metallogenic Belts			
Sergeevka (SG)			Belt started in late Early Cretaceous.
Taukha (TK)			Belt started in late Early Cretaceous.
Kema (KM)			Belt started in late Early Cretaceous.
Luzhinsky (LZ)			Belt started in late Early Cretaceous.
Lower Amur (LA)			Belt started in late Early Cretaceous.
Koryak Highlands (KH)			Belt started in early Late Cretaceous and possibly extended into early Tertiary.
Vatyn (VT)			Belt started in early Late Cretaceous.
Okhotsk zone (EAOH), Eastern Asia metallogenic belt			Belt started in early Late Cretaceous.
Adycha-Taryn (EAAT), Eastern Asia metallogenic belt			Belt started in early Late Cretaceous.
Verkhne-Kolyma zone (EAVK), Eastern Asia metallogenic belt			Belt started in early Late Cretaceous.
Korkodon-Nayakhan zone (EAKN), Eastern Asia metallogenic belt			Belt started in early Late Cretaceous.
Omsukchan zone (EAOM), Eastern Asia metallogenic belt			Belt started in early Late Cretaceous.
Chaun zone (EACN)			Belt started in early Late Cretaceous.
Metallogenic Belt Formed in Late Mesozoic and Early Cenozoic Olyutorka Island Arc, Russian Northeast			
Iruneiskiy (IR)	Porphyry Cu (Kirganik)	Island arc. Iruneiskiy terrane	Subduction-related granitic plutonism that formed the Olyutorka-Kamchatka island-arc.
Metallogenic Belts Formed in Late Mesozoic and Early Cenozoic Part of Okhotsk-Chukotka Continental-Margin Arc, Russian Northeast and Western Alaska			
Continuing Metallogenic Belt			
Vostochno-Verkhoyansk (EAVV), Eastern Asia metallogenic belt			Belt started in early Late Cretaceous.
Verkhne-Yudomsky (Yuzhno-Verkhoyansk) zone (EAVY), Eastern Asia-Arctic Metallogenic Belt	Sn & Ag polymetallic vein. (Zarnitsa-Kutinskoe, Khaardak)	Continental-margin arc. Back arc part of Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the back-arc part of Okhotsk-Chukotka continental margin arc. Zone part of Eastern Asia metallogenic belt.
Verkhoyansk-Indigirka (Dulgalak) zone (EAVI), Eastern Asia-Arctic Metallogenic Belt	Clastic sediment-hosted Hg, Sb-Au vein. (Zagadka, Kyuchyus)	Continental-margin arc. Back arc part of Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related magmatism associated with back-arc part of Okhotsk-Chukotka continental margin arc. Zone part of Eastern Asia metallogenic belt.
Anuyi-Beringovsky zone (EAAB), Eastern Asia-Arctic Metallogenic Belt	Au-Ag epithermal vein, disseminated Au sulfide) (Valunistoe, Maiskoe))	Continental-margin arc. Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the Okhotsk-Chukotka continental-margin arc. Zone part of Eastern Asia metallogenic belt.
Chukotka zone (EACH), Eastern Asia-Arctic Metallogenic Belt	Sediment-hosted Hg, hot-spring Hg, volcanic-hosted Hg. (Palyanskoe, Plamennoe)	Continental-margin arc. Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the back-arc part of Okhotsk-Chukotka continental-margin arc. Youngest zone in Eastern Asia metallogenic belt.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Seward Peninsula (SP)	Sn skarn & greisen, Sn granite, porphyry Mo, polymetallic vein, & others. (Lost River, Eagle Creek, Death Valley)	Continental-margin arc. Western Alaska part of Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the back-arc part of Okhotsk-Chukotka continental-margin arc. Eastern extension of Eastern Asia metallogenic belt.
Northwestern Koyukuk Basin (NWK)	Felsic plutonic U. (Wheeler Creek, Clear Creek, Zane Hills)	Continental-margin arc. Western Alaska part of Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the back-arc part of Okhotsk-Chukotka continental-margin arc. Eastern extension of Eastern Asia metallogenic belt.
West-Central Alaska (WCA) (Hogatza)	Porphyry Cu. (Indian Mountain, Purcell Mountain, Zane Hills) Manto-replacement deposit (polymetallic Pn-Zn, Au) (Illinois Creek)	Continental-margin arc. Western Alaska part of Okhotsk-Chukotka volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the Okhotsk-Chukotka continental-margin arc. Eastern extension of Eastern Asia metallogenic belt.
Metallogenic Belts Formed in Late Mesozoic and Early Cenozoic Kluane Continental-Margin Arc, Southern Alaska			
Kuskokwim Mountains (KMT) (Kuskokwim mineral belt)	Sn-Cu-Ag greisen, Hg-Sb-Au epithermal vein, Au-As polymetallic vein, porphyry Mo, porphyry Cu-Au, porphyry Au, granitoid-related Au. (McLeod, Fox Hills, Chicken Mountain, Beaver Mountains, Cirque, Tolstoi,Von Frank Mountain, Donlin Creek, Vinasale, Arnold)	Continental-margin arc. Kuskokwim Mountains sedimentary and volcanic belt.	Subduction-related granitic plutonism that formed the Kluane continental-margin arc.
East-Central Alaska, (younger part) (ECA) (Includes Carmacks belt of porphyry Cu-Mo deposits)	Sn greisen and vein, tourmaline-topaz-quartz-sulfide greisen, felsic plutonic U, W skarn, porphyry Cu-Mo. (Asarco, Casino Ketchem Dome, Lime Peak, Road Metal, Roy Creek, Taurus)	Continental-margin arc. Yukon-Tanana igneous belt.	Subduction-related granitic plutonism that formed the Kluane continental-margin arc.
Southern Alaska (SA)	Porphyry Cu, porphyry Cu-Au, polymetallic vein, Ag-Au skarn, Cu-Au-Ag skarn. (Kijik River, Golden Zone, Nabesna River).	Continental-margin arc. Alaska Range-Talkeetna Mountains igneous belt.	Subduction-related granitic plutonism that formed the Kluane continental-margin arc.
Metallogenic Belts Formed During Early Tertiary Oblique Subduction of Kula-Farallon Oceanic Ridge Under Margin of Southern and Southeastern Alaska			
Maclaren (MC)	Au quartz vein. (Lucky Hill and Timberline Creek)	Extensional. Veins in low-grade part of Maclaren Glacier metamorphic belt.	Oblique subduction of Kula-Farallon oceanic ridge under margin of southern Alaska.
Talkeetna Mountains (TM)	Au quartz vein (Independence)	Extensional. Veins in low-grade part of Talkeetna Formation..	Oblique subduction of Kula-Farallon oceanic ridge under margin of southern Alaska.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Chugach Mountains (CM)	Au quartz vein. (Cliff, Alaska Oracle, Crown Point, & others)	Extensional. Veins in Valdez Group, Chugach terrane.	Oblique subduction of Kula-Farallon oceanic ridge under margin of southern Alaska.
Baranof (BN)	Au quartz vein. (Chichagoff, Hirst-Chichagof, Bauer, Silver Bay, and others)	Extensional. Veins in Valdez Group, Chugach terrane.	Oblique subduction of Kula-Farallon oceanic ridge under margin of southeastern Alaska.
Juneau (JU)	Au quartz vein. (Jualin, Kensington, Alaska-Juneau, Treadwell, Sundum Chief, Gold Standard, & others)	Extensional. Veins in foliated tonalite sill between Wrangellia and Stikinia terranes.	Oblique subduction of Kula-Farallon oceanic ridge under margin of southeastern Alaska.
Metallogenic Belts Formed During Early Tertiary Spreading Along Kula-Farallon Oceanic Ridge, Southern and Southeastern Alaska			
Prince William Sound (PW)	Besshi massive sulfide, Cyprus massive sulfide. (Beatson (Latouche), Copper Bullion (Rua Cove), Ellamar, Fidalgo-Alaska)	Oceanic ridge. Prince William terrane.	Sea-floor spreading along Kula-Farallon oceanic ridge.
Yakobi (YK)	Gabbroic Ni-Cu (Bohemia Basin, Brady Glacier, Mirror Harbour, Mt. Fairweather)	Oceanic ridge. Mafic-ultramafic plutons intruding Chugach terrane.	Intrusion of mafic-ultramafic plutons during oblique subduction of Kula-Farallon oceanic ridge under margin of southeastern Alaska.
Metallogenic Belts Formed in Late Cretaceous and Early Tertiary Coast Continental-Margin Arc, Southeastern Alaska, and Southern Canadian Cordillera			
Surprise Lake (SL)	Porphyry Mo-Cu, Au-Ag polymetallic vein. (Mount Ogden, Red Mountain, Adanac-Adera, Boswell River, & others)	Continental-margin arc. Coast-North Cascade plutonic belt.	Subduction-related granitic plutonism that formed the Coast continental-margin arc.
Central-Southeastern Alaska (CSE)	Porphyry Mo, porphyry Cu. (Margerie Glacier, Nunatak, Groundhog Basin, Quartz Hill)	Continental-margin arc. Coast-North Cascade plutonic belt.	Subduction-related granitic plutonism that formed the Coast continental-margin arc.
Bulkley (BK)	Porphyry Cu-Mo, Au-Ag polymetallic vein. (Huckleberry, Ox Lake, Poplar, Red Rose, Dome Mountain, & others)	Continental-margin arc. Coast-North Cascade plutonic belt.	Subduction-related granitic plutonism that formed the Coast continental-margin arc.
Fish Lake-Bralorne (FLB)	Porphyry Cu-Mo, porphyry Cu-Au, Au quartz vein, Au-Ag polymetallic vein, and related deposit types. (Bralorne, Carolin, Fish Lake, Giant Copper, Pioneer, Poison Mountain)	Continental-margin arc. Coast-North Cascade plutonic belt.	Subduction-related granitic plutonism that formed the Coast continental-margin arc. Related to Tyaughton -Yalakom metallogenic belt of Hg-Au-W-Sb polymetallic vein deposits.
Tyaughton-Yalakom (TY)	W-Sb polymetallic vein and Hg-Sb vein (Tungsten Queen)	Continental-margin arc. Veins intruding Coast-North Cascade plutonic belt and older units.	Subduction-related granitic plutonism that formed the Coast continental-margin arc. Associated with Cretaceous to Eocene dikes intruded along Eocene dextral-slip faults of the Talakom, Relay Creek, and Fortress Ridge faults. Related to Fish Lake-Bralorne metallogenic belt of granitic-magmatism-related deposits.
Gambier (GB)	Porphyry Cu-Mo, Zn-Pb-Cu skarn. (O.K., Gambier Island, HI-MARS)	Continental-margin arc. Coast-North Cascade plutonic belt.	Subduction-related granitic plutonism that formed the Coast continental-margin arc.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
Catface (CF)	Porphyry Cu-Mo-Au, Au-Ag polymetallic vein. (Catface, Domineer, Privateer)	Continental-margin arc. Granitic plutons intruding southern Wrangellia terrane.	Subduction-related granitic plutonism that formed the Coast continental margin arc.
Metallogenic Belts Formed in Backarc Part of Early Tertiary Coast Continental-Margin Arc, Southern Canadian Cordillera			
Skeena (SK)	Porphyry Cu-Mo, porphyry Mo, Ag polymetallic vein, Au-Ag polymetallic vein. (Berg, Lucky Ship, Nanika, Red Bird, Kitsault, Equity Silver, & others)	Continental-margin arc. Coast-North Cascade plutonic belt and Kamloops magmatic belt.	Granitic plutonism occurring during back arc extension or transtension occurring continentward of subduction-related Coast continental-margin arc. Related to Nelson metallogenic belt.
Nelson (NS)	Ag polymetallic vein, Ag-Pb-Zn manto, Au-Ag epithermal vein. (Bluebell, Highland Bell, Vault, Dusty Mac)	Continental-margin arc. Eocene plutonic rocks intruding Quesnellia terrane.	Granitic plutonism occurring during back arc extension or transtension occurring continentward of subduction-related Coast continental-margin arc. Related to Skeena metallogenic belt.
EARLY TO MIDDLE TERTIARY (Middle Eocene through early Miocene - 52 to 23 Ma) (Figures 17, 18)			
Metallogenic Belts Formed in Tertiary Collision of Outboard Terranes, Russian Southeast			
Central Sakhalin (CS)	Au quartz vein and talc (Langeriiskoe)	Collisional. Aniva subduction zone terrane.	Collisional event during the early Tertiary(?) accretion of outboard terranes to the east.
Sredinny (SR)	Au quartz vein. (Tumannoe) Metamorphic REE vein(?). (Anomalnoe)	Collisional. Veins in Sredinny-Kamchatka terrane.	Accretion of outboard Olyutorka arc and generation of hydrothermal fluids.
Metallogenic Belts Formed in Tertiary Backarc Rifting and Continental-Margin Transform, and Transcurrent Faulting, Russian Southeast			
Kvinumsky (KV)	Hornblende peridotite Cu-Ni, gabbroic Ni-Cu. (Shanuch, Kvinum, and Kuvalorog)	Backarc. Mafic igneous intruding Sredinny-Kamchatka metamorphic terrane.	Backarc intrusion related to subduction beneath the Kamchatka Peninsula part of Central Kamchatka continental margin arc.
Central Koryak (CKY)	Sn polymetallic vein, Au-Ag epithermal vein, Hb-Sb vein, porphyry Mo-Cu. (Ainatvetkin, Ametistovoe, Lyapgani, Tamvatney, Kuibiveen)	Continental-margin arc. Kamchatkak-Koryak volcanic-plutonic belt.	Granitic plutonism associated with transform faulting along the margin of the North Asian continent.
Metallogenic Belts Formed in Tertiary Continental-Margin Arcs, Kamchatka Peninsula, and Southern Canadian Cordillera			
Olyutor (OT)	Au-Ag epithermal vein, Sn polymetallic vein, clastic sediment-hosted Hg. (Lalankytap, Maleotoivayam)	Continental-margin arc. East Kamchatka volcanic & sedimentary basin.	Subduction-related granitic plutonism that formed the Kamchatka Peninsula part of Northeast Asia continental margin arc.
Pinchi Lake (PC)	Hg epithermal vein, Sb-Au vein, silica-carbonate Hg (Pinchi Lake)	Continental-margin arc(?). Shear zone.	Transcurrent faulting along Cascade volcanic-plutonic belt.
Owl Creek (OC)	Porphyry Cu-Mo, porphyry Mo, Au polymetallic vein. (Harrison Lake, Boundary, Red Mountain, Lone Jack, Clear Creek, Owl Creek, & others)	Continental-margin arc. Cascade volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the early part of Cascade continental margin arc. Belt extended into Miocene and Pliocene.

Metallogenic Belt (Abbreviation)	Major Mineral Deposits Types. (Significant Mineral Deposits)	Environment. Host Unit.	Tectonic Event. Comments
MIDDLE TERTIARY METALLOGENIC BELTS (Miocene - 20 to 10 Ma) (Figures 17, 18)			
Metallogenic Belts Formed in Tertiary Continental-Margin Arcs, Kamchatka Peninsula, Southern Alaska, and Southern Canadian Cordillera			
East Kamchatka (EK)	Au-Ag epithermal vein. (Asachinskoe, Mutnovskoe, Rodnikovoe)	Continental-margin arc. Central Kamchatka volcanic & sedimentary basin.	Subduction-related granitic plutonism that formed the Kamchatka Peninsula part of Northeast Asia continental margin arc.
Central Kamchatka (CK)	Au-Ag epithermal vein, porphyry Cu-Mo. (Ozernovskoe, Aginskoe, Kirganik)	Continental-margin arc. Central Kamchatka volcanic & sedimentary basin.	Subduction-related granitic plutonism that formed the Kamchatka Peninsula part of Northeast Asia continental margin arc.
Alaska Peninsula & Aleutian Islands (AP)	Au-Ag epithermal vein, porphyry Cu & Cu-Mo, polymetallic vein. (Pyramid, Bee Creek, Apollo-Sitka)	Continental-margin arc. Aleutian volcanic belt.	Subduction-related granitic plutonism that formed the Aleutian continental margin arc. Belt extended into Pliocene and Quaternary.
Continuing Metallogenic Belts			
Olyutor (OT)			Belt started in late Paleogene or Miocene.
Owl Creek (OC)			Belt started in Eocene and extended into Pliocene.
LATE TERTIARY and QUATERNARY METALLOGENIC BELTS (Pliocene through Present - 4 to 0 Ma) (Figures 17, 18)			
Metallogenic Belts Formed in Late Tertiary and QuaternaryContinental-Margin Arcs, Kamchatka Peninsula, Southern Alaska, and Southern Canadian Cordillera			
Sakhalin Island (SH)	Silica-carbonate, volcanic-hosted Hg deposits. (In' River, Inskoe Ostrinskoe, Svetlovskoe , Yasnoe)	Rear of a continental-margin arc? Shear zones.	Backarc spreading behind Kuril arc?
Kuril (KU)	Au-Ag epithermal vein, polymetallic vein, Sn vein, sulfur-sulfide, & others. (Novoe, Prasolovskoe, Koshkina, Valentinovskoe)	Continental-margin arc. Kuril volcanic-plutonic belt.	Subduction-related granitic plutonism that formed the Kuril Island part of Northeast Asia continental margin arc.
Continuing Metallogenic Belts			
Alaska Peninsula & Aleutian Islands (AP)			Belt started in Miocene.
Owl Creek (OC)			Belt started in Eocene.

TABLE 4. Significant lode deposits, locations, and major metals for major Proterozoic and Phanerozoic metallogenic belts in the Russian Far East, Alaska, and the Canadian Cordillera. Refer to Figures 2-18 for location of metallogenic belts. For each time interval (time-stage), metallogenic belts are listed in a clockwise order, according to similar tectonic environments, starting with the area of the Russian Southeast and ending with the area of the southern Canadian Cordillera. Attributes of lode deposits and characteristics of metallogenic belts are defined and adapted from Nokleberg and others (1997a, b, 1998b) and as modified herein. Abbreviations given for metallogenic belts as depicted on generalized maps of metallogenic belts and host rocks (Figures 2-18) and on metallogenic-tectonic model for Devonian through Present (Figures 19-32). For each metallogenic belt, mineral deposits listed in alphabetical order. Most major mineral deposits for the Yukon Territory (northwest Canadian Cordillera) have deposit numbers from the MINFILE of the Yukon Geological Survey (Dekelerk, 2002) listed in parens after the deposit name. These deposits descriptions can be accessed from the Yukon Geological Survey MINFILE Web site at: http://www.geology.gov.yk.ca/minfile/. Most major mineral deposits for British Columbia (southwest Canadian Cordillera) have deposit numbers from MINFILE (2002) listed in parens after the deposit name. These deposit descriptions can be accessed from the MINFILE Web site at www.em.gov.bc.ca/mining/geolsurv/minfile/.

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
PROTEROZOIC (2500 TO 570 Ma)			
Oroek Metallogenic Belt of Ironstone and Sediment-Hosted Cu Deposits (Middle and Late Proterozoic) West-Central Part of Russian Northeast (Belt OK)			
Oroek	Sediment-hosted Cu	Cu	64°54'N 152°48'E
Pobeda	Ironstone	Fe	65°43'N 152°12'E
Lantarsky-Dzhugdzhur Belt of Anorthosite Apatite-Ti-Fe and Gabbroic Ni-Cu (PGE) Deposits (Mesoproterozoic), Southern Part of Russian Northeast (Belt LD)			
Bogidenskoe	Anorthosite apatite Ti-Fe	Ti, P	55°38'N 133°42'E
Dzhaninskoe	Anorthosite apatite Ti-Fe	Ti, P	55°31'N 134°09'E
Gayumskoe	Anorthosite apatite Ti-Fe	Ti, P	55°43'N 134°15'E
Maimakanskoe	Anorthosite apatite Ti-Fe	Ti, P	55°37'N 134°30'E
Avlandzhinsky, Kontaktovy, Nyandomi, Odorin, Ozerny.	Gabbroic Ni-Cu Cu-Ni-Co-PGE	Cu, Ni, PGE	58°08'N 137°55'E
Ulkan Metallogenic Belt of Felsic Plutonic REE Deposits (Mesoproterozoic), Southeastern Part of Russian Northeast (Belt UL)			
Ulkanskoe	Felsic plutonic REE	REE, Be, Zr	56°19'N 134°49'E
Bilyakchan Metallogenic Belt of Sediment-hosted Cu and basalt Cu Deposits (Mesoproterozoic and Neoproterozoic), Southeastern Part of Russian Northeast (Belt BI)			
Dzhagdag	Basaltic Cu	Cu	57°22'N 137°13'E
Omolon Metallogenic Belt of Ironstone (Superior Fe) Deposits (Archean to Early Proterozoic) Central Part of Russian Northeast (Belt OM)			
Verkhny-Omolon	Ironstone	Fe	63°21'N 158°22'E
Kilbuck Metallogenic Belt of Ironstone (Superior Fe) Deposits (Early Proterozoic), Southwestern Alaska (Belt KI)			
Canyon Creek	Ironstone	Fe	59°38'N 161°08'W
Sinuk River Metallogenic Belt of Stratiform Massive Sulfide-Barite and Stratabound Fe and Mn Deposits (Late Proterozoic or older), Western Alaska (Belt SR)			
Aurora Creek	Kuroko massive sulfide?	Zn, Pb, Cu, Ba, Ag, Au	64°46'N 164°58'W
American, Bear, Cub, Monarch	Stratabound Fe-Mn	Fe, Mn, F	64°48'N 165°24'W
Gillespie Metallogenic Belt of SEDEX Pb-Zn Deposits (Early Proterozoic), Yukon Territory (Belt GE)			
Blende	Sedimentary exhalative Pb-Zn	Zn, Cu, Pb, Au, Ag	64°25'N 134°30'W
Hart River	Sedimentary exhalative Zn-Cu-Pb	Zn, Cu, Ag	64°39'N 136°51'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Wernecke Metallogenic Belt of U-Cu-Fe (Au-Co) Vein And Breccia Deposits (Early Proterozoic), Yukon Territory (Belt WR)			
Dolores	U-Cu-Fe (Au-Co) vein and breccia	Cu, Co, Au	64 54'N 133 31'W
Igor	U-Cu-Fe (Au-Co) vein and breccia	Cu, Au, U, Co	65 03'N 134 38'W
Irene	U-Cu-Fe (Au-Co) vein and breccia	Cu, U	65 05'N 134 15'W
Pagisteel	U-Cu-Fe (Au-Co) vein and breccia	Fe, Cu	64 50'N 134 18'W
Porphyry	U-Cu-Fe (Au-Co) vein and breccia	Cu, Au, U, Co	64 55'N 133 15'W
Slab	U-Cu-Fe (Au-Co) vein and breccia	Cu, Au, U, Co	65 00'N 134 02'W
Rapitan Metallogenic Belt of Sedimentary Iron Formation Deposits (Neoproterozoic), Central Yukon Territory (Belt RA)			
Crest Iron	Ironstone	Fe	65 15'N 133 00'W
Redstone Metallogenic Belt of Sediment-Hosted Cu-Ag Deposits (Neoproterozoic), Central Yukon Territory (Belt RS)			
Coates Lake (Redstone)	Sediment-hosted Cu	Cu, Ag	62 42'N 126 38'W
June Creek (Baldwin, Shell)	Sediment-hosted Cu	Cu, Ag	63 49'N 127 46'W
Churchill Metallogenic Belt of Cu vein Deposits Deposits (Mesoproterozoic), Central Yukon Territory (Belt CH)			
Churchill (Davis Keays)	Cu vein	Cu	58 23'N 125 11'W
Monashee Metallogenic Belt of SEDEX Zn-Pb-Ag Deposits (Neoproterozoic), Southern British Columbia (Belt MO)			
Big Ledge (Pingston Creek) (082LSE 012)	SEDEX Zn-Pb	Zn, Pb	50 29'N 118 03'W
Cottonbelt	SEDEX Pb-Zn	Pb, Zn, Ag	51 27'N 118 49'W
Mount Copeland (082M 022)	Porphyry Mo	Mo	51 08'N 118 28'W
River Jordan (King Fissure)	SEDEX Zn-Pb	Pb, Zn, Ag	51 08'N 118 25'W
Ruddock Creek (082M 084)	SEDEX Zn-Pb	Zn, Pb, Ag	51 47'N 118 57'W
Purcell Metallogenic Belt of SEDEX Zn-Pb-Ag Deposits (Middle Proterozoic), Southern British Columbia (Belt PR)			
Moyie (St. Eugene) (082GSW 025)	Ag polymetallic vein	Pb, Ag	49 17'N 115 50'W
Sullivan (Kimberley) (082GSW 049-51)	SEDEX Pb-Zn	Pb, Zn, Ag	49 43'N 116 00'W
Vine	Ag-Au polymetallic vein	Pb, Zn, Ag, Au	49 24'N 115 49'W
Clark Range Metallogenic Belt of Sediment-Hosted Cu-Ag Deposits (Mesoproterozoic) Southern British Columbia (Belt CR) (Various occurrences; no significant deposits)			
CAMBRIAN THROUGH SILURIAN (570 to 408 Ma)			
Voznesenka Metallogenic Belt of Korean Pb-Zn Deposits (Cambrian), Southern Part of Russian Southeast (Belt VZ)			
Chernyshevskoe	Korean Zn massive sulfide	Zn, Pb	44 24'N 133 17'E
Voznesenka-I	Korean Zn massive sulfide	Zn	44 18'N 132 08'E
Kabarga Metallogenic Belt of Ironstone (Superior Fe) Deposits (Early Cambrian), Southern Russian Southeast (Belt KB)			
Ussuri deposits	Ironstone	Fe	45 18'N 133 38'E
South Khingan Metallogenic Belt of Ironstone (Superior Fe) Deposits (Late Proterozoic and Early Paleozoic), Southern part of Russian Southeast (Belt SK)			
South-Khingan	Ironstone	Fe	48 39'N 131 53'E
Gar Metallogenic Belts of Volcanogenic Fe Deposits and Stratiform Cu and Pb-Zn Deposits (Late Proterozoic) Western Part of Russian Southeast (Belt GA)			
Chagoyan	Stratiform Pb-Zn	Pb, Zn, Ag	52 19'N 128 22'E
Gar	Volcanogenic Fe	Fe	52 34'N 129 04'E
Kamenushinskoe	Cu massive sulfide	Cu, FeS	52 43'N 129 07'E
Galam Metallogenic Belt of Volcanogenic Fe, Volcanogenic Mn, and Sedimentary P Deposits (Cambrian) Northern Part of Russian Southeast (Belt GL)			
Galamskoe	Volcanogenic Fe	Fe	53 37'N 133 56'E
Gerbikanskoe	Volcanogenic Fe	Fe	53 29'N 133 12'E
Ir-Nimiiskoe-1	Volcanogenic Mn	Mn	54 09'N 134 36'E
Ir-Nimiiskoe-2	Sedimentary phosphorite	P	54 08'N 134 38'E
Itmatinskoe	Volcanogenic Fe	Fe	53 21'N 133 24'E
Kurumskoe	Volcanogenic Fe	Fe	53 23'N 132 53'E
Lagapskoe	Sedimentary phosphorite	P	53 54'N 134 16'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Milkanskoe	Volcanogenic Fe	Fe	54°04'N 134°08'E
Nelkanskoe	Sedimentary phosphorite	P	54°18'N 134°59'E
North-Shantarskoe	Sedimentary phosphorite	P	55°09'N 137°35'E
Omulevka River Metallogenic Belt of Austrian Alps W and Kipushi Cu-Pb-Zn Deposits (Middle Ordovician) West-Central Part of Russian Northeast (Belt OR)			
Omulev	Austrian Alps W	W	64°13'N 148°23'E
Vesnovka	Kipushi Cu-Pb-Zn	Cu, Pb, Zn, Ge	64°32'N 149°23'E
Rassokha Metallogenic Belt of Basaltic Cu and Sediment-Hosted Cu Deposits (Ordovician), Western Part of Russian Northeast (Belt RA)			
Agyndja	Basaltic Cu and sediment-hosted Cu	Cu	65°13'N 148°02'E
Dzhardzhan River Metallogenic Belt of Southeast Missouri Pb-Zn, Sediment-Hosted Cu and Sandstone-Hosted U deposits (Late Proterozoic through late Paleozoic), Northern Part of Eastern Siberia (Belt DZR)			
Aga-Kukan	Southeast Missouri Pb-Zn and sediment-hosted Cu	Pb, Zn, Cu	69°04'N 126°46'E
Kyongdei	Sediment-hosted U	U	71°27'N 127°20'E
Manganiler	Southeast Missouri Pb-Zn	Pb, Zn	71°40'N 127°18'E
Anvil Metallogenic Belt of SEDEX Zn-Pb-Ag Deposits (Cambrian to Silurian), Southern Yukon Territory (Belt AN)			
Faro (Anvil)	SEDEX Pb-Zn	Zn, Pb, Ag	62°22'N 133°22'W
Swim (Sea, SB)	SEDEX Pb-Zn	Zn, Pb, Ag	62°13'N 133°02'W
Vangorda Creek (Grum, Firth, DY)	SEDEX Pb-Zn	Zn, Pb, Ag	62°14'N 133°02'W
Howards Pass Metallogenic Belt of SEDEX Zn-Pb Deposits (Silurian), Southern Yukon Territory (Belt HP)			
Anniv	SEDEX Pb-Zn	Zn, Pb	62°34'N 129°31'W
Howards Pass	SEDEX Pb-Zn	Zn, Pb	62°28'N 129°10'W
Kootenay Metallogenic Belt of Carbonate or Sediment-Hosted Deposits (Cambrian), Southern British Columbia (Belt KO)			
Duncan Lake Area (082KSE 023)	SEDEX Zn-Pb	Pb, Zn	50°22'N 116°57'W
H.B. (Zincton)	SEDEX Pb-Zn	Zn, Pb, Ag	49°09'N 117°12'W
Jersey	SEDEX Pb-Zn(?)	Zn, Pb, Ag	49°06'N 117°13'W
Mastadon (J&L) (082M 005)	SEDEX Pb-Zn(?)	Zn, Pb, Au, Ag	51°15'N 118°07'W
Reeves-MacDonald (Reemac)	Southeast Missouri Pb-Zn	Zn, Pb, Ag	49°02'N 117°21'W
Prince of Wales Island Metallogenic Belt of Continental-Margin Arc-Related Deposits (Ordovician and Silurian) Southeastern Alaska (Belt PW)			
Dawson	Polymetallic vein	Au	55°28'N 132°42'W
Kasaan Peninsula (Mount Andrew)	Cu-Fe skarn	Cu, Fe	55°31'N 132°18'W
McLean Arm district	Porphyry Co-Mo	Co, Mo	53°49'N 132°01'W
Salt Chuck	Zoned mafic-ultramaficCu-Au-PGE	Cu, Pd, Pt, Au	55°38'N 132°34'W
MIDDLE AND LATE DEVONIAN (387 to 360 Ma)			
Yaroslavka Metallogenic Belt of Fluorite and Sn Greisen Deposits (Late Cambrian) Southern Part of Russian Southeast (Belt YA)			
Voznesenka-II	Fluorite greisen	Fluorite	44°11'N 132°08'E
Yaroslavskoe	Sn greisen	Sn	44°16'N 132°13'E
Kedon Metallogenic Belt of Au-Ag Epithermal Vein, Porphyry Mo, Fe Skarn, and Associated Deposits (Middle Paleozoic) Central Part of Russian Northeast (Belt KE)			
Grisha	Au-Ag epithermal vein	Au, Ag	63°48'N 159°28'E
Kubaka	Au-Ag epithermal vein	Au, Ag	63°44'N 160°01'E
Obyknovennoe	Au-Ag epithermal vein	Au, Ag	64°52'N 158°39'E
Olcha	Au-Ag epithermal vein	Au, Ag	64°57'N 156°26'E
Tumannaya	Au-Ag epithermal vein	Au, Ag	64°16'N 160°02'E
Vechernee	Porphyry Mo-Cu	Mo, Cu	63°29'N 158°50'E
Yolochka	Au-Ag epithermal vein	Au, Ag	63°33'N 159°38'E
Zet	Au-Ag epithermal vein	Au, Ag	65°18'N 156°57'E
Eastern Seward Peninsula (Kiwalik Mountain)Belt of Kuroko Massive Sulfide Deposits (Middle Paleozoic) Northern Alaska (Belt ES) (No significant deposits)			

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.	
Arctic Metallogenic Belt of Kuroko and Kipushi Massive Sulfide Deposits (Devonian and Mississippian) Northern Alaska (Belt AT)				
Arctic	Kuroko massive sulfide	Zn, Cu, Pb, Ag, Au	67°11'N	156°22'W
BT, Jerri Creek	Kuroko massive sulfide	Cu, Zn, Pb, Ag	67°08'N	155°52'W
Michigan Creek	Kuroko massive sulfide	As, Au, Ag, Cu, Zn, Pb	67°19'N	151°14'W
Roosevelt Creek	Kuroko massive sulfide	Cu, Zn, Pb, Ag, Au	67°10'N	152°30'W
Ruby Creek, (Bornite)	Kipushi Cu-Pb-Zn	Cu, Co, Zn, Ag	67°04'N	156°59'W
Smucker	Kuroko massive sulfide	Cu, Zn, Pb, Ag	67°18'N	157°12'W
Sun, (Picnic Creek)	Kuroko massive sulfide	Cu, Zn, Pb, Ag, Au	67°04'N	155°01'W
Brooks Range Metallogenic Belt of Granitic Magmatism Deposits (Devonian), Northern Alaska (Belt BR)				
Ann (Ernie Lake)	Polymetallic vein (metamorphosed)	Pb, Zn, Ag	67°25'N	152°50'W
Bear Mountain	Porphyry Mo	Mo, W	68°23'N	142°11'W
Esotuk Glacier	Pb-Zn skarn and fluorite vein	Pb, Zn, Sn, Cu, W	69°18'N	145°15'W
Galena Creek	Polymetallic vein	Cu, Zn, Pb, Ag	68°23'N	142°02'W
Geroe Creek	Porphyry Cu-Mo	Cu, Mo	67°41'N	148°49'W
Jim-Montana	Cu-Zn skarn	Cu, Zn, Ag, Pb	67°45'N	149°05'W
Mount Igikpak and Arrigetch Peaks	Polymetallic vein, Au quartz vein, Sn skarn, Cu-Pb-Zn skarn	Cu, Pb, Zn, Ag, Au, Sn, W, As	67°26'N	154°07'W
Porcupine Lake	Polymetallic vein(?)	Cu, Zn, Ag, F	68°48'N	146°27'W
Romanzof Mountains	Polymetallic vein, Pb-Zn and possibly Sn skarn	Pb, Cu, Zn, Mo, Sn, Ag, F	69°18'N	143°50'W
Sukakpak Mountain	Sb-Au vein	Au, Sb, Mo	67°36'N	149°50'W
Victor, Venus, Evelyn Lee, and Ebo	Porphyry Cu and Cu skarn	Cu, Ag, Mo	67°38'N	149°20'W
Alaska Range and Yukon-Tanana Upland Metallogenic Belt of Kuroko Massive Sulfide Deposits (Devonian and Mississippian), Central and East-Central Alaska (Belt AKY)				
Anderson Mountain	Kuroko massive sulfide?	Cu, Pb, Zn, Ag	63°48'N	147°57'W
Delta District	Kuroko massive sulfide	Pb, Zn, Cu, Ag, Au	63°14'N	144°10'W
Liberty Bell	Kuroko massive sulfide(?) or polymetallic gold vein	Au, Ag, Cu, Bi	64°37'N	148°51'W
McGinnis Glacier	Kuroko massive sulfide	Zn, Cu, Pb, Ag	63°36'N	146°14'W
Miyaoka, Hayes Glacier	Kuroko massive sulfide	Cu, Pb, Zn, Au, Ag	63°41'N	146°39'W
Sheep Creek	Kuroko massive sulfide?	Zn, Pb, Ag, Sn	63°54'N	148°17'W
WTF, Red Mountain	Kuroko massive sulfide	Cu, Pb, Zn, Ag, Au	63°45'N	147°22'W
Dawson Metallogenic Belt of Volcanogenic Pb-Zn-Cu Massive Sulfide, SEDEX Pb-Cu-Zn-Ba Deposits (Devonian and Mississippian), Central Yukon Territory (Belt DA)				
Lucky Joe	Besshi massive sulfide	Cu, Zn, Pb	63°35'N	139°31'W
Mickey	SEDEX Zn-Pb	Pyrite, Pb, Zn, Ba	64°19'N	140°29'W
Lone Star	Kuroko massive sulfide	Pb, Zn, Cu (Au, Ba)	63°53'N	139°13'W
Frances Lake Metallogenic Belt of Volcanogenic Zn-Cu-Pb Massive Sulfide Deposits (Devonian and Mississippian), Southern Yukon Territory (Belt FR)				
Kuda Ze Kayah (105G 117)	Kuroko massive sulfide	Zn, Cu, Pb, Ag, Au	61°28'N	130°35'W
Wolverine-Lynx (105G 072)	Kuroko massive sulfide	Zn, Cu, Pb, Ag, Au	61°25'N	130°07'W
Tracy Metallogenic Belt of Kuroko Massive Sulfide Deposits (Devonian and Mississippian) Southeastern Alaska (Belt TR)				
Alamo	Kuroko massive sulfide(?)	Ag, Au, Cu, Zn	55°45'N	130°45'W
Ecstall (103H 011)	Kuroko Zn-Pb-Cu massive sulfide	Zn, Cu, Au, Pb, Ag, Fe	53°52'N	129°31'W
Red River	Kuroko massive sulfide	Cu, Mo	55°04'N	130°31'W
Sumdum	Kuroko massive sulfide(?)	Ag, Cu, Zn	57°47'N	133°28'W
Sweetheart Ridge	Kuroko massive sulfide	Ag, Au, Cu, Pb, Zn	57°55'N	133°37'W
Mount Sicker Metallogenic Belt of Kuroko Volcanogenic Massive Sulfide Zn-Cu-Pb-Au-Ag Deposits (Devonian), Vancouver Island (Belt MS)				
Mount Sicker (Lenora-Tyee (092b 001), Twin J, Lara (092B 129), Copper Canyon) (	Kuroko massive sulfide	Cu, Zn, Ag	48°52'N	123°47'W
Myra Falls (Lynx, Myra, Price,	Kuroko massive sulfide	Zn, Cu, Ag, Au	49°34'N	125°36'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
HW) (092F 330)			
Kootenay-Shuswap Metallogenic Belt of Volcanogenic Zn-Pb-Cu-Ag-Au Massive Sulfide Deposits (Devonian and Mississippian), Southern British Columbia (Belt KS)			
Chu Chua (082P 140)	Cyprus massive sulfide	Cu, Zn, Au, Ag	51°23'N 120°04'W
Goldstream (Pat) (082M 141)	Besshi massive sulfice	Cu, Zn, Ag	51°38'N 118°26'W
Harper Creek (082M 009)	kuroko massive sulfide	Cu, Ag, Au	51°31'N 119°49'W
Homestake (Squaam Bay) (082M 025)	kuroko Zn-Pb-Cu massive sulfide	Ag, Pb, Zn, Au, Cu, Ba	51°07'N 119°50'W
Rea (Hilton)	kuroko Zn-Pb-Cu massive sulfide	Ag, Pb, Zn, Au, Cu	51°09'N 119°49'W
Rexspar (Birch Island)	Felsic plutonic U-REE	U, F, Sr, REE, Th	51°34'N 119°54'W
Khamna River Metallogenic Belt of Carbonatite-Related Nb, Ta, and REE Deposits (Devonian), Southern Part of Eastern Siberia (Belt KR)			
Gornoe Ozero	Carbonatite-related REE	REE, Ta, Nb	59°56'N 137°00'E
Khamna	Carbonatite-related REE	REE, Nb	59°43'N 136°25'E
Sette-Daban Range Metallogenic Belt of Southeast Missouri Pb-Zn, Sediment-Hosted Cu, and Basaltic Cu Deposits (Late Proterozoic), Southern Part of Eastern Siberia (Belt SD)			
Dzhalkan	Basaltic Cu	Cu	63°38'N 136°38'E
Kurpandja	Sediment-hosted Cu	Cu	63°31'N 137°01'E
Lugun	Southeast Missouri Pb-Zn	Pb, Zn	59°08'N 136°39'E
Sakyryr	Southeast Missouri Pb-Zn	Zn, CaF_2	62°43'N 138°22'E
Sardana	Southeast Missouri Pb-Zn	Pb, Zn	60°06'N 136°45'E
Segenyakh	Southeast Missouri Pb-Zn	Pb, Zn, CaF_2	63°10'N 137°51'E
Urui	Southeast Missouri Pb-Zn	Pb, Zn	59°52'N 136°47'E
Selennyakh River Metallogenic Belt of Southeast Missouri Pb-Zn, Stratabound Hg and Au, and Pb-Zn Vein Deposits (Devonian to Permian), Northwestern Part of Russian Northeast (Belt SEL)			
Chistoe	Pb-Zn vein	Pb, Zn	68°12'N 141°26'E
Gal-Khaya	Carbonate-hosted Hg	Hg	68°53'N 140°18'
Khatynnakh-Sala	Au quartz vein	Au	68°18'N 141°24'E
Kondakovskoe	Southeast Missouri Pb-Zn	Pb, Zn	69°19'N 149°49'E
Tommot River Metallogenic Belt of Carbonatite-Related Nb, Ta, and REE Deposits (Devonian to Mississippian) Northwestern Part of Russian Northeast (Belt TO)			
Tommot	Carbonatite-related REE (Ta, Nb)	REE, Ta, Nb	68°24'N 141°14'E
Urultun and Sudar Rivers Metallogenic Belt of Southeast Missouri Pb-Zn, Carbonate-Hosted Hg, Basaltic Cu and Volcanogenic Mn Deposits (Devonian and Carboniferous), West-Central Part of Russian Northeast (Belt URS)			
Batko	Basaltic Cu	Cu	63°25'N 149°42'E
Lyglykhtakh	Sedimentary Mn	Mn	62°59'N 151°20'E
Prizovoe	Bedded barite	Ba	63°29'N 149°34'E
Prolivnoe	Southeast Missouri Pb-Zn	Pb, Zn	63°30'N 149°18'E
Uochat	Carbonate-hosted Hg	Hg	63°45'N 148°45'E
Urultun	Southeast Missouri Pb-Zn	Pb, Zn	63°40'N 148°42'E
Yarkhodon Metallogenic Belt of Southeast Missouri Pb-Zn Deposits (Late Devonian to Mississippian) Central Part of Russian Northeast (Belt YR)			
Slezovka	Southeast Missouri Pb-Zn	Pb, Zn	66°51'N 153°54'E
Gornoe	Southeast Missouri Pb-Zn	Pb, Zn	66°36'N 154°19'E
Berezovka River Metallogenic Belt of Kuroko Massive Sulfide and Sulfide Vein Deposits (Late Devonian to Mississippian), Central Part of Russian Northeast (Belt BE)			
Berezovskoe	Kuroko massive sulfide and sulfide vein	Pb, Zn, Cu, Ag	66°43'N 157°21'E
Mystic Metallogenic Belt of SEDEX Massive Bedded Barite and Southeast Missouri Pb-Zn Deposits (Devonian and Mississippian), West-Central Alaska (Belt MY)			
Gagaryah	SEDEX massive bedded barite	Cu, Ba	61°49'N 154°28'W
Reef Ridge	Southeast Missouri Pb-Zn	Zn, Pb	63°29'N 154°20'W
Northern Cordillera Metallogenic Belt of Southeast Missouri Zn-Pb Deposits (Late Proterozoic to Devonian) Central Yukon Territory (Belt NCO)			
Bear-Twit	Southeast Missouri Pb-Zn	Zn, Pb	64°03'N 129°25'W
Gayna River	Southeast Missouri Pb-Zn	Zn, Pb	64°56'N 130°41'W
Goz Creek Area (Barrier Reef)	Southeast Missouri Pb-Zn	Zn, Pb	64°23'N 132°31'W
Rusty Springs (Termuende)	Southeast Missouri Zn-Pb-Ag	Ag, Zn, Cu	66°30'N 140°20'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Dempster Metallogenic Belt of SEDEX Ba, SEDEX Ni-Zn-PGE-Au, Kuroko Zn-Pb-Cu Massive Sulfide Deposits (Devonian and Mississippian), Central Yukon Territory (Belt DE)			
Marg	Kuroko Zn-Pb-Cu massive sulfide	Zn, Pb, Cu, Ag, Au	64°01'N 134°28'W
Nick	SEDEX Ni-Zn	Ni, Zn, PGE	64°43'N 135°13'W
Macmillan Pass Metallogenic Belt of SEDEX Zn-Pb-Ag-Ba Deposits (Devonian and Early Mississippian) Central Yukon Territory (Belt MP)			
Cathy (Bar, Walt, Hess)	SEDEX Ba	Ba, (Pb, Zn, Ag)	63°17'N 130°33'W
Gravity (BA)	SEDEX Ba	Ba	63°44'N 128°52'W
Jeff (Naomi, Baroid)	SEDEX Ba	Ba	63°37'N 129°40'W
MacMillan Pass (Tom, Jason)	SEDEX Pb-Zn	Pb, Zn, Ag, Ba	63°10'N 130°12'W
Moose (Spartan, Racicot)	SEDEX Ba	Ba	63°04'N 130°12'W
Oro (Buc, Mar, Dar, Tang)	SEDEX Ba	Ba	62°37'N 129°46'W
Tea (Brock)	SEDEX Ba	Ba	63°01'N 130°37'W
Finlayson Lake Metallogenic Belt of SEDEX Zn-Pb-Ag-Cu-Au Deposits (Devonian and Mississippian) Southern Yukon Territory (Belt FL)			
Matt Berry	SEDEX Pb-Zn	Pb, Zn, Ag, Cu, Sb	61°29'N 129°24'W
Liard Metallogenic Belt of Southeast Missouri Ba-F Deposits (Devonian), Southern Yukon Territory (Belt LI)			
Leguil	Bedded Ba	Ba	59°46'N 127°12'W
Lower Liard	Southeast Missouri Ba-F	F, Ba	59°27'N 126°05'W
Gataga Metallogenic Belt of SEDEX Zn-Pb-Ag-Ba Deposits (Devonian and Mississippian), Northern British Columbia (Belt GA)			
Akie	SEDEX Zn-Pb	Zn, Pb, Ag, Ba	57°13'N 124°29'W
Cirque (Stronsay) (094F 008)	SEDEX Pb-Zn	Pb, Zn, Ag, Ba	57°31'N 125°09'W
Driftpile Creek (Saint, Roen) (094K 066)	SEDEX Pb-Zn	Pb, Zn, Ba	58°05'N 125°54'W
Robb Lake Metallogenic Belt of Southeast Missouri Zn-Pb-Ag Deposits (Devonian), Southern Northern Columbia (Belt RL)			
Robb Lake	Southeast Missouri Pb-Zn	Zn, Pb	57°22'N 123°52'W
Southern Rocky Mountains Metallogenic Belt of Stratabound Barite-Magnesite-Gypsum Deposits (Early Paleozoic through Triassic), Southern British Columbia (Belt SRM)			
Brisco Area	Ba vein and breccia	Ba	50°50'N 116°20'W
Forgetmenot Pass	Stratbound gypsum	Gypsum	53°45'N 119°53'W
Kootenay River Gypsum	Stratiform gypsum	Gypsum	50°34'N 115°16'W
Lussier River (United Gypsum)	Stratiform gypsum	Gypsum	50°03'N 115°31'W
Marysville (082JNW 001)	Stratiform magnesite	Magnesite	49°36'N 115°58'W
Mount Brussilof (Baymag)	Stratabound Mg	Magnesite	50°47'N 115°41'W
Parson (082N 002)	Barite vein and gypsum	Ba	51°01'N 116°39'W
Windermere Creek (Western Gypsum)	Stratiform gypsum	Gypsum	50°29'N 115°52'W
Ingenika Metallogenic Belt of Southeast Missouri Zn-Pb-Ag Deposits (Devonian?), Southern British Columbia (Belt IN)			
Susie, Beveley and Regent	Southeast Missouri Pb-Zn	Pb, Zn, Ag, Ba	56°09'N 125°03'W
Cathedral Metallogenic Belt of Southeast Missouri Zn-Pb-Ag Deposits (Devonian?), Southern British Columbia (Belt CA)			
Monarch (Kicking Horse)	Southeast Missouri Zn-Pb-Ag	Zn, Pb, Ag	51°25'N 116°26'W
MISSISSIPPIAN (360 to 320 Ma)			
Northwestern Brooks Range Metallogenic Belt of SEDEX Zn-Pb, Kuroko Massive Sulfide, Bedded Barite, and Vein Sulfide Deposits (Mississippian and Pennsylvanian), Northwestern Alaska (Belt NBR)			
Drenchwater	Sedimentary Zn-Pb and (or) kuroko massive sulfide	Zn, Pb, Ag	68°34'N 158°41'W
Frost	Cu-Zn-Pb-Ba vein	Cu, Zn, Pb, barite	67°28'N 161°35'W
Hannum Creek	Metamorphosed SEDEX Zn-Pb?	Pb, Zn, Ag	65°56'N 163°21'W
Lik	SEDEX Zn-Pb-barite	Zn, Pb, Ag, Barite	68°12'N 163°07'W
Nimiuktuk	Bedded barite	Barite	68°24'N 159°54'W
Omar	Kipushi Cu-Pb-Zn	Cu, Pb, Zn, Ag, Co	67°30'N 161°50'W
Red Dog Creek	SEDEX Zn-Pb-barite	Zn, Pb, Ag, Ba	68°04'N 162°50'W
Story Creek	Pb-Zn-Au-Ag vein	Pb, Zn, Ag, Au	68°22'N 157°56'W
Whoopee Creek	Zn-Ag-Au vein	Zn, Ag, Au	68°14'N 157°51'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
PENNSYLVANIAN (320 to 286 Ma)			
Laoelin-Grodekovsk Metallogenic Belt of Porphyry Cu-Mo and Au-Ag Epithermal Vein Deposits (Permian) Southern Part of Russian Southeast (Belt LG)			
Baikal	Porphyry Cu-Mo	Cu, Mo	44°12'N 131°06'E
Komissarovskoe (Vorob'eva plad)	Au-Ag epithermal vein	Au, Ag	44°34'N 131°27'E
Aluchin Metallogenic Belt of Podiform Cr Deposits (Middle Paleozoic or older), Central Part of Russian Northeast (Belt AC)			
Teleneut	Podiform Cr	Cr, Ni	66°29'N 164°49'E
Ust-Belaya Metallogenic Belt of Podiform Cr Deposits (Early Paleozoic), Northeastern Part of Russian Northeast (Belt UB)			
Ust-Belaya	Podiform Cr	Cr, PGE	65°27'N 173°04'E
Alaska Range-Wrangell Mountains Metallogenic Belt of Granitic Magmatism Deposits (Pennsylvanian and Permian) Central and Eastern-Southern Alaska (Belt ARW)			
Chistochina District	Porphyry Cu and polymetallic vein	Cu, Pb, Ag, Au	63°05'N 144°47'W
Rainbow Mountain	Porphyry Cu	Cu, Ag	63°20'N 145°41'W
Rainy Creek District	Cu-Ag skarn	Cu, Ag, Au	63°20'N 146°02'W
Slate Creek	Porphyry Cu(?)	Cu, Ag, Au	63°09'N 144°48'W
Ketchikan Metallogenic Belt of Kuroko Massive Sulfide Deposits (Pennsylvanian? or Permian?) Southeastern Alaska (Belt KK)			
Moth Bay	Kuroko massive sulfide	Cu, Pb, Ag, Au	55°18'N 131°21'W
LATE TRIASSIC (Carnian through Norian - 230 to 208 Ma)			
Farewell Metallogenic Belt of Gabbroic Ni-Cu-PGE Deposits (Late Triassic), Western Alaska (Belt FW)			
Farewell District (Gargaryah, River Roberts, Straight Creek)	Gabbroic Ni-Cu-PGE	Ni, Cu, PGE	62°14'N 154°30'W
Kodiak Island and Border Ranges Metallogenic Belt of Podiform Cr Deposits (Late Triassic, Early or Middle Jurassic) Southern Coastal Alaska (Belt KOD)			
Bernard Mountain, Dust Mountain	Podiform Cr	Cr, PGE	61°32'N 145°09'W
Claim Point	Podiform Cr	Cr	59°12'N 151°49'W
Halibut Bay	Podiform Cr	Cr	57°22'N 154°36'W
Red Mountain	Podiform Cr	Cr	59°22'N 151°30'W
Spirit Mountain	Gabbroic Ni-Cu	Ni, Cu, Co, Ag	61°19'N 144°13'W
Eastern Alaska Range Metallogenic Belt of Gabbroic Ni-Cu and Besshi Massive Sulfide Deposits (Late Triassic) Southern Alaska and Northwestern Canadian Cordillera (Belt EAR)			
Denali	Besshi massive sulfide	Cu	63°09'N 147°08W
Bullion Creek	Strataform gypsum	Gypsum	60°59'N 138°39'W
Fish Lake	Gabbroic Ni-Co	Cr, Ni	63°13'N 146°48'W
Wellgreen	Gabbroic Ni-Cu	Ni, Cu, PGE	61°28'N 139°31'W
Alexander Metallogenic Belt of Volcanogenic Cu-Pb-Zn and Carbonate-Hosted Massive Sulfide Deposits (Ordovician through Triassic), Southeastern Alaska (Belt AX)			
Castle Island, Kupreanof Island	Bedded barite, kuroko Ba-Zn-Pb-Cu massive sulfide	Ba	56°39'N 133°10'W
Glacier Creek	Kuroko massive sulfide	Ba, Cu, Zn	59°24'N 136°23'W
Greens Creek	Kuroko massive sulfide	Ag, Zn, Au, Pb	58°05'N 134°38'W
Khayyam	Kuroko massive sulfide	Cu, Au	55°18'N 132°23'W
Lime Point	Bedded barite	Ba	55°03'N 132°38'W
Moonshine	Carbonate-hosted massive sulfide	Ag, Pb	55°11'N 132°23'W
Niblack	Kuroko massive sulfide	Cu, Au, Ag	55°04'N 132°09'W
Orange Point	Kuroko Zn-Pb-Cu massive sulfide	Zn, Cu	58°55'N 136°60'W
Windy Craggy (Alsek River Area) (114P 002)	Cyprus to Besshi massive sulfide	Cu, Co	59°44'N 137°45'W
Galore Creek Metallogenic Belt of Porphyry Cu-Au Deposits (Late Triassic and Early Jurassic) Northern British Columbia (Belt GL)			
Galore Creek (Stikine Copper) (104G 090)	Porphyry Cu-Au, Cu-Au skarn	Cu	57°08'N 131°27'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Gnat Lake Area (June, Stikine)	Porphyry Cu	Cu	58°15'N 129°50'W
Red Chris (Money) (104H 005)	Porphyry Cu-Au	Cu, Au, (Zn, Pb, Mo)	57°42'N 129°48'W
Susut Metallogenic Belt of Basaltic Cu Deposits (Late Triassic), Northern British Columbia (Belt SU)			
Sustut	Basaltic Cu	Cu	56°37'N 126°41'W
Copper Mountain (North) Metallogenic Belt of Porphyry Cu-Au Deposits (Jurassic), Northern British Columbia (Belt CMN)			
Lorraine (Duckling Creek) (093N 002)	Porphyry Cu-Mo	Cu	55°56'N 125°26'W
Mount Milligan (093N 194)	Porphyry Cu-Au	Cu, Au	55°08'N 124°02'W
Copper Mountain (South) Metallogenic Belt of Porphyry Cu-Au Deposits (Jurassic), Southern British Columbia (Belt CMS)			
Copper Mountain (Ingerbelle, and others) (092HSE 004)	Porphyry Cu-Au	Cu	49°20'N 120°32'W
Iron Mask Area (Afton (0921NE 023), Ajax (103P 223))	Porphyry Cu-Au	Cu	50°40'N 120°31'W
Lodestone Mountain (092HSE 034)	Zoned mafic-ultramafic Fe-V	Fe, V	49°28'N 120°50'W
Mt. Polley (Cariboo-Bell) (09314 008)	Porphyry Cu-Au	Cu, Au	52°34'N 121°38'W
Guichon Metallogenic Belt of Porphyry Cu-Mo-Au and Au Skarn Deposits (Late Triassic and Early Jurassic) Southern British Columbia (Belt GU)			
Axe (Summers Creek, Axe)	Porphyry Cu-Mo	Cu	49°39'N 120°32'W
Bethlehem-JA	Porphyry Cu-Mo	Cu, Mo	50°30'N 120°59'W
Brenda (Peachland Area) (092HNE 047)	Porphyry Cu-Mo	Cu, Mo	49°53'N 120°00'W
Craigmont (092ISE 035)	Cu-Fe skarn	Cu, Fe	50°13'N 120°56'W
Gibraltar (Pollyanna, Granite Mt)	Porphyry Cu-Mo	Cu, Mo	52°31'N 122°16'W
Hedley Camp (Nickel Plate, Mascot) (092HSE 038)	Au skarn	Au, Ag	49°22'N 120°02'W
Highmont (Gnawed Mountain)	Porphyry Cu-Mo	Cu, Mo	50°26'N 120°60'W
Lornex	Porphyry Cu-Mo	Cu, Mo	50°27'N 121°03'W
Primer (North Zone)	Porphyry Cu	Cu, Fe	49°45'N 120°28'W
Valley Copper (092ISW 012)	Porphyry Cu-Mo	Cu, Mo	50°29'N 121°03'W
Texas Creek Metallogenic Belt of Porphyry Cu-Mo-Au and Au-Ag Polymetallic Vein Deposits (Late Triassic to Middle Jurassic), Northern British Columbia (Belt TC)			
Brucejack Lake (West Zone, Shore Zone)	Au-Ag polymetallic vein	Au, Ag	56°28'N 130°12'W
Kerr (Main Zone)	Porphyry Cu-Au	Cu, Au, Ag	56°28'N 130°16'W
Muddy Lake (Golden Bear, Totem) (104K 079)	Au quartz vein	Au	58°13'N 132°17'W
Polaris-Taku (Whitewater) (104K 003)	Au quartz vein	Au, Ag, Cu, As, Sb	58°42'N 133°38'W
Red Mountain (103P086)	Au-Ag polymetallic vein	Au, Ag	55°57'N 129°42'W
Schaft Creek (Liard Copper) (104G 015)	Porphyry Cu-Mo	Cu, Mo	57°22'N 130°56'W
Silbak-Premier (Premier Gold) (104B 054)	Au-Ag epithermal vein	Au, Ag, Pb, Zn	56°03'N 130°01'W
Snip (Shan) (104B 250)	Au-Pb-Zn polymetallic vein	Au	56°40'N 131°06'W
E & L (Snippaker Creek)	Gabbroic Ni-Cu	Ni, Cu	56°35'N 130°41'W
Snowfields (Sulphurets)	Au-Ag polymetallic vein	Au, Ag	56°28'N 130°11'W
Sulphurets (Gold Zone)	Porphyry Cu-Au	Au, Cu	56°30'N 130°16'W
EARLY JURASSIC (Hettangian through Pleinsbachian - 208 to 193 Ma)			
Alaska Peninsula Metallogenic Belt of Granitic Magmatism Deposits (Jurassic), Alaska Peninsula (Belt AP)			
Crevice Creek (McNeil)	Cu-Au skarn	Au, Cu	59°08'N 154°40'W
Glacier Fork	Cu-Zn skarn	Cu, Au	60°51'N 153°12'W
Kasna Creek (Kontrashibuna)	Cu-Fe skarn	Cu	60°13'N 154°05'W
Magnetite Island (Tuxedni Bay)	Fe skarn	Fe, Ti	60°14'N 152°51'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Talkeetna Mountains-Alaska Range Metallogenic Belt of Kuroko Massive Sulfide Deposits (Early Jurassic) Northern Part of Southern Alaska (Belt TM)			
Johnson River	Kuroko massive sulfide	Au, Zn, Cu, Pb	60°07'N 152°57'W
Island Porphyry Metallogenic Belt of Porphyry Cu-Mo; Cu Skarn, and Fe and Cu Skarn Deposits (Jurassic) Vancouver Island (Belt IP)			
Benson Area (Empire, Coast Copper)	Cu-Fe skarn	Cu, Fe	50°23'N 127°15'W
Burnaby Iron (Jib)	Fe skarn	Fe	52°25'N 131°18'W
Island Copper (Rupert Inlet) (092L 158)	Porphyry Cu-Mo	Cu, Mo, Au	50°37'N 127°31'W
Hushamu (092L 240)	Porphyry Cu-Mo	Cu, Mo, Au	50°40'N 127°50'W
Kennedy Lake (Brynnor) (103B 026)	Fe skarn	Fe	49°03'N 125°26'W
Red Dog	Porphyry Cu	Cu	50°43'N 127°58'W
Tasu Sound (Wesfrob, Tasu, Garnet) (103C 003)	Fe skarn	Fe, Cu	52°46'N 132°03'W
Texada (Prescott, Yellow Kid, Paxton Vananda, Marble Bay, etc.) (092F 106; 092F 258; 092F 107)	Cu-Au skarn	Cu, Au, Ag	49°45'N 124°33'W
Texada Iron	Fe skarn	Fe	49°43'N 124°33'W
Zeballos Iron (Ford)	Fe skarn	Fe	50°03'N 126°50'W
Klotassin Porphyry Metallogenic Belt of Porphyry Cu-Au-Ag Deposits (Early Jurassic) Southern Yukon Territory (Belt KL)			
Minto Copper	Porphyry Cu-Au	Cu	62°36'N 137°15'W
Williams Creek	Porphyry Cu-Au	Cu	62°21'N 136°42'W
Toodoggone Metallogenic Belt of Au-Ag Epithermal Vein Deposits (Early Jurassic), Northern British Columbia (Belt TO)			
Toodoggone District (Lawyers)	Au-Ag epithermal vein	Au, Ag	57°20'N 127°11'W
Kemess (Kemess N., Kemess S.)	Porphyry Cu-Au	Au, Au	57°00'N 126°45'W
Coast Mountain Metallogenic Belt of Volcanogenic Cu-Zn-Au-Ag Massive Sulfide Deposits (Late Triassic and Early Jurassic), Northern British Columbia (Belt CM)			
Alice Arm Silver (Dolly Varden, etc.)	Kuroko Zn-Pb-Cu massive sulfide	Ag, Pb, Zn	55°44'N 129°33'W
Anyox Area (Hidden Creek, Bonanza) (103P 021, 023)	Cyprus massive sulfide	Cu, Ag, Au	55°27'N 129°50'W
Eskay Creek-21B Zone (104B 008)	Kuroko Zn-Pb-Cu massive sulfide	Au, Ag, Pb, Zn, Cu	56°38'N 130°27'W
Granduc (South Leduc) (104B 021)	Besshi massive sulfide	Cu	56°13'N 130°21'W
Tulsequah Chief (Big Bull) (104K 002)	Kuroko Zn-Cu-Pb massive sulfide	Zn, Cu, Au, Ag, Pb	58°44'N 133°35'W
MIDDLE JURASSIC (Toarcian through Callovian - 193 to 163 Ma) (All metallogenic belts started earlier)			
LATE JURASSIC (Oxfordian through Kimmerigian - 163 to 144 Ma)			
Ariadny Metallogenic Belt of Zoned Mafic-Ultramafic Ti Deposits (Late Jurassic), Southern Part of Russian Southeast (Belt AR)			
Ariadnoe	Zoned mafic-ultramafic Ti	Ti	45°13'N 134°28'E
Katenskoe	Zoned mafic-ultramafic Ti	Ti	47°17'N 136°13'E
Koksharovskoe	Zoned mafic-ultramafic Ti	Ti	44°28'N 134°08'E
North Bureya Metallogenic Belt of Au-Ag Epithermal Vein and Granitoid-Related Au Deposits (Early Cretaceous) Northwestern Part of Russian Southeast (Belt NB)			
Pioneer	Granitoid-related Au	Au	53°27'N 126°27'E
Pokrovskoe	Au-Ag epithermal vein	Au, Ag	53°08'N 126°17'E
Chersky-Argatass Ranges Inferred Metallogenic Belt of Kuroko Massive Sulfide Deposits (Late Jurassic) West-Central Part of Russian Northeast (Belt CAR)			
Khotoidokh	Kuroko Pb-Zn massive sulfide	Pb, Zn, Ag	66°27'N 141°09'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Yasachnaya River Metallogenic Belt of Pb-Zn Skarn, Porphyry Cu, and Cu-Ag Vein Deposits (Late Jurassic) Western Part of Russian Northeast (Belt YS)			
Cherninskoe	Fe (Cu, Pb, Zn) skarn	Fe	63°20'N 151°05'E
Datsytovoe	Porphyry Cu	Cu, Ag, Bi	63°29'N 151°01'E
Kunarev	Pb-Zn-Cu-Ag skarn	Pb, Zn, Cu, Ag	63°24'N 150°55'E
Terrassnoe	Pb-Zn skarn	Pb, Zn	63°33'N 148°56'E
Oloy Metallogenic Belt of Porphyry Cu-Mo and Au-Ag Epithermal Vein Deposits (Late Jurassic and Early Cretaceous?) North-Central Part of Russian Northeast (Belt OL)			
Asket	Porphyry Cu-Mo and Polymetallic vein	Cu, Mo, Au	67°14'N 163°44'E
Dalny	Porphyry Cu-Mo and polymetallic vein	Cu, Mo, Au	67°31'N 160°49'E
Innakh	Polymetallic vein and Porphyry Cu-Mo	Cu, Mo, Au	67°17'N 159°22'E
Klen	Au-Ag epithermal vein	Au, Ag	67°08'N 161°13'E
Peschanka	Porphyry Cu-Mo	Cu, Mo, Au	66°36'N 164°30'E
Vesennee	Au-Ag epithermal vein	Au, Ag	66°30'N 164°24'E
Pekulney Metallogenic Belt of Basaltic Cu Deposits (Late Jurassic), East-Central Part of the Russian Northeast (Belt PK)			
Skalistaya	Basaltic Cu	Cu	65°25'N 174°08'E
Tamvatney-Mainits Metallogenic Belt of Podiform Cr Deposits (Late Jurassic and Early Cretaceous) East-Central Part of the Russian Northeast (Belt TAM)			
Chirynai	Podiform Cr	Cr, PGE	63°27'N 175°44'E
Krassnaya Gora	Podiform Cr	Cr, PGE	63°16'N 175°24'E
Mainits Metallogenic Belt of Massive Sulfide Deposits (Late Jurassic and Early Cretaceous) Eastern Part of Russian Northeast (Belt MA)			
Ugryumoe	Kuroko Cu-Zn-Ag massive sulfide(?)	Cu, Zn, Pb, Au	63°16'N 176°39'E
Svyatoy-Nos Metallogenic Belt of Au-Ag Epithermal Vein Deposits (Belt SVN) Western Part of Russian Northeast (Belt SVN)			
Polevaya	Au-Ag polymetallic vein	Au, Ag	69°08'N 149°06'E
Kuyul Metallogenic Belt of Podiform Cr, PGE and Associated Deposits (Middle or Late Jurassic) East-Central Part of Russian Northeast (Belt KUY)			
Talov	Podiform Cr	Cr	61°49'N 165°49'E
Tikhorechen	Podiform Cr	Cr	61°37'N 164°50'E
Eastern Seward Peninsula and Marshall Metallogenic Belt of Podiform Cr Deposits (Jurassic) Northern Alaska (Belt ESM) (No significant deposits)			
Kobuk Metallogenic Belt of Podiform Cr Deposits (Jurassic), Northern Alaska (Belt KB)			
Asbestos Mountain	Serpentine-hosted asbestos	Asbestos, jade, asbestos, talc	67°01'N 156°50'W
Avan	Podiform Cr	Cr, PGE	68°20'N 161°52'W
Iyikrok Mountain	Podiform Cr	Cr	67°54'N 163°40'W
Misheguk Mountain	Podiform Cr	Cr, PGE	68°15'N 161°05'W
Siniktanneyak Mountain	Podiform Cr	Cr, Ni, PGE	68°20'N 158°30'W
Southwestern Alaska Metallogenic Belt of Zoned Mafic-Ultramafic PGE Deposits (Late Triassic and Jurassic?) Southwestern Alaska (Belt SWA)			
Kemuk Mountain	Zoned mafic-ultramafic	Fe, Ti, PGE	59°44'N 157°45'W
Red Mountain	Zoned mafic-ultramafic	PGE	59°00'N 161°10'W
Yukon River Metallogenic Belt of Podiform Cr Deposits (Jurassic), West-Central Alaska (Belt YR)			
Caribou Mountain, Lower Kanuti River, Holonada	Podiform Cr	Cr	66°05'N 150°55'W
Kaiyuh Hills (Yuki River)	Podiform Cr	Cr	64°10'N 156°40'W
Mount Hurst	Podiform Cr	Cr, PGE	63°14'N 156°55'W
Eastern-Southern Alaska Metallogenic Belt of Granitic Magmatism Deposits (Late Jurassic and Early Cretaceous) Eastern-Southern Alaska (Belt ESA)			
Baultoff, Horsfeld, Carl Creek	Porphyry Cu	Cu	62°05'N 141°13'W
London and Cape	Porphyry Cu-Mo	Cu, Mo, Ag	61°34'N 143°43'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Midas (Berg Creek)	Cu-Au skarn	Au, Cu, Ag	61°33'N 143°47'W
Nabesna, Rambler	Fe-Au skarn	Au	62°23'N 143°00'W
Orange Hill, Bond Creek	Porphyry Cu-Mo and Cu-Au skarn	Cu, Mo, Au	62°12'N 142°45'W
Pebble Copper	Porphyry Au-Cu	Au, Cu, Mo	59°53'N 155°24'W
Klukwan-Duke Metallogenic Belt of Mafic-Ultramafic Ti-Fe-Cr-PGE Deposits (mid-Cretaceous) Southeastern Alaska (Belt KL)			
Duke Island	Zoned mafic-ultramafic Cr-PGE	Cr, PGE	54°55'N 131°21'W
Funter Bay	Gabbroic Ni-Cu	Cu, Ni, Co	58°14'N 134°52'W
Haines	Zoned mafic-ultramafic Fe-Ti	Fe, Ti	59°15'N 135°30'W
Klukwan	Zoned mafic-ultramafic Fe-Ti	Fe, PGE, Ti, V	59°26'N 135°53'W
Union Bay (Cleveland Peninsula)	Zoned mafic-ultramafic Cr-PGE	Fe, V, Ti, Cr, PGE	55°48'N 132°12'W
Fortymile Alaska Metallogenic Belt of Serpentinite-Hosted Asbestos Deposits (Cretaceous?) East-Central Alaska and Northwestern Canadian Cordillera (Belt FM)			
Clinton Creek	Serpentine-hosted asbestos	Asbestos	64°27'N 140°43'W
Slate Creek (Fortymile)	Serpentine-hosted asbestos	Asbestos	64°31'N 142°30'W
Cassiar Metallogenic Belt of Serpentine-Hosted Asbestos Deposits (mid-Cretaceous), Central British Columbia (Belt CS)			
Cassiar (McDame)	Serpentine-hosted asbestos	Asbestos	59°20'N 129°49'W
Francois Lake Metallogenic Belt Porphyry Deposits (Late Jurassic to Early Cretaceous) Southern British Columbia (Belt FL)			
Endako	Porphyry Mo	Mo	54°02'N 125°07'W
Cariboo Metallogenic Belt of Au Quartz Vein Deposits (Middle Jurassic to Early Cretaceous) Southern British Columbia (Belt CB)			
Cariboo-Barkerville (Aurum, Mosquito Ck.) (093H 019; 093H 010)	Au quartz vein	Au	53°05'N 121°34'W
Frasergold (Eureka Peak, Kay, Mac) (-93A 150)	Au quartz vein	Au	52°18'N 120°35'W
Rossland Metallogenic Belt of Au-Ag Polymetallic Vein Deposits (Middle Jurassic) Southern British Columbia (Belt RL)			
Rossland (Le Roi, War Eagle, etc.) (082FSW 093; 082FSW 097; 082FSW 048; 083FSW068)	Au-Ag polymetallic vein	Au, Ag	49°05'N 117°49'W
Sheep Creek Area (Kootenay Belle, etc.)	Au-Ag polymetallic vein	Au, Ag, Pb, Zn	49°08'N 117°08'W
Ymir-Erie Creek (Yankee Girl)	Au-Ag polymetallic vein	Au, Ag	49°18'N 117°11'W
EARLY CRETACEOUS (Neocomian - 144 to 120 Ma)			
Samarka Metallogenic Belt of W Skarn, and Porphyry Cu-Mo Deposits (Early Cretaceous) West-Central Part of Russian Southeast (Belt SA)			
Benevskoe	W skarn	W	43°06'N 133°43'E
Kafen	Porphyry Cu-Mo	Cu, Mo	47°36'N 136°15'E
Khvoshchovoe	Porphyry Cu-Mo	Cu, Mo	47°58'N 136°11'E
Lermontovsky	W skarn and greisen	W	46°57'N 134°27'E
Malakhitovoe	Porphyry Cu-Mo	Cu, Mo	47°06'N 135°04'E
Skalistoe	Porphyry Mo	Mo	43°36'N 133°45'E
Skrytoe	W skarn	W	45°05'N 134°35'E
Vostok-2	W skarn	W	46°28'N 135°53'E
Algama Metallogenic Belt of Stratiform Zr Deposits (mid-Cretaceous?), Northern Part of Russian Southeast (Belt AL)			
Algaminskoe	Stratiform Zr	Zr	58°40'N 135°34'E
Kondyor Metallogenic Belt of Zoned Mafic-Ultramafic PGE-Cr Deposits (mid-Cretaceous?) Northern Part of Russian Southeast (Belt KO)			
Kondyor	Zoned mafic-ultramafic Cr-PGE	Pt	57°33'N 134°38'E
Selemdzha-Kerbi Metallogenic Belt of Au Quartz Vein Deposits (Late Jurassic and Early Cretaceous) Northwestern Part of Russian Southeast (Belt SK)			
Afanas'evskoe	Au quartz vein	Au	52°50'N 133°24'E
Ingagli	Au quartz vein	Au	53°04'N 133°22'E
Kharga	Au quartz vein	Au	52°57'N 133°38'E
Malomyr	Au quartz vein	Au	53°06'N 131°50'E
Poiskovoe	Granitoid-related Au	Au	53°08'N 132°12'E
Sagurskoe	Au quartz vein	Au	52°59'N 132°36'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Talaminskoe	Sb-Au vein	Sb, Au	52°42'N 133°24'E
Tokur	Au quartz vein	Au	53°09'N 132°49'E
Zazubrinskoe	Au quartz vein	Au	53°09'N 132°22'E
Stanovoy Metallogenic Belt of Granitoid-related Au Deposits (Cretaceous?) Northern Part of the Russian Southeast (Belt ST)			
Bamskoe (Chul'bango)	Au-Ag epithermal vein	Au, Ag	55°59'N 123°54'E
Burindinskoe	Au-Ag epithermal vein	Au, Ag	53°41'N 124°54'E
Kirovskoe	Granitoid-related Au	Au	54°27'N 124°14'E
Zolotaya Gora	Au quartz vein	Au	54°19'N 126°44'E
Kular Metallogenic Metallogenic Belt of Au Quartz Vein, Granitoid-Related Au, Au-REE Quartz Vein, and Sn Quartz Vein Deposits (Early Cretaceous), Northern Part of Eastern Siberia (Belt KU)			
Burguat	Au quartz vein	Au	70°42'N 134°31'E
Dzhuotuk	Au quartz vein	Au	70°13'N 134°17'E
Novoe	Granitoid-related Au	Au	69°36'N 133°07'E
Solur	Granitoid-related Au	Au	70°01'N 133°24'E
Tirekhtyak district (Nagornoe, Podgornoe, Poputnoe)	Sn quartz vein	Sn, W	69°58'N 134°41'E
Allakh-Yun Metallogenic Belt of Au Quartz Vein Deposits and Associated W-Sn Quartz Vein Deposits (Late Jurassic to Early Cretaceous), Southern Part of Russian Northeast (Belt AY)			
Bular	Au quartz vein	Au	61°13'N 137°50'E
Burgali	Porphyry-Mo (W)	Mo, W	59°56'N 138°51'E
Dies	Cu skarn	Cu	59°10'N 138°11'E
Duet	Au quartz vein	Au	59°48'N 137°44'E
It-Yuryak	W vein, Sn (W)-quartz vein	W	62°42'N 139°38'E
Levo-Dybin	Granitoid-related Au	Au, W, Bi	62°50'N 139°35'E
Malyutka	Au quartz vein	Au	58°38'N 137°16'E
Muromets	Cu-Mo skarn	Cu, Mo, W	58°48'N 137°38'E
Nezhdaninka	Au quartz vein	Au, Ag	62°34'N 139°19'E
Novinka	Au quartz vein	Au	61°42'N 138°17'E
Onello (Lider)	Au quartz vein	Au	62°23'N 137°52'E
Svetly	Au quartz vein	Au	61°28'N 137°19'E
Voskhod	Au quartz vein	Au	61°22'N 139°22'E
Yur	Au quartz vein	Au	59°55'N 137°48'E
Zaderzhnoe	Au quartz vein	Au	
Zhar	Au quartz vein	Au	
Yana-Polousnen Metallogenic Metallogenic Belt of Granitoid-Related Sn Quartz Vein, W Vein, Sn Greisen, Co-, Au-, and Sn-Skarn, Sn-Silicate Sulfide Vein and Related Deposits (Early Cretaceous), Central Part of Russian Northeast (Belt YP)			
Altinskoe	Polymetallic vein	Pb, Zn	69°47'N 142°14'E
Alys-Khaya	Sn polymetallic vein	Sn	65°56'N 135°43'E
Anomalnoe	Sn silicate-sulfide vein	Sn	65°37'N 131°49'E
Aragochan	Polymetallic vein	Pb, Zn	69°44'N 137°00'E
Arbatskoe	Co skarn	Co	69°28'N 149°41'E
Argin	Sn quartz vein	Sn	68°03'N 135°50'E
Balyktaah, Ploskoe	Sn greisen	Sn	69°50'N 151°48'E
Bugdogar	Sn polymetallic vein	Sn	65°12'N 133°59'E
Burgachan	Sn polymetallic vein	Sn	65°46'N 134°45'E
Chistoe	Granitoid-related Au	Au	69°43'N 150°15'E
Dalnee	Polymetallic vein	Pb, Zn	69°49'N 138°30'E
Dokhsun	Polymetallic vein	Pb, Zn, Cu	69°26'N 144°27'E
Ege-Khaya	Sn polymetallic vein	Sn, Zn	67°38'N 134°47'E
Ilin-Tas	Sn silicate-sulfide vein	Sn	65°60'N 135°56'E
Kandidatskoe	Au skarn	Au, Co, As	69°24'N 149°44'E
Kester	Sn greisen	Sn, Ta, Nb, Li	67°17'N 134°38'E
Khoton-Khaya	Sn-polymetallic vein, Sn silicate-sulfide vein	Sn	67°17'N 133°47'E
Polyarnoe	Sn greisen and vein	Sn, W	69°37'N 141°45'E
Takalkan	Sn greisen	Sn	68°59'N 139°44'E
Tuguchak-1	Mo quartz vein	Mo	69°30'N 149°19'E
Tuguchak-2	Granitoid-related Au	Au, W, Bi, Te	69°30'N 149°19'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Ulakhan-Egelyakh	Sn silicate-sulfide vein	Sn	67°09'N 134°21'E
Ulakhan-Sala	Sn silicate-sulfide vein	Sn	69°48'N 136°40'E
Verkhne-Naanchan	Polymetallic vein	Pb, Zn	69°39'N 150°41'E
Darpir Metallogenic Belt of Sn and Associated Felsic-Magmatism Deposits (Early Cretaceous) Western Part of Russian Northeast (Belt DP)			
Bastion	Sn greisen	Sn	63°17'N 153°13'E
Bolshoy Kanyon	Sn skarn	Sn	63°15'N 151°05'E
Chepak	Granitoid-related Au	Au, W, Bi	63°05'N 152°45'E
Chibagalakh	Sn-B skarn	B, Sn	68°13'N 139°51'E
Darpir	Sn silicate-sulfide vein	Sn	64°02'N 147°42'E
Lazo	Sn silicate-sulfide vein	Sn	63°12'N 152°13'E
Titovskoe	Sn (B) magnesian skarn	B	67°33'N 139°14'E
Verkhne-Seimchan	Co-As vein	Co, Bi	63°17'N 151°23'E
Tompon Metallogenic Metallogenic Belt of Cu, W, Sn Skarn, and Sn Quartz Vein Deposits (Early Cretaceous) West-Central Part of Eastern Siberia (Belt TO)			
Agylki	W skarn	W, Cu	64°17'N 137°16'E
Erikag	Sn quartz vein	Sn	64°30'N 137°18'E
Khunkhada	W-Sn skarn	W, Sn	64°34'N 134°49'E
Shamanikha Metallogenic Belt of Au Quartz Vein and Cu-Ag Quartz Vein Deposits (Late Jurassic to Early Cretaceous) Central Part of the Russian Northeast (Belt SH)			
Glukhariny	Au quartz vein	Au	64°58'N 153°04'E
Kopach	Au quartz vein	Au	65°21'N 152°57'E
Opyt	Cu-Ag quartz vein?	Cu, Au, Pb, Zn, Ag, Au	63°54'N 152°33'E
Verkhoyansk Metallogenic Belt of Au Quartz Vein, Au-Sn Polymetallic Vein Deposits (Late Jurassic and Early Cretaceous), Western Part of Russian Northeast (Belt VK)			
Anna-Emeskhin	Au quartz vein	Au	68°56'N 128°24'E
Balbuk	Pb polymetallic vein	Pb	64°49'N 130°37'E
Bochiyskoe	Sn polymetallic vein	Sn	66°14'N 129°58'E
Chochimbal	Polymetallic vein	Au, Ag, Pb	65°54'N 129°45'E
Dyabkhanya	Au polymetallic vein	Au, Ag	65°30'N 129°60'E
Enichan-Tolono	Au quartz vein	Au	68°11'N 128°11'E
Galochka	Au quartz vein	Au	65°42'N 128°26'E
Imtandzha	Sn polymetallic vein	Sn	66°08'N 129°36'E
Nikolaevskoe, Otkrytoe	Au quartz vein	Au	70°20'N 129°33'E
Syncha-I & II	Au quartz vein	Au	67°50'N 128°03'E
Syugyunyakh-Kende	Au quartz vein	Au	68°42'N 127°46'E
Yana-Kolyma Metallogenic Belt of Au Quartz Vein, Sn Vein and Greisen, W Vein and Clastic-Sediment-Hosted Hg Deposits (Late Jurassic and Early Cretaceous), Central Part of Russian Northeast (Belt YA)			
Aleshkino	Au quartz vein	Au	67°11'N 138°22'E
Alyaskitovoe	Sn-W greisen	Sn, W	64°48'N 141°52'E
Badran	Au quartz vein	Au	64°12'N 141°41'E
Baryllyelakh	Sn greisen	Sn, W	63°35'N 143°54'E
Bazovskoe	Au quartz vein	Au	64°42'N 141°26'E
Bekkem	W-Mo-Sn vein and greisen	W	64°04'N 142°37'E
Bokhapcha	W vein and greisen	W	61°45'N 150°44'E
Burgavli	Sn quartz vein	Sn	66°28'N 137°39'E
Burkat	Sn quartz vein	Sn	65°35'N 140°59'E
Burkhala	Au quartz vein	Au	62°36'N 149°04'E
Butugychag	Sn quartz vein	Sn	61°15'N 149°05'E
Chai-Yurya	Au quartz vein	Au	62°41'N 147°24'E
Chelbanya	Au quartz vein	Au	62°37'N 148°02'E
Daika Novaya	Au quartz vein	Au	62°45'N 148°06'E
Darpir	Au quartz vein	Au	65°30'N 138°55'E
Degdekan	Au quartz vein	Au	61°58'N 146°60'E
Delyuvialnoe	Granitoid-related Au	Au	66°17'N 136°53'E
Dirin-Yuryak	Au quartz vein	Au	64°25'N 142°19'E
Djelgala-Tyellakh	Au quartz vein	Au	62°19'N 148°50'E
Dorozhnoe	Au quartz vein	Au	62°50'N 148°02'E
Ekspeditsionnoe	Au quartz vein	Au	61°41'N 150°33'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Ergelyakh	Granitoid-related Au	Au	63°43'N 143°53'E
Goletsov (Golets)	Au quartz vein	Au	62°40'N 150°07'E
Igumen	Au quartz vein	Au	61°25'N 148°21'E
Imtachan	Au quartz vein	Au	65°32'N 140°18'E
Kamenistoe	Au quartz vein	Au	62°16'N 151°44'E
Kere-Yuryak	Sn-W greisen	Sn, W	66°17'N 137°58'E
Khangalass	Au quartz vein	Au	64°03'N 144°49'E
Khaptagai-Khaya	Au quartz vein	Au	65°24'N 142°60'E
Kontrandya	Au quartz vein	Au	63°13'N 146°55'E
Krokhalin	Sb-Au vein (simple Sb)	Sb, Au	62°22'N 152°01'E
Kuzmichan	Clastic sediment-hosted Hg or hot-spring Hg?	Hg	62°18'N 152°39'E
Laryukov	Au quartz vein	Au	62°06'N 151°52'E
Lazo	Au quartz vein	Au	66°38'N 136°51'E
Maldyak	Au quartz vein	Au	62°56'N 148°14'E
Mitrei	Au quartz vein	Au	64°57'N 144°01'E
Nadezhda	Au quartz vein	Au	62°23'N 150°05'E
Natalka	Au quartz vein	Au	61°39'N 147°41'E
Pavlik	Au quartz vein	Au	61°32'N 147°57'E
Pil	Au quartz vein	Au	63°49'N 143°38'E
Rodionov	Au quartz vein	Au	61°16'N 148°37'E
Sana	Au quartz vein	Au	64°08'N 143°04'E
Shturm	Au quartz vein	Au	62°47'N 149°46'E
Sokh	Au quartz vein	Au	64°45'N 143°50'E
Srednekan	Au quartz vein	Au	62°20'N 152°22'E
Stakhanov	Au quartz vein	Au	63°06'N 147°48'E
Svetloe, Kholodnoe	Au quartz vein	Au	62°44'N 147°52'E
Svetloe, Medvezhje	Sn quartz vein and greisen	Sn, W	65°40'N 142°07'E
Taboga	Au quartz vein	Au	63°04'N 148°16'E
Talalak	Au quartz vein	Au	64°32'N 141°43'E
Tokichan	Au quartz vein	Au	62°01'N 146°45'E
Tumannoe	Au quartz vein	Au	65°36'N 138°33'E
Tunguss	Au quartz and Sb vein	Au, Sb	64°09'N 146°16'E
Tuora-Tas	Au quartz vein	Au	64°45'N 142°43'E
Uchui	Au quartz vein	Au	65°47'N 138°22'E
Utinka	Au quartz vein	Au	62°31'N 151°04'E
Verkhne-Khakchan	Au quartz vein	Au	63°15'N 146°14'E
Vetrenskoe	Au quartz vein	Au	61°45'N 149°33'E
Yugler	Au quartz vein	Au	62°10'N 150°37'E
Yukhondja	Au quartz vein	Au	65°28'N 140°32'E
Zatessnoe	Au quartz vein	Au	61°52'N 152°35'E
Zhdannoe	Au quartz vein	Au	64°57'N 141°07'E
Left Omolon Metallogenic Belt of Granitic-Magmatism-Related Deposits (Early Cretaceous) Russian Northeast (Belt LO)			
Bebekan	Porphyry Cu-Mo	Mo, Cu	64°22'N 160°22'E
Medgora	Mo-Cu skarn	Mo, Cu	65°17'N 159°32'E
Western-Southeastern Alaska Metallogenic Belt of Granitic-Magmatism-Related Deposits (Late Jurassic and Early Cretaceous), Southeastern Alaska (Belt WSE)			
Bokan Mountain (Ross-Adams)	Felsic plutonic U-REE	U, Th, Be, Nb, Pb, REE	54°55'N 132°08'W
Jumbo district	Cu-Au skarn	Fe, Ag, Au, Cu, Mo	55°15'N 132°37'W
Britannia Metallogenic Belt of Kuroko Cu-Zn Massive Sulfide Deposits (Late Jurassic and Early Cretaceous) Southern British Columbia Alaska (Belt BR)			
Britannia (092GN 003)	kuroko massive sulfide	Cu, Zn, Ag, Au	49°37'N 123°08'E
Maggie (092GNW 042)	kuroko massive sulfide	Cu, Zn, Pb, Ag	49°39'N 123°22'E
Northair (092JW 012)	kuroko massive sulfide?	Au, Ag, Pb, Zn, Cu	49°39'N 123°22'E
Nifty (093D 006)	kuroko massive sulfide	Ag, Cu, Au, Zn	52°35'N 126°24'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.	
LATE EARLY CRETACEOUS (Cenomanian through Albian - 120 to 100 Ma)				
Badzhal-Ezop-Khingan Metallogenic Belt of Sn Greisen, Sn Skarn, and Sn Quartz Vein Deposits (Late Cretaceous and early Tertiary), West-Central Part of Russian Southeast (Belt BZ-KH)				
Dzhalinda	Rhyolite-hosted Sn	Sn	49°09'N	131°25'E
Ezop	Sn polymetallic vein	Sn	52°28'N	134°11'E
Festivalnoe	Sn quartz vein	Sn	50°41'N	136°21'E
Ippatinskoe	Sn quartz vein	Sn	51°30'N	133°55'E
Kapral	Porphyry Mo	Mo	50°41'N	136°08'E
Khingan	Sn greisen	Sn	48°59'N	131°15'E
Loshadinayagriva (Main)	Sn quartz vein	Sn	50°33'N	135°14'E
Olgakanskoe	Sn greisen	Sn	52°21'N	134°04'E
Pravourmiiskoe	Sn greisen	Sn	50°26'N	134°15'E
Solnechnoe	Sn quartz vein	Sn	50°48'N	136°16'E
Verkhnebidzhanskoe	Sn quartz vein	Sn	48°37'N	131°30'E
Anadyr River Metallogenic Belt of Au Quartz Vein Deposits (late Early) Cretaceous), Russian Northeast (Belt AD)				
Nutekin	Au quartz vein	Au	63°25'N	176°52'E
Vaegi	Au quartz vein	Au	63°33'N	171°09'E
Nome Metallogenic Belt of Au Quartz Vein Deposits (Early to mid-Cretaceous), Seward Peninsula, Alaska (Belt NO)				
Big Hurrah	Au quartz vein	Au	64°39'N	164°14'W
Daniels Creek, (Bluff)	Au quartz vein	Au, Ag	64°34'N	163°44'W
Nome district, Mt. Distin	Au quartz vein	Au	64°40'N	165°28'W
Rock Creek	Au quartz vein	Au, Ag, W	64°35'N	165°29'W
Southern Brooks Range Metallogenic Belt of Au Quartz Vein Deposits (Early to mid-Cretaceous), Northern Alaska (Belt SBR)				
Chandalar district (Mikado, Little Squaw)	Au quartz vein	Au	67°32'N	148°15'W
Fish River Metallogenic Belt of Sedimentary P and Fe Deposits (Late Cretaceous), Northern Yukon Territory (Belt FR)				
Rio Alto	Stratabound Fe	Fe	66°32'N	140°17'W
Fish River	Sedimentary P and Fe	Fe, P, Mn, Gems	68°29'N	136°29'W
Selwyn Metallogenic Belt of W-Cu Skarn, Zn-Pb-Ag Skarn, and Zn-Pb-Ag Manto Deposits (mid-Cretaceous) Southern Yukon Territory (Belt SW)				
Bailey (Pat)	W skarn	W, Cu	60°46'N	128°51'W
Cantung (Canada Tungsten)	W skarn	W, Cu	61°57'N	128°15'W
Lened (Rudi, Godfrey)	W skarn	W, Cu	62°23'N	128°37'W
MacTung (MacMillan Tungsten)	W skarn	W, Cu	63°17'N	130°09'W
McMillan (Quartz Lake)	Pb-Zn skarn and manto	Pb, Zn, Ag	60°30'N	127°57'W
Prairie Creek (Cadillac)	Pb-Zn skarn and manto	Pb, Zn, Ag	61°34'N	124°48'W
Sa Dena Hes (Mt. Hundere)	Pb-Zn skarn and manto	Pb, Zn, Ag	60°31'N	128°53'W
Tombstone Metallogenic Belt of Ag Polymetallic Vein, Au-Sb Vein, and W-Sn-Au Skarn and Cu Deposits (mid-Cretaceous), Central Yukon Territory (Belt TS)				
Brewery Creek (Loki Gold)	Sb-Au vein	Au	64°04'N	138°14'W
Craig (Tara, Nadaleen Mtn)	Ag polymetallic vein	Pb, Zn, Ag, Au	64°10'N	133°22'W
Keno Hill (Galena Hill)	Ag polymetallic vein	Ag, Pb, Zn, Cd	63°55'N	135°15'W
Ray Gulch (Potato Hills, Mar)	W skarn	W	64°02'N	135°46'W
Rusty Mountain (Vera, Val, Cavey)	Ag-Pb-Zn polymetallic vein	Ag, Pb	64°19'N	133°45'W
Cassiar Metallogenic Belt of Porphyry Mo-W; W Skarn, Zn-Pb-Ag Manto, Sn Skarn, and Au Skarn Deposits (mid-Cretaceous), Southern Yukon Territory (Belt CA)				
JC (Viola)	Sn skarn	Sn	60°12'N	131°42'W
Logan	Zn-Ag polymetallic vein	Zn, Ag	60°30'N	130°28'W
Logtung (Logjam Creek)	Porphyry W-Mo	W, Mo	60°01'N	131°37'W
Midway (Silver Tip) (104O 038)	Pb-Zn-Ag skarn and manto	Ag, Pb, Zn	59°56'N	130°20'W
Risby (Cab)	W skarn	W	61°52'N	133°23'W
Whitehorse Metallogenic Belt of Cu-Fe Skarn, Porphyry Cu-Au-Ag, and Au-Ag Polymetallic Vein Deposits (mid-Cretaceous), Southern Yukon Territory (Belt WH)				
Hopkins (Giltana)	Cu skarn	Cu	61°18'N	136°55'W
Whitehorse Copper Belt (Little Chief, War Eagle, etc.)	Cu skarn	Cu, Au, Ag	60°37'N	135°03'W
Bayonne Metallogenic Belt of Porphyry Mo and Cu-Mo-W-Zn Skarn Deposits (mid-Cretaceous),				

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Southern British Columbia (Belt BA)			
Boss Mountain (093A 001)	Porphyry Mo	Mo	52°06'N 120°54'W
Emerald-Invincible (082FSW 010)	W skarn	W, Mo	49°06'N 117°14'W
Mineral King	Zn-Pb skarn and manto	Zn, Pb, Ag	50°20'N 116°25'W
Phoenix-Greenwood District (082ESE 020)	Cu-Au skarn	Cu, Au, Ag, Fe	49°05'N 118°36'W
Red Mountain Moly (Coxey, Novelty, Nevada) (103P 086)	Mo skarn	Mo	49°05'N 117°50'W
Trout Lake (082KN 087)	Porphyry Mo	Mo	50°38'N 117°36'W
EARLY LATE CRETACEOUS (Cenomanian through Santonian - 100 to 84 Ma)			
Sergeevka Metallogenic Belt of Granitoid-Related Au Deposits (Late Cretaceous), Southern Part of Russian Southeast (Belt SG)			
Askold	Granitoid-related Au	Au	42°44'N 132°20'E
Balykovskoe	Granitoid-related Au	Au	42°58'N 132°57'E
Krinichnoe	Granitoid-related Au	Au	42°54'N 132°29'E
Porozhistoe	Granitoid-related Au	Au	42°54'N 133°28'E
Progress	Granitoid-related Au	Au	42°52'N 132°50'E
Taukha Metallogenic Belt of B Skarn, Pb-Zn Skarn, Pb-Zn Polymetallic Vein, and Related Deposits (mid-Cretaceous to early Tertiary), Eastern Part of Russian Southeast (Belt TK)			
Belogorskoe	Fe skarn	Fe	43°52'N 135°12'E
Dalnegorsk	Boron skarn	B	44°29'N 135°35'E
Fasolnoe	Polymetallic vein	Pb, Zn	43°35'N 134°42'E
Krasnogorskoe	Pb-Zn polymetallic vein	Pb, Zn	44°24'N 135°58'E
Lidovskoe	Pb-Zn polymetallic vein	Pb, Zn	44°26'N 135°49'E
Nikolaevskoe	Pb-Zn Skarn	Pb, Zn	44°35'N 135°40'E
Novo-Monastyrskoe	Pb-Zn polymetallic vein	Pb, Zn	44°21'N 135°43'E
Partizanskoe (Soviet 2, Svetliy Otvod)	Pb-Zn skarn	Pb, Zn	44°25'N 135°30'E
Plastun	Porphyry Cu	Cu	44°39'N 136°12'E
Shcherbakovskoe	Polymetallic vein	Pb, Zn	43°35'N 134°28'E
Soyuz	Au-Ag epithermal vein	Ag, Au	43°25'N 134°20'E
Kema Metallogenic Belt of Ag-Au Epithermal Vein, and Porphyry Cu-Mo Deposits (mid-Cretaceous to early Tertiary), Eastern Part of Russian Southeast (Belt KM)			
Burmatovskoe	Au-Ag epithermal vein	Au, Ag	47°06'N 138°06'E
Glinyanoe	Au-Ag epithermal vein	Au, Ag	46°11'N 137°55'E
Moinskoe	Porphyry Mo	Mo	48°06'N 138°38'E
Mopau	Porphyry Sn	Sn	49°20'N 138°47'E
Nesterovskoe	Porphyry Cu	Cu	46°04'N 137°49'E
Nochnoe	Porphyry Cu	Cu	48°34'N 138°35'E
Salyut	Au-Ag epithermal vein	Au, Ag	46°22'N 137°41'E
Sukhoe	Au-Ag epithermal vein	Au, Ag	46°58'N 138°09'E
Sukhoi Creek	Porphyry Cu-Mo	Cu, Mo	48°12'N 138°12'E
Tayozhnoe	Ag epithermal vein	Ag	45°30'N 136°39'E
Yagodnoe	Au-Ag epithermal vein	Au, Ag	47°09'N 138°35'E
Luzhkinsky Metallogenic Belt of Sn Greisen, Sn Polymetallic Vein, Sn silica-sulfide vein, and Porphyry Sn Deposits (mid-Cretaceous to early Tertiary), Southern Part of Russian Southeast (Belt LZ)			
Arsenyevskoe	Sn silicate-sulfide vein	Sn	44°25'N 134°47'E
Dalnetayozhnoe	Sn polymetallic vein	Sn, Pb, Zn	45°40'N 136°08'E
Iskra	Sn polymetallic vein	Sn,	44°13'N 134°32'E
Khrustalnoe	Sn silicate-sulfide vein	Sn	44°28'N 134°59'E
Lazurnoe	Porphyry Cu-Mo	Cu, Mo	44°06'N 134°24'E
Malinovskoe	Porphyry Cu	Cu	45°08'N 135°02'E
Nizhnee	Sn polymetallic vein	Sn, Pb, Zn	43°37'N 134°15'E
Smirnovskoe	Polymetallic vein	Pb, Zn, Sn	44°38'N 135°20'E
Tigrinoe	Sn-W greisen	Sn, W, Ta, Nb, In	46°05'N 135°45'E
Verkhnezolotoe	Porphyry Cu	Cu, Sn	46°32'N 136°26'E
Vysokogorskoe	Sn silicate-sulfide vein	Sn	44°21'N 135°10'E
Yantarnoe	Porphyry Sn	Sn	46°20'N 136°34'E
Yuzhnoe	Polymetallic vein	Pb, Zn, Ag	44°45'N 135°21'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Zabytoe	W-Sn greisen	W, Sn, Bi	45°39'N 135°25'E
Zarechnoe	Porphyry Cu	Cu	44°39'N 134°39'E
Zimnee	Sn polymetallic vein	Sn, Pb, Zn	45°46'N 135°58'E
Zvezdnoe	Porphyry Sn	Sn	46°10'N 136°30'E
Lower Amur Metallogenic Belt of Au-Ag Epithermal Vein, Porphyry Cu, and Sn Greisen Deposits (mid-Cretaceous to early Tertiary), Northern Part of Russian Southeast (Belt LA)			
Belaya Gora	Au-Ag epithermal Vein	Au, Ag	53°23'N 140°14'E
Bichinskoe	Sn greisen	W, Sn	52°32'N 139°32'E
Bukhtyanskoe	Au-Ag epithermal vein	Au, Ag	53°03'N 140°29'E
Mnogovershinnoe	Au-Ag epithermal vein	Au, Ag	53°53'N 139°48'E
Tyrskoe	Porphyry Cu	Cu	52°57'N 140°27'E
Aniva-Nabil Metallogenic Belt of Volcanogenic Mn and Fe and Cyprus Massive Sulfide Deposits (Late Cretaceous), Eastern Part of Russian Southeast (Belt LA)			
Bereznyakovskoe	Volcanogenic Mn	Mn	47°04'N 142°56'E
Lyukamskoe	Volcanogenic Mn	Mn	49°58'N 143°35'E
Novikovskoe	Cyprus massive sulfide(?)	Cu, Zn, Pb	46°18'N 143°26'E
Rys'e	Cyprus massive sulfide	Cu, Pb, Zn	49°31'N 144°01'E
Koryak Highlands Metallogenic Belt of Zoned Mafic-Ultramafic PGE Deposits (Upper Cretaceous) East-Central Part of Russian Northeast (Belt KH)			
Karagin group	Gabbroic Cu	Cu, Zn, Au, Pt, Ni, Co	58°52'N 164°02'E
Snezhnoe	Zoned mafic-ultramafic Cr-PGE	Cr, PGE	61°37'N 171°39'E
Galmeonsky-Seinavsky	Alaskan PGE	PGE, Cr	61°34'N 166°05'E
Vatyn Metallogenic Belt of Volcanogenic Mn and Fe Deposits (Early Cretaceous), Southeastern Part of Russian Northeast (Belt VT)			
Itchayvayam	Volcanogenic Mn	Mn	61°24'N 172°20'E
Dogdo-Erikit Zone (Eastern Asia-Arctic Metallogenic Belt) of Au-Ag Epithermal Vein, Sn-polymetallic vein (Southern Bolivian type?), and Volcanic-Hosted Hg (Plamennoe type) Deposits (Late Cretaceous and early Tertiary) West-Central Part of Russian Northeast (Belt EADE)			
Dogdo	Volcanic-hosted Hg	Hg	67°21'N 139°27'E
Kysylga	Au-Ag epithermal vein	Au, Ag	67°33'N 137°55'E
Shirokoe	Au-Ag epithermal vein	Au, Ag	65°36'N 144°33'E
Solkuchan (Khatys)	Sn polymetallic vein	Ag, Sn	65°15'N 143°51'E
Tikhon	Au-Ag epithermal vein	Ag, Au	65°48'N 143°27'E
Okhotsk Zone (Eastern Asia-Arctic Metallogenic Belt) of Au-Ag Epithermal Vein Deposits (mainly Late Cretaceous and early Tertiary), Southeastern Part of Russian Northeast (Belt EAOH)			
Agat	Au-Ag epithermal vein	Au, Ag	60°58'N 150°53'E
Aldigych	Au-Ag epithermal vein	Au, Ag	62°19'N 159°58'E
Burgagylkan	Au-Ag epithermal vein	Au, Ag	60°38'N 146°45'E
Druchak	Au-Ag epithermal vein	Ag, Au	62°60'N 160°03'E
Evenskoe	Au-Ag epithermal vein	Au, Ag	62°32'N 159°45'E
Irbychan	Au-Ag epithermal vein	Au, Ag	62°41'N 159°55'E
Julietta	Au-Ag epithermal vein	Au, Ag	61°10'N 153°59'E
Karamken	Au-Ag epithermal vein	Au, Ag	60°14'N 150°60'E
Kegali	Au-Ag epithermal vein	Au, Ag	63°23'N 161°42'E
Khakandzhinskoe (Khakandzha)	Au-Ag epithermal vein	Au, Ag	60°02'N 142°36'E
Kinzhal	Sn silicate-sulfide vein	Sn	62°17'N 151°58'E
Kolkhida	Au-Ag epithermal vein	Ag, Au, Sn	60°37'N 151°27'E
Krasivoe	Au-Ag epithermal vein	Au, Ag	59°28'N 140°22'E
Maltan Stock	Granitoid-related Au	Au, Bi, Te	61°28'N 150°52'E
Nevenrekan	Au-Ag epithermal vein	Au, Ag	62°14'N 159°11'E
Oira	Au-Ag epithermal vein	Au, Ag	60°09'N 149°45'E
Olyndja	Au-Ag epithermal vein	Ag, Au	62°26'N 157°35'E
Senon, Utro, Serebryanoe	Epithermal vein and volcanic-hosted Sb vein	Ag, Au, Sb	60°40'N 148°05'E
Sentyabr	Au-Ag epithermal vein	Ag, Au	60°44'N 149°22'E
Skarnovoe	Pb-Zn-Ag skarn	Zn, Pb, Ag	60°46'N 150°38'E
Spiridonych, Teply	Au-Ag epithermal vein	Au, Ag	61°20'N 156°17'E
Utessnoe	Au-Ag epithermal vein	Ag, Au, Hg	60°26'N 150°41'E
Verkhnenyotskoe	Au-Ag epithermal vein	Au, Ag	58°17'N 139°06'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Vetvisty	Au-Ag epithermal vein	Ag, Au	62°07'N 152°08'E
Yurievka	Au-Ag epithermal vein	Au, Ag	59°41'N 141°44'E
Koni-Yablon Zone (Eastern Asia-Arctic Metallogenic Belt) of Porphyry Cu-Mo and Cu-Mo Skarn Deposits (Cretaceous) Southern Part of Russian Northeast (Belt EAKY)			
Berezovogor	Au-Ag epithermal vein	Au, Ag, Pb	65°50'N 170°08'E
Etandzha	Porphyry Cu-Mo	Cu, Mo	57°29'N 138°39'E
Gora Krassnaya	Porphyry Cu-Mo	Mo, Cu, Au	66°35'N 175°31'E
Guan-Ti (Arkhimed)	Porphyry Mo	Mo, W	61°30'N 143°51'E
Ikrimun	Porphyry Cu-Mo	Cu, Mo	59°21'N 146°59'E
Irgunei	Au-Ag epithermal vein	Au, Ag	64°42'N 166°50'E
Khakandya	Porphyry Mo	Mo	60°49'N 153°32'E
Lastochka	Mo greisen and vein	Mo	64°32'N 165°07'E
Maly Komui	Cu skarn	Cu	57°23'N 137°32'E
Molybdenitovy	Porphyry Mo	Mo	61°33'N 142°59'E
Nakhtandjin, Lora	Porphyry Cu	Cu	59°25'N 153°29'E
Nyavlenga	Au-Ag epithermal vein	Au, Ag	60°44'N 153°28'E
Osennee, Oksa, Usinskoe	Porphyry Cu-Mo	Mo, Cu	59°44'N 150°16'E
Sergeev	Au-Ag epithermal vein	Au, Ag	63°52'N 165°41'E
Serovskoe	Au-Ag epithermal vein	Au, Ag	65°17'N 169°00'E
Tikas	Porphyry Mo	Mo	61°40'N 161°21'E
Travka	Porphyry Mo	Mo	64°48'N 168°36'E
Tsirkovy	Granitoid-related Au	Au, Ag, Cu, W, Bi	63°33'N 165°07'E
Uralskoe	Volcanic-hosted Hg	Hg, Sb, Au, Ag	66°28'N 166°48'E
Viking	Porphyry Cu-Mo	Cu, Mo	58°58'N 152°34'E
Yapon	Porphyry Cu	Cu	59°25'N 154°52'E
Korkodon-Nayakhan Zone (Eastern Asia-Arctic Metallogenic Belt) of Porphyry Mo and Granitoid-Related Au Deposits (Late Cretaceous), East-Central Part of Russian Northeast (Belt EAKN)			
Khetagchan	Granitoid-related Au	Au, W, Bi	63°24'N 157°04'E
Orlinoe	Porphyry Mo	Mo	62°35'N 157°16'E
Sedoi	Ag-Co arsenide vein and Fe-Pb-Cu-Ag-Au skarn	Ag, Co	63°49'N 158°25'E
Skarn	Fe (±Au, Cu, W, Sn) skarn	Fe	63°29'N 158°32'E
Verkhny-Koargychan	Au-Ag Polymetallic vein	Au, Ag, Pb, Zn	63°07'N 159°19'E
Verkhne–Kolyma Zone (Eastern Asia-Arctic Metallogenic Belt) of Sn-Ag Polymetallic Vein, (Southern Bolivian type), Sn Polymetallic Vein, Rhyolite-Hosted Sn, and Granitoid-Related Au Deposits (Cretaceous), Southeastern Part of Russian Northeast (Belt EAVK)			
Aida	Au-Ag epithermal vein	Ag, Au	63°36'N 144°01'E
Baryllyelakh-Tsentralny	Sn polymetallic vein	Sn, Ag	63°26'N 143°48'E
Bogatyr	Sn silicate-sulfide vein	Sn	61°02'N 145°55'E
Bulunga	Pb-Zn-Ag vein or skarn	Pb, Zn, Ag	62°18'N 145°42'E
Dneprov	Sn silicate-sulfide vein and Sn greisen	Sn	61°20'N 151°36'E
Kandychan	Sn polymetallic vein	Sn, Ag	60°36'N 150°20'E
Kharan	Sn polymetallic vein	Sn	61°56'N 146°03'E
Khenikandja	Sn silicate-sulfide and Sn polymetallic vein	Sn	61°49'N 146°31'E
Kheta	Sn polymetallic vein	Sn, Zn, Pb, Cu, Bi, Ag	61°06'N 151°47'E
Khuren	Sn polymetallic vein	Sn	60°54'N 147°10'E
Kuranakh-Sala	Sn silicate-sulfide vein	Sn	63°03'N 144°19'E
Kyurbelykh	Sn silicate-sulfide vein and Sn polymetallic vein	Sn	62°46'N 145°29'E
Netchen-Khaya	Granitoid-related Au	Au, Mo, Bi	61°42'N 151°32'E
Ossolonyn	Sn greisen	Sn	61°43'N 153°19'E
Porozhistoe	Sn polymetallic vein	Sn	61°36'N 146°28'E
Shkolnoe	Granitoid-related Au	Au	61°28'N 148°48'E
Suvorov	Rhyolite-hosted Sn	Sn	61°00'N 152°09'E
Svetloe	Sn polymetallic vein	Sn	60°46'N 150°16'E
Tankist	Porphyry Mo	Mo	61°21'N 147°56'E
Tektonicheskoe	Pb-Zn-Ag vein	Pb, Zn, Ag, Sn	62°26'N 145°15'E
Tigrets-Industriya	Sn polymetallic vein	Sn, Ag, Pb, Zn	62°16'N 146°31'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Verkhne-Seimkan	Co-Bi-As vein	Co, Bi	60°31'N 149°60'E
Zerkalnoe	Au-Ag epithermal vein	Au, Ag, Bi, Te	60°58'N 151°10'E
Vostochno-Verkhoyansk Zone (Eastern Asia-Arctic metallogenic belt) of Ag Polymetallic Vein Deposits (Late Cretaceous and early Tertiary), West-Central Part of Russian Northeast (Belt EAVV)			
Altaiskoe	Ag polymetallic vein	Pb, Zn, Ag	63°01'N 140°43'E
Bezymyannoe	Ag polymetallic vein	Ag, Pb	65°39'N 130°36'E
Imtachan	Sn polymetallic vein	Pb, Zn, Sn	62°57'N 139°44'E
Kuolanda	Ag polymetallic vein	Pb, Zn, Ag	67°11'N 127°45'E
Mangazeika	Ag polymetallic vein	Pb, Ag	65°46'N 130°35'E
Prognoz	Ag polymetallic vein	Ag, Pb	65°41'N 133°29'E
Verkhnee Menkeche	Ag polymetallic vein	Pb, Zn, Ag	62°56'N 139°27'E
Adycha-Taryn Zone (Eastern Asia-Arctic Metallogenic Belt) of Clastic Sediment-Hosted Sb-Au, Au-Ag Epithermal Vein, and Ag-Sb Polymetallic Vein Deposits (Cretaceous and early Tertiary), Western Part of Russian Northeast (Belt EAAT)			
Ak-Altyn	Au-Ag epithermal vein	Au	67°02'N 133°60'E
Billyakh	Au-Sb polymetallic vein	Sb, Au	67°35'N 134°06'E
Maltan	Sb-Au vein	Au, Sb	64°03'N 143°19'E
Sarylakh	Sb-Au vein	Au, Sb	64°17'N 142°46'E
Sentachan	Sb-Au vein or clastic sediment-hosted Sb-Au	Sb	66°29'N 137°03'E
Uzlovoe	Sb-Au vein or clastic sediment-hosted Sb-Au	Au, Sb	66°06'N 137°48'E
Omsukchan Zone (Eastern Asia-Arctic Metallogenic Belt) of Sn Polymetallic Vein, Sn Silicate-Sulfide, Porphyry Sn, Ag Epithermal Vein, Porphyry Mo-Cu, and Associated Deposits (Late Cretaceous) Southeastern Part of Russian Northeast (Belt EAOM)			
Arylakh	Au-Ag epithermal vein	Ag, Au	63°08'N 154°58'E
Dukat	Au-Ag epithermal vein	Ag, Au	62°36'N 155°11'E
Egorlyk	Sn silicate-sulfide vein	Sn	63°27'N 154°55'E
Elombal, Yakor	Sb-Au vein?	Au, As, Sb	67°45'N 165°27'E
Galimoe	Sn silicate-sulfide vein	Sn, Ag	62°21'N 155°49'E
Ircha	Porphyry Sn	Sn, Ag	61°51'N 155°39'E
Khataren-Industrial	Sn silicate-sulfide vein	Sn	62°33'N 155°34'E
Maly Ken	Sn polymetallic vein	Sn, Ag	62°44'N 154°60'E
Mechta	Ag-Pb-Zn vein , Polymetallic vein(?)	Ag, Pb, Zn	62°48'N 155°05'E
Nevskoe	Porphyry Sn	Sn, W, Se	62°16'N 155°26'E
Novy Djagyn	Porphyry Sn	Sn	62°48'N 155°25'E
Okhotnichie	Sn silicate-sulfide vein	Sn	62°04'N 155°14'E
Podgornoe	Au-Co-As vein	Au, Co, Bi, Te, (As)	62°37'N 155°48'E
Rogovik	Au-Ag epithermal vein	Ag, Au	64°18'N 153°58'E
Tidit	Ag-Pb-Zn vein, Polymetallic vein(?)	Ag, Pb, Zn	62°51'N 155°11'E
Trood	Sn polymetallic vein	Sn, Pb Zn, Ag	62°04'N 155°42'E
Chokurdak Metallogenic Belt of Granitoid-Related Sn Greisen, Sn-Polymetallic Vein, Sn Greisen, and Au-Ag Epithermal Vein Deposits (Early and mid-Cretaceous), Northern Part of Russian Northeast (Belt CD)			
Chokurdakh	Sn silicate tourmaline, Sn silicate-sulfide vein	Sn	72°14'N 140°18'E
Churpunnya	Sn silicate-sulfide vein	Sn	71°06'N 141°43'E
Deputatskoe	Sn polymetallic vein(?)	Sn	69°15'N 139°58'E
Djaktardakh	Sn polymetallic vein	Sn	69°10'N 141°20'E
Khomustak	Sn greisen	Sn	70°05'N 152°28'E
Odinokoe	Sn greisen	Sn	69°42'N 142°01'E
Pavel-Chokhchurskoe	Sn polymetallic vein and greisen	Sn	70°10'N 140°48'E
Primorskoe	Sn polymetallic vein	Sn	69°56'N 153°22'E
Sigilyakh	Sn silicate-sulfide vein	Sn	69°54'N 136°47'E
Ukachilkan	Sn polymetallic vein	Sn	69°55'N 139°19'E
Yuzhnoe	Polymetallic vein	Pb, Zn	69°31'N 150°42'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Chaun Zone (Eastern Asia-Arctic Metallogenic Belt) of Granitic-Magmatism-Related Deposits (Late Cretaceous) Northeastern Part of Russian Northeast (Belt EACN)			
Barin	Ag polymetallic vein and replacement	Ag, Zn	66°22'N 172°04'W
Chechekuyum	Pb-Zn skarn	Pb, Zn, Cu, Ni	64°36'N 172°45'W
Dioritovoe	Sn polymetallic vein	Sn	65°40'N 174°06'W
Ekug	Porphyry Sn or Sn greisen	Sn, W	67°34'N 178°04'W
Elmaun	Sn silicate-sulfide vein	Sn	66°19'N 179°46'W
Enpylkhkan	Pb-Zn skarn	Pb, Zn, Cu, Ag	65°20'N 174°16'W
Erulen	Sn silicate-sulfide vein	Sn	66°09'N 173°17'W
Eruttin	Sn silicate-sulfide vein	Sn	66°24'N 178°55'W
Granatnoe	Porphyry Mo	Mo	67°12'N 179°09'W
Ichatkin	Sn silicate-sulfide vein	Sn	69°41'N 163°11'E
Kekur	Sn silicate-sulfide vein	Sn	69°49'N 171°52'E
Kuekvun	Granitoid-related Au	Au, Bi, Te, Sn, W	68°46'N 178°53'E
Kukenei	Sn polymetallic vein	Sn, Ag	69°08'N 174°05'E
Lunnoe	Sn silicate-sulfide vein	Sn, W	68°49'N 174°49'E
Melyul	Pb-Zn-(Cu)-Ag skarn	Pb, Zn, Ag, (Cu)	66°16'N 172°04'W
Mramornoe	Sn polymetallic vein	Sn, Ag	68°06'N 176°30'E
Mymlerennet	Sn silicate-sulfide vein	Sn	67°47'N 179°46'E
Pepenveem	Au-Ag epithermal vein	Au, Ag	65°52'N 175°37'W
Pyrkakai	Porphyry Sn	Sn, W	69°33'N 171°57'E
Reechen	Fe-Pb-Zn-Sn skarn	Fe, Pb, Zn, Sn	64°57'N 172°29'W
Serdtse-Kamen	Pb-Zn skarn	Pb, Zn, Cu, Sn, Ag	66°50'N 171°44'W
Shurykan	Porphyry Cu-Mo	Mo, Cu	68°44'N 174°23'E
Telekai	Sn silicate-sulfide vein and Sn greisen	Sn	67°59'N 178°05'E
Tumannoe	Disseminated Au-sulfide	Au, As, Sb	67°40'N 178°06'W
Valkumei	Sn silicate-sulfide vein	Sn	69°39'N 170°12'E
Vodorazdelnoye	Sn silicate-sulfide vein	Sn	67°55'N 178°51'E
Yassnoe	Clastic sediment-hosted Hg or hot-spring Hg?	Hg	68°23'N 167°48'E
Chukotka Metallogenic Belt of Au Quartz Vein and Sn and Sn-W Polymetallic Vein Deposits (Early Cretaceous) Northern Part of Russian Northeast (Belt CH)			
Chaantal	Sn quartz vein and Sn greisen	Sn, W	67°52'N 179°25'W
Dvoinoi	Au quartz vein	Au	69°33'N 176°02'E
Iultin	Sn quartz vein	Sn, W	67°51'N 178°44'W
Karalveem	Au quartz vein	Au	68°11'N 166°09'E
Lenotap	Au quartz vein	Au	67°47'N 178°47'W
Ozernoe	Au quartz vein	Au	68°15'N 165°56'E
Ryveem	Au quartz vein	Au	69°21'N 178°19'E
Sredne-Ichuveem	Au quartz vein	Au	69°14'N 172°56'E
Svetlin	Au quartz vein	Au	67°49'N 167°28'E
Svetloe	Sn quartz vein	Sn, W	68°04'N 178°19'W
Tenkergin	Sn quartz vein	W, Sn	68°11'N 178°55'W
East-Central Alaska Metallogenic Belt of Granitic Magmatism Deposits (Early Cretaceous to early Tertiary) East-Central Alaska (Belt ECA) (Older Part)			
Avnet (Buzby)*	Mn-Ag vein	Mn, Ag	65°16'N 150°25'W
Banjo (Kantishna district)	Polymetallic vein	Au, Ag, Pb, Zn, Sb	63°34'N 150°44'W
Bedrock Creek*	Porphyry Cu(?)	Cu, W, Th	65°27'N 144°50'W
Blue Lead, Tibbs Creek, Gray Lead	Polymetallic vein or Sb-Au vein	Au, Ag, Sb	64°20'N 144°14'W
Bluff*	Porphyry Cu-Mo	Cu, Mo	63°38'N 141°29'W
Caribou Creek, Eagles Den, Slate Creek (Kantishna district)	Sb-Au vein	Sb	63°25'N 151°12'W
Cleary Summit	Polymetallic vein, Au-quartz vein	Au, Ag	65°04'N 147°25'W
Democrat (Mitchell Lode)	Granitoid-related Au	Au, Ag, Pb, Sb	64°20'N 146°22'W
Dempsey Pup	Sb-Au vein or polymetallic vein(?)	Sb, Au(?)	65°21'N 146°33'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Ester Dome (Ryan Lode)	Polymetallic vein(?)	Au, Ag	64°52'N 148°05'W
Fort Knox	Granitoid-related Au	Au, Ag, Mo	65°07'N 147°23'W
Gertrude Creek, Griffen, Ruth Creek	Sb-Au vein	Au, Sb	65°31'N 148°30'W
Granite Mountain*	Porphyry Cu-Mo	Cu, Mo	62°19'N 136°58'W
Hot Springs Dome*	Polymetallic vein	Pb, Ag, Zn, Au	65°02'N 150°45'W
Hudson Cinnabar	Hg quartz vein	Hg	65°30'N 148°22'W
Miller House*	Au-As polymetallic vein	Au	65°33'N 145°15'W
Pogo	Granitoid-related Au	Au, As, Cu, Bi	
Quigley Ridge (Kantishna district)	Polymetallic vein	Ag, Au, Pb, Zn	63°33'N 150°45'W
Salcha River*	W skarn	W	65°07'N 144°38'W
Sawtooth Mountain	Sb-Au vein	Sb	65°23'N 149°30'W
Scrafford	Sb-Au vein	Sb, Au	65°00'N 147°49'W
Spruce Creek (Kantishna district)	Polymetallic vein	Au, Ag, Pb, Zn, Sb	63°35'N 151°35'W
Stampede (Kantishna district)	Sb-Au vein	Sb	63°45'N 150°25'W
Stepovich Lode	W skarn	W, Au	64°59'N 147°21'W
Table Mountain	Sn polymetallic vein	Au	65°29'N 145°53'W
*** - Age not well established; deposit could be part of younger part of East-Central Alaska metallogenic belt (Late Cretaceous and early Tertiary)**			
Yukon-Tanana Upland Metallogenic Belt of Au Quartz Vein Deposits (Late Cretaceous), East-Central Alaska (Belt YT)			
Purdy	Au-quartz vein	Au	64°07'N 141°55'E
Wrangell Mountains Metallogenic Belt of Cu-Ag Quartz Vein and Kennecott Cu Deposits (mid-Cretaceous) Eastern-South Alaska (Belt WR)			
Erickson	Basaltic Cu	Cu	61°25'N 142°15'W
Kathleen-Margaret	Cu-Ag quartz vein	Cu, Ag, Au	63°17'N 146°33'W
Kennecott District	Kennecott Cu	Cu, Ag	61°31'N 142°50'W
Nelson (Glacier Creek)	Kennecott Cu	Cu, Ag	61°27'N 142°23'W
Nikolai	Cu-Ag quartz vein	Cu, Ag	61°28'N 142°41'W
Nugget Creek	Cu-Ag quartz vein	Cu, Ag	61°39'N 143°43'W
Westover	Kennecott Cu	Cu, Ag	61°24'N 142°30'W
LATE CRETACEOUS AND EARLY TERTIARY (Campanian through early Eocene - 84 to 52 Ma)			
Iruneiskiy Metallogenic Belt of Porphyry Mo Deposits (Late Cretaceous), Southern Kamchatka Peninsula (Belt IR)			
Kirganik	Porphyry Mo	Mo	55°01'N 157°38'E
Verkhne-Yudomsky (Yuzhno-Verkhoyansk) Zone (Eastern Asia-Arctic Metallogenic Belt) of Sn Polymetallic Vein (Southern Bolivian type) Deposits (Cretaceous), Western Part of Russian Northeast (Belt EAVY)			
Balaakkalakh, Diring-Yuryak	Sn polymetallic vein	Sn	59°51'N 139°01'E
Dzhaton	Pb-Zn polymetallic vein	Pb, Zn, Ag	61°49'N 140°15'E
Khaardak	Sn polymetallic vein	Sn	62°03'N 140°44'E
Khoron	Sn polymetallic vein	Sn	62°39'N 140°49'E
Nivandzha	Polymetallic vein	Pb, Zn, Ag	61°33'N 141°14'E
Zarnitsa, Kutinskoe	Polymetallic vein	Pb, Zn, Ag	62°27'N 140°18'E
Verkhoyansk-Indigirka (Dulgalak) Zone (Eastern Asia-Arctic Metallogenic Belt) of Clastic Sediment-Hosted Hg and Sb-Au Vein Deposits (Late Cretaceous and early Tertiary), Western Part of Russian Northeast (Belt EAVI)			
Baidakh	Sb-Au vein	Sb	70°05'N 135°32'E
Beryugen	Sb vein	Sb	67°06'N 131°36'E
Erel	Clastic sediment-hosted Hg	Hg	64°30'N 138°25'E
Imnekan	Sb vein	Sb	64°46'N 135°44'E
Iserdek	Clastic sediment-hosted Hg	Hg	67°08'N 130°41'E
Kholbolok	Clastic sediment-hosted Hg	Hg	66°15'N 131°48'E
Kyuchyuss	Sb-Au-Hg vein	Au, Hg, Sb	69°48'N 134°45'E
Seikimyan	Clastic sediment-hosted Hg	Hg	64°08'N 139°52'E
Selerikan	Sb vein	Sb	64°13'N 140°25'E
Senduchen	Sb-As vein	As, Sb	63°21'N 138°24'E
Singyami	Clastic sediment-hosted Hg	Hg	64°42'N 137°40'E
Stibnitovoe	Sb vein	Sb	63°14'N 138°30'E
Zagadka	Clastic sediment-hosted Hg	Hg, Sb	66°55'N 131°01'E
Zvezdochka	Clastic sediment-hosted Hg	Hg	66°43'N 131°03'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Anuyi-Beringovsky Zone (Eastern Asia-Arctic Metallogenic Belt) of Au-Ag Epithermal Vein and Disseminated Gold Sulfide Deposits (Late Cretaceous), Northeastern Part of Russian Northeast (Belt EAAB)			
Chineyveem	Au-Ag epithermal vein	Au, Ag	66°11'N 171°26'E
Draznyashy, Upryamy	Au-Ag epithermal vein	Au	68°34'N 168°34'E
Elveney	Au sulfide disseminated	Au, As	68°20'N 168°34'E
Enmyvaam	Au-Ag epithermal vein	Au, Ag	67°02'N 171°58'E
Gora Sypuchaya	Au quartz vein and Au-sulfide disseminated	Au	68°59'N 172°57'E
Gornostai	Au-Ag epithermal vein	Au, Ag	66°15'N 169°34'E
Maiskoe	Disseminated Au sulfide	Au, As, Sb, Ag	69°02'N 173°44'E
Maly Peledon	Au-Ag epithermal vein	Au, Ag	66°14'N 167°56'E
Pelvuntykoinen	Granitoid-related Au	Au, Bi, Te	68°08'N 168°51'E
Promezhutochnoe	Au-Ag epithermal vein	Au, Ag	68°53'N 173°48'E
Shakh, Zhilny	Au-Ag epithermal vein	Au, Ag	66°22'N 177°11'E
Sopka Rudnaya	Au-Ag epithermal vein	Au, Ag	68°58'N 174°03'E
Valunistoe	Au-Ag epithermal vein	Au, Ag	66°28'N 177°38'E
Chukotka Zone (Eastern Asia-Arctic Metallogenic Belt) of Igneous-Related Hg Deposits (Late Cretaceous) Northeastern Part of Russian Northeast (Belt EACH)			
Kulpolney	Volcanic-hosted Hg	Hg	67°13'N 166°16'E
Kyttamlai	Clastic sediment-hosted Hg or hot-spring Hg?	Hg, Sb	68°54'N 167°60'E
Matachingai	Silica-carbonate Hg	Hg	66°25'N 179°22'W
Omrelkai	Volcanic-hosted Hg	Hg, Sb	67°60'N 170°36'E
Palyan	Clastic sediment-hosted Hg or hot-spring Hg?	Hg	69°01'N 172°09'E
Plamennoe	Volcanic-hosted Hg	Hg, Sb	68°21'N 177°12'E
Seward Peninsula Metallogenic Belt of Granitic Magmatism Deposits (Late Cretaceous), Northwestern Alaska (Belt SP)			
Cape Mountain	Sn quartz vein	Sn	65°35'N 168°00'W
Death Valley	Sediment-hosted U	U	65°03'N 162°15'W
Eagle Creek	Felsic plutonic U	U, Th, REE	64°42'N 162°46'W
Ear Mountain area (Winfield)	Sn skarn	Sn, Cu, Ag, Pb, Zn	65°56'N 166°12'W
Independence	Polymetallic vein	Pb, Ag	65°41'N 162°28'W
Kougarok	Sn greisen with Ta and Nb	Sn, Ta, Nb	65°41'N 165°14'W
Lost River	Sn-W skarn, Sn greisen, Carbonate-replacement Sn(?)	Sn, W, F, Be	65°28'N 167°10'W
Omilak area	Polymetallic vein	Pb, Ag, Sb	65°02'N 162°41'W
Potato Mountain	Sn quartz vein	Sn	65°38'N 167°35'W
Quartz Creek	Polymetallic vein	Pb, Zn, As, Ag	65°30'N 161°26'W
Serpentine Hot Springs	Polymetallic vein	Pb, Zn, As, Ag, Au, Sn	65°48'N 164°32'W
Windy Creek	Porphyry Mo	Mo	65°10'N 162°37'W
Northwestern Koyukuk Basin Metallogenic Belt of Felsic Plutonic U and Manto-Replacement (Polymetallic Pn-Zn, Au) Deposits (Late Cretaceous), West-Central Alaska (Belt NWK)			
Clear Creek	Felsic plutonic U	U	66°15'N 156°03'W
Wheeler Creek	Felsic plutonic U	U	66°16'N 157°20'W
Zane Hills	Felsic plutonic U	U, Th	66°12'N 156°15'W
Illinois Creek	Manto-replacement deposit (polymetallic Pn-Zn, Au)	Au, Ag	64°05'N 158°00'W
West-Central Alaska Metallogenic Belt of Porphyry Cu-Au Deposits (Hogatza) (Late Cretaceous) West-Central Alaska (Belt WCA)			
Indian Mountain and Purcell Mountain	Porphyry Cu-Au	Cu, Au	66°22'N 155°02'W
Zane Hills	Porphyry Cu-Au	Cu, Au	66°38'N 155°55'W
Kuskokwim Mountains Metallogenic Belt of Granitic-Magmatism-Related Deposits (Late Cretaceous and early Tertiary), Southwestern Alaska (Belt KMT)			
Arnold prospect	Granitoid-related Au	Au, Ag	61°52'N 161°58'W
Beaver Creek	Polymetallic vein	Ag, Pb, Zn	64°45'N 155°30'W
Beaver Mountains	Porphyry Cu-Au	Cu, Au, Ag	62°54'N 156°58'W
Broken Shovel, Iditarod	Polymetallic vein	Ag, Pb, Sb	62°37'N 157°10'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Candle	Polymetallic vein or porphyry Cu?	Cu, Pb, Ag	62°51'N 155°48'W
Chicken Mountain, Black Creek (Flat District)	Granitoid-related Au-Ag (Cu)	Au, As, Hg, Sb, Cu, Mo	62°30'N 158°00'W
Cinnabar Creek	Hot-spring Hg	Sb, Hg	60°46'N 158°46'W
Cirque, Tolstoi	Polymetallic vein and porphyry Cu	Cu, Ag, Sn	62°53'N 156°59'W
DeCourcey Mountain	Hot-spring Hg	Hg, Sb, As	62°15'N 158°30'W
Donlin Creek	Porphyry Au	Au	62°18'N 158°24'W
Fortyseven Creek	Polymetallic vein(?)	Au, W	61°07'N 158°15'W
Golden Horn, Minnie Gulch, Malemute, Iditarod (Flat District)	Polymetallic vein or Sb-Au vein	Au, Ag, Sb, Hg, W	62°31'N 157°55'W
Independence	Porphyry Au	Au	62°57'N 156°59'W
Kagati Lake	Sb-Hg vein	Sb, Hg	59°52'N 159°54'W
McLeod	Porphyry Mo	Mo	63°16'N 159°16'W
Medfra	Fe skarn	Fe, Cu, Zn, Au	63°40'N 154°04'W
Mission Creek, Headwall, Louise, and Owhat Prospect	Polymetallic vein	Au, Ag, Cu, As	61°46'N 158°32'W
Molybdenum Mountain	Porphyry Mo	Mo	62°05'N 158°48'W
Nixon Fork-Medfra	Cu-Au skarn	Au, Cu, Ag, Bi, Sn, W, Th	63°14'N 154°47'W
Perseverance	Polymetallic vein(?)	Pb, Ag, Sb	64°45'N 157°30'W
Red Devil	Clastic sediment-hosted Hg	Hg, Sb	61°45'N 157°23'W
Sischu Creek	Felsic plutonic U	U, Th	63°58'N 153°17'W
Sleitat	Sn greisen and skarn	Sn, Ag, W, As	60°03'N 157°05'W
Snow Gulch-Donlin	Sb-Au vein	Sb, Au, As, Hg	62°13'N 158°15'W
Taylor Mountains	Hg-Ag epithermal vein(?)	Hg, Au	60°52'N 157°40'W
Vinasale Mountain	Granitoid-Related (Porphyry) Au	Au	62°36'N 156°08'W
Von Frank Mountain	Porphyry Cu-Ag	Cu, Ag	63°38'N 155°04'W
Win-Won or Cloudy Mountain	Sn polymetallic vein	Sn, Ag, Cu	63°13'N 156°04'W
Wolf Mountain	Felsic plutonic U	U, Th, As, Nb, Mo, REE	62°20'N 161°29'W
East-Central Alaska Metallogenic Belt of Granitic Magmatism Deposits (Younger, Late Cretaceous and Early Tertiary Part) (East-Central Alaska and Western Yukon Territory – Carmacks area) (Belt ECA)			
Asarco	Porphyry Cu-Mo	Cu, Mo	63°22'N 142°30'W
Cash (Klazan, Johnny)	Porphyry Cu-Mo	Cu, Mo	62°26'N 137°37'W
Casino (Patton Hill)	Porphyry Cu-Mo	Cu, Mo	62°44'N 138°49'W
Ketchem Dome	Sn greisen	Sn	65°29'N 144°53'W
Lime Peak	Sn greisen and Sn vein	Sn, Ag, Zn, U, W	65°37'N 146°43'W
Mosquito	Porphyry Cu-Mo	Cu, Mo	63°53'N 143°28'W
Roy Creek (former Mt. Prindle)	Felsic plutonic U	U, Th	65°29'N 147°05'W
Road Metal	Tourmaline-topaz-quartz-sulfide greisen	Au, Ag, Cu, Bi	63°02'N 141°20'W
Taurus	Porphyry Cu-Mo	Cu, Mo	63°39'N 141°19'W
Southern Alaska Metallogenic Belt of Granitic Magmatism Deposits (Late Cretaceous and early Tertiary) Central and Northern Part of Southern Alaska (Belt SA)			
Bonanza Hills	Polymetallic vein and Porphyry Cu	Ag, Cu, Pb, Au	60°45'N 154°30'W
Boulder Creek (Purkeypile)	Sn greisen(?)	Sn	62°53'N 152°08'W
Bowser Creek	Pb-Zn skarn	Ag, Pb, Zn	62°11'N 153°40'W
Coal Creek	Sn greisen(?) and Sn vein	Sn, Ag, W, Zn	63°15'N 149°14'W
Golden Zone	Polymetallic vein and Au-Ag breccia pipe or Cu-Au porphyry	Au, Cu, Zn, As, Sb, Ag, Pb	63°13'N 149°39'W
Kijik River	Polymetallic vein and porphyry Cu	Cu, Mo	60°17'N 154°15'W
Miss Molly (Hayes Glacier)	Porphyry Mo	Mo	60°51'N 151°48'W
Nabesna Glacier and adjacent areas.	Polymetallic vein(?)	Cu, Zn, Au	62°07'N 142°50'W
Nim, Nimbus, Silver King	Polymetallic vein and Porphyry	Au, Ag, Cu	63°17'N 149°27'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
	Cu(?)		
Ohio Creek	Sn greisen and Sn vein	Sn	63°11'N 149°55'W
Partin Creek	Polymetallic vein or Cu-Ag quartz vein	Cu, Au, Ag	62°54'N 149°57'W
Rat Fork, Sheep Creek	Cu-Pb-Zn skarn	Cu, Zn, Pb	62°14'N 153°48'W
Ready Cash	Polymetallic vein(?)	Au, Cu, Pb, Ag, Sn, Zn	63°09'N 149°52'W
Tin Creek	Cu-Pb-Zn skarn	Pb, Zn, Cu	62°23'N 153°38'W
Treasure Creek	Porphyry Cu-Mo	Mo, Cu	62°53'N 149°18'W
Zackly	Cu-Au skarn	Au, Cu, Ag	63°13'N 146°42'W
Baranof Metallogenic Belt of Au Quartz Vein Deposits (early Tertiary), Southeastern Alaska (Belt BN)			
Apex and El Nido	Au quartz vein	Au, Ag	57°57'N 136°16'W
Chichagoff, Hirst-Chichagof	Au quartz vein	Au	57°40'N 136°06'W
Cobol	Au quartz vein	Au	57°51'N 136°13'W
Reid Inlet	Au quartz vein	Au, Pb	58°52'N 136°52'W
Maclaren Metallogenic Belt of Au Quartz Vein Deposits (Early Tertiary), Central and Northern Part of Southern Alaska (Belt MC)			
Lucky Hill and Timberline Creek	Au quartz vein	Au	63°11'N 147°16'W
Talkeetna Mountains Metallogenic Belt of Au Quartz Vein Deposits (early Tertiary), Northern Part of Southern Alaska (Belt TM)			
Independence (Willow Creek District that also includes Gold Bullion, Gold Cord, Lucky Shot, Thope)	Au quartz vein	Au	61°45'N 149°30'W
Chugach Mountains Metallogenic Belt of Au Quartz Vein Deposits (early Tertiary), Southern Alaska (Belt CM)			
Alaska Oracle, Gilpatrick	Au quartz vein	Au	60°37'N 149°34'W
Chalet Mountain (Cornelius Creek)	Au quartz vein	W, Au, Ag	57°48'N 152°20'W
Cliff (Port Valdez)	Au quartz vein	Au	61°07'N 146°33'W
Crown-Point, Kenai-Alaska	Au quartz vein	Au	60°27'N 149°18'W
Gold King	Au quartz vein	Au	61°12'N 146°44'W
Granite	Au quartz vein	Au	60°58'N 148°13'W
Lucky Strike (Palmer Creek)	Au quartz vein	Au	60°46'N 149°33'W
Mineral King (Herman and Eaton)	Au quartz vein	Au	60°57'N 148°21'W
Monarch, Jewel	Au quartz vein	Au	61°02'N 149°06'W
Nuka Bay District (Nualaska, Lost Creek, Alaska Hills)	Au quartz vein	Au	59°33'N 150°35'W
Ramsay-Rutherford	Au quartz vein	Au	61°12'N 146°06'W
Juneau Metallogenic Belt of Au Quartz Vein Deposits (early Tertiary), Southeastern Alaska (Belt JU)			
Alaska-Juneau	Au quartz vein	Au	58°18'N 134°20'W
Gold Standard (Helm Bay)	Au quartz vein	Au	55°39'N 132°00'W
Goldstream	Au quartz vein	Au, Cu, Pb, Zn	55°18'N 131°39'W
Jualin	Au quartz vein	Au	58°52'N 135°05'W
Kensington	Au quartz vein	Au	58°52'N 135°05'W
Riverside	Au quartz vein or polymetallic vein	Ag, Au, Cu, Pb, W, Zn	56°00'N 130°04'W
Sea Level	Au quartz vein	Au, Ag	55°22'N 131°12'W
Sumdum Chief	Au quartz vein	Au, Ag, Cu, Pb, Zn	57°39'N 133°27'W
Treadwell	Au quartz vein	Au, Ag, Cu	58°15'N 134°21'W
Prince William Sound Metallogenic Belt of Besshi and Cyprus Massive Sulfide Deposits (early Tertiary) Eastern-Southern Alaska (Belt PW)			
Copper Bullion, Rua Cove	Cyprus massive sulfide	Cu	60°21'N 147°39'W
Ellamar	Besshi massive sulfide	Cu, Au, Ag	60°54'N 146°42'W
Fidalgo-Alaska, Schlosser	Besshi massive sulfide(?)	Cu, Zn	60°46'N 146°25'W
Knight Island, Pandora	Cyprus massive sulfide	Cu	60°20'N 147°42'W
Latouche, Beatson	Besshi massive sulfide(?)	Cu, Ag, Zn	60°02'N 147°51'W
Midas	Besshi massive sulfide(?)	Cu, Ag, Au, Zn	61°01'N 146°16'W
Threeman, Standard Copper	Cyprus massive sulfide	Cu, Au, Ag	60°51'N 146°33'W
Yakobi Metallogenic Belt of Gabbroic Ni-Cu Deposits (Tertiary), Southeastern Alaska (Belt YK)			

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Bohemia Basin (Yakobi Island)	Gabbroic Ni-Cu	Ni, Cu	57°59'N 136°25'W
Brady Glacier	Gabbroic Ni-Cu	Cu, Ni, PGE	58°33'N 136°56'W
Mirror Harbor	Gabbroic Ni-Cu	Ni, Cu	57°47'N 136°19'W
Surprise Lake Metallogenic Belt of Porphyry Mo-W-Cu, and Au-Ag Polymetallic Vein Deposits (Late Cretaceous and early Tertiary), Northern British Columbia (Belt SL)			
Adanac-Adera (Ruby Creek) (104N 052)	Porphyry Mo	Mo, W	59°43'N 133°24'W
Mount Ogden (Nan, Moly-Taku)	Porphyry Mo	Mo	58°26'N 133°22'W
Mt. Haskin West (Joem, Rain, Moly Zone) (104P 059)	Porphyry Mo-W, Mo skarn	Mo, W	59°21'N 129°31'W
Red Mountain (Bug, Fox, Boswell River)	Porphyry Mo	Mo	60°59'N 133°44'W
S.Q.E. (Storie, Casmo) (104P 069)	Porphyry Mo	Mo	59°15'N 129°52'W
Sutlahine River Area (Thorn, Kay) (094D 005)	Porphyry Cu-Mo	Cu, Mo, Ag	58°32'N 132°47'W
Windy (Balsam, Star, Kuhn, Dead Goat) (104P 071; 104P 003; 104P 079)	W skarn	W, Mo	59°21'N 129°52'W
Engineer Mine (104M 014)	Au-Ag Polymetallic Vein	Au, Ag	54°29'N 134°14'W
Venus (082FSW 166)	Au-Ag Polymetallic Vein	Au, Ag	49°27'N 117°20'W
Central-Southeastern Alaska Metallogenic Belt of Porphyry Mo and Cu Deposits (Oligocene) Southeastern Alaska (Belt CSE)			
Groundhog Basin	Polymetallic vein(?), Sn granite, Porphyry Mo	Ag, Pb, Zn	56°31'N 132°04'W
Margerie Glacier	Porphyry Cu and lesser polymetallic vein	Cu, Ag, Au	59°01'N 137°05'W
North Bradfield Canal	Fe skarn	Fe, Cu	56°23'N 131°23'W
Nunatak (Muir Inlet)	Porphyry Mo-Cu	Mo	58°59'N 136°06'W
Quartz Hill	Porphyry Mo	Mo	55°24'N 130°29'W
Bulkley Metallogenic Belt of Porphyry Cu-Mo and Polymetallic Vein Deposits (Late Cretaceous) Central British Columbia (Belt BK)			
Glacier Gulch (Hudson Bay Mountain) (093L 110)	Porphyry Mo	Mo	54°49'N 127°18'W
Huckleberry (093E 037)	Porphyry Cu-Mo	Cu, Mo	53°41'N 127°10'W
Ox Lake (093E 004)	Porphyry Cu-Mo	Cu, Mo	53°41'N 127°03'W
Poplar (093L 239)	Porphyry Cu-Mo	Cu, Mo, Ag	54°01'N 126°59'W
Red Rose (093M 067)	W polymetallic vein	W, Au, Cu, Ag	55°08'N 127°36'W
Capoose Lake (093F 040)	Polymetallic vein	Au, Ag, Cu, Pb, Zn	55°08'N 127°36'W
Nadina (Silver Queen) (093L 083)	Ag polymetallic vein	Zn, Pb, Ag, Au, Cu	54°05'N 126°44'W
Fish Lake-Bralorne Metallogenic Belt of Porphyry Cu-Mo, Porphyry Cu-Au, Au Quartz Vein, and Polymetallic Ag-Au Vein and Related Deposit Types (Late Cretaceous and early Tertiary) Southern British Columbia (Belt FLB)			
Bralorne (092JNE 001), Pioneer (092JNE 004) (Bridge River Area)	Au-Sb polymetallic vein	Au	50°47'N 122°49'W
Fish Lake (092O 041)	Porphyry Cu-Mo	Cu, Au	51°28'N 123°38'W
Giant Copper (Canam, A.M.)	Porphyry Cu-Mo	Cu, Mo	49°10'N 121°01'W
Maggie (Bonaparte River)	Porphyry Cu-Mo	Cu, Mo	50°55'N 121°25'W
Poison Mountain (Copper Giant) (092O 046)	Porphyry Cu-Mo	Cu, Mo	51°08'N 122°37'W
Tyaughton-Yalakom Metallogenic Belt of W-Sb Polymetallic Vein and Hg-Sb Vein Deposits (early Tertiary) Southern British Columbia (Belt GB)			
Tungsten Queen	W-Sb polymetallic vein and Hg-Sb vein	Hg	51°03'N 122°49'W

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Gambier Metallogenic Belt of Porphyry Cu-Mo and Zn-Pb-Cu Skarn Deposits (early Tertiary) Southern British Columbia (Belt GB)			
Gambier Island (092GNW 025)	Porphyry Cu-Mo	Cu, Mo	49°31'N 123°22'W
Hi-Mars (Lewis Lake) (092F 292)	Porphyry Cu-Mo	Cu, Mo	49°57'N 124°21'W
Lynn Creek (092GSW 003)	Zn-Pb skarn	Zn, Pb	49°25'N 123°04'W
O.K. (092K 008; 092K 057)	Porphyry Cu-Mo	Cu, Mo	50°03'N 124°39'W
Catface Metallogenic Belt of Porphyry Cu-Mo-Au and Au-Ag Polymetallic Vein Deposits (Eocene) Vancouver Island (Belt CF)			
Catface (092F 120)	Porphyry Cu-Mo	Cu	49°15'N 125°59'W
Domineer-Lakeview (092F 117)	Porphyry Cu-Mo	Cu, Mo	49°46'N 125°18'W
Privateer (092L 008)	Polymetallic vein	Au, Ag, Zn, Cu, Pb	50°02'N 126°49'W
Skeena Metallogenic Belt of Porphyry Cu-Mo; Porphyry Mo; Ag Polymetallic Vein and Au-Ag Epithermal Vein Deposits (early Tertiary), Central British Columbia (Belt SK)			
Ajax (103P 223)	Porphyry Mo	Mo	55°35'N 129°24'W
Bell Copper (Newman) (093M 001)	Porphyry Cu-Au (Mo)	Cu, Au, Ag	55°00'N 126°14'W
Bell Moly (Alice Arm) (103P 234)	Porphyry Mo	Mo, W	55°28'N 129°20'W
Berg (093E 046)	Porphyry Cu-Mo	Cu, Mo	53°48'N 127°26'W
Big Onion (093L 124)	Porphyry Cu-Mo	Cu, Mo	54°49'N 126°54'W
Capoose Lake (093F 040)	Ag-Au polymetallic vein	Ag	53°17'N 125°10'W
Dorothy (093M 009)	Porphyry Cu-Mo	Cu, Mo	55°15'N 126°10'W
Equity Silver (Sam Goosly) (093L 001)	Ag polymetallic vein	Ag, Cu	54°11'N 126°16'W
Granisle (093L 146)	Porphyry Cu-Au (Mo)	Cu, Au, Ag	54°57'N 126°09'W
Kitsault (BC Moly) (103P 120)	Porphyry Mo	Mo	55°25'N 129°25'W
Lucky Ship (093L 053)	Porphyry Mo	Mo	54°02'N 126°59'W
Morrison	Porphyry Cu-Au (Mo)	Cu, Ag, Au	55°11'N 126°19'W
Mount Thomlinson (093M 080)	Porphyry Mo	Mo	55°35'N 127°29'W
Nanika (DW, New Nanik) (093E 055)	Porphyry Cu-Mo	Cu	53°45'N 127°41'W
Prosperity-Porter Idaho (103P 089)	Ag-Pb-Zn polymetallic vein	Ag, Pb, Zn	55°55'N 129°56'W
Redbird (093E 026)	Porphyry Mo	Mo	53°18'N 127°00'W
Roundy Creek (103P 113)	Porphyry Mo	Mo	55°25'N 129°26'W
Serb Creek (093L 083)	Porphyry Mo	Mo	54°39'N 127°45'W
Nelson Metallogenic Belt of Ag Polymetallic Vein; Ag-Pb-Zn Manto; Au-Ag Epithermal Vein, Porphyry Mo, Paleoplacer U and Deposits (Eocene), Southern British Columbia (Belt NS)			
Ainsworth District	Ag polymetallic vein	Zn, Pb, Ag	49°43'N 116°55'W
Carmi Moly (082ENW 036)	Porphyry Mo	Mo, Cu	49°31'N 119°10'W
Highland Bell (Beaverdell) (082ESW 030)	Ag polymetallic vein	Ag, Pb, Zn	49°26'N 119°03'W
Lassie Lake Area (Blizzard) (082ENE 046)	Paleoplacer U	U	49°38'N 118°55'W
Millie Mack (082KSW 057)	Au-Ag polymetallic vein	Au, Ag	50°03'N 117°43'W
Bluebell (Riondel) (082ENE 42, 43, 44)	Zn-Pb-Ag skarn and manto	Zn, Pb, Ag	49°46'N 116°52'W
Silverton District (Sandon, Silver Ridge)	Ag polymetallic vein	Ag, Pb, Zn	49°56'N 117°18'W
Vault (082ESW173)	Au-Ag epithermal vein	Au, Ag	49°22'N 119°37'W
Dusty Mac (082ESW078)	Au-Ag epithermal vein	Au, Ag	
EARLY TO MIDDLE TERTIARY (Middle Eocene through early Miocene - 52 to 23 Ma)			
Central Sakhalin Metallogenic Belt of Au Quartz Vein and Talc Deposits Cu Deposits (early Tertiary) Russian Southeast (Belt CS)			
Langeriiskoe	Au quartz vein	Au	50°11'N 143°04'E
Sredinny Metallogenic Belt of Au Quartz Vein and Metamorphic REE Vein(?) deposit Deposits (early Tertiary) East-Central Part of Russian Northeast (Belt SR)			
Tumannoe	Au quartz vein	Au	54°21'N 157°23'E
Anomalnoe	Metamorphic REE vein(?)	Ta, Nb	54°04'N 157°24'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.	
Kvinumsky Metallogenic Belt of Hornblende Peridotite and Gabbroic Ni-Cu Deposits (early Tertiary) Russian Southeast (Belt KV)				
Kuvalorog	Hornblende peridotite Cu-Ni.	Cu, Ni	53°28'N	157°24'E
Kvinum	Gabbroic Cu-Ni	Ni, Cu, Co, Au, Pt	53°38'N	157°02'E
Shanuch	Hornblende peridotite Cu-Ni.	Ni, Cu, Co, Au, Pt	55°09'N	157°12'E
Central Koryak Metallogenic Belt of Igneous Arc Deposits (Late Cretaceous and early Tertiary) East-Central Part of Russian Northeast (Belt CKY)				
Agranai	Volcanic-hosted Hg	Hg	63°53'N	173°10'E
Ainatvetkin	Sn polymetallic vein	Sn, Ag	60°58'N	165°17'E
Ametistovoe	Au-Ag epithermal vein	Au, Ag	61°19'N	164°49'E
Berezovaya	Sn polymetallic vein	Sn	63°60'N	173°52'E
Ivolga	Epithermal vein	Ag, Sn	61°16'N	165°21'E
Khrustal (Khrustalnoe)	Sn polymetallic vein	Sn	61°28'N	167°10'E
Krassnaya Gorka	Clastic sediment-hosted Hg or hot-spring Hg?	Hg	61°54'N	168°48'E
Kuibiveen	Porphyry Cu-Mo	Mo, Cu, Au	62°43'N	170°06'E
Lalankytap	Porphyry Cu-Mo	Mo, Cu	62°09'N	173°11'E
Lamut	Volcanic-hosted Hg	Hg	64°05'N	172°60'E
Lyapganai	Clastic sediment-hosted Hg or hot-spring Hg?	Hg, Sb	61°34'N	168°01'E
Neptun	Clastic sediment-hosted Hg or hot-spring Hg?	Hg, Sb, As	61°40'N	168°16'E
Orlovka	Epithermal vein	Au, Zn, Cu, Hg	64°00'N	168°34'E
Parkhonai	Sn polymetallic vein and Sn silicate-sulfide vein	Sn	64°04'N	173°18'E
Pervenets	Silica-carbonate Hg	Hg, As, Sb	63°28'N	173°51'E
Reznikov	Sn polymetallic vein	Sn, Ag, Au	60°50'N	164°39'E
Rzhavy	Porphyry Cu-Mo	Cu, Mo, Au	65°47'N	165°06'E
Sprut	Au-Ag epithermal vein	Ag, Au	61°21'N	165°07'E
Tamvatney	Silica-carbonate Hg	Hg, W, As	63°29'N	174°13'E
Unnei	Sn polymetallic vein	Sn, Ag, Au	61°31'N	166°07'E
Olyutor Metallogenic Belt of Igneous-Arc-Related Deposits (late Paleogene, Miocene, and Pliocene) Kamchatka Peninsula (Belt OT)				
Maletoivayam	Sulfur-sulfide	S	60°26'N	164°23'E
Olyutor	Clastic sediment-hosted Hg or hot-spring Hg?	Hg, Sb, As	60°35'N	167°49'E
Pinchi Lake Metallogenic Belt of Hg Epithermal Vein, Sb-Au Vein, Silica-Carbonate Hg Deposits (Oligocene and Miocene), Central British Columbia (Belt PC)				
Pinchi Lake	Silica-carbonate Hg	Hg	54°38'N	124°26'W
Owl Creek Metallogenic Belt of Porphyry Cu-Mo; Porphyry Mo and Au Polymetallic Vein Deposits (Oligocene and Miocene), Southern British Columbia (Belt OC)				
Clear Creek (Gem) (092HNW 001)	Porphyry Mo	Mo	49°43'N	121°43'W
Owl Creek district (092JSE 004, 006, 007)	Porphyry Cu-Mo	Cu, Mo	50°23'N	122°45'W
Salal Creek (092JW 005)	Porphyry Mo	Mo	50°46'N	123°24'W
MIDDLE TERTIARY (Miocene - 20 to 10 Ma)				
East Kamchatka Metallogenic Belt of Au-Ag Epithermal Deposits (Miocene) Central and Southern Kamchatka Peninsula (Belt EK)				
Asachinskoe	Au-Ag epithermal vein	Au, Ag, Se	52°08'N	157°54'E
Kitkhoi	Au-Ag epithermal vein	Au, Ag, Zn, Pb	53°26'N	158°17'E
Kumroch	Au-Ag epithermal vein	Au, Ag, Cu, Pb, Zn	55°40'N	161°10'E
Mutnovskoe	Au-Ag epithermal vein	Au, Ag, Cu, Zn, Pb	52°44'N	158°24'E
Rodnikovoe	Au-Ag epithermal vein	Au, Ag	52°50'N	158°16'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Central Kamchatka Metallogenic Belt of Au-Ag Epithermal and Porphyry Cu-Mo Deposits (middle and late Tertiary) Kamchatka Peninsula (Belt CK)			
Aginskoe (Aga)	Au-Ag epithermal vein	Au, Ag, Te	55°31'N 157°52'E
Baran'evskoe	Au-Ag epithermal vein	Au, Ag	55°06'N 158°13'E
Chempura	Volcanic-hosted Hg	Hg	56°12'N 159°18'E
Krasnogorskoe	Porphyry Cu-Mo	Mo	53°58'N 157°28'E
Oganchinskoe	Au-Ag epithermal vein	Au, Ag	54°57'N 157°46'E
Ozernovskoe	Au-Ag epithermal vein	Au, Ag, Te	57°35'N 160°47'E
Sukharikovskie Grebni	Au-Ag epithermal vein	Au, Ag	55°40'N 158°39'E
Tutkhlivayam	Au-Ag epithermal vein	Au, Ag, Cu, Pb, Zn, Te, Cd	59°04'N 161°44'E
Zolotoi	Au-Ag epithermal vein	Au, Ag	55°03'N 158°21'E
Alaska Peninsula and Aleutian Islands Metallogenic Belt of Igneous Arc Deposits (middle Tertiary) Western-Southern Alaska (Belt AP)			
Apollo-Sitka	Au-Ag epithermal vein	Au, Ag, Pb, Zn, Cu	55°12'N 160°37'W
Aquila	Au-Ag epithermal vein	Au, Ag	55°11'N 160°40'W
Bee Creek	Porphyry Cu	Cu, Au	56°31'N 158°24'W
Canoe Bay	Au-Ag epithermal vein	Au, Ag	55°35'N 161°16'W
Cathedral Creek, Braided Creek	Polymetallic vein	Cu, As, Zn, Pb	56°30'N 158°44'W
Fog Lake (Pond)	Au-Ag epithermal vein	Au, Cu, Ag	59°31'N 154°23'W
Kawisgag (Ivanof)	Porphyry Cu and (or) polymetallic vein	Cu, Mo, Au	55°57'N 159°24'W
Kilokak Creek	Polymetallic vein(?)	Pb, Zn	57°11'N 156°24'W
Kuy	Au-Ag epithermal vein	Au, Ag, Cu	59°16'N 154°38'W
Mallard Duck Bay	Porphyry Cu-Mo and(or) polymetallic vein(?)	Cu, Mo	56°14'N 158°30'W
Mike	Porphyry Mo	Mo	57°03'N 157°13'W
Pyramid	Porphyry Cu	Cu, Au	55°37'N 160°41'W
Rex	Porphyry Cu	Cu, Au	57°12'N 157°00'W
San Diego Bay	Au-Ag epithermal vein(?)	Ag, Au, Cu, Pb, Zn	55°34'N 160°27'W
Sedanka (Biorka)	Polymetallic vein	Zn, Pb, Cu	53°45'N 166°10'W
Shumagin	Au-Ag epithermal vein	Au, Ag	55°12'N 160°35'W
Warner Bay (Prospect Bay)	Porphyry Cu, Polymetallic vein	Cu, Mo, Pb, Zn	56°10'N 158°20'W
LATE TERTIARY and QUATERNARY (Pliocene through Present - 4 to 0 Ma)			
Sakhalin Island Belt of Silica-Carbonate and Volcanic-Hosted Hg Deposits (late Tertiary) Kuril Islands, Sakhalin Island, Russian Far East (Belt SH)			
In' River	Volcanic-hosted Hg	W, Hg, Cu	50°33'N 142°32'E
Inskoe	Volcanic-hosted Hg	Hg	48°52'N 142°38'E
Ostrinskoe	Silica-carbonate Hg	Hg	49°44'N 143°12'E
Svetlovskoe	Silica-carbonate Hg	Hg	50°09'N 143°23'E
Yasnoe	Silica-carbonate Hg	Hg	50°38'N 142°27'E
Kuril Metallogenic Belt of Au-Ag Epithermal Vein, Cu-Pb-Zn Polymetallic Vein, Sn silica-sulfide vein, Sn Vein, Sulfur-sulfide (Volcanic S), Kuroko Massive Sulfide, and Porphyry Mo Deposits (middle Tertiary to Holocene) Kuril Islands, East-Central Part of Russian Far East (Belt KU)			
Carpinsky Caldera	Porphyry Mo	Mo	50°10'N 155°28'E
Dushnoe	Cu-Pb-Zn polymetallic vein	Cu, Zn, Pb	46°58'N 152°04'E
Ebeko	Sulfur-sulfide	S, FeS_2	50°38'N 156°03'E
Golovninskoe	Sulfur-sulfide.	S, FeS	43°53'N 145°36'E
Koshkina	Polymetallic vein	Cu, Zn, Pb	50°44'N 156°16'E
Krishtofovich Volcano	Sulfur-sulfide	S, FeS_2	45°47'N 149°43'E
Novoe	Sulfur-sulfide	S, FeS_2	44°56'N 147°30'E
Prasolovskoe	Au-Ag epithermal vein	Au, Ag	44°19'N 146°05'E
Reidovskoe	Porphyry Mo	Mo	45°12'N 148°12'E
Rifovoe	Au-Pb-Zn epithermal vein	Au, Zn, Pb	50°24'N 156°02'E
Rudnikovskoe	Sn silicate-sulfide vein	Sn, Pb, Zn	44°37'N 147°22'E
Sernaya River	Au epithermal vein	Au, Zn, Cu	45°10'N 148°02'E
Sof'ya	Au epithermal vein	Au	45°27'N 148°43'E
Spiridonovskoe	Sn polymetallic vein	Sn, Pb, Zn	44°01'N 145°45'E
Tet'yaevskoe	Cu-Pb-Zn polymetallic vein	Cu, Zn, Pb	45°41'N 149°35'E

Deposit Name	Mineral Deposit Model	Major Metals	Latitude N; Longitude E, W.
Valentinovskoe	Kuroko Cu-Pb-Zn massive sulfide	Cu, Pb, Zn	44°12'N 145°58'E
Vysokoe	Sulfur-sulfide	S, FeS_2	45°01'N 147°54'E
Zaozernoe	Sulfur-sulfide	S, FeS_2	50°30'N 156°02'E