Metallogenesis and Tectonics of Northeast Asia
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Chapter 8

Middle Jurassic through Quaternary Metallogenesis and Tectonics of Northeast Asia

By Sergey M. Rodionov[1], Alexander I. Khanchuk[2], Alexander A. Obolenskiy[3], Masatsugu Ogasawara[4], Zhan V. Seminskiy[5], Andrei V. Prokopiev[6], Vladimir F. Timofeev[6], and Warren J. Nokleberg[7]

Introduction

This article presents an overview of the regional geology, tectonics, and metallogenesis of Northeast Asia for the Middle Jurassic through Quaternary (154 to 0 Ma). The major purposes are to provide a detailed summary of these features for readers who are unfamiliar with Northeast Asia. Several parts of this book on Northeast Asia provide background information. An overview of the regional geology, metallogenesis, tectonics of the region, and other materials, such as an employed geologic time scale and standard geologic definitions, are provided in Chapter 1. The methodology for the metallogenic and tectonic analysis of this region is provided Chapter 2. Descriptions of mineral-deposit models are provided in Chapter 3. Additional information on project publications, descriptions of major geologic units, and summaries of metallogenic belts are provided in appendixes A through C.

Compilations Employed for Synthesis, Project Area, and Previous Study

The compilation of regional geology and metallogenesis in this introduction is based on publications of the major international collaborative studies of the metallogenesis and tectonics of Northeast Asia that were led by the U.S. Geological Survey (USGS). These studies have produced two broad types of publications. One type is a series of regional geologic, mineral deposit, and metallogenic-belt maps and companion descriptions for the regions. Examples of major publications of this type are Obolenskiy and others (2003, 2004), Parfenov and others (2003, 2004a, b), Nokleberg and others (2004), Rodionov and others (2004), and Naumova and others (2006). The other type of publication is a suite of metallogenic and tectonic analyses of these same regions. Examples of major publications of this type are Rodionov and others (2004), Nokleberg and others (2000, 2004, 2005), and Naumova and others (2006). Detailed descriptions of lode deposits are available in Ariunbileg and others (2003). For more detail. refer to the detailed descriptions of geologic units and metallogenic belts in the publications listed above.

The Northeast Asia project area consists of eastern Russia (most of Siberia and most of the Russian Far East), Mongolia, Northern China, South Korea, Japan, and adjacent offshore areas (fig. 1). This area is approximately bounded by 30 to 82° N. latitude and 75 to 144° E. longitude. The major participating agencies are the Russian Academy of Sciences; Academy of Sciences of the Sakha Republic (Yakutia); VNIIOkeangeologia and Ministry of Natural Resources of the Russian Federation; Mongolian Academy of Sciences; Mongolian University of Science and Technology; Mongolian National University; Jilin University, Changchun, China; the China Geological Survey; the Korea Institute of Geosciences and Mineral Resources; the Geological Survey of Japan/AIST; University of Texas Arlington; and the USGS.

The Northeast Asia project extends and builds on data and interpretations from a previous project on the *Major Mineral Deposits, Metallogenesis, and Tectonics of the Russian Far East, Alaska, and the Canadian Cordillera* that was done by the USGS, the Russian Academy of Sciences, the Alaska Division of Geological and Geophysical Surveys, and the Geological Survey of Canada. A summary of the major products of this project are available online at http://pubs.usgs.gov/of/2006/1150/PROJMAT/ and in appendix A.

[1]Russian Academy of Sciences, Khabarovsk.
[2]Russian Academy of Sciences, Vladivostok.
[3]Russian Academy of Sciences, Novosibirsk.
[4]Geological Survery of Japan/AIST, Tsukuba.
[5]Irkutsk State Technical University, Irkutsk.
[6]Russian Academy of Sciences, Yakutsk.
[7]U.S. Geological Survey, Menlo Park, Calif.

Major Geologic Units

The major Middle Jurassic through Quaternary geologic and tectonic units of Northeast Asia are cratons, craton-margins, tectonic collages, superterranes (microcontinents) and terranes, and overlap sedimentary basins and intrusive belts (fig. 2, table 1). Short descriptions of map units are given in appendix B. Summary descriptions of the major units are provided in descriptions of metallogenic belts (below), and detailed descriptions of geologic units are provided by Nokleberg and others (2000, 2004), and Parfenov and others (2004b).

Major Cratons, Cratonal Margins, and Cratonal Margin Terranes

The backstop or core units for the region of Northeast Asia are the Archean and Proterozoic North Asian craton and Sino-Korean craton and their cratonal margins (Baikal-Patom, East Angara, South Taimyr, and Verkhoyansk (North Asian).

The North Asian craton (NAC) consists of Archean and Proterozoic metamorphic basement, and nondeformed, flat-laying platform cover consisting of late Precambrian, Paleozoic, and Mesozoic sedimentary and volcanic rock.

Figure 1. Regional summary geographic map for Northeast Asia showing major regions and countries.

The Sino-Korean craton (SKC) consists of several major Archean and Proterozoic metamorphic basement terranes and younger Paleozoic through Cenozoic overlap units.

The Baikal-Patom cratonal margin (BP) consists of a fault-bounded basin containing Riphean carbonate and fine-grained marine sedimentary rock, and younger Vendian and Cambrian sedimentary rock that discordantly overlie a fragment of the preRiphean basement of the North Asian craton.

The East Angara cratonal margin (EA) consists of late Riphean fine-grained marine sedimentary rock and carbonate sedimentary rock (interlayered dolomite and limestone) that overlie a fragment of the North Asia craton.

The South Taimyr cratonal margin (ST) consists chiefly of a thick wedge of Ordovician through Jurassic cratonal margin deposits and deep basin deposits.

The Verkhoyansk (North Asian) cratonal margin (VR) consists chiefly of a thick wedge of Devonian through Jurassic miogeoclinal deposits.

Superterrane

The major Proterozoic through Permian Bureya-Jiamusi supterterrane (BJ) occurs along the margins of the North Asian and Sino-Korean cratons (fig. 2). The superterrane consists of a collage of early Paleozoic metamorphic, continental-margin arc, subduction zone, passive continental-margin and island-arc terranes. The superterrane is interpreted as being a fragment of Gondwana that was accreted to the Sino-Korean craton in the Late Permian and accreted to the North Asian craton in the Late Jurassic during final closure of the Mongol-Okhotsk Ocean.

Tectonic Collages East of North Asian and Sino-Korean Cratons

To the east of the North Asian and Sino-Korean cratons are a series of tectonic collages that were successively accreted from west to east (older to younger) during closures of parts of the ancestral Pacific and modern Pacific Oceans and older oceans in the region. Because of successive accretions from west to east, the ages of the collages are generally young from west to east. However, this pattern is locally disrupted because some collages have been interspersed by subsequent strike-slip faulting.

Except for the Verkhoyansk-Kolyma and Chukotka collages, the other tectonic collages contain one or more island arcs or continental-margin arcs and tectonically-linked subduction zones. The tectonic collages that occur east of the North Asian and Sino-Korean cratons are as follows.

(1) The Badzhal collage (BD) (Triassic through Early Cretaceous age and accreted in Late Cretaceous) consists of the Umlekan-Ogodzhin continental-margin arc and tectonically-linked subduction-zone terranes to the east with Tethyan fauna.

(2) The Chukotka collage (CH) (Paleozoic through Triassic age and accreted in Late Jurassic through Early Cretaceous) consists of passive continental-margin terranes that formed along the long-lived Neoproterozoic through early Mesozoic North American continental margin. After subsequent rifting of the North American cratonal margin in the Late Jurassic and Early Cretaceous and translation, the collage was accreted to the northern Verkhoyansk-Kolyma collage in the Late Cretaceous.

(3) The East Kamchatka Peninsula collage (EP) (mainly Paleocene age and accreted in Pliocene) consists of the Kronotskiy island arc and associated ophiolite.

(4) The East Sakhalin collage (ES) (Late Cretaceous through early Tertiary age and accreted in early Tertiary) consists of the Late Cretaceous through middle Eocene Terpeniy-Tokoro-Nemuro-Shmidt island-arc and tectonically-linked subduction-zone terranes.

(5) Honshu-Sikhote-Alin collage (HS) (Jurassic and Early Cretaceous age and accreted in Cretaceous). Consists of fragments of island-arc, continental-margin turbidite (flysch), and subduction-zone terranes. The collage is interpreted as having formed along a transform continental margin.

(6) The Koryak collage (KOR) (Late Triassic through Cretaceous age and accreted in Late Cretaceous) consists of the Late Jurassic and Early Cretaceous Manitskiy island arc and tectonically-linked subduction-zone terranes to the east.

(7) The Olyutorka-Kamchatka collage OK) (Late Cretaceous and Paleocene age and accreted in early Cenozoic) consists of the Olyutorka island-arc and tectonically-linked subduction-zone terranes to the east.

(8) The Penzhina-Anadyr collage (PA) (Late Jurassic through Early Cretaceous age and accreted in Late Cretaceous) consists of the Murgal island-arc terrane and tectonically-linked subduction-zone terranes to the east. The collage rims the eastern Kolyma-Omolon superterrane and Verkhoyansk-Kolyma collage. The collage is also linked to the Uda continental-margin arc.

(9) The Sakhalin-Hokkaido collage (SK) (Cretaceous age and accreted in Eocene) consists of the Late Cretaceous flysch terranes of Sakhalin and Hokkaido Islands, and tectonically-linked subduction-zone terranes to the east. The collage is interpreted as being a continental-margin fore-arc basin and tectonically-linked subduction-zone terranes that are associated with the East Sikhote-Alin continental-margin arc.

(10) The South Anyui collage (SA) (Permian through Early Jurassic age and accreted in Late Cretaceous) consists of the Oloy island arc and tectonically-linked subduction-zone terranes.

(11) The West Kamchatka collage (WK) (Mid-Cretaceous through early Tertiary age and accreted in early Cenozoic) consists of late Paleozoic through Cretaceous subduction-zone terranes in the Russian Northeast. The collage was tectonically linked to Okhotsk-Chukotka continental-margin arc.

(12) The Verkhoyansk-Kolyma collage (VK) (Late Paleozoic through Early Jurassic age and accreted in Late Jurassic through early Early Cretaceous) consists of a deformed passive continental margin and accreted ophiolite and subduction-zone terranes. This collage is interpreted as having formed during accretion of the outboard Kolyma-Omolon superterrane.

Tectonic Collage Between North Asian and Sino-Korean Cratons

In the Jurassic, the Mongol-Okhotsk collage (MO) was actively forming between the North Asian and Sino-Korean cratons. The Mongol-Okhotsk collage contains units ranging from the Devonian through Late Jurassic and was completely

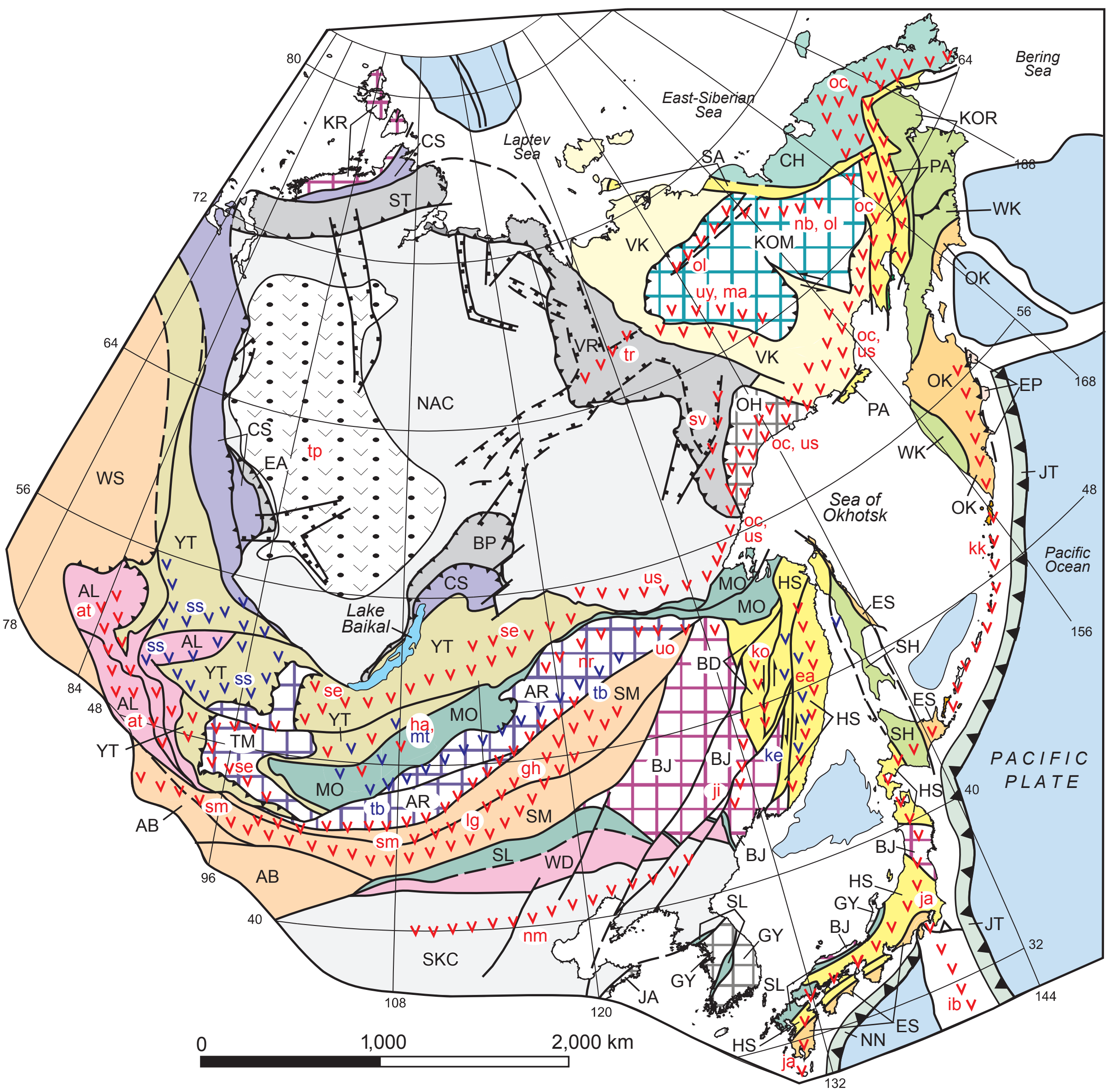


Figure 2. Northeast Asia summary geodynamics map. Map is derived from (1) a Generalized Northeast Asia Geodynamics Map at 10 million scale (Parfenov and others, 2004), (2) a more detailed Northeast Asia Geodynamics Map at 5 million scale (Parfenov and others, 2003), and (3) the western part of a Circum-North Pacific tectonostratigraphic terrane map at 10 million scale (Nokleberg and others, 1997). Map shows locations major geologic and tectonic units including cratons, and cratonal margins; cratonal terranes and superterranes; tectonic collages, overlap and transform continental-margin arcs; island arcs, and sea and ocean units. Refer to table 1 (tables 1 and 2 are found at the back of this chapter) and text for unit descriptions.

EXPLANATION

Cratons and Cratonal Margins

Cratons: NAC - North Asian (Archean and Proterozoic); SKC - Sino-Korean (Archean and Proterozoic)

Cratonal Margin: BP - Baikal-Patom (Riphean through Cambrian and older basement; EA - East Angara (Riphean and older basement; ST - South Taimyr (Ordovician through Jurassic); VR - Verkhoyansk (Devonian through Jurassic).

Tectonic Collages Between the North Asian and Sino-Korean Cratons

CS - Circum-Siberia (Proterozoic)

YT - Yenisey-Transbaikal (Vendian through Early Ordovician)

AL - Altay (Vendian to Ordovician)
WD - Wundurmiao (Riphean through Ordovician)

AB - Atasbogd (Ordovician through Permian); SM - South Mongolia-Khingan (Ordovician through Carboniferous); WS - West Siberian (Ordovician through Carboniferous)

MO - Mongol-Okhotsk (Devonian through Late Jurassic); SL - Solon (Carboniferous and Permian)

Tectonic Collages Along the Northern and Eastern Margins of North Asian and Sino-Korean Cratons

CH - Chukotka (Paleozoic and Triassic)

VK - Verkhoyansk-Kolyma Paleozoic through Early Jurassic)

BD - Badzhal (Triassic through Early Cretaceous); PA - Penzhina-Anadyr (Late Jurassic and Cretaceous); HS - Honshu-Sikhote-Alin (Jurassic and Early Cretaceous); SA - South Anyui (Permian through Jurassic);

KOR - Koryak (Late Jurassic through Paleocene; SH - Sakhalin-Hokkaido (Cretaceous); WK - West Kamchatka (Mid-Cretaceous through Early Tertiary)

ES - East Sakhalin (Late Cretaceous and Early Tertiary); OK - Olyutorka-Kamchatka (Late Cretaceous to Paleocene)

EP - East Kamchatka Peninsular (Mainly Paleocene)

Active Subduction Zones

JT- Japan Trench (including Kuril-Kamchatka trench) (Miocene through Holocene; NN - Nankai (Miocene through Holocene)

Cratonal Terranes and Superterranes

Cratonal terranes (Archean and Proterozoic): GY - Gyeonggi-Yeongnam; JA - Jiaonan; OH - Okhotsk

Late Proterozoic and Cambrian superterranes: AR - Argun-Idermeg; TM - Tuva-Mongolia

Archean through Permian superterranes: BJ - Bureya-Jiamusi; KR - Kara

Jurassic Superterrane: KOM - Kolyma-Omolon (Archean through Jurassic)

Pelagic and Oceanic Rocks

Surficial deposits

Oceanic crust

Overlap Continental-Margin Arcs and Igneous Belts

at - Altay arc (Devonian and early Carboniferous, 381 to 290 Ma)
ea - East Sikhote-Alin arc (Late Cretaceous through early Tertiary, 96-65 Ma)
gh - Gobi-Khankaisk-Daxing'anling arc (Permian, 295 to 250 Ma)
ha - Hangay arc (Late Carboniferous and Early Permian, 320 to 272 Ma)
ji - Jihei arc (Permian, 295 to 250 Ma)
ko - Khingan arc (Early and mid-Cretaceous)
lg - Lugyngol arc (Permian and Triassic, 295 to 250 Ma)
ma - Main granite belt (Late Jurassic, 144 to 134 Ma)
nb - Northern granite belt (Early Cretaceous, 138 to 120 Ma)
nm - North Margin (Late Carboniferous and Permian, 320 to 272 Ma)
nr - Norovlin arc (Devonian and Early Carboniferous, 410 to 255 Ma)
oc - Okhotsk-Chukotka arc (Late Cretaceous and early Tertiary, 96 to 53 Ma)
ol - Oloy arc (Late Jurassic, 154 to135 Ma)
se - Selenga arc (Permian through Jurassic, 295 to135 Ma)
sm - South Mongolian arc (Carboniferous through Triassic, 320 to 203 Ma)
ss - South Siberian arc (Devonian)
sv - South Verkhoyansk granite belt (Late Jurassic through mid-Cretaceous, 157 to 93 Ma)
tr - Transverse granite belt (Early Cretaceous, 134 to 124 Ma)
uo - Umlekan-Ogodzhin arc (Cretaceous, 135 to 65 Ma)
us - Uda-Murgal and Stanovoy arc (Jurassic and Early Cretaceous, 203 to 96 Ma)
uy - Uyandina-Yasachnaya arc (Late Jurassic and Early Cretaceous, 154 to 120 Ma)

Plume-Related Igneous Province

tp - Tungus Plateau igneous province - (Late Permian and Early Triassic, 245 Ma)

Active Arcs

ib - Izu-Bonin (late Cenozoic, 20 to 0 Ma)
ja - Japan (late Cenozoic, 23 to 0 Ma)
kk - Kuril-Kamchatka (late Cenozoic, 11 to 0 Ma)

Transpressional Arcs

ke - Kema (Mid-Cretaceous)
mt - Mongol-Transbaikal (Late Triassic through Early Cretaceous, 230 to 96 Ma)
ss - South Siberian (Early Devonian, 415 to 400 Ma)
tb - Transbaikalian-Daxinganling (Middle Jurassic through Early Cretaceous,175 to 96 Ma)

Symbols, Faults, and Contacts

Overlap-continental-margin arc
Transform-continental-margin arc
Active subduction zone
Thrust
Strike-slip fault
Fault
Contact
Riphean aulacogen
Devonian aulacogen
Modern rift system (Gakkel Ridge)
os Metallogenic belt

Figure 2.—Continued

accreted in Late Jurassic. The collage consists mainly of the Permian through Jurassic Selenga, Late Carboniferous and Early Permian Hangay, and Uda-Murgal and Stanovoy continental-margin arcs. These arcs are composed of continental-margin igneous overlap assemblages, continental-margin turbidite terranes, and tectonically-linked, outboard subduction-zone terranes. The arcs overlap the southern margin of the North Asian craton and margin and previously-accreted terranes. The collage is interpreted as having formed during long-lived closure of the Mongol-Okhotsk Ocean with oblique subduction of terranes beneath of southern North Asian cratonal margin and previously-accreted terranes. Closure and accretion extend from the Permian through the Late Jurassic (140 to 90 Ma). After closure of the Mongol-Okhotsk Ocean, left-lateral slip continued along the Mongol-Okhotsk fault that bounded the former ocean and resulted in formation of the Trans-Baikalian-Daxinganling bimodal igneous belt. More detailed descriptions of the terranes in each tectonic collage are provided in appendix B and in Parfenov (2003, 2004a,b).

Jurassic through Early Cretaceous Continental-Margin Arcs Occurring Along Southeastern Margin of the North Asian Craton and Adjacent Accreted Terranes

Two major continental-margin arcs occur along the southeastern margin of the North Asian craton or on adjacent accreted terranes. The arcs are interpreted as being related to subduction of the late Paleozoic and early Mesozoic Mongol-Okhotsk Ocean Plate beneath the North Asian craton and cratonal margin. This ocean occurred between the North Asian craton to the north and the Argun-Idermeg superterrane to the south (present-day coordinates).

(1) The Selenga arc (se) (Permian through Jurassic) overlies and intrudes the Yenisey-Transbaikal collage and Tuva-Mongolia superterrane. The arc is interpreted as having formed during oblique subduction of the Mongol-Okhotsk Ocean Plate under the North Asian cratonal margin and previously-accreted terranes.

(2) The Uda-Murgal and Stanovoy arcs (us) (Jurassic through Early Cretaceous) occur on the southern margin of the North Asian craton. The arcs are interpreted as having formed during the final stage of subduction of the Mongol-Okhotsk Ocean Plate.

Jurassic and Early Cretaceous Island Arcs Occurring on or Adjacent to Kolyma-Omolon Superterrane

The major island arcs occurring on the Kolyma-Omolon superterrane are the Late Jurassic through Early Cretaceous Uyandina-Yasachnaya island arc and the Late Jurassic Oloy island arc.

(1) The Oloy arc (ol) (Late Jurassic) occurs along the margin of the Kolyma-Omolon superterrane. The arc is interpreted forming on the Kolyma-Omolon superterrane during subduction of the South Anyui Ocean Plate beneath the superterrane.

(2) The Uyandina-Yasachnaya arc (uy) (Late Jurassic through Early Cretaceous) occurs along the margin of the Kolyma-Omolon superterrane. The arc is interpreted as having formed during subduction of the Oimyakon Ocean Plate between the North Asian cratonal margin and the Kolyma-Omolon superterrane. Remnants of the Oimyakon oceanic crust are preserved in small obducted ophiolites along the western margin of superterrane. This ocean occurred between the Verkhoyansk (North Asian) cratonal margin to the southwest and the Kolyma-Omolon superterrane to the northeast (present-day coordinates).

Jurassic through Early Tertiary Continental-Margin Arcs and Granite Belts Occurring along the Eastern Margin of Northern Asia

A series of Jurassic through early Tertiary continental-margin arcs and granite belts occurs along the eastern margin of the North Asian and Sino-Korean cratons and outboard accreted terranes to the east. From older to younger, the arcs and belts are as follows.

(1) The Umlekan-Ogodzhin arc (uo) (Jurassic and Cretaceous) occurs along the northern margin of the Bureya-Jiamusi superterrane. The arc is interpreted as having formed during subduction of the ancestral Pacific Ocean Plate along the margin of the superterrane.

(2) The South Verkhoyansk granite belt (sv) (Late Jurassic through mid-Cretaceous) occurs in central Russian Far East. The belt extends longitudinally along the central part of the South Verkhoyansk synclinorium in the Verkoyansk (North Asian) cratonal margin. The belt is interpreted as having formed during the accretion of the outboard Okhotsk terrane.

(3) The Main granite belt (ma) (Late Jurassic) occurs along the adjacent margins of the North Asian cratonal margin and Kolyma-Omolon superterrane. The belt is interpreted as having formed during and immediately after collision of the Kolyma-Omolon superterrane onto the North-Asian cratonal margin.

(4) The Transverse granite belt (tr) (Early Cretaceous) radiates outwards from the southwestern bend of the Kolyma-Omolon superterrane. The belt is interpreted as having formed during the late stage of accretion of the Kolyma-Omolon superterrane.

(5) The Northern granite belt (nb) (Early Cretaceous, 138 to 120 Ma) occurs along northwestern margin of the Kolyma-Omolon superterrane. The belt is interpreted as having formed during the subduction of oceanic crust that caused closure of a small oceanic basin that was associated with late stage of accretion of the Kolyma-Omolon superterrane.

(6) The Khingan-Okhotsk arc (ko) (Early and mid-Cretaceous) occurs in the Russian Southeast and consists of the Khingan-Okhotsk volcanic-plutonic belt. The arc is interpreted as having formed during subduction of the ancestral Pacific Ocean Plate. The arc was tectonically paired to the Early Cretaceous Zhuravlevsk-Amur River and Kiselevka-Manoma subduction-zone terranes, part of the Honshu-Sikhote-Alin collage.

(7) The Okhotsk-Chukotka arc (oc) (Late Cretaceous through early Tertiary) occurs along the eastern margin of central and northern Russian Far East. The arc is interpreted as having formed during subduction of the ancestral Pacific Ocean Plate with formation of the West Kamchatka, Ekonay, and Yanranay subduction-zone terranes.

(8) The East Sikhote-Alin arc (ea) (Late Cretaceous through early Tertiary) occurs along the margin of southern Russian Far East. The arc is interpreted as having formed during subduction of the ancestral Pacific Ocean Plate with formation of the older part of the Hidaka subduction zone, the younger part of the Aniva subduction-zone terrane, and the Nabilsky, and Tokoro subduction-zone terranes.

Active Continental-Margin Arcs Occurring along the Eastern Margin of Northern Asia

Three active continental-margin arcs occur along the eastern margin of the North Asian and Sino-Korean cratons and outboard accreted terranes to the east.

(1) The Izu-Bonin arc (ib) (Miocene through Present) occurs south of southern Japan and consists of a volcanic arc composed chiefly of basalt to rhyolite, associated volcaniclastic rock, and intercalated hemipelagic mudstone. The arc is interpreted as having formed from subduction of the Philippine Sea Plate with creation of the Nankai subduction zone.

(2) The Japan arc (ja) (Miocene through Present) occurs along the Japan Islands and consists of extensive Quaternary volcanic and associated rock. The arc is interpreted as having formed during subduction of the Pacific Ocean and Philippine Sea Plates with formation of the Japan Trench and Nankai subduction zones.

(3) The Kuril-Kamchatka arc (kk) (Miocene through Present) occurs along Kamchatka Peninsula and the Kuril Islands and consists of the Pliocene to Quaternary Central Kamchatka volcanic belt, the central Kamchatka volcanic and sedimentary basin, and the East Kamchatka volcanic belt. The arc is interpreted as having formed during subduction of the Pacific Ocean Plate with formation of the Kuril-Kamchatka trench and subduction zone.

Transpressional Arcs (Triassic through Early Cretaceous)

Two major transpressional arcs occur along the margins of the North Asian craton and previously accreted terranes to the south. The arc formations are associated with a combination of strike-slip faulting and local compression and extension.

(1) The Mongol-Transbaikal arc (mt) (Late Triassic through Early Cretaceous) occurs in northern Mongolia and southern Siberia. The arc is interpreted as having formed during strike-slip faulting and rifting along the Mongol-Okhotsk fault during and after the final closure of the Mongol-Okhotsk Ocean.

(2) The Transbaikal-Daxinganling arc (tb) (Middle Jurassic through Early Cretaceous) occurs in Southern Siberia, Mongolia, and Northeastern China. The arc is interpreted as having formed during strike-slip faulting and rifting along the Mongol-Okhotsk fault during and after the final closure of the Mongol-Okhotsk Ocean.

Summary of Middle Jurassic through Quaternary (175 to 0 Ma) Metallogenesis

Major Middle Jurassic through Early Cretaceous Metallogenic Belts

The major Middle Jurassic through Early Cretaceous metallogenic belts are the Allakh-Yun, Ariadny, Bindong, Chara-Aldan, Chybagalakh, Djeltulaksky, Dzid-Selenginskiy, Daxinganling, East Mongolian-Priargunskiy-Deerbugan, Govi-Tams, Hartolgoi-Sulinheer, Jiliaolu, Kitakami, Kondyor-Feklistov, Kular, Nerchinsky, North Bureya, North Jilin, North Stanovoy, Onon-Turinskiy, Polousny, Samarka, Shilkinsko-Tukuringrskiy, Taebaegsan, Tompo, Verkhne-Ingodinsky, Verkhoyansk, Yana-Adycha, and Yanshan belts (fig. 3; appendix C).

Metallogenic Belts Related to Trans-Baikalian-Daxinganling Transpressional Arc

Eleven metallogenic belts possess geologic units favorable for a wide variety of siliceous igneous-rock related deposits, including the Daxinganling, Dzid-Selenginski, East Mongolian-Priargunskiy-Deerbugan, Govi-Tamsag, Hartolgoi-Sulinheer, Nerchinsky, Onon-Turinskiy, Shilkinsko-Tukuringrskiy, and Verkhne-Ingodinsky belts. The belts contain a wide variety of deposits. The major types of deposits are Au skarn; Zn-Pb (±Ag, Cu) skarn; W±Mo±Be skarn; Au-Ag epithermal, cassiterite-sulfide-silicate vein and stockwork; fluorspar vein;, granitoid-related Au vein; peralkaline granitoid-related Nb-Zr-REE; polymetallic metasomatite; polymetallic Pb-Zn vein and stockwork; porphyry Au; porphyry Cu-Mo, Mo, and Au; sediment-hosted U, Sn skarn; Sn-W greisen; stockwork, and quartz vein; Ta-Nb-REE alkaline metasomatite; volcanic-hosted Au-base-metal metasomatite; carbonate-hosted Ag-Pb and Hg-Sb; volcanic-hosted zeolite; W-Mo-Be greisen, stockwork, and quartz vein; W skarn; and Zn-Pb skarn. The isotopic ages of the igneous rocks that host the deposits range from 190 to 125 Ma. The belts are hosted in the major Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt that overlaps terranes that were previously accreted to the southern of the North Asian craton and cratonal margin (present-day coordinates). The host rocks and metallogenic belts are interpreted as having formed along the major Trans-Baikalian-Daxinganling transpressional arc that formed along the major Mongol-Okhotsk suture that cuts previously-accreted terranes south of the southern margin (present-day coordinates) of the North Asian craton and cratonal margin. Displacement along the suture and arc formation occurred after the closing of the Mongol-Okhotsk Ocean.

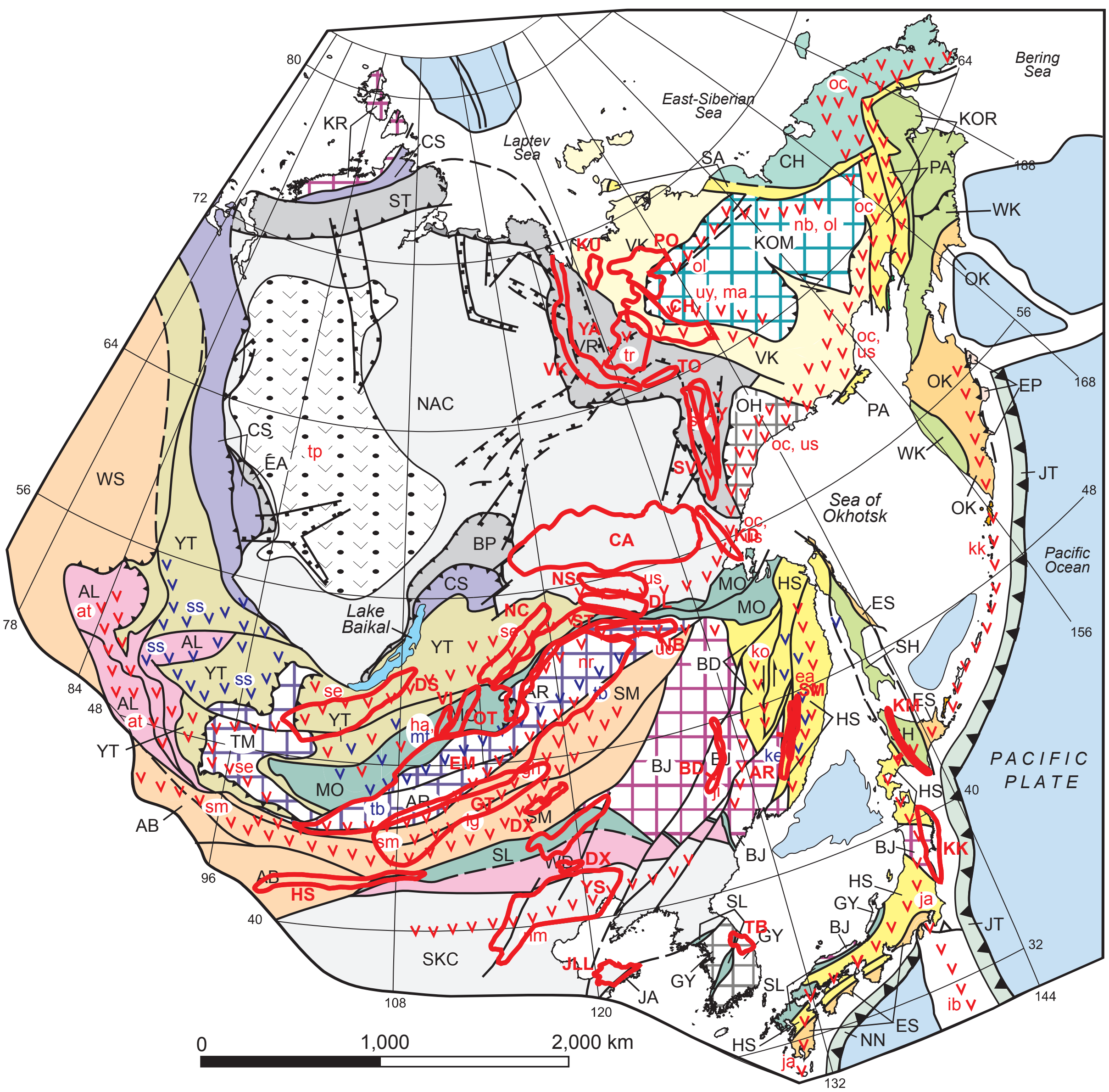


Figure 3. Generalized map of major Middle Jurassic through Early Cretaceous metallogenic belts and major geologic units for Northeast Asia. Refer to text and appendix C for summary descriptions of belts. Refer to figure 2 for explanation of geologic units. Metallogenic belt outlines adapted from Obolenskiy and others (2003, 2004) and Parfenov and others (2003, 2004). Metallogenic belts for area to east of 144 E (eastern boundary of Northeast Asia project area) are described and interpreted by Nokleberg and others (2003).

Metallogenic Belts Related to Accretion of the Kolyma-Omolon Superterrane and Okhotsk Terrane

Eight metallogenic belts possess geologic units favorable for a wide variety of Au-vein deposits and collisional granite-related deposits, including the Allakh-Yun, Chybagalakh, Kular, Polousny, South Verkhoyansk, Tompo, Verkhoyansk, and Yana-Adycha belts (with Au in shear zone and quartz vein, granitoid-related Au vein; Cu skarn; Au in black shale; W skarn; polymetallic Pb-Zn vein and stockwork; cassiterite-sulfide-silicate vein and stockwork; Sn-W greisen, stockwork, and quartz vein; W-Mo-Be greisen, stockwork, and quartz vein; and Au-Ag epithermal-vein deposits). The ages of the veins and associated granites range from Late Jurassic through Aptian. The belts and deposits are hosted in veins and granitoids (such as the South Verkhoyansk, Main, and Northern granite belts) that intrude the Verkhoyansk (North Asian) cratonal margin and (or) the margin of the adjacent Kolyma-Omolon superterrane. The host rocks and metallogenic belts are interpreted as having formed during collision and accretion of the Kolyma-Omolon superterrane to the North Asian cratonal margin that resulted in regional metamorphism and generation of anatectic granitoids and related hydrothermal fluids. The Allakh-Yun and South Verkhoyansk metallogenic belts are interpreted as having formed immediately before the accretion of the Okhotsk terrane to the North Asian cratonal margin.

Metallogenic Belts Related to Uda-Stanovoy Continental-Margin Arc

Three metallogenic belts possess geologic units favorable for granitoid-related deposits, including the Chara-Aldan, Djeltulaksky, and North Stanovoy belts (with granitoid-related Au vein, Au-Ag epithermal vein, Au skarn, Au in shear zone and quartz vein, Au potassium metasomatite, and charoite metasomatite deposits). The isotopic ages for the granitoids hosting or related to the deposits range from Jurassic through Early Cretaceous. These metallogenic belts are interpreted as having formed during intrusion of granitoids of the Stanovoy granite belt that was part of the Uda-Stanovoy continental-margin arc. The arc is interpreted as having formed during subduction and closure of the Mongol-Okhotsk Ocean beneath the North Asian craton to the north (present-day coordinates).

Metallogenic Belts Related to Transpression

Four metallogenic belts possess geologic units favorable for a wide variety of transpressional granitoid-related deposits, including the Jiliaolu, North Jilin, Samarka, and Yanshan belts (with Au-Ag epithermal vein, Cu skarn W skarn, fluorspar vein, granitoid-related Au vein, polymetallic Pb-Zn vein and stockwork, polymetallic volcanic-hosted metasomatite, porphyry Cu and porphyry Cu-Mo, and W and Zn-Pb skarn deposits). The isotopic ages for the granitoids hosting the deposits range from 186 to 110 Ma. The granitoids and veins intrude either overlap assemblages on the Sino-Korean craton or the Samarka subduction-zone terrane (part of Honshu-Sikhote-Alin collage). The metallogenic belts are interpreted as having formed during intrusion of granitoids along transpressional zones along micro plate boundaries, underthrusting of the Kula oceanic ridge, and formation of bimodal igneous rocks along a transform continental margin, or during interplate magmatism associated with extensional tectonism related to oblique subduction of the ancestral Pacific Oceanic Plate beneath the Eurasian Plate.

Unique Metallogenic Belts

Six unique metallogenic belts formed during this time span. (1) The Kondyor-Feklistov belt with zoned mafic-ultramafic Cr-PGE deposits is hosted in mafic-ultramafic intrusions and is interpreted as having formed during intrusion of mafic-ultramafic plutons along a deep-seated fault that formed along the North Asian cratonal margin during collision and accretion of outboard terranes. (2) The North Bureya belt with Au-Ag epithermal vein and granitoid-related Au-vein deposits is hosted in the Umlekan-Ogodzhin volcanic-plutonic belt. The belt is interpreted as having formed during formation of Umlekan-Ogodzhin continental-margin arc through subduction of part of the ancestral Pacific Ocean Plate. (3) The Ariadny belt with mafic-ultramafic rock-related deposits is hosted in Middle Jurassic and Early Cretaceous plutons intruding the Samarka subduction-zone terrane, part of the Honshu-Sikhote-Alin collage. The belt is interpreted as having formed during generation of ultramafic and gabbroic plutons during underthrusting of the Kula oceanic ridge and formation of igneous rocks along a transform continental margin. (4) The Taebaegsan belt with a wide assortment of granitoid-related deposits is hosted in and related to the Late Jurassic through Early Cretaceous Daebo granite. The granitioid are interpreted as being part of a continental-margin arc that was linked to subduction of the ancestral Pacific Ocean Plate. (5) The Kitakami belt with Cu skarn and granitoid-related Au deposits is hosted in the Early Cretaceous Hiroshima granite belt (with isotopic ages of 120 to 110 Ma) and is interpreted as having formed during intrusion of granitoids associated with a continental-margin arc and siliceous magmatism. (6) The Bindong belt with Zn-Pb (±Ag, Cu) skarn and W±Mo±Be skarn deposits is hosted in small granitoids in the Mesozoic Jihei volcanic and plutonic belt and is interpreted as having formed during interplate extensional tectonism and generation of subalkaline to alkaline volcanism and related sedimentation along northeast and east-west regional faults.

Major Cenomanian through Campanian Metallogenic Belts

The major Cenomanian through Campanian metallogenic belts are the Badzhal-Komsomolsk, Central Polousny, Chelasin, Chokhchur-Chekurdakh, Eckyuchu-Billyakh, Gyeongnam, Gyeongpuk, Hidaka, Inner Zone Southwest Japan, Khandyga, Kukhtuy-Uliya, Luzhkinsky, Malo-Khingan, Pilda-Limuri, Preddzhugdzhursky, Selennyakh, Sergeevka-Taukha, South Verkhoyansk, Tumnin-Anyui, and Upper Uydoma belts (fig. 4, appendix C).

Metallogenic Belts Related to Okhotsk-Chukotka and East Sikhote-Alin Continental-Margin Arcs

Seven metallogenic belts possess geologic units favorable for a wide variety of granitoid-related deposits, including the Chelasin, Kukhtuy-Uliya, Luzhkinsky, Preddzhugdzhursky, Sergeevka-Taukha, Tumnin-Anyui, and Upper Uydoma belts (with Au-Ag epithermal vein; boron (datolite) skarn; cassiterite-sulfide-silicate vein and stockwork; granitoid-related Au vein; polymetallic Pb-Zn vein and stockwork; polymetallic volcanic-hosted metasomatite;, porphyry Cu, Cu-Mo; and Mo, Cu skarn; porphyry Sn; Sn-W greisen, stockwork, and quartz vein; Sn-B skarn; W-Mo-Be greisen, stockwork, and quartz vein; and Zn-Pb skarn deposits). The ages of the associated granites range from mid-Cretaceous through Paleocene. The belts and deposits are hosted in granitoids in the Okhotsk-Chukotka volcanic-plutonic belt or the East Sikhote-Alin volcanic-plutonic belt. Both units are major overlap assemblages in the Russian Far East and are interpreted as being part of the extensive, nearly coeval, and colinear continental-margin Okhotsk-Chukotka and East Sikhote-Alin arcs that overlie the North Asian craton and cratonal margin and previously-accreted terranes to the east (present-day coordinates).

Metallogenic Belts Related to Opening of Eurasia Basin

Four metallogenic belts possess geologic units favorable for a wide variety of vein and replacement and granitoid-related deposits, including the Central Polousny, Chokhchur-Chekurdakh, Eckyuchu-Billyakh, Khandyga, and Selennyakh belts (with Ag-Sb vein; Au-Ag epithermal vein; carbonate-hosted As-Au metasomatite; cassiterite-sulfide-silicate vein and stockwork; clastic sediment-hosted Hg±Sb and Sb-Au, Hg-Sb-W vein and stockwork; polymetallic Pb-Zn vein and stockwork; carbonate-hosted Hg-Sb; volcanic-hosted Hg;, and Sn-W greisen, stockwork, and quartz-vein deposits). The isotopic ages for the-vein deposits range from 120 to 97 Ma, and the interpreted ages for the deposits range from Aptian through Late Cretaceous. The belts and deposits are hosted in units that intrude the Northern and Transverse granite belts, the Svyatoi Nos volcanic belt, and the Uyandina-Yasachnaya volcanic belt that intrude or overlie the Verkhoyansk (North Asian) cratonal margin and outboard accreted terranes. The belts are interpreted as having formed during extension related to the formation of the Eurasia Basin during initial opening of the Arctic Ocean.

Metallogenic Belts Related to Khingan Continental-Margin Arc

Four metallogenic belts possess geologic units favorable for a wide variety of vein and replacement and granitoid-related deposits, including the Badzhal-Komsomolsk, Ezop-Yam-Alin, Malo-Khingan, and Pilda-Limuri belts (with Cu skarn; porphyry Mo; granitoid-related Au vein; polymetallic Pb-Zn; porphyry Sn; rhyolite-hosted Sn; Sn-W greisen, stockwork, and quartz vein; cassiterite-sulfide-silicate vein and stockwork; and W-Mo-Be greisen, stockwork, and quartz-vein deposits). The isotopic ages for the granitoids hosting or associated with the deposits range from 100 to 75 Ma. The belts and deposits are hosted in granitoids related to the Khingan-Okhotsk volcanic-plutonic belt that is interpreted as having formed during the generation of granitoids along the Khingan continental-margin arc. The arc is related to oblique subduction of the ancestral Pacific Ocean Plate and formation of the Early Cretaceous Zhuravlevsk-Amur River and Kiselevka-Manoma subduction-zone terranes, part of the Honshu-Sikhote-Alin collage.

Unique Metallogenic Belts

Three unique metallogenic belts formed during the Cenomanian through Campanian.

(1) The Gyeongpuk and Gyeongnam belts (with granitoid-related deposits) have isotopic ages of Cenomanian through Campanian and are hosted in the Cretaceous Bulgugsa granite that intrudes the Sino-Korean craton.

(2) The Hidaka belt with Cyprus Cu-Zn massive sulfide deposits is hosted in Middle Cretaceous through Eocene stratiform units that occur in tectonic fragments in the Shimanto subduction-zone terrane, part of the East Sakhalin collage.

(3) The Inner Zone Southwest Japan belt, with a wide variety of vein and replacement and granitoid-related deposits, is hosted in the Nohi rhyolite volcanic belt and coeval Hiroshima granitic belt that intrude and overlie previously-accreted terranes. The host rocks and deposits have isotopic ages of Cretaceous through Paleogene.

Major Maastrichtian through Oligocene Metallogenic Belts

The major Maastrichtian through Oligocene metallogenic belts are the Kema, Lower Amur, and Popigay belts (fig. 5; appendix C).

Two metallogenic belts possess geologic units favorable for a wide variety of vein and replacement and granitoid-related deposits, including the Kema and Lower Amur belts (with Ag-Au epithermal vein; porphyry Cu-Mo; porphyry Cu; porphyry Au; porphyry Mo; Au-Ag epithermal vein; epithermal quartz-alunite; and Sn-W greisen, stockwork, and quartz-vein deposits). The isotopic ages for the granitoids hosting or associated with the deposits range from Late Cretaceous through Paleocene. The belts and deposits are hosted in granitoids in the East Sikhote-Alin volcanic-plutonic belt that is a major overlap assemblage in the Russian Far East. The belt is interpreted to be part of an extensive continental-margin arc that formed along the eastern margin (present-day coordinates) of the North Asian craton and cratonal margin and previously-accreted terranes to the east. The arc is interpreted as having formed during subduction of the ancestral Pacific Ocean Plate.

The unique Popigay metallogenic belt contains impact diamond deposits. Isotopic age from tagamite (impact melt rock) and impact glasses is 35.7 Ma. The belt is hosted in

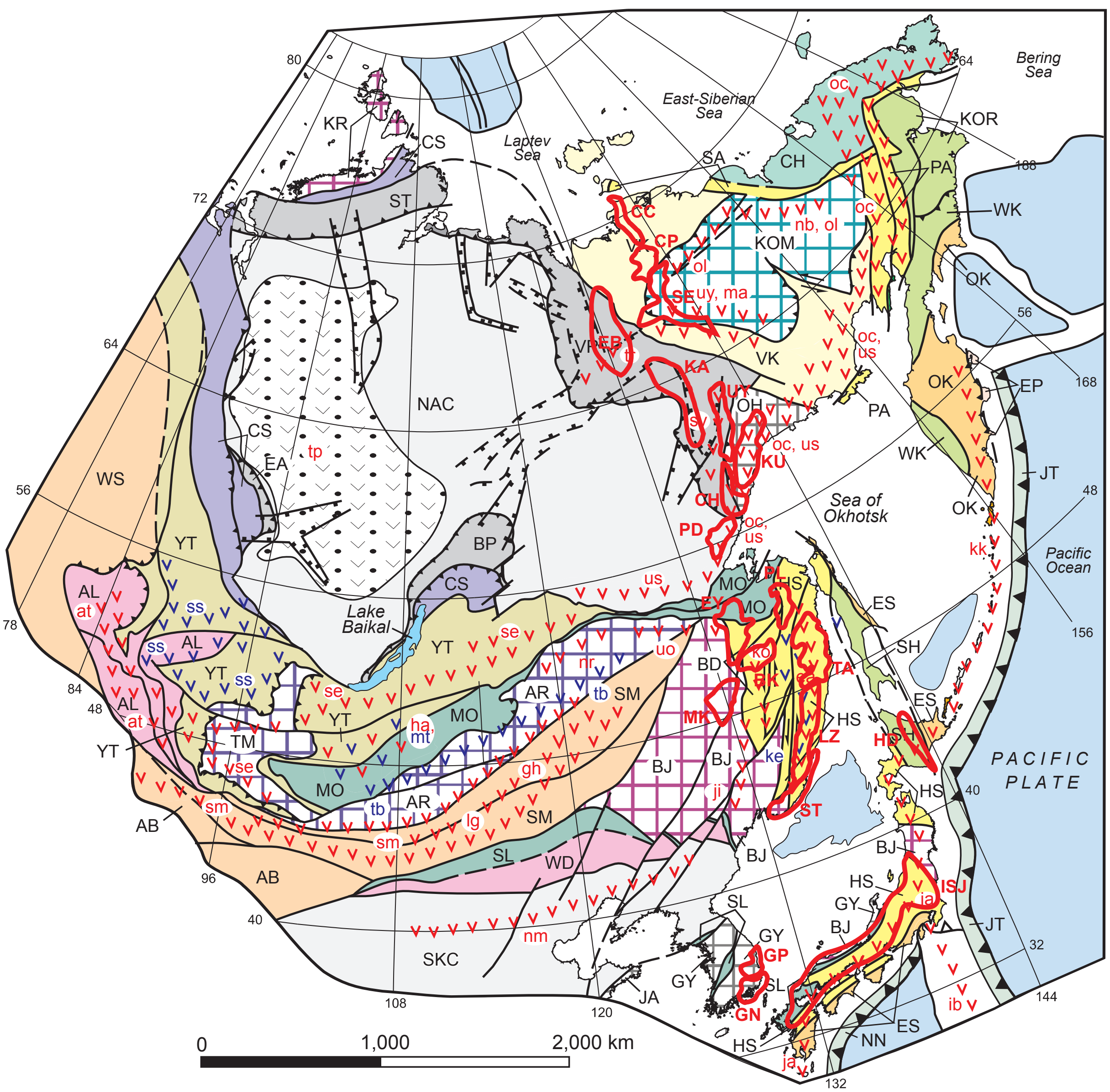


Figure 4. Generalized map of major Cenomanian through Campanian metallogenic belts and major geologic units for Northeast Asia. Refer to text and appendix C for summary descriptions of belts. Refer to figure 2 for explanation of geologic units. Metallogenic belt outlines adapted from Obolenskiy and others (2003, 2004) and Parfenov and others (2003, 2004). Metallogenic belts for area to east of 144 E (eastern boundary of Northeast Asia project area) are described and interpreted by Nokleberg and others (2003).

the Popigay ring structure and is interpreted as resulting from meteoritic impact with formation of pseudotachylite, diamond, high-grade shock metamorphic minerals, and allogenic breccia.

Major Miocene through Quaternary Metallogenic Belts

The major Miocene through Quaternary metallogenic belts are the Kyushu, Northeast Hokkaido, Hokuriku-Sanin, Northeast Japan, and Outer Zone Southwest Japan belts (fig. 5; appendix C).

All five major metallogenic belts possess geologic units favorable for a wide variety of volcanic-rock-related deposits. These belts contain a wide variety of deposits, including Au-Ag epithermal vein; cassiterite-sulfide-silicate vein and stockwork; chemical-sedimentary Fe-Mn; clastic sediment-hosted Hg±Sb; clastic-sediment-hosted Sb-Au;Ag-Sb and Hg-Sb-W vein and stockwork; limonite from spring water; Mn vein; polymetallic Pb-Zn vein and stockwork; polymetallic volcanic-hosted metasomatite; Sn skarn; Sn-W greisen, stockwork, and quartz vein; sulfur-sulfide; volcanic-hosted Hg; Ag-Sb vein; volcanogenic Zn-Pb-Cu massive sulfide; volcanogenic-sedimentary Mn; W-Mo-Be greisen, stockwork, and quartz vein; and Zn-Pb skarn deposits. The isotopic ages of the igneous rocks hosting the deposits range from 15 to 0.3 Ma. The belts and deposits are hosted in the Quaternary Japan volcanic belt and the Neogene Japan sedimentary basin that are interpreted as being part of the modern-day Japan continental-margin arc. This arc is tectonically related to subduction of the Pacific Ocean and Philippine Sea plates beneath the East Asia continental margin.

Late Middle Jurassic through Early Cretaceous (154 to 96 Ma) Metallogenic Belts

Allakh-Yun’ Metallogenic Belt of Au in Shear Zone and Quartz-Vein, Cu (±Fe, Au, Ag, Mo) Skarn, and Au in Black Shale Deposits (Belt AY) (Russia, Verkhoyansk-Kolyma Region)

This Late Jurassic through Early Cretaceous metallogenic belt is related to veins that cut the southern Verkhoyansk fold and thrust belt in the North Asian cratonal margin. The belt extends longitudinally for 300 km in the Minorsk-Kiderikinsk zone of highly deformed Late Carboniferous and Permian sedimentary rock in the western South Verkhoyansk synclinorium. The Au in shear zone and quartz-vein deposits that are characteristic in the belt, is relatively older than the large anatectic granitic plutons of the South Verkhoyansk synclinorium that have a $^{40}Ar/^{39}Ar$ isotopic age of 123 to 120 Ma. The main deposits are concordant and crosscutting veins that occur in hinges and limbs of minor folds. The concordant-vein deposits thin outward into concordant stockworks. Also occurring are tabular deposits along tension fractures. The major deposits are at Yur, Muromets, and Svetly.

The main references on the geology and metallogensis of the belt are Konstantinov and others (1988), Fridovsky (1998), and Parfenov and others (1999).

Yur Au in Shear-Zone and Quartz-Vein Deposit

This deposit (Strona, 1960; Kobtseva, written commun., 1988) consists of four interbedded quartz veins that occur along a zone of meridional faults in Middle Carboniferous sandstone and shale. Veins range from 0.3 to 0.4 meters thick and are 100 to 500 meters long. The main ore minerals are gold, arsenopyrite, galena, pyrite, and sphalerite and comprise as much as 2 percent veins. Gangue minerals are quartz, ankerite, and albite. Wallrock alteration is insignificant and consists of sericite, silica minerals, and arsenopyrite. The deposit is small and has an average grade of 3.5 to 5.7 g/t Au.

Muromets Cu (±Fe, Au, Ag, Mo) Skarn Deposit

This deposit (Krasny and Rasskazov, 1975; Nikitin and Rasskazov, 1979) is hosted in Middle Cambrian dolomite along the contact with an Early Cretaceous quartz monzodiorite. The deposit consists of a band of skarn bodies that are 1 km long and dip gently (20 to 40°) under the intrusion. The bodies range from 6 to 12 meters thick and occur in disseminations, stringers, and rare masses. Minor magnesian skarn consists of spinel, forsterite, phlogopite, tremolite, diopside, and serpentine. Predominant limestone skarn consists of salite, diopside, scapolite, grossular, and andradite. Ore minerals are magnetite, chalcopyrite, molybdenite, scheelite, pyrrhotite, bornite, pyrite, galena, and sphalerite. The skarn formed three stages (1) magnesian skarn with magnetite; (2) calcareous pyroxene-garnet skarn with magnetite and scheelite; and (3) metasomatic quartz-feldspar rock with molybdenite and Cu sulfides. Disseminated Cu sulfides also occur in adjacent altered quartz monzodiorite is a skarn-related porphyry Cu deposit. The deposit is medium size and the average grades are as much as 10 percent Cu, 0.92 percent WO_3, and 0.3 percent Mo.

Origin and Tectonic Controls for Allakh-Yun’ Metallogenic Belt

The belt is interpreted as having formed during accretion of the Okhotsk terrane to the North Asian craton. The belt occurs in the Minorsk-Kiderikinsk zone of highly deformed Late Carboniferous and Permian sedimentary rock in the western South Verkhoyansk synclinorium. The deformation associated with formation of the Allakh-Yun’ belt occurred in the Late Jurassic through Early Cretaceous and is interpreted as having formed during accretion of the Okhotsk terrane to the North Asia craton.

Ariadny Metallogenic Belt of Mafic-Ultramafic Related Ti-Fe (±V) and Zoned Mafic-Ultramafic Cr-PGE Deposits (Belt AR) (Russia, Far East)

This Middle Jurassic and Early Cretaceous metallogenic belt is related to mafic-ultramafic plutons intruding the Samarka subduction-zone terrane. The zoned intrusions that host the Ariadny metallogenic belt consist of Late Jurassic ultramafic and gabbroic plutons with K-Ar isotopic ages of about 160 Ma. The complexes are interpreted as being synvolcanic intrusives that intruded the turbidite deposits of the Samarka subduction-zone terrane immediately before accretion of the terrane in the Early Cretaceous.

The major deposits are at Katenskoe, Ariadnoe, and Koksharovskoe. The deposits consist mainly of disseminated to massive ilmenite that is hosted in layers in gabbro and pyroxenite. Titanium-magnetite and apatite are rare. The deposits also contain sparse PGE minerals, and sparse PGE minerals

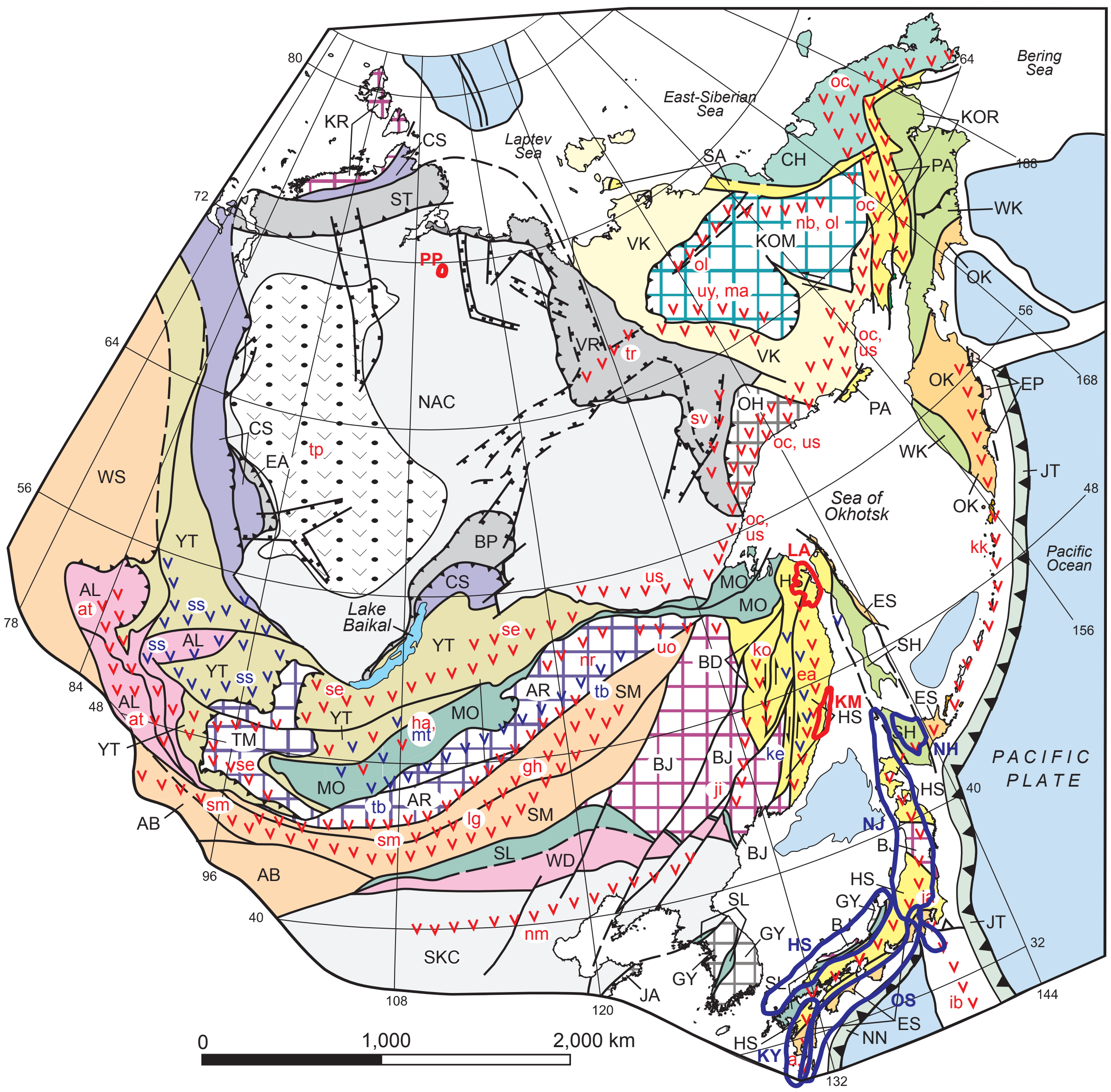


Figure 5. Generalized map of major Maastrichtian through Quaternary metallogenic belts and major geologic units for Northeast Asia. Refer to text and appendix C for summary descriptions of belts. Refer to figure 2 for explanation of geologic units. Metallogenic belt outlines adapted from Obolenskiy and others (2003, 2004) and Parfenov and others (2003, 2004). Metallogenic belts for area to east of 144 E (eastern boundary of Northeast Asia project area) are described and interpreted by Nokleberg and others (2003).

also occur in stream-sediment samples. The host plutonic bodies are several tens of meters thick and several hundred meters long. K-Ar isotopic ages are 170 to 160 Ma. The petrochemical features and mineral composition of the gabbro and pyroxenite intrusions hosting the mafic-ultramafic related Ti-Fe (+V) deposits are similar to those hosting the Kondyor PGE deposit.

The main references on the geology and metallogenesis of the belt are Shcheka and Vrzhosek (1985), Philippov (1990), A.I. Khanchuk, written commun. (1992), Nechaev and others (1996, 1997), and Nokleberg and others (1997, 1998, 2003).

Katenskoe Zoned Mafic-Ultramafic Cr-PGE Deposit

This deposit (Shcheka and others, 1991) consists of disseminated ilmenite in Early Cretaceous pyroxene-hornblende gabbro and olivine gabbro. The deposit consists of lenticular bodies that are several tens of meters thick and at least 1 km long. The deposit is large.

Ariadnoe Mafic-Ultramafic Related Ti-Fe (+V) Deposit

The deposit (Shcheka and Vrzhosek, 1985) consists of abundant disseminated ilmenite that occurs in layers in pyroxene-hornblende gabbro and pyroxenite in layered intrusions. The ilmenite layers are several tens of meters thick and several hundred meters long. A K-Ar isotopic age for the host intrusion is 170 to 160 Ma. Ilmenite contains rare PGE inclusions. The deposit is large, and the average grades are 1.0 to 11.8 percent TiO_2 and 0.086 percent V_2O_5.

Koksharovskoe Mafic-Ultramafic Related Ti-Fe (+V) Deposit

This Koksharovskoe deposit (Shcheka and others, 1991) consists of disseminated ilmenite, magnetite, and apatite that occur in a hornblende and biotite pyroxenite with a K-Ar isotopic age of 160 Ma. Minor PGE minerals also occur. Intrusive rocks are weathered and weathered pyroxenite may have economic concentrations of vermiculite. The deposit is large, and the average grades are 1.0 to 10 percent P_2O_5, and 3.3 to 4.5 percent TiO_2.

Origin and Tectonic Controls for Ariadny Metallogenic Belt

The belt is interpreted as having formed during generation of ultramafic and gabbroic plutons during underthrusting of the Kula oceanic ridge and formation of igneous rocks along a transform continental margin that consisted of intensive strike-slip faulting and magmatism close to the Khingan arc. The Middle and Late Jurassic clastic matrix of the Samarka terrane consists of parautochthonous turbidite and olistostrome with fragments of mainly Middle and late Paleozoic ophiolitic rock and greenstone, Middle Triassic chert, Early Jurassic schist and shale, and Triassic through Jurassic clastic rock. Olistostromes, particularly in the northern terrane, contain large fragments of Carboniferous through 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. The Samarka subduction-zone terrane and correlative subduction zone units in Japan are tectonically linked to Jurassic granitoids in Korea. These subduction-related units are interpreted as being offset from their tectonically-linked igneous arcs by left-lateral movement during the Cretaceous and Cenozoic.

Bindong Metallogenic Belt of Zn-Pb (±Ag, Cu) Skarn W±Mo±Be Skarn, Cu (±Fe, Au, Ag, Mo) Skarn, and Fe-Zn Skarn Deposits (Belt BD) (Northeastern China)

This metallogenic belt is related to Late Jurassic through Early Cretaeous granitoids intruding the Jihei volcanic and plutonic belt of mainly Permian age that intrudes and overlies the Zhangguangcailing superterrane, the Zhangguangcailing sedimentary overlap assemblage, and adjacent units. The belt occurs in the Zhangguangcailing Mountains in the East Heilongjiang Province, and is hosted in a Late Jurassic and Early Cretaceous plutonic belt that intrudes various units of the Paleoproterozoic Zhangguangcailing continental-margin arc superterrane and younger overlap sedimentary assemblages (Shi Lindao, 1994). The skarn deposits occur at contacts between the Devonian and Permian limestone strata and granitoid intrusions. The significant deposits are at Erguxishan, Chuihongshan, Goupengzi, and Wudaling.

The main reference on the geology and metallogenesis of the belt is Shi (1994).

Ergu-Xishan Zn-Pb (±Ag, Cu) Skarn Deposit

This deposit occurs (Xu, Enshou and others, 1994) in the axial part of the Ergu-Xujiugou anticline in the Zhangguangcailing fold belt that contains Early Permian siltstone and marble that in xenoliths in Hercynian medium-grained biotite plagiogranite, porphyritic biotite granite, and granodiorite. The deposit is controlled by the east-west-trending, north-dipping fractures and the contacts. The main wallrock alteration is skarn. The deposit is small and has reserves of 129,800 tonnes Pb and 221,300 tonnes Zn; the average grades are 2.55 to 3.37 percent Pb and 3.23 percent Zn.

Chuihongshan Fe Skarn Deposit

This deposit (Cao, Jingxian, 1993a,b) consists of several skarn lenses that occur concordant to the bedding of host rocks and trend northwest along the contact between the alaskite granite and dolomite. The skarns occur mainly in masses, layers, stockworks, and veinlets. The ore minerals are magnetite, cassiterite, molybdenite, scheelite, galena, sphalerite, chalcopyrite, and pyrrhotite. The gangue minerals are diopside, phlogopite, garnet, actinolite, wollastonite, clino-humite, and fluorite. Horizontal zoning in the main deposit occurs and consists from inward to outward of Mo W-Fe, Mo-W-Fe, Fe-Zn-Cu, and Pb-Zn ore minerals. At the contact zone are contact metasomatic scheelite, cassiterite, and magnetite, and younger hydrothermal deposits of molybdenite and Cu-Pb-Zn sulphides. The host strata are Middle to Late Carboniferous slate, marble, and metamophosed sandstone and dolomite. Late Permian tuffeous pebble sandstone and intermediate to siliceous volcanic rock occur but do not contain skarn. Both sequences are intruded by granite. The deposit is medium size and has reserves of 531,000 tonnes Cu, 121,600 tonnes WO_3, 194,300 tonnes Pb, and 478,600 tonnes Zn. The average grades are 40 to 50 percent Fe, 0.45 percent Cu, 0.32 percent WO_3, 3.30 percent Pb, and 2.43 percent Zn.

Wudaoling W±Mo±Be Skarn Deposit

This deposit (Hwang and others, 1994) consists of irregular masses at a contact zone between quartz porphyry and intermediate and siliceous volcanic rock of Late Permian Wudaoling Formation. The quartz porphyry is silica-rich with more than 75 percent SiO_2, 7.97 to 8.04 percent K_2O+Na_2O, 1.21 to 1.31 percent K_2O/Na_2O; it has a whole rock K-Ar isotopic age of 157.8 Ma. Both the porphyry and W±Mo±Be skarn bodies are controlled by an east-west striking fault. Ore minerals are mainly molybdenite, pyrite, and magnetite, with lesser hematite, specularite, chalcopyrite, galena, sphalerite, bornite, chalcocite, tetrahedrite, and bismuthinite. Mo bodies occur in disseminations and minor veins. The wallrocks are altered to skarn, silica, beresite, and carbonates. The deposit occurs at the southeast part of Yuquan-Sandaogang anticlinorium in the Variscan Jilin-Heilongjiang orogenic belt. The deposit is medium size.

Origin and Tectonic Controls for Bindong Metallogenic Belt

The belt is interpreted as having formed during interplate extensional tectonism and subalkaline to alkaline volcanism and related sedimentation. The belt occurs along northeast and east-west-trending regional faults, consists of various skarn zones and deposits that occur at contacts between some small intrusions of granodiorite, biotite granite, granite porphyry, quartz porphyry and Devonian limestone and clastic rock, Early Permian marble, sandstone, shale, and the Late Permian felsic volcanic rock. Previously, the belt was interpreted as having formed during the Triassic (Indosinian Orogeny); however, new isotope data indicate the belt is the Middle Jurassic and Early Cretaceous (Shi, Lindao, 1994). The skarns contain numerous metals, including Fe, Cu, Pb, Zn, W, Sn, and Mo. Like other Middle Jurassic and Early Cretaceous metallogenic belts in Northeastern China, the magmatism and deposits in this belt are interpreted as having formed in a tensile tectonic setting along north-northeast-trending regional faults (Tanlu fault system or fracture zone). The origin of the Mesozoic magmatic and related deposits in Northeastern China is a controversial topic. Some authors relate the magmatism and deposits to the subduction of the ancestral Pacific Oceanic Plate under the Eurasian Plate; however, this interpretation may be too simple.

Chara-Aldan Metallogenic Belt of Au Potassium Metasomatite, U-Au, Au in Shear-Zone and Quartz-Vein, Au-Ag Epithermal-Vein, Au-Skarn, Charoite Metasomatite, and Felsic Plutonic U-REE Deposits (Belt CA) (Russia, Aldan-Stanovoy Shield)

This Jurassic through Early Cretaceous metallogenic belt is related to replacements and granitoids in the South Yakutian subalkaline and alkaline igneous belt that intrudes the North Asian craton and Central Aldan superterrane in the southeastern part of North Asian craton. The belt consists of Au sheets, veins, crush zones and U-Au zones that are related to the Jurassic and Early Cretaceous subalkaline and alkaline granitoids. The belt contains several districts of Mesozoic subalkaline and alkaline plutons, stocks, and sills of alkali syenite, monzonite, granosyenite, alkali gabbro, and associated volcanic rocks. These magmatic rocks intrude the Early Precambrian crystalline basement and Vendian and Early Cambrian sedimentary cover of the Aldan-Stanovoy shield. The belt is promising for undiscovered REE and U deposits. The major deposits are at Kuranakh, Klin, Krutoy, and Murunskoye.

The main references on the geology and metallogenesis of the belt are Naumov and Shumilin (1994), Konev and others (1996), Vetluzhskikh and Kim (1997), Miguta (1997), Boitsov and Pilipenko (1998), Parfenov and others (1999), and Fredericksen and others (1999).

Kuranakh Au Potassium Metasomatite (Kuranakh type) Mine

This mine (Benevolskiy, 1995; Fredericksen, 1998; Fredericksen and others, 1999) consists of Au-bearing potassium metasomatite that occurs along horizontal Cambrian calcareous rock and Jurassic sandstone where intruded by lamprophyre dikes emplaced along high-angle fault and especially bedding. Host rocks are Jurassic arkose, Early Cambrian limestone and dolomite, underlying Precambrian metamorphic basement, and abundant Mesozoic plutonic rock. The deposit occurs in subhorizontal sheets that range from a few meters to a few tens of meters thick and extend for several kilometers along sublongitudinal faults and Mesozoic dikes. The deposit formed during Jurassic and Early Cretaceous intrusion of dike swarms and (or) small plugs and sills of bostonite, microgabbro, and minette. Gold deposits are spatially related to dikes that range from premineral to postmineral in relative age. Several subhorizontal deposits occur in blankets or ribbons, are as much as a few dozen meters thick, and are located mainly along and (or) above or under the contact between the Cambrian calcareous footwall and the overlying Jurassic clastic rock in a long narrow zone that is bounded by several north-south-trending faults. The two types of metasomatite are quartz-adularia and quartz-replacing adularia.

The main metasomatite minerals are quartz, pyrite, marcasite, gold, Ag, bismuth, pyrrhotite, chalcopyrite, arsenopyrite, galena, sphalerite, carbonate, and barite. The main part of the Au deposits contains pyrite, arsenopyrite, sphalerite, and galena with sulfide comprising only a few percent of rock volume. The deposit is thoroughly oxidized and only a few traces of arsenopyrite and pyrite occur. The Au occurs primarily as grains less than 5 microns in size and usually contains friable porous goethite. Fluid inclusion homogenization temperatures range from 80°C to 220°C but generally average 110 to 160°C. Metasomatite is controlled by interplate rift structures. Local areas are complicated by formation of karst cavities with deposition of secondary rubble ore, and by surficial weathering of ore minerals and replacement of Au. The Kuranakh deposit was discovered in 1947 and modest production began in 1955. Large scale open pit mining began in 1965 and continues to the present. The Kuranakh mine is one of the largest lode gold mines in Russia. Gold recovery averages 83 percent using resin columns. The deposit is large and it produced 7.1 million ounces of gold through 1997 from 74.1 million tonnes of ore. The average grade is 3.57 g/t Au.

El’kon Group of Au in Shear-Zone and Quartz-Vein deposits

The El’kon group of Au in shear-zone and quartz-vein deposits (Naumov and Shumilin, 1994; Boitsov and Pilipenko, 1998) occurs on the eastern margin of the Central Aldan ore district that contains several hydrothermal deposits that occur along northwestern striking Mesozoic faults that cut the crystalline basement of the Aldan-Stanovoy shield. These deposits contain the largest U reserves in Russia. Three types of deposits occur, Au-brannerite, Au-uraninite, and Au-Ag brannerite. Au-brannerite deposits consist of metasomatite zones that extend as much as 20 km long, range from 1.0 to 40 meters thick, and formed from replacement of host gneiss, schist, metadiorite, and blastomylonite. The sequence of mineral assemblages is (1) pyrite, ankerite, and K-feldspar; (2) pyrite, dolomite, K-feldspar; and (3) calcite and adularia. Au grade in pyrite of the first assemblage is 60 to 90 g/t. The third assemblage contains native gold and ranges from 40 to 100 g/t. Brannerite is the only U mineral in the metasomatite and occurs in a matrix of microbreccia and veinlets. Typical U-ore shoots extend for 20 km and form distinct deposits (Druzhnoye, Kurung, El’kon Plato, El’kon). Au-uraninite deposits occur in the northwestern part of the belt (Nadezhnoye and Interesnoye deposits) and consist of auriferous pyrite-carbonate-K-feldspar metasomatite with superposed U. In the southern part of the area, Brannerite-Au-Ag deposits are characteristic of the Fedorovskoye deposit which contains U minerals and consisits of a metasomatite zone that ranges from 8 to 30 km thick and is 10 km long. The metasomatite and brannerite deposits are overprinted by a late-stage mineral assemblage of quartz, carbonate, native gold, native silver, and acanthite. Grades range from 3 to 10 g/t Au, 15 to 200 g/t (as much as 1,400 g/t) Ag, and 0.02 to 0.5 percent U.

Murunskoe-Tokski Group of Charoite Metasomatite Deposits

The Murun-Tokski group (Konev and others, 1996) occurs in western Northern Transbaikalia along the margin of the West-Aldan cratonal terrane, and is related to magmatic complexes of the overlap Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt. The major deposit is at Murunskoye. The group of deposits occurs in the extreme northeastern of Baikal-Patom highland, extends northeast for 200 km, and si as much as 75 km wide. The Middle to Late Jurassic igneous rocks of the Transbaikalian sedimentary and volcanic-plutonic belt consist of minor ultrapotassic and alkaline intrusions (stocks and laccolith), and subvolcanic rock of the Aldan Complex. The igneous rocks occur at intersections of large faults that trend northeast, northwest and submeridional (Atbastakh-Torgoy and others) and cut the periphery of the Archean Chara block. The main igneous rock types are K-Na nepheline syenite, alkaline syenite, quartz syenite, alkaline granite, biotite pyroxenite, lamproite, ijolite, leucite fergusite, and shonkinite. Zones of alkaline metasomatite occur along margins of alkaline intrusions. The deposit-hosting Murun laccolith is a zoned intrusive complex composed of syenite, alkaline syenite, and fenite, and is surrounded by alkaline ring dikes (Konev and others, 1996). Comagmatic trachyte lavas occurs in separate volcanic structures that are mostly eroded. This laccolith contains a wide spectrum of high- and medium-temperature hydrothermal deposits (Th-Ti, Th-U, U) and metasomate that contain charoite as the major useful mineral. This deposit is the only global occurrence of charoite. The charoite bodies occur in veins and irregular shapes in metasomatite.

Origin and Tectonic Controls for Chara-Aldan Metallogenic Belt

The belt is interpreted as having formed in a back-arc region of an Andean-type continental-margin arc that formed along the Early Cretaceous margin of the North Asian craton. The belt is hosted in subalkaline and alkaline plutons, stocks, and sills of syenite, monzonite, granosyenite, and alkali gabbro, and related volcanic rocks.

Chybagalakh Metallogenic Belt of Sn-W Greisen, Stockwork, and Quartz Vein, Sn-B (Fe) Skarn (ludwigite), and Granitoid-Related Au-Vein Deposits (Belt CH) (Russia, Verkhoyansk-Kolyma Region)

This Late Jurassic through Early Neocomian metallogenic belt is related to veins and replacements in the Main granite belt. The belt extends for 250 km, is as much as 75 km wide, and coincides spatially with the Main batholithic belt (Trunilina, 1992). The northwestern part of the belt contains the Burgavli-Chalba Sn-W and Upper Tirekhtyakh B-Sn districts. The Burgavli-Chalba Sn-W district extends sublatitudinally for 70 km, is as much as about 10 km wide (Flerov and others, 1979), and contains complexly-deformed Jurassic flysch in the Inyaly-Debin synclinorium that is intruded by Early Neocomian granitoid. In the subsurface, contact-metamorphic zones occur adjacent to granitoid plutons. The deposits are related to granite and leucogranite and contain cassiterite-quartz and cassiterite-wolframite-quartz veins and stockwork. The Upper Tirekhtyakh B-Sn district occurs to the northeast of the Burgavli-Chalba district and is hosted in a homogeneous granodiorite and granite pluton (Trunilina, 1992). The district extends to the northwest for 40 km and is as much as 10 to 15 km wide. B-Sn and magnetite skarn deposits occur along the margins of the granodiorite in Paleozoic carbonate rock. Granitoid-related Au-REE deposits also occur in the belt. The major deposits are the Kere-Yuryakh Sn-W greisen, stockwork, and quartz-vein deposit, the Titovskoe Sn-B (Fe) skarn (ludwigite) deposit, and the Chuguluk and Nenneli granitoid-related Au-vein deposits.

The main references on the geology and metallogenesis of the belt are Shoshin and Vishnevsky (1984), Trunilina (1992), and Parfenov and others (1999).

Kere-Yuryak Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (Flerov and others, 1979) occurs in the apical portion of a granite pluton that intrudes an anticline formed in Middle Jurassic sandstone. The deposit consists of stockwork veins and stringers that occur along the upper contact of the pluton. The veins and stringers are 0.1 to 2 meters thick and are as much as 100 meters long. Outcrops of vein and stringer zones vary from 50 to 150 meters wide. Major minerals are quartz, tourmaline, muscovite, arsenopyrite, cassiterite, and wolframite. Rare minerals are topaz, apatite, scheelite, tetrahedrite, pyrite, molybdenite, and bismuthine. The deposit exhibits intense greisen alteration. The average grades are 0.6 percent Sn, 0.487 percent As, and 0.62 percent W.

Titovskoe Sn-B (Fe) Skarn (ludwigite) Deposit

This deposit (Dorofeev, 1979) consists of 40 bodies of Mg skarn that occur along the contact between the quartz monzonite phase of an Early Cretaceous granitoid intrusion and Silurian and Devonian dolomite and limestone. The skarn ranges from 5 cm to 20 meters thick and ranges from 50 to 1,000 meters long. The main ore mineral is ludwigite and it forms as much as 70 to 80 percent some deposits. The skarn also contains 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 sulfides, including pyrrhotite, sphalerite, pyrite, arsenopyrite, and chalcopyrite. Kotoite ore veins occur along margins of ludwigite bodies. Contact between the intrusion and carbonate is highly irregular. Most skarn bodies occur in embayments into the intrusion. The deposit occurs in an area 3 by 6 km, is medium to large in size and has average grades of 9.5 percent B_2O_3 and 0.3 percent Sn.

Origin and Tectonic Controls for Chybagalakh Metallogenic Belt

The belt is interpreted as having formed during collision of the Kolyma-Omolon superterrane and the North Asian craton and generation of anatectic high-alumina granitoids. The collision was accompanied by deformation, metamorphism, and formation of the high-alumina granitoid Main batholithic belt.

Djeltulaksky Metallogenic Belt of Granitoid-Related Au-Vein Deposits (Belt DL) (Russia, Far East)

This Early Cretaceous metallogenic belt is related to granitoids in the Stanovoy granite belt that intrude the Tynda terrane and the Dzugdzur anorthositic belt. The deposits generally consist of quartz and quartz-carbonate veins that are spatially related to Jurassic through Early Cretaceous granite and granodiorite that are generally interpreted as having formed in a collisional setting. Also occurring in the area are numerous placer Au mines and local, large placer Au mines in the west-central part of the Russian Far East. The major deposit is at Zolotaya Gora.

The main references on the geology and metallogenesis of the belt are Mel'nikov (1984) and Nokleberg and others (2000, 2003).

Zolotaya Gora Granitoid-Related Au-Vein Deposit

This deposit (Mel'nikov, 1984) consists of quartz veins and zones of hydrothermally altered metamorphic rock that are conformable to host rock layering. Alteration assemblages are predominantly sericite and quartz, and chlorite, amphibole, and quartz. The main mineral assemblages are sulfide, biotite, and quartz; sulfide, sericite, and quartz; and biotite, quartz, amphibole, and chlorite. Less common is an assemblage of amphibole, quartz, and feldspar. Four successive stages of deposition are identified (1) magnetite, chalcopyrite, pyrrhotite, and quartz; (2) gold, carbonate, and sulfide; (3) zeolite; and (4) supergene. Gold occurs both in early and late quartz and in hydrothermally-altered rock. Gold generally occurs in 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 hosted in gneissic granite, granulite, calcareous shale, and quartzite of the Tynda terrane. The deposit is small, and the average grade is about 52 g/t Au. The deposit was intermittently mined from 1917 to 1948; it has produced 2.5 tonnes gold.

Origin and Tectonic Controls for Djeltulaksky Metallogenic Belt

The belt is interpreted as having formed during late-stage accretion of the Bureya superterrane to the south with the North Asian craton to the north, during final closure of the Mongol-Okhotsk Ocean. The Paleozoic rocks contain beds of Au-bearing, pyrite-bearing graphitic shale.

Daxinganling Metallogenic Belt of Zn-Pb (±Ag, Cu) Skarn, Sn-Skarn, Cassiterite-Sulfide-Silicate Vein and Stockwork, Polymetallic Pb-Zn, Cu (Au, Ag) Veins and Stockwork, Peralkaline Granitoid-Related Nb-Zr-REE, and Au-Ag Epithermal-Vein Deposits (Belt DX) (Northeastern China)

This Late Jurassic and Early Cretaceous metallogenic belt is related to veins, replacements, and granitoids in the Daxinganling part of the Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt. The belt overlies and intrudes the Gobi-Khankaisk-Daxinganling volcanic-plutonic belt. The belt occurs in the central and southern Daxingaling region (Great Khingan Mountains), southeastern Inner Mongolia. The belt consists of three northeast-trending, subparallel zones. The middle zone is the largest, and is 500 km long and 100 km wide. The Daxinganling volcanic-plutonic belt contains very thick, multiple stages of volcanic rock that are as much as 2,000 to 3,000 meters thick, and it consists mainly of basalt, andesite, trachyandesite, trachyte, and dacite. Felsic volcanic rock is dominant. The volcanic rocks are calc-alkalic with slightly high alkaline content. The associated plutonic rocks occur in a batholith, stocks, and dikes, and consist mainly of granodiorite, granite, tonalite diorite porphyry, granite porphyry and quartz monzonite, orthoclase granite and alkaline granite. The plutonic rocks intrude Permian oceanic volcanic and sedimentary rocks that are interpreted as having formed in an island arc in a residual oceanic basin (Xu, Zhigang, 1993). The island arc assemblage forms an overlap assemblage that formed after accretion of the Xilinhot, Solon, and Hegenshan terranes. The metallogenic belt includes a variety of deposits and metals. The major cassiterite-sulfide-silicate vein and stockwork deposit is at Maodeng, the major polymetallic Pb-Zn, Cu (Au, Ag) veins and stockwork deposits are at Meng'entaolegai and Aonaodaba; the major peralkaline granitoid-related Nb-Zr-REE deposit is at Baerzhe, and the major Au-Ag epithermal-vein deposit is at Guandi.

The main references on the geology and metallogenesis of the belt are Li (1993), Xu (1993), and Zhang, and others (1994).

Baiyinnuoer Zn-Pb (±Ag, Cu) Skarn Deposit

This deposit (Li and others, 1993) occurs in the central part of Huanggangliang-Wulanhaote polymetallic belt. The deposit occurs in a secondary anticline of the Sifangcheng-Baiyinwula anticlinorium. Northeast-striking faults control the formation and distribution of igneous intrusions in the deposit. The strata consist of Early Permian low-grade metamorphic rock and late Jurassic siliceous and intermediate volcanic rock. The Early Permian strata host most of the deposit. The strata are composed of sandy slate, carbonate, and pelitic slate and occur in the central and southeast parts of the associated district. The Yanshannian granitoids consists of granodiorite, granodioritic porphyry, quartz syenite porphyry, and granite porphyry. The deposit occurs mainly in skarn along a contact zone between granodioritic porphyry and country rock. The main ore minerals are sphalerite and garnet, and the minor ore minerals are chalcopyrite, pyrite, pyrrhotite, and stannite, and Ag minerals. The main gangue minerals are hedenbergite, epidote, andradite, actinolite, diopside, wallstonite, quartz, and calcite. The deposit is large and has reserves of 2.4 million tonnes of Pb+Zn grading 3.24 percent Pb and 5.46 percent Zn.

Maodeng Cassiterite-Sulfide-Silicate Vein and Stockwork Deposit

This deposit (Liu, 1996) occurs in the western contact zone of the Alubaogeshan granite porphyry with a Rb-Sr isotopic age of 149 Ma. The deposit is hosted in a Jurassic bimodal volcanic sequence, including a lower basalt and upper rhyolite unit, in the Maoding volcanic basin. The deposit occurs in veins controlled by a northwest-trending fault system. The major ore minerals are cassiterite, chalcopyrite, arsenopyrite, sphalerite, and molybdenite. The minor ore minerals are pyrite, galena, magnetite, hematite, wolframite, bornite, scheelite, and bismuthine. Nonmetallic minerals are quartz, fluorite, K feldspar, biotite, calcite, tourmaline, topaz, and muscovite. The ore minerals are idiomorphic to hypidiomorphic granular texture and occur in metasomatic fillings, disseminations, masses, veins, veinlets, stockwork, and breccia. In the magnetite, cassiterite, and sulphide deposits–potassic silicates, greisen, and silica, respectively. The deposit is interpreted as having formed during hydrothermal conditions at a moderate depth of 1.6 to 2 km and moderate temperature of 450 to 200°C. The deposit is medium size.

Meng'entaolegai Polymetallic Pb-Zn, Cu (Au, Ag) Vein and Stockwork Deposit

This deposit (Li and others, 1993) occurs along the west junction between the Daxinganling orogenic belt and the Songliao Basin. The main part of the deposit is controlled by east-west-and northeast-trending faults. The deposit is hosted in Permian and Jurassic tuffaceous sandstone, slate, tuffaceous clastic rock, marble, arkose, pelitic siltstone, lava, and bioclastic limestone. Both Hercynian and Yanshannian-age granitoids occur. The Mengentaolegai granite covers an area of 240 km^2, has a K-Ar isotopic age of 286 Ma, and a U-Pb isotopic age of 235 Ma. The Duerji granite complex consists of coarse-grained biotite-plagioclase granite, granodiorite, moyite, alaskite, and fine-grained biotite granite. The complex covers an area of 150 km^2 and has a U-Pb zircon age of 150 Ma. Forty-four sizes of veins occur. The main wall-rock alterations are sericite, Mn siderite, silica, and chlorite. The main ore minerals are sphalerite, galena, and Ag minerals, and the minor minerals are chalcopyrite, pyrite, pyrrhotite, arsenopyrite, chalcocite, and cassiterite. The deposit formed at temperatures of 140 to 340°C, and the deposit is closely related to the Yanshannian Duerji granite. The deposit is large and has reserves of 84,300 tonnes Pb and 2,300 tonnes Zn. The average grades are 84 g/t Ag, 1.02 percent Pb, and 2.30 percent Zn.

Baerzhe Peralkaline Granitoid-Related Nb-Zr-REE Deposit

The deposit (Lin, Chuanxian and others, 1994) is hosted in a riebeckite granite that intrudes Middle Jurassic volcanic rock and occurs in two areas. The western part of the intrusion covers an area of 0.11 km^2, the eastern part covers an area of 0.24 km^2, and at the depth, the two parts merge. A Rb-Sr isotopic age is 125 Ma. The main minerals are barbierite, quartz, and riebeckite, the minor minerals are aegrite and albiteoligoclase, and accessory minerals are zircon, monazite, bunsite, fluorite, calcite, galena, sphalerite, pyrrhite, and ferrothorite. In the eastern intrusion, from the surface to depth, successive zones of pegmatitic granite, albite-altered granite, and porphyritic riebeckite granite occur. Weak alterations are silica, chlorite, carbonate, aegrute, and sulphides. The ratio of K+Na/Al is greater than 1, and SiO_2 content is high. REE distribution patterns slope slightly to the right. The rocks are rich in REE, and Eu is intensely depleted. The main economic minerals are bunsite (500 to 800 g/t), monazite (79 to 2,000 g/t), pyrrhite (80 g/t), titano euxenite (20 to 80 g/t), xinganite (600 to 7000 g/t) and niobite (94 to 5000 g/t). The initial $^{87}Sr/^{86}Sr$ is 0.689±1. The deposit is large and has it has an average grade of 0.051 percent BeO and 0.258 percent Nb_2O_5 .

Ag-Sn Deposits

Various Ag-Sn deposits (Meng'entaolegai, Aonaodaba, and others), mainly polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork deposits (Li Henian and others, 1994) occur in the middle Hercynian Daxinganling orogenic belt. The main structures are a north-northeast-trending syncline and northeast-striking faults. The host rocks are Early Permian low-grade metamorphosed sandstone, graywacke, sericite slate, and knotted slate. The igneous intrusion is mainly the Yanshannian granite porphyry that occurs at the core of the syncline and is intruded by slightly younger granodioritic porphyry and quartz syenite porphyry. The granite porphyry has a Rb-Sr whole-rock isochron age of 148.3 Ma. The main alterations are silica, topaz beresite, K-feldspar and chlorite. The deposits occur in veins and, locally, in lenses. The main ore minerals are pyrite, chalcopyrite, arsenopyrite, sphalerite, and pyrrhotite, and the minor ore minerals are loelingite, garnet, and tetrahedrite. Rare argentite, molybdenite, and marcasite also occur. The deposit-forming temperatures are 160 to 426°C.

Aonaodaba Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (Li and others, 1993; Zhang and others, 1994) occurs in the southeastern part of the Daxinganling Hercynian orogenic belt that is hosted in Early Permian, low-grade metamorphosed sandstone, graywacke, sericite slate, and knotted slate. The Yanshannian granite porphyry, that intrudes the core of a syncline, is intruded by slightly younger granodiorite porphyry and quartz syenite porphyry. The granite porphyry has a Rb-Sr whole-rock isochron age of 148.3 Ma and is altered to silica, topaz-beresite, K-feldspar, and chlorite. The dposit occurs in veins and rare lenses. The main ore minerals are pyrite, chalcopyrite, arsenopyrite, sphalerite, and pyrrhotite, and minor loelingite, garnet, and tetrahedrite, along with very minor argentite, molybdenite, and marcasite. The deposit formed at temperatures of 160 to 426 C. The deposit is large.

Guandi Au-Ag Epithermal-Vein Deposit

This deposit (Zhang and others, 1994) consists of several Ag veins in a volcanic rock belt. The ore mineral textures range from hypidiomorphic to xenomorphic to varied metasomatic. The ore minerals occur in disseminations, masses, veins and stockwork. Ag minerals are freibergite, Ag tetrahedrite, vitreous Ag, stromeyerite, and electrum. Other metallic minerals are sphalerite, galena, pyrite, chalcopyrite, tetrahedrite, cerusite, and magnetite. Gangue minerals are quartz, rhodochrosite, calcite, dolomite, sericite, chlorite, siderite, and fluorite. The deposit is large and grades 60 to 1500 g/t Ag (locally as much as 2,400 g/t Ag), and Au ranges from 0.68 to 4.4 g/t.

Origin and Tectonic Controls for Daxinganling Metallogenic Belt

The belt is interpreted as having formed during Middle Jurassic through Early Cretaceous extensional tectonism associated with generation of the Trans-Baikalian-Daxinganling volcanic-plutonic belt that was related to the back arc of a continental-margin arc. The metallogenic belt is controlled by major, regional northeast-and northwest-trending faults. The basins and granitoids are controlled by northeast-north-northeast and east-west striking regional faults that to certain degree reflect the preMesozoic structures (Xu, 1993, Zhang and others, 1994). The granitoids related to W and Sn deposits are mainly K feldspar granite, whereas the granitoids related to Pb, Zn and Cu deposits are granodiorite and quartz syenite. The two types of granite differ greatly in petrochemical and geochemical features (Zhang and others, 1994). The Permian volcanic and sedimentary rock may be the main source for Sn, Pb, Zn and Ag (Li Henian, 1993; Zhang and others, 1994).

Dzhid-Selenginskiy Metallogenic Belt of W-Mo-Be Greisen, Stockwork, and Quartz-Vein, Granitoid-Related Au Vein, Au Skarn, Porphyry Mo (±W, Bi) (+W, Sn, Bi), Fluorspar-Vein; and Magmatic, and Metasomatic Apatite Deposits (Belt DS) (Russia, West Transbaikalia, Mongolia)

This Middle Jurassic through Early Cretaceous metallogenic belt is related to veins, replacements, and plutons related to the Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt that overlies and intrudes the Dzhida, Hamar-Davaa, and Orhon-Ikatsky terranes, the Selenga sedimentary-volcanic plutonic belt, the Barguzin-Vitim granitoid belt, and adjacent units. The belt occurs in the Selenga and Dzhida River Basins and extends from Mongolia northeast to southern Lake Baikal in Russa. The belt is 725 km long and 85 to 175 km wide. The Transbaikalian sedimentary and volcanic-plutonic belt occurs in numerous rift basins in two sequences (1) Middle and Late Jurassic shoshonite and latite; and (2) Late Jurassic and Early Cretaceous trachybasalt. Plutonic rocks occur in several intrusive Jurassic complexes: (1) the Kyrinsky complex with large plutons of calc-alkaline biotite, biotite-amphibole diorite, granodiorite, granite, and leucogranite; (2) the Sokhondinsky complex with subvolcanic dacite and rhyolite bodies; (3) the Asakan-Shumilovsky complex of biotite and biotite-amphibole granite, granite, and leucogranite; (4) the Kharalginsky complex of high alkaline biotite leucogranite, syenite porphyry, leucogranite, and alaskite; and (5) gabbro and syenite and local carbonatite. Deposits and occurrences are located in various districts. The most widespread are W and Mo deposits of different model types (Reif and Bazheev, 1982; Petrovskaya and Spiridonov, 1977; Dzhida ore region, 1984, Khodanovich, 1995). The major deposits are in the Dzidinskoye district, and at Malo-Oinogorskoye, Arsentievskoye, Naranskoye, and Oshurkovskoye. The belt may contain undiscovered deposits.

The main references on the geology and metallogenesis of the belt are Tsyba (1990), Bulnaev (1995), Khodanovich (1995), Litvinovsky and others (1999), and Dondovyn (1999).

Dzhidinskoe District of W-Mo-Be Greisen, Stockwork, and Quartz-Vein Deposits

This district (fig. 6) (Gordienko, 1987; Khodanovich, 1995; Skursky, 1996) occurs in three areas in the apical part of a small Triassic granite massif.

The Pervomayskoye stockwork Mo deposit (with dimensions of 620 by 540 meters) is mushroom-shaped, and extends to a depth of 240 to 250 meters. Ore consists of molybdenite, pyrite, sphalerite, chalcopyrite, bismuthine, fluorite, aud beryllium. Gangue minerals are quartz, K-feldspar, and muscovite. Ore contains 0.1-0.15 percent Mo, 0.018 percent BeO, and 0.031 percent W_20_5.

The Kholtosonkoye vein W deposit consists of economic hubnerite-sulfide-quartz veins (500-2,000 by 0.8 by 500 to 600 meters). Ore consists of hubnerite (10.4 to 4.5 percent), scheelite (0.1 to 3.5 percent), galena (0.1 to 11.9 percent), sphalerite (0.1 to 3.5 percent), pyrite (0.2 to 7.6 percent), chalcopyrite (0.001 to 0.8 percent), fluorite (0.2 to 7.6 percent). The grade of WO_3 varies from 1.10 to 0.42 percent.

The Inkurskoye stockwork W deposit (with dimensions of 1700 by 400-600 by 300-400 meters) consists a network of quartz, quartz-feldspar, quartz-muscovite and quartz-sulfide veinlets with hubnerite and scheelite. The major minerals are hubnerite and scheelite. Less widespread minerals are pyrite, galena, sphalerite, chalcopyrite, and gray ore. The average grade in stockwork is 0.147 percent WO_3; 0.019 percent Pb; 0.045 percent Zn; 0.0035 percent Cu; 0.046 percent BeO; 0.7 ppm Au, and 6 ppm Ag. Many veins occur along the dike belt with diorite porphyry, microdiorite, aplite, syenite porphyry, and lamprophyre. The early and middle Paleozoic host granitoid rock is altered to berisite, sericite, and greisen. The deposit is large and has a a grade in stockwork ores of 0.16 to 0.18 percent WO_3 and a grade in vein bodies 0.5 to 1.0 percent WO_3. The average grades are 0.1 to 0.15 percent Mo, 0.3 to 0.5 percent Pb, 0.3 percent Cu, and as much as 2.8 ppm Au, and as much as 315 ppm Ag. The deposit is explored to 700 meters depth.

In northern Mongolia, the district is related to granitoids intruding the Vendian through early Paleozoic Dzida island-arc terrane. The district contains W-Mo-Be greisen, stockwork, and quartz vein; W-Mo-W±Mo±Be skarn; granitoid-related Au vein; and Au-skarn deposits. The major deposits are the Bulagtai vein and stockwork W-Mo deposit, Sohatinh W-Mo skarn occurrence, the Baruunhujirt granitoid-related vein Au occurrence, Tavt granitoid-related vein Au (Cu, Ag) deposit, and Teshig group Cu, Au, Fe skarn deposit and occurrences. The granitoid-related deposits are closely related to Late Jurassic leucogranite stocks of the Gudjir Complex that also contains REE granite stocks. Isotopic ages for granitoids in the Gudjir complex are 180 to 170 Ma and 145 to 140 Ma. The related granitoids in the district consist of small stocks of granite porphyry and leucogranite, and dikes of aplite, aplite porphyry, fine-grained granite, syenite, syenite porphyry, and granite porphyry.

Tavt (Ereen) Granitoid-Related Au-Vein Deposit

This deposit (Tsyba, 1990; Jargalsaihan and others, 1996) is hosted mainly in early Paleozoic gabbro and granitoids with xenoliths of Vendian through Lower Cambrian limestone that are intruded by Late Permian granitoids of the Selenge complex, and by early Mesozoic granitoid stocks and dikes of the Orkhon intrusive complex. Abundant quartz veins occur and contain gold and sulphides, mostly in the early Paleozoic gabbro and gabbro-diorite, and in the first phase granitoids of the Selenge complex. About 100 gold-sulfide-quartz veins occur in mainly 10 zones that range from 2.0 to 7.5 km long and 50.0 to 800.0 meters wide, and strike northwest, and dip steeply southwest. The length of individual veins ranges from 100 to 250 meters and rarely as much as 800 meters, and range from 6.0 to 8.0 meters wide with an average thickness of 0.5 to 1.5 meters. Ore minerals are native gold and silver, pyrite, chalcopyrite, galena, molybdenite, and sphalerite. Sulphides are replaced by carbonates and hydroxides in an oxidized zone. Grade ranges from 0.1 to 230.0 g/t Au, and rarely as much as 1.5 kg/t Au. The average grade is 21.2 g/t Au in 0.7 meters average thickness of vein. The high grade of Cu and Ag also occurs with an average grade of 61.2 g/t Ag, and 1.94 percent Cu. Drilling shows the deposit extends 300.0 meters below land surface and decreases in grades and thickness. The deposit is large and has resources of 12 million tonnes of ore.

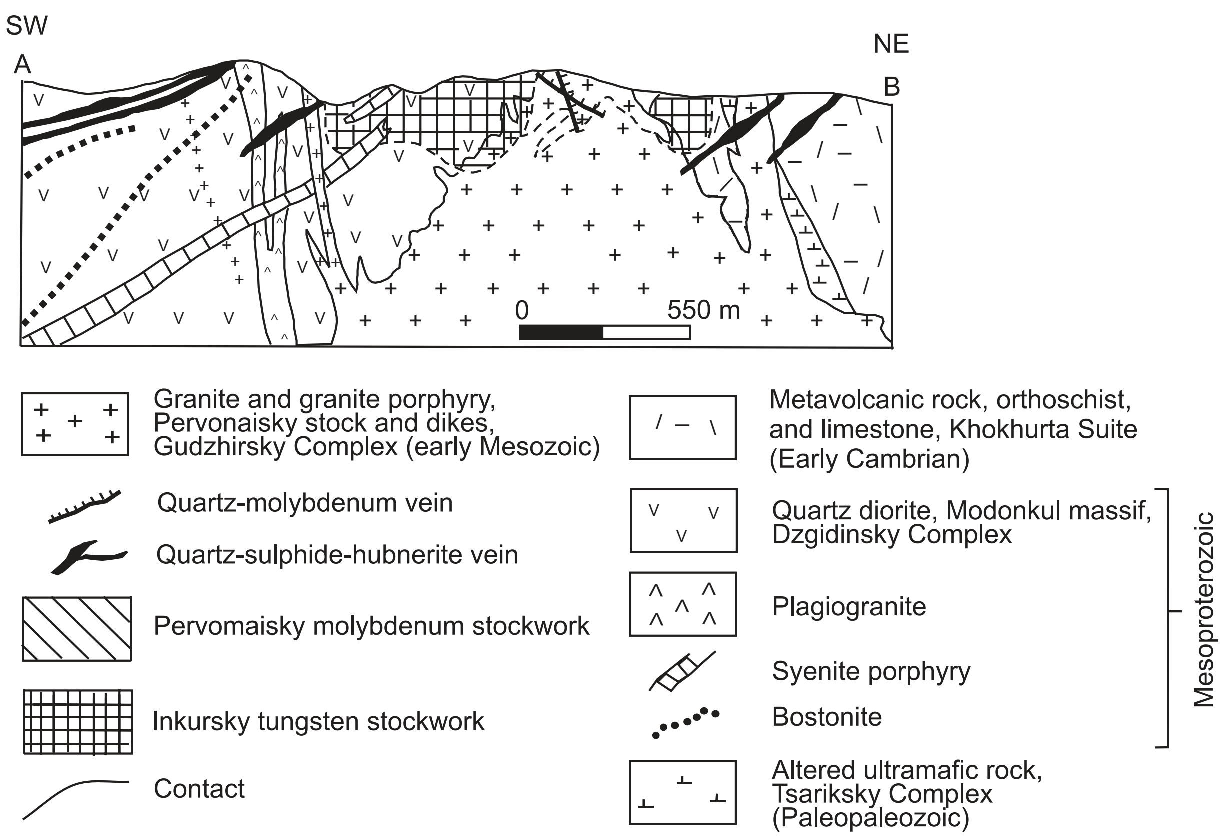


Figure 6. Schematic cross section of Dzhidinskoe W-Mo-Be greisen, stockwork, and quartz-vein deposit, Dzid-Selenginskiy metallogenic belt, Transbaikal region. Adapted from Ignatovich (1961).

Teshig 1 Cu-Au Skarn Deposit

This deposit (Alaev and others, 1985) is hosted in Vendian through Early Cambrian volcanic and sedimentary rocks of the Buuraltai Unit that is intruded by gabbro, quartz syenite of the Late Permian Selenge Complex, and by various early Mesozoic dikes and stocks. The deposit consists of a Cu-Au magnetite-garnet-epidote skarn that occurs along the contact between the Vendian through Lower Cambrian limestone and the early Mesozoic diorite-granite intrusive stock. The contact is cut by a northwest-trending fault zone that contains vein magnetite Cu and Au, and postdeposit intermediate dikes. The magnetite bodies dip steeply northeast and are intensely altered to limonite and Fe hydroxides. The skarn is 1,500.0 meters long and varies from 25.0 meters to 80.0 meters wide. The same Cu and Au minerals occur in skarn, magnetite, and limonite-magnetite bodies. The ore minerals are mainly malachite, rare azurite, chalcopyrite, pyrite, bornite, covellite, and gold. Au grains vary from 0.001 to 0.7 mm and have an average size 0.05 to 0.2 mm. The deposit is divided into three parts. The skarn contains 0.1 to 1.0 g/t Au with average grade of 0.5 g/t Au. Magnetite bodies average 0.3 percent Cu, as much as 0.5 g/t Au (average 0.1 g/t Au). The average grade is 0.12 percent Cu in skarn without magnetite.

Naranskoye Fluorspar Vein Deposit

This deposit (Kozhemyachenko and others, 1971; Bulnaev, 1995) consists of 17 steeply-dipping veins. The nine largest are 600 to 1200 by 1.0 to 6 by 170 to 300 meters). The deposit occurs in both veins and crush zones with major quartz and fluorite in variable proportions (10 to 85 percent CaF_2 with an average of 31 percent) and lesser kaolinite, montomorillonite, hydromuscovite, pyrite, and very rare galena and sphalerite. The minerals occur in breccia and masses. S, P, Fe are as much as about 0.01 percent. The host rocks are diverse and include mainly Middle Triassic granosyenite and lesser Mesoproterozoic sedimentary-metamorphic, Early Triassic through Early Jurassic volcanic and sedimentary, and Middle Triassic through Middle Jurassic granitoids. Peripheral alterations are weak to absent. The deposit occurs in a highly-deformed tectonic block (about 8 km^2) that occurs along a local fault. The deposit is large and has an average grade of 31 percent CaF_2.

Oshurkovskoye Magmatic and Metasomatic Apatite Deposit

This deposit (Litvinovsky and others, 1999) consists of apatite in a plutonic sheeted complex and occurs in concordant, lenses, plates and dikes of coarse- and medium-grained alkaline gabbro and syenite. Apatite is disseminated in alkaline gabbro with average grade of 4 percent P_2O_5. Locally are sites that range from 100 to 400 meters wide, 300-600 meters long and contains 5 to 6 percent P_2O_5 and locally 10 to 20 percent P_2O_5. Apatite forms tabular, short prismatic, and rare spicular crystals in cumulates. Poikilitic apatite inclusions occur in pyroxene and amphibole, in phenocrysts in microgabbro dikes, and in variably-trending lenses and nests with dimensions of 0.2 to 2.0 meters. The includins are composed of 80 to 90 percent tabular apatite grains with minor hornblende and titanic magnetite. Gabbro also has numerous apatite inclusions. The deposit includes fracture and hydrothermal alteration zones that range from 5 to 20 meters thick and 50 to 80 meters long that are enriched in carbonate, chlorite, local apatite (about 35 percent), and zeolite. The host rock is granite and gneiss. This large deposit formed in during Early Cretaceous rifting and has an average grade of 4.1 percent P_2O_5.

Origin and Tectonic Controls for Dzhid-Selenginskiy Metallogenic Belt

The belt is interpreted as having formed during subalkaline and alkaline granitoid magmatism associated with transform-continental margin faulting (Mongok-Okhotsk and related faults) and magmatism during and following late-stage closing of the Mongol-Okhotsk Ocean. The metallogenic belt is hosted in the Transbaikalia sedimentary-volcanic-plutonic belt. The main characteristics of the granitoid-related Au vein and Au skarn deposits and occurrences in the Tseshig district are (1) complex major metals of Au, Ag, and Cu; (2) a close relation to a high alkaline syenite-diorite and monzonite-granite sequence; (3) a close relation of W, Mo vein, greisen and skarn, granitoid-related Au-vein deposits and occurrences with siliceous and leucocratic granite; and (4) a relation of Au-Ag-Cu vein and skarn deposits to intermediate intrusives and melanocratic granitoid sequences that intruded during continental rifting.

East Mongolian-Priargunskiy-Deerbugan Metallogenic Belt of Polymetallic Metasomatic Carbonate and Volcanic Hosted, Zn-Pb (Ag, Cu, W) Skarn, Au Skarn, Au-Base-Metal Metasomatic Volcanic Hosted, W-Mo-Be Greisen, Stockwork, and Quartz-Vein, Porphyry Cu-Mo (±Au, Ag), Porphyry Mo (±W, Bi) (W, Sn, Bi), Granitoid-Related Au Vein, Carbonate-Hosted As-Au Metasomatite, Au-Ag Epithermal-Vein, Sedimentary Siderite Fe, Sn-W Greisen, Stockwork, and Quartz-Vein, Carbonate-Hosted Hg-Sb, Sb, Fluorspar Vein, and Volcanic-Hosted U Deposits (Belt EM) (Russia, Eastern Transbaikalia; Central and Eastern Mongolia, Northeastern China)

This Middle Jurassic through Early Cretaceous metallogenic belt is related to Middle Jurassic through Early

Cretaceous veins, volcanic complexes, replacements, and granitoids in the Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt that overlies and intrudes the Argunsky terrane, Idermeg terrane, Gazimur sedimentary basin, Gobi-Khankaisk-Daxinganling volcanic-plutonic belt, Lower Borzja fore-arc basin, Upper Borzja marine molasse basin. The belt extends from central Mongolia to northeastern Mongolia, and into Russia and China. This metallogenic belt is one of the largest in Northeast Asia and contains about 80 mines, deposits, or occurrences.

The Russian part of the belt occurs in the Priargunsky passive continental-margin terrane that is overlapped by the Gazimur sedimentary basin, Lower Borzja fore-arc basin, Upper Borzja Basin, and Transbaikalian sedimentary and volcanic-plutonic belt. The Mongolian part the belt is related to granitic and volcanic units on the Paleoproterozoic Ereendavaa and Idermeg terranes. In Russia, the belt extends nearly for 500 km, ranges from 100 to 150 km wide, and occurs along the Gazimur, Urov, Uryumkan, and Argun Rivers. The belt is the largest and richest in Central Asia.

In Mongolia, the belt extends approximately 2,000 km and varies in width from 100 km in southwestern part to 550 km in northeastern part. The eastern Mongolian part of the metallogenic belt is overprinted on the Hangay-Dauria subuction zone, Onon subuction zone, Ereendavaa passive continental margin, Herlen ophiolite, Idermeg passive continental margin, Govi-Altay turbidite, and Mandal Ovoo island-arc terranes (Tomurtogoo and others, 1999).

In Northeastern China the belt contains the Deerbugan group of porphyry Cu-Mo (±Au, Ag), granitoid-related Au vein, and Au-Ag epithermal vein occur in the western side of the Daxinganling Mountain ranges in Northeast Inner Mongolia of Northeastern China. The tectonic setting and metallogenic features of the group are similar to those in Russia and Mongolia (Hu and others, 1998).

In China, the metallogenic belt is locally named the Deerbugan metallogenic belt, and it is controlled by the northeast-trending Deerbugan fault. The belt extends for 800 km, ranges from 50 to 100 km wide, and is related to the Middle Jurassic through Early Cretaceous Daxinganling volcanic-plutonic belt that formed after accretion of the Argun terrane. The multiple units of continental volcanic rock in the Daxinganling belt consist mainly of calc-alkalic felsic volcanic rock, including basalt, andesite, trachyandesite, dacite, and rhyolite. The associated plutonic rocks are diorite, granodiorite, biotite granite, granite porphyry, quartz monzonite, monzonite, and quartz monzonite porphyry. The metlalogenic belt contains several Cu, Mo, Au, and Ag deposits with great economic potential. The significant deposits are at Wunugetushan, Jiawula, and Erentalegai.

The main references on the geology and metallogenesis of the belt are Mironov and Solovyev (1993), Sotnikov and others (1995), Mironov and Trofimov (1993), Bat-Ulzii (1996, 1999), Batjargal and others (1997), Deng and others (1996), Dejidmaa (1996, 1998), Hu and others (1998), and Lin and others (1998).

Akatuevsky and Blagodatskoye District–Transbaikalia

The Akatuevsky and Blagodatskoye districts contain widespread polymetallic (Pb, Zn, Ag) carbonate-hosted metasomatite deposits (Ekaterino-Blagodatskoye, Vozdvizhenskoye). The sphalerite-galena deposits contain significant Ag, Cd, and local Au.

Au Deposits and Occurrences–Mongolia

Various Au deposits and occurrences (Dejidmaa, 1996) are at Dochiin gol, Turgen gol, Narsyn hondlon, Onon-Berh, Herlen, Dornot, Tsav, and Bulgan (Dejidmaa, 1996). Au deposits and occurrences in Dochiin gol, Dornot and Tsav districts (Mironov and Solovyev, 1993) are subdivided into various age groups. Many deposits are related to diorite, granodiorite, monzonite, and granite that occur in hypabyssal stocks and have K-Ar isotopic ages of 190 to 180 Ma and 175 to 165 Ma. Other deposits are closely related to a Late Jurassic through Late Cretaceous basalt and rhyolite bimodal sequence.

The major deposit types are granitoid-related Au deposit and granitoid-related Au-Ag-Sb-As and Au-Ag-Cu deposits. The granitoid-related vein and replacement Au (Tsagaanchuluut and others) occurrences are related to multiphase stocks of gabbro, diorite, granodiorite and granite that are cut by abundant granodiorite and granite porphyry and diorite dikes. Granitoid-related-vein and replacement Au-Ag-Sb-As occurrences (Borondor, Ovorhooloi and others) occur mostly in the northeastern Mongolian part of the belt in the exocontacts of granodiorite stocks in the Middle and Late Jurassic Yamalh complex that intrudes clastic rock. Granitoid-related vein and replacement Au-Te (Dagai, Harguit and Urliin ovoo and others) deposits and occurrences are closely related to microsyenite, lamprophyre, and diabase dikes with K-Ar isotopic ages of 220 to 190 Ma (Mironov and Solovyev, 1993; Mironov and Trofimov, 1993). The granitoid-related vein and stockwork and replacement Au-Ag-Cu occurrences at Nomint and Soyo Ondor are related to the Avdar tolgoi porphyry Cu-Mo (±Au, Ag) (W, Au, Ag) deposit that is located at the intersection of the Ulz gol and Doch gol Rivers. The Avdar porphyry Cu-Mo (±Au, Ag) tolgoi deposit is small and is Mo dominated. The granitoid-related Au (Il turuut) and Ag-Pb-Zn (Lutaagiin) occurrences are closely related to the Avdar tolgoi deposit.

Au-Ag Epithermal Vein Occurrences–Mongolia

Various poorly-studied Au-Ag epithermal vein occurrences are located mostly along the Onon and Ulz faults in the northern part of the metallogenic belt and along the major Mongolian and Nariin-hiid faults in the southeastern part of the Mongolian part of the belt. The Au-Ag epithermal vein occurrences in the Turgen gol, Dornot, and Onon-Berh Au districts (Dejidmaa, 1996), located in the northern part of the belt, consist of vein and linear stockworks composed mostly of chalcedony and quartz in breccia with minor fluorite. The major occurrences are at Tsagaanchuluut khudag II in the Turgen gol district, the Ugtam occurrence in the Dornot district, and the Tenuun gol, Tsagaan, Bayanzurh, and others in the Onon-Berh district. The Au-Ag epithermal-vein occurrences are located mostly along the southeastern margin of the belt and are mainly related to a large hydrothermal-metasomatite that exhibits mainly argillic alteration. Potential deposits of this type occur between the Ma lineament in Mongolia and the Nariinhiid fault in China.

Baga Gazar Polymetallic (Pb, Zn, Ag) Carbonate-Hosted Metasomatite Deposit

This deposit (Polyakova, 1963; Sanin and Zorina, 1980) consists of a series of veins and stockworks. The large Kadainsly vein is characterized by varying thickness, presence of gentle bends over strike, and dipping branches and pinches. The deposit occurs in carbonate rock along the contact with a thick, extensive dike of lamprophyre. The vein extends more than 360 to 560 meters, downdip to 180 meters, and varies in thickness from 0.4 to 6 meters (average 1.7 meters). The deposit occurs in breccia, veinlets, and disseminations and consists of rare massive sphalerite, pyrite, and galena. The deposit is intensely oxidized to a depth of 150 meters. The large Osinovsky stock is wedge-shaped. The upper horizon has a 3000 m^2 area and the lower one has a 100 m^2 area. The inner structure of the stock is complicated by non-metalliferous limestone and abundant, intricately branching bodies of lamprophyre. The stock contains rich galena and sphalerite. The ore minerals occur in veinlets and disseminations. Gangue minerals are quartz, ankerite, calcite, dolomite, sericite, and rare tourmaline. Depth of zone of oxidation is 20 to 25 meters. At the predeposit stage, the host limestone was altered to skarn, dolomite, serpentinite, and silica, and shale to pyrite. A predeposit stage consisted of Fe-Mn metasomatite. The syndeposit stage consists of quartz-dolomite-ankerite metasomatite. Dikes of lamprophyre and granite porphyry are altered to beresite. The deposit is small and has an average grade of 3.5 percent Pb and 5.6 percent Zn.

Bayan uul 1 Granitoid-Related Au-Vein Deposit

This deposit (Yu.B. Mironov and others, written commun., 1993; Jargalsaihan and others, 1996) is high grade (as much as 250 g/t Au). The deposit consists of a few quartz veins, measuringt as much as 5.0 by 1500 meters that occur in a weak fault zone that ranges from 7.7 to 15.95 meters wide. The deposit contains 9.36 to 123.0 g/t Ag, 0.11 to 1.46 percent Pb, 0.05 to 1.06 percent Zn, and 0.01 to 0.1 percent Cu. Heavy mineral concentrates grade as much as 30.0 to -50.0 g/t Au in pyrite, as much as 10.0 to 30.0 g/t Au in sphalerite and chalcopyrite, and 0.4 to 2.0 g/t Au in galena. Also occurring is lower fineness gold that ranges from 1 micron to 0.1 to 0.2 mm. High grade Au associated with rich polymetallic mineral concentrations. Also occurring are zones of berisite alteration that range from 1.0 to 2.0 meters thick, having abundant pyrite and that contain from 8.0 to 20.0 g/t Au. Quartz occurs in stringers, from 0.1 to 5.0 mm thick and along with pyrite, galena, sphalerite, and chalcopyrite, and grades as much as 100.0 g/t Au. Microprobe analyse of gold grains shows compositions of 28.7 to 66.65 percent Au, 32.0 to 67.35 percent Ag, 0.2 to 2.5 percent Bi, and 0.3 to 3.8 percent Cu. The deposit is medium size and has reserves of 7 tonnes Au and has an average grade of 9.36 to 123.0 g/t Ag, 0.11 to 1.46 percent Pb, 0.05 to 1.06 percent Zn, and 0.01 to 0.1 percent Cu.

Bayandun Fe-Zn Skarn Deposit

This deposit (D. Dorjgotov, written commun., 1990; Jargalsaihan and others, 1996) consists of numerous, steeply-dipping lenticular bodies of Fe- Zn skarn that occurs along the contact between Devonian limestone and early Mesozoic subalkaline granite. The size of skarn bodies ranges from 40 by 100 to 100 by 800 meter. The bodies extend 100 meters downdip. The sulfide-bearing skarn ranges from 100 to 300 meters wide and extends for several hundred meters. The major ore minerals are sphalerite and magnetite. Gangue minerals are garnet, pyroxene, amphibole, quartz, and calcite. The deposit is medium size and has reserves of 240,000 tonnes of ore grading 25 percent Fe and 4 to 7.1 percent Zn.

Erentaolegai Au-Ag Epithermal-Vein Deposit–China

This deposit (Li and others, 1993) consists of layers, veins, and pods hosted in Late Jurassic volcanic rock, mainly Mesozoic Yanshanian adamellite and rhyolite porphyry. The deposits are strongly controlled by fractures. Two ore mineral assemblages are recognized, Mn-Ag and Ag quartz-vein minerals. The Mn-Ag assemblage consists of chlorargyrite and psilomelane with minor argentite, iodargyrite, cryptomelane, coronadite, pyrolusite, manganite, and limonite. The Ag quartz-vein assemblage consists of argentite and freibergite with minor polybasite, miargyrite, and jalpaite. Alterations are sericite, chlorite, silica, adularia, and carbonate. The deposit occurs in a Variscan orogenic belt between the Siberian and North China Platforms. The deposit is large.

Fluorspar-Vein Deposits–Transbaikalia and Mongolia

In Transbaikalia, widespread development fluorspar-vein deposits occur at Abagaituiskoye and Solonechnoye and in nearby areas. The richer deposits occur in the southwestern end of the belt. The deposits consist of quartz-fluorite veins hosted in variable rocks in the southern (Abagaituiskoye) and central (Solonechnoye, Shakhmatnoye) parts of the belt. In Mongolia, the fluorite-vein deposits occur in northern and southern fluorite zones (Khrapov, 1977) that were first named the North Herlen, South Herlen, and Har Airag-Buyant fluorite zones (Kandinov and Dobrolyubov, 1984).

Jiawula Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite Deposit, China

This deposit (Pan and Sun, 1992; Li and others, 1993) consists of more than 40 vein-like bodies that occur along northwest-striking fractures. The wallrocks are a complicated sequence of Late Permian volcaniclastic rock of the Laolongto Formation, intermediate to mafic volcanic rock of the Late Jurassic Tamulangou Formation, intermediate to siliceous volcanic rock of Late Jurassic Shangkuli Formation, Variscan granite and Mesozoic diorite porphyry, feldsparphyre, quartz porphyry, and beschtauite. The main ore minerals are galena, sphalerite, pyrite, marcasite, pyrrhotite, and chalcopyrite. The minor ore minerals are magnetite, hemalite, bornite, and arsenopyrite. Alterations are silica, chlorite, carbonate, sericite, fluoritie, epidote, and hydromica. The deposit occurs in a Variscan orogenic belt between the Siberian and North China Platforms. The deposit is large and has reserves of 236,300 tonnes Pb and 379,000 tonnes Zn grading 130 to 173 g/t Ag, 3.16 percent Pb, and 5.24 percent Zn.

Kadainskoye Polymetallic (Pb, Zn, Ag) Carbonate-Hosted Metasomatite Deposit

This deposit (fig. 7) (Polyakova, 1963; Sanin and Zorina, 1980) consists of a series of veins and stockworks. The largest vein is characterized by varying thickness, presence of gentle bends over strike, and dipping branches and pinches. The deposit occurs in carbonate rock along the contact with a thick, extensive dike of lamprophyre. The vein extends more than 360 to 560 meters, downdip to 180 meters, and thickness varies from 0.4 to 6 meters (average 1.7 meters). The deposit occurs in breccia, veinlets, and disseminations, and consists of rare massive sphalerite, pyrite, and galena. The deposit is intensely oxidized to a depth of 150 meters. The large Osinovsky stock is wedge -shaped. The upper horizon has a 3000m^2 area, the lower one has a 100 m^2 area. The inner structure of the stock is complicated by non-metalliferous limestone and abundant, intricately branching bodies of lamprophyre. The stock contains rich galena and sphalerite. The ore minerals occur in veinlets and disseminations. Gangue minerals are quartz, ankerite, calcite, dolomite, sericite, and rare tourmaline. Depth of zone of oxidation is 20 to 25 meters. At the predeposit stage, the host limestone was altered to skarn, dolomite, serpentinite, and silica, and shale to pyrite. A predeposit stage consisted of Fe-Mn metasomatism. The syn-deposit stage consists of quartz-dolomite-ankerite metasomatite. Dikes of lamprophyre and granite porphyry are altered to beresite. The deposit is small and has an average grade of 3.5 percent Pb and 5.6 percent Zn.

Klichkinskoye District (Transbaikal)

The Klichkinskoye district contains polymetallic (Pb, Zn, Ag) carbonate-hosted metasomatite (Klichkinskoye) and Zn-Pb (Ag, Cu, W) skarn (Savinskoye-5) deposits. The deposits are hosted in early Paleozoic dolomite, carbonaceous shale, and shale with interbedded limestone, sandstone, and conglomerate. These sedimentary rocks are intruded by late Mesozoic stocks and dikes of diorite, leucocratic granite and porphyry. The host rocks and deposits are cut by faults and deformed into folds that control the location of bed, vein, and pipe-shaped deposits.

Klichkinskoye Polymetallic (Pb, Zn, Ag) Carbonate-Hosted Metasomatite Deposit

This deposit (Arkhangelskaya, 1963; Sanin and Zorina, 1980) consists of a series of thin and discontinuous plates, veins, and pipes with sphalerite and galena in dolomite having thin beds of shale. The deposit occurs in the same tectonic zone as the Savinsky-5 deposit to the south. The bodies strike for a few hundred meters, extend downdip for tens of meters, and range from 0.1 to 1.1 meters thick with an average thickness of 0.2 to 0.3 meters. The major ore minerals are pyrite, galena, sphalerite, and arsenopyrite; minor pyrrhotite, chalcopyrite, and tetrahedrite, and rare bulanzherite, cassiterite, and scheelite. Major gangue minerals are quartz and calcite. The main ores assemblages are pyrite-arsenopyrite, sphalerite-galena, and pyrite-arsenopyrite-sphalerite-galena. Sulfide bodies are cut by the quartz-fluorite (and local barite) veins and streaks. Oxidized ore minerals are limonite, cerussite, smithonite, kalamine, anglesite, skorodite, jarosite, galena, and quartz. The host dolomite is intruded by Late Jurassic granite, diorite stock, and rare granite porphyry dikes. The deposit and host rocks are altered to dolomite, serpentinite, silica, skarn, greisen, and beresite. The deposit is small with grade ranging from tens of fractions to 50 percent Pb (average 12 percent), as much as 17 percent Zn, and about 400 ppm Ag.

Novo-Shirokinskoye Volcanic-Hosted Au-Base-Metal Metasomatite Deposit

This deposit (fig. 8) (Kormilitsyn and Ivanova, 1968; Sanin and Zorina, 1980; Tauson and others, 1987) consists of a thick metasomatic zone of listvenite-beresite and sulfides that occurs in en-echelon branching bodies. The zone is hosted in trachyandesite latite volcanic rock that is intruded by small stocks and dikes of diorite porphyry, granodiorite porphyry and lamprophyre. The host rock is propiliticaly-altered to quartz, chlorite and dolomite. The zone extends for more than 6 km, varies from 20 to 300 meters thick and has no clear outlines. The sulfide bodies occur in pipes, nests, lenses and veins, extend along strike for 1500 meters and range from 1.5 to 30 meters thick. The sulfides occur in layers, streaks, and disseminations. Sulfide bodies consist of 60 to 80 percent pyrite, galena and sphalerite with local sulphosalt, quartz, and dolomite. The sulfide body structures are massive, banded, dense disseminations, spots and coliform. Streaks and disseminations form haloes around massive sulfides, but commonly form independent bodies with irregular distribution of sulfides. Several assemblages occur (1) tourmaline; (2) pyrite with Au (pyrite, rare areson-pyrite and chalcopyrite); (3) polymetallic with Au (pyrite, galena, sphalerite, quartz, carbonates); (4) sulphosalt with Au (gray ore, tetrahedrite, shwartzite, tennatite, cleiophane, dolomite); and (5) realgar-antimonite with Au and Hg-barite-antimonite. Gold is fine-grained and occurs in sulfides. The oxidation zone occurs to a depth of 16 meters. The deposit is medium size and has an average grade of 3.53 percent Pb, 1.35 percent Zn, 3.11 ppm Au, 62 ppm Ag, 0.25 percent Cu, 3.47 ppm Cd, 9.77 ppm In, 3.75 ppm Se, and 6.44 ppm Te.

Savinskoye-5 Zn-Pb (Ag, Cu, W) Skarn Deposit

This deposit (Sanin and Zorina, 1980) consists of lenses, veins, nests, and pipes that occur in a thick (150 to 200 meters) and extensive (more than 2 km) zone. The zone contains skarn, propylite, relict of host limestones, schist, diorite, rare dolerite dikes, and fluorite and zeolite veins and nests. The deposit occurs in a tectonic zone and is bounded by the western and eastern bodies of quartz diorite of the Paleozoic Savinsky stock. The skarn bodies extend for 80 to 500 meters and, locally, as much as 960 meters, extend downdip for 100 to 500 meters, and range from 0.7 to 17 meters thick. The major ore minerals are pyrite, pyrrhotite, galena, and sphalerite, and lesser arsenopyrite, chalcopyrite, bulanzherite, markasite, and melnikovite. The major gangue minerals are quartz and calcite. Pyrite-galena in aksinite and diopside skarn occur in the upper and middle layers, and pyrrhotite-sphalerite occur in garnet skarns in lower layers. Oxidation zone extends to 80 meters depth. Oxidized minerals include limonite, cerussite, smithsonite, kalamine, anglesite, skorodite, jarosite, residual galena, and quartz. The deposit age is interpreted as being Late Jurassic. The deposit is medium size and has an average grade of 2.45 percent Pb and 4.5 percent Zn.

Sediment-Hosted Hg and Sb Occurrences–Mongolia

Sediment-hosted Hg (Obolenskiy, 1985) and sediment-hosted Sb occurrences are located in the northeastern part of the metallogenic belt and are hosted in Late Permian and Triassic marine sedimentary rock in central part of the Doch gol district. The major occurrences are at Harzat Hg, Tagiinburd Sb, Gorhit bulag Sb, Baruun bulag Sb, and Huts Ondor Sb. These and other occurrences are located along a northeast-striking fault zone. Vocanic-rock-hosted Hg occurrences, such as at Dalai Am gol and Hotol and others, occur in the northeast-striking Ulz fault that occurs between Cretaceous grabens and preCretaceous horsts. The Hg deposits consist of Hg-quartz-carbonate and barite vein and stockworks and curt early Paleozoic and Permian granite. The occurrence of barite-vein deposits is similar to volcanic-hosted Hg occurrences.

Shakhtaminskoye Porphyry Mo (±W, Sn, Bi) Deposit

This deposit (Kormilitsyn, 1973; Sidorenko, 1961; Sotnikov and others, 1995) consists of more than 300 steeply-dipping veins (30 to 800 by 0.2 to 0.5 meters) having low-grade stockwork inbetween. Three types deposit mineral assemblages occur (1) early-quartz-tourmaline with rare disseminations of large-scaly molybdenite; (2) average-fine-grained quartz with small-scaly molybdenite and rare pyrite; and (3) sphalerite, chalcopyrite, galena, tetrahedrite, bismuthite, pyrarhyrite, gray ore, antimonite, and native gold. Assemblages are zonally combined in the veins of complex composition. Stock-and veins formed in a predeposit explosive breccia have dimensions of 500 by 600 meters. The deposit minerals contain impurities (ppm)—10 to 70 Re; 10 to 30 Se and Te; 0.1 to 1.6 Au; and 17.0 Ag; as well as Cd, In, Ga, Ge. The deposit occurs in the southern part of the multiphase Shakhtaminsky massif (135 sq. km) of biotite-hornblende granite and granodiorite (Middle and Late Jurassic) cut by late Mesozoic dikes producing the zone of 40 by 7 km. Granitoids are altered to K-feldspar, sericite, beresite and argillite. The deposit is medium size with a grade of 0.03-1 to 2 percent (average 1 percent) MoS_2, 0.5 to 0.7 percent Cu, 0.8 percent Pb, and about 0.9 percent Zn.

Solonechnoye Fluospar-Vein Deposit

This deposit (Ivanova, 1974) consists of an intricate zone that extends ENE for 1.5 km along strike and dips steeply northwest. The zone contains two bodies. The main body is a linear stockwork (with dimensions of 350 by 25 to 30 by 200 meters) that contains a series of closely-spaced, subparallel feathering veins that are cut by a network of small and variably-oriented veinlets. The eastern vein (with dimensions of 300 by 1.5 to 3.0 meters) is a gash vein. All veins and veinlets display a symmetrically-zoned structure and consist of quartz and fluorite (90 percent), minor adularia and hydromicas, and sporadically disseminations of calcite, pyrite, and arsenopyrite. Fluorite is mainly green and rarely violet. Structures are massive and rare bands, and texture is coarse-crystalline. The hosting middle Paleozoic biotite-hornblende granite (PZ2) is altered to silicified and chlorite adjacent to the deposit. The deposit is small and has an average grade of 67 percent CaF_2. The surrounding area contains a resource of 2.8 million tonnes CaF_2.

Tsagaanchuluut khudag II Au-Ag Epithermal-Vein Deposit

This deposit (Dejidmaa and others, 1993) occurs along a sublatitudinal weak fault zone that occurs between

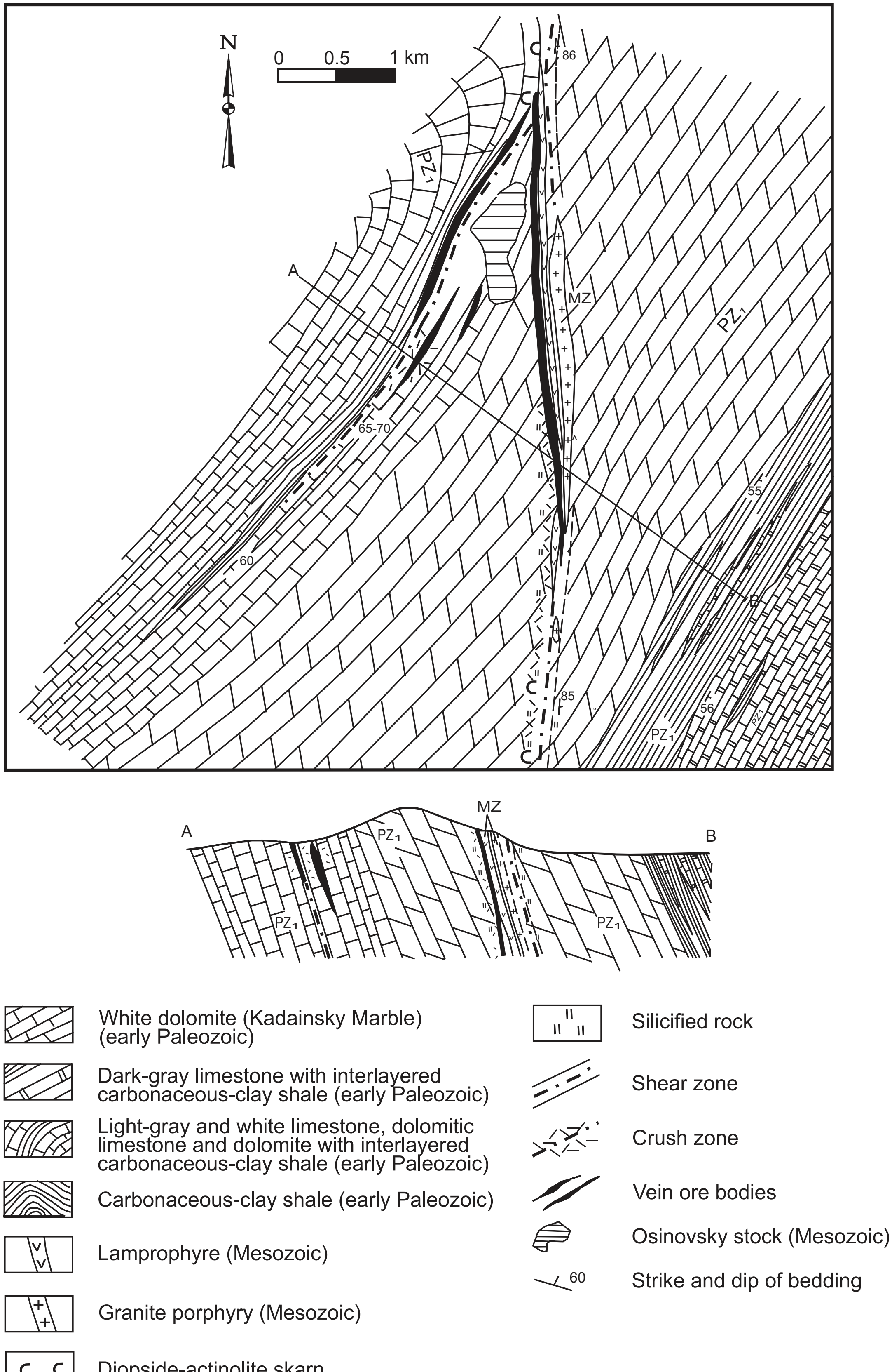


Figure 7. Generalized geologic map and schematic cross section of Kadainskoye polymetallic (Pb, Zn, Ag) carbonate-hosted metasomatite deposit, East Mongolian-Priargunskiy-Deerbugan metallogenic belt, Transbaikal region. Adapted from Polyakova (1963).

Proterozoic basement and a late Mesozoic graben. The deposit consists of a zone of quartz breccia, veinlets, and crystalline and porcelain quartz veins. The veins and breccia are variably oriented, and are extensively developed in early Paleozoic cataclastic granite and form a stockwork. The zone ranges from 0.1 to 3.0 meters wide and 10 toa few hundreds meters long. The average grades are as much as 0.1 as 0.5 g/t Au and altered zones are as much as 10.0 to 30.0 g/t Au. The altered zones consist of limonite and are intensely deformed. Samples with high-grade Au contain high grade of Pb, Zn, Mo, As, and Ag.

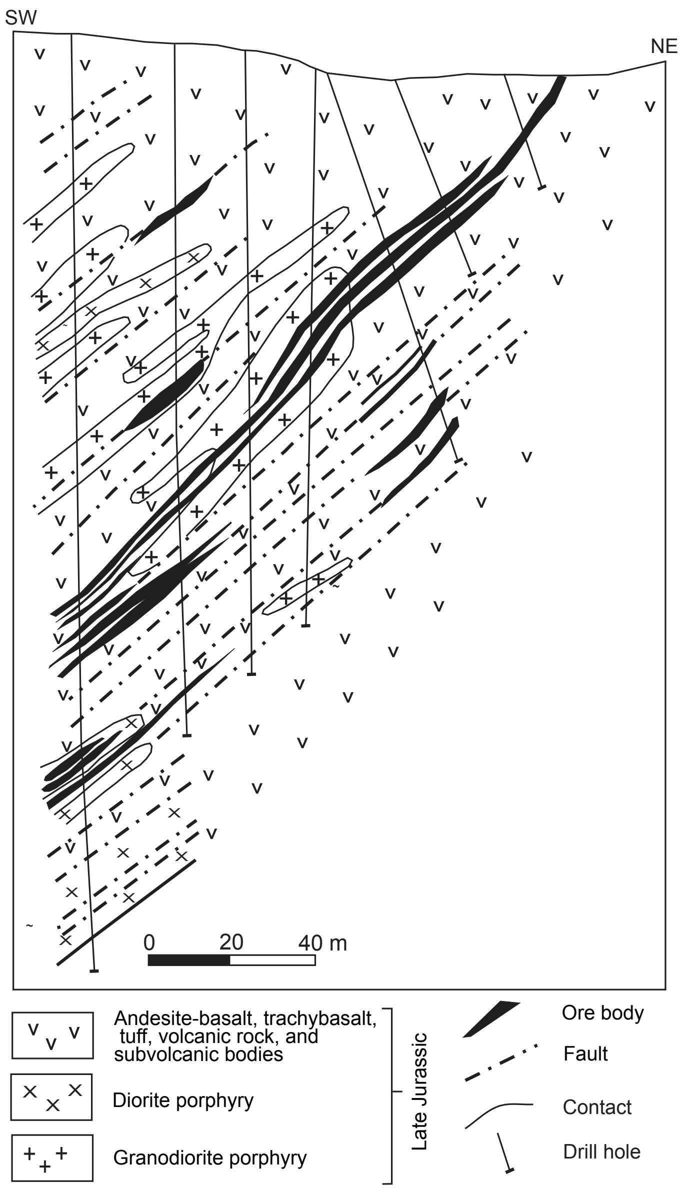


Figure 8. Schematic cross section of Novo-Shirokinskoye volcanic-hosted Au-base-metal metasomatite deposit, East Mongolian-Priargunskiy-Deerbugan metallogenic belt, Transbaikal region. Adapted from Kormilotsun and Ivanova (1968).

Tsav and Bayan Uul Granitoid-Related Au Vein Deposits–Mongolia

Various granitoid-related Au vein (Bayan uul 1 deposit) and Ag-Pb-Zn vein (Tsav deposit) deposits and occurrences occur extensively in the Tsav-Delgermonh and Dochiin gol districts and are closely related to Late Jurassic monzodiorite, granodiorite, and granite stocks (Batjargal and others, 1997; Bat-Ulzii, 1996 and 1999). Similar deposits occur to the southeast in China (Ke-Zhang and others, 1995).

Tsav Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (fig. 9) (D. Dorjgotov, written commun., 1990; Jargalsaihan and others, 1996) consists of quartz-sulfide and quartz-carbonate-sulfide veins in NW-trending, steeply-dipping altered zones hosted in Jurassic diorite, granodiorite and granite porphyry intruding Proterozoic metamorphic rock. The alteration consists of beresite (quartz-sericite-pyrite metasomatite). The alteration zone is 10 to 20 meters wide. Metasomatic alteration has a zonal structure, with a central part that contains an assemblage of quartz-sericite-pyrite and a peripheral zone with less pyrite, sericite, chlorite, and carbonate. Bodies are 700 to 1900 meters long, 0.5 to 1.2 meters thick, and 125 to 500 meters down dip. The deposit minerals are sphalerite, galena, pyrite, magnetite, chalcopyrite, pyrrhotite, arsenopyrite, and Ag minerals. Major gangue minerals are quartz, sericite, muscovite, eligonite, rhodochrosite, chlorite and calcite. Numerous occurrences of polymetallic-vein deposits are also in the area. The deposit is medium size, has grades grade of 6.48 percent Pb, and 3.53 percent Zn, and has a resource of 420,000 tonnes.

Tumentsogt W-Mo-Be Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (Khasin, 1977; Kovalenko and others, 1985) consists of wolframite and molybdenite related to a Mesozoic granite pluton that consists of coarse-grained porphyritic granites and fine- and medium-grained leucocratic granite. The deposit occurs in granite porphyry and fine-grained granite that intrude porphyritic granites. Greisen formed during alteration of coarse-grained porphyritic granites, and, rarely, in fine-grained granite. Greisen bodies are irregular and extend to a depth of 150 meters. Quartz-muscovite and muscovite form the core of greisen bodies along with assemblages of muscovite, fluorite-muscovite, molybdenite-muscovite, and rare beryl-muscovite. Pyrite and scheelte also occur. Muscovite contains anomalous Li, Rb, and Cs. Also occurring are pegmatite, veins, and albitite. The deposit is small and has resources of 1,043 tonnes WO_3 in the main deposit. The West Tumentsogt deposit has resources of 2,302 tonnes WO_3.

Urliin Ovoo Granitoid-Related Au Vein Deposit

This deposit is hosted in Proterozoic gneiss intruded by early Paleozoic granite and by Mesozoic microdiorite, microsyenite, and lamprophyry dikes. The deposit contains three zones with more than 20 quartz veins. The zone occurs in a northwest-trending area with dimensions of 10.0 km by 3.0 km. Veins are 80 to 160 meters long and 0.1 to 1.0 meters thick. Quartz veins extend for 100-200 meters in four areas. Grade ranges from 0.5 g/t to 30.0 g/t Au in quartz veins and from 0.5 g/t to 20.0 g/t Au in altered host rock. The three mineral associations are (1) medium-grained, white quartz, rare pyrite, chalcopyrite (3 to 5 percent) with a grade of 1.0 to 3.0 g/t Au; (2) chalcopyrite, rare galena, sphalerite, tellurides (gessite, veissite, silvanite, crennerite, and rikkardite), bornite, rare tetrahedrite in quartz-carbonate viens with as much as 0.1 percent Te and 10 to 30 g/t Au; and (3) postdeposit carbonate veinlets with as much as 4.2 percent Ag, 0.11 percent Cu, and 0.09 percent Hg, and trace of Te. The deposit is medium size and has an average grade of 0.5 to 30.0 g/t Au, 4.2 percent Ag, 0.11 percent Hg, and 0.09 percent Cu.

Vozdvizhenskoye Polymetallic (Pb, Zn, Ag) Carbonate-Hosted Metasomatite Deposit

This deposit (Kulagashev, 1963; Sanin and Zorina, 1980) consists of sulfide bodies that occur in two parallel pseudo-layers spaced 10 to 40 meters apart. The layers extend for over 600 meters along the strike and 400 meters downdip. Individual sulfide bodies occur in flattened pipes, nests, and layers. The dimensions along strike vary from 80 to 200 meters, downdip from 20 to 200 meters, and from 0.97 to 6.2 meters thick. The main ore minerals are pyrite, galena, and sphalerite, and localy arsenopyrite, bulanzherite, burnonite, chalcopyrite, grey ore, and geokronite. Vein minerals are dolomite, quartz, and calcite. Sulfides occur in masses and disseminations. An oxidation zone extends to a depth 160 meters and consists of Fe oxides, cerussite, smithsonite, anglesite, calamine, plumbojarosite, skorodite, and psilomelane, and local malachite and azurite. Host rocks are carbonaceous limestone and dolomite with local coal shale and dikes of felsite-porphyry, quartz porphyry, and lamprophyre. The main sulfide bodies occur in dolomite, locally close to or along the contact with lamprophyre and shale. Host rocks are altered to dolomite, silica, serpentine, sericite, sericite, chlorite, and argillite. Sulfide bodies formed along with quartz-dolomite-ankerite metasomatite. The deposit is medium size and has an average grade of 6.3 percent Pb, 8.5 percent Zn, and 106 ppm Ag.

W-Mo-Be Greisen, Stockwork, and Quartz-Vein Deposits–Mongolia

This type of deposit occurs mainly in small outcrops of bedrock that are intruded by granitoids and (or) overlain by a Late Jurassic through Early Cretaceous basalt and rhyolite bimodal sequence. Major W-Mo deposits are related to Late Jurassic leucogranite, granite porphyry stocks in the Chuluunhoroot REE complex in northeastern Mongolia. These deposits occur in veins and stockworks in the Chuluunhoroot, Ondor-tsagaan, Tumentsogt, Burentsogt, and Ikh Nartynhiid deposits. Most deposits were exhausted before 1970, but the Ondortsagaan W-Mo and Tsagaanchuluut Mo stockwork and greisen deposits are new discoveries.

Wunugetushan Porphyry Cu-Mo (±Au, Ag) Deposit–China

This deposit (Wei and Lu, 1994) occurs at the intersection between the northeast-trending Manzhouli-Dalaidong thrust and strike-slip fault with a secondary northwest-striking Hanigou normal fault that is a secondary structure of the northeast-striking Deerbugan major fault zone. The deposit is hosted in the Yanshannian granodiorite porphyry that is exposed over an area of 0.12 km^2. A K-Ar age for the porphyry is 164 Ma. The wallrock alteration forms a circular-zoned pattern that has an inner quartz-K-feldspar zone, a middle quartz-sericite-hydromica zone, and an outer illite-hydromica zone. There are 33 Cu and 13 Mo bodies in the deposit that are controlled by the porphyry body and the contact zone. From the center of the porphyry outward, the zonation pattern is a pyrite-molybdenite zone, apyrite-chalcopyrite zone, and a pyrite-galena-sphalerite zone. Cu and Mo minerals occur mainly in disseminations and networks. The temperatures of formation of the porphyry intrusion and deposits are 1003 to 1205°, and 140 to 500° C, respectively. The ore-forming fluids exhibit high salinity (51 percent NaCl) and high density (1.12 g/cm^3). The deposit is large and has resources of 2.232 million tonnes grading 0.4 percent Cu, and resources of 0.412 million tonnes grading 0.05 percent Mo.

Zapokrovskoye District–Transbaikalia

The Zapokrovskoye district contains carbonate-hosted As-Au metasomatite deposits (Gurulevskoye, Oktyabrskoye, Zapokrovskoye) that occur in veins, pillars, nests and lenses. The deposits are hosted in faulted carbonate rock that is intruded by dikes and stocks of granite, diorite, and monzonite porphyry (Volfson, 1963). The Shakhtaminskoye porphyry Mo (±W, Sn, Bi) deposit occurs in the Shakhtaminskoye granodiorite and granite pluton (Sotnikov and others, 1995). The deposits consist of typical quartz-Mo veins that occur in the southeastern margin of an eroded subvolcanic structure (Seminsky, 1980).

Zapokrovskoye Carbonate-Hosted As-Au Metasomatite Deposit

This deposit (Zavorotnykh and Titov, 1963) consists of various bodies of As-Au minerals that occur in fractured veins, pillars, pipes, nests, and lenses that are hosted in carbonate rock, primarily along the contacts between marble and schists and other sedimentary rock. The bodies occur along faults and have sharp and folded contacts. The bodies extend along strike for about 20 to 250 meters, and 300 meters down dip. The main gangue minerals are quartz, calcite, and dolomite. In swells, the bodies are banded with alternating bands of grey quartz with rare disseminations of arsenopyrite and bands with massive arsenopyrite that contains nests of quartz and inclusions of host rock. Along faults that bound the veins is local serpentine. An oxidation zone occurs from 5 to 20 meters depth. Oxidized ore minerals are scorodite and red-brown ochres. Limestone in the southern part of the deposit is intruded by the Zapokrovsky monzonite intrusion that also contains metasomatic hybride quartz syenite with local skarn along contacts. The deposit is cut by numerous dikes of quartz porphyry, granodiorite porphyry, granodiorite porphyry, and lamprophyre. Alterations consist of zones of dolomite, serpentine, silica, ankerite, chlorite, sericite, and kaolinite. The deposit is medium size and has an average grade of 6.93 percent As in primary ore and 2.2 to 9.65 percent As in oxidized ore.

Zn-Pb (±Ag, Cu) Skarn Deposits–Mongolia

Various Zn-Pb (±Ag, Cu) skarn deposits and occurrences are in the Bayandun district and are hosted in Proterozoic gneiss and carbonate rock, Devonian carbonate and clastic rock, and in Permian volcanic and sedimentary rock. The deposits and occurrences are closely related to Middle and Late Jurassic granodiorite and granite stocks.

Origin and Tectonic Controls for East Mongolian-Priargunskiy Metallogenic Belt

The belt is interpreted as having formed during Middle Jurassic through Early Cretaceous extensional tectonism

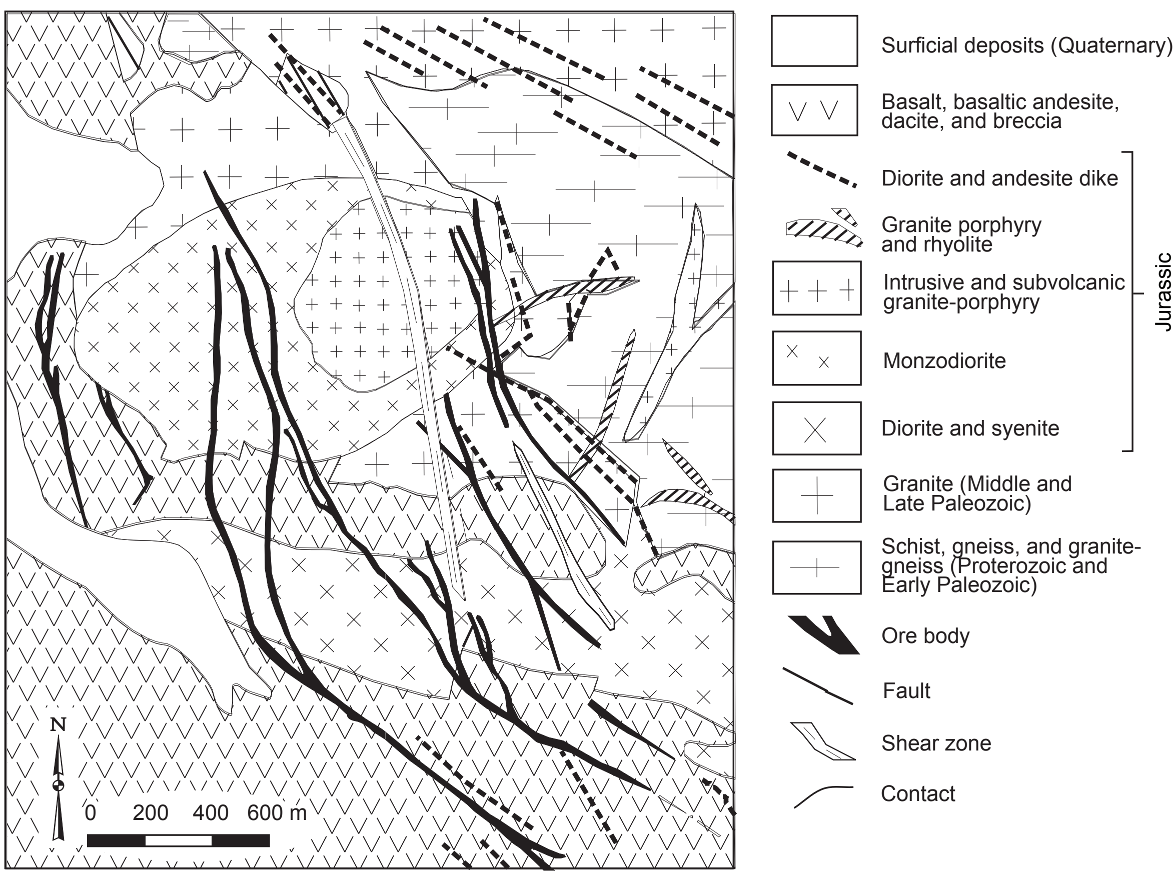


Figure 9. Generalized geologic map of Tsav and Bayan Uul granitoid-related Au-vein deposits, Mongolia. Adapted from Jargalsaihan and others (1996).

associated with generation of the Trans-Baikalian-Daxinganling volcanic-plutonic belt that was related to the back arc of a continental-margin arc. The metallogenic belt is controlled by major, regional northeast- and northwest-trending faults. The northeast-striking faults (Byrkinsky-Urovsky, Gazimur-Urjumkan, Argunsky) control the magmatic and hydrothermal activity and internal structure of the belt.

In Russia, the related major volcanic units are basalt, rhyolite, and andesite (Shadoronsky, Berjozovsky, Ust-Kara, and Argunsky Suites) and comagmatic hypabyssal and subvolcanic units (Shakhtaminsky, Samudzhikan and Akatuevsky complexes). The volcanic units occur in grabens, paleocalderas, volcanic comes, plutonic domes, and volcanic basins. Cassiterite-silicate-sulfide vein and stockwork occurrences (Shalz and Narsyn khondlon) and granitoid-related Au-magnetite vein and stockwork occurrences (Delberhei bulag and Salhit) are related to Middle Jurassic diorite stocks in the Narsynhondlon district. Cassiterite-silicate-sulfide vein occurrences are mainly in the central part of the belt, and granitoid-related Au-magnetite-hematite vein and stockwork occurrences are in the north-northwest and in southeastern marginal parts of the belt.

In Mongolia, the metallogenic belt contains the Early Cretaceous Onon graben that is interpreted as an extensional feature superimposed on the Hentii megadome. The Onon graben contains Early Cretaceous basalt and arkose (Enkhtuvshin, 1995) that are down-faulted against postcollisional Mesozoic intrusions (Gerel, 1998). The Au deposits in the Onon graben are interpreted as having formed during early Mesozoic, postorogenic back-arc volcanism-plutonism that occurred along a late Paleozoic suture zone between the North China Plate and the North Asian craton. During collision, some terranes were consumed in a subduction zone that dipped toward the North Asian craton prior to transpressional tectonism and continental magmatism. Various Au hydrothermal systems formed during the transpression and were subsequently downdropped into the Onon graben (Cluer and others, 2000). An alternative interpretation is that the Onon graben is related to the Mongol-Okhotsk system of northeast-trending, Late Jurassic and Early Cretaceous grabens that formed after collision between the North Asian craton with microcontinents (Zonenshain and others, 1975).

In China, several different interpretations exist for the origin of the metallogenic belt. (1) Some studies discuss the effect of Argun terrane during the closing of the Mongolia-Okhotsk Ocean (Hu and others, 1998). (2) Some studies suggest that the distance between the Late Mesozoic volcanic belts and the subduction zone of the ProtoPacific Plate would be more than 1000 km and a plate subduction model is regarded as difficult. Instead, the Late Jurassic through Creaceous Daxinganling volcanic belt is interpreted in some studies as being a ring-shaped volcanic belt related to uprising of deep, hot mantle plumes in the ancient Asian Ocean (Lin, Qiang and others, 1998). (3) Continental plume tectonics are also employed in some studies to interpret the region (Deng and others, 1996). During the Jurassic, to the east was the Zianagi Ocean, and to the north was the Mongolia-Okotsk Ocean that was subducted under east China with de-rooting and thinning of lithosphere and upwelling of asthesnosphere. The upwelling is interpreted as the cause of intense Jurassic magmatism and formation of large and superlarge deposits from mantle plumes (Hu and others, 1998). (4) In this study, the Nariinhiid fault is interpreted as the direct continuation of northeast-striking Ergun-Hulun fault that controlled the distribution of Middle Jurassic through Late Cretaceous volcanic and plutonic rocks and related porphyry Cu-Mo (±Au, Ag), Ag-Au-Pb-Zn-vein deposits, epithermal Ag(Au) deposits, hot spring Au-Ag occurrences (Ke-Zhang Qin and others, 1995), and the new intrusion-related Zalaa Uul sediment hosted Au+(As ± Sb) Au occurrence (Cluer and others, 2000).

Govi-Tamsag Metallogenic Belt of Sediment-Hosted U, Evaporate Sedimentary Gypsum, Sedimentary Celestite, and Volcanic-Hosted Zeolite Deposits (Belt GT) (Southern Mongolia)

This Late Jurassic through Early Cretaceous metallogenic belt is related to stratiform units in the Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt that overlies and intrudes the Dzhida, Govi Altai, and Mandalovoo-Onor terranes. The major sediment-hosted U deposits are at Haraat and Narsyn, and the major evaporate sedimentary gypsum deposits are at Taragt, Unegt, and Modonus.

The main references on the geology and metallogenesis of the belt are Goldenberg and others (1978), Ochirbat (1998), and Ganbaatar (1999).

Sediment-Hosted U Deposits

The sediment-hosted U deposits at Haraat and Narst, and various occurrences are hosted in an Early Cretaceous sedimentary graben and a Late Cretaceous sedimentary basin in the Late Mesozoic Eastern Mongolian continental rift. Some deposits are interlayered with coal deposits that contain high-grade U. The U deposits and occurrences consist of U-bearing sandstone beds and lenses (Ochirbat, 1998).

Haraat Sediment-Hosted U Deposit

The deposit (Jargalsaihan and others, 1996; Ochirbat, 1998; Wetz and others, 1999) is hosted in the Early Cretaceous Choir graben. The deposit surface area is more than 100 km^2. The host rocks are intercalated sandstone and siltstone and range from 0.2 to 20.0 meters thick. The deposit bed is approximately horizontal, 20 km long, 0.5 to 2.0 km wide, ranges from 1.0 to 30.0 meters thick, and is covered by 0.5 meters to 45 meters of barren rocks. Two explored bodies are 400 meters and 2500 meters long, range from 50-300 meters wide, and from 1.0 to 12.0 meters thick. Ore minerals are nasturan (pitchblende), autunite, and torbernite. The average grade ranges from 0.01 to 0.04 percent U to 0.05-0.2 percent U, partly 1.2 to 4.0 percent U. Uranium ore contains 0.02 to 0.3 percent Ce, 0.017 to 0.17 percent La, 0.7 to 60 g/t Sc, 25 to 30 g/t Y, 2 to 12 g/t Yb, 0.1 to 8 g/t Re, 10 to 90 g/t Ge, and as much as 0.03 percent Mo, as much as 0.01 percent Se, and as much as 3.0 g/t Ag. An in-place leach-mining method has been successfully tested. The deposit is medium size and has an average grade of 0.01 to 0.2 percent U and reserves of 22,700 tonnes U.

Evaporate Sedimentary Gypsum Occurrences

Evaporate sedimentary gypsum deposits are extensive and occur mainly in sandstone and shale in a Late Cretaceous and local Paleogene basin (Ganbaatar, 1999). The occurrences are related to continental evaporate basins. The Unegt and Shiree Uul (Taragt-2) deposits are in operation at the present.

Shiree Uul (Taragt-2) Evaporate Sedimentary Gypsum Mine

This mine (D. Begzsuren, written commun., 1999; Ganbaatar, 1999) consists of gypsum and calcite concretions that occur in Tertiary sedimentary rock. The gypsum thickness is 1 meters. The gypsum concretions range from 30 to 40 cm in size. The deposit age is interpreted as middle and late Oligocene. The deposit is small and has production and reserves of 4.5 million tones grading 83 to 84 percent gypsum.

Sedimentary Celestite Occurrences

Sedimentary celestite occurrences are hosted in Early Cretaceous sandstone, siltstone and mudstone. Sandstone beds contain thin (1 to 5 cm) layers or roses of celestite (Goldenberg and others, 1978). Sedimentary celestite is poorly studied, and occurrences are mainly in southern part of metallogenic belt.

Horgo Uul Sedimentary Celestite Deposit

This deposit (V.I. Goldenberg and others, written commun., 1978) consists of 1.0 to 5.0 cm thick layers of celestite in Early Cretaceous sandstone. Celestite also occurs as isometric black concretions with a diameter of 0.3 to 0.4 cm, and as celestite roses. These concretions contain as much as 6.56 percent Sr. The thickness of celestite-bearing beds with concretions ranges from 10 to 50 meters. The beds are intercalated with barren sandstone (as much as 0.07 percent Sr) beds that range from 50 to 100 meters thick. The average grade is 45.59 percent Sr.

Tsagaantsav Volcanic-Hosted Zeolite Deposit

This deposit (P.Shaandar and others, written commun., 1992; Petrova and Amarjargal, 1996) consists of zeolite beds and layers in siliceous tuff, tuffaceous sandstone, and argillite of the Early Cretaceous Tsagaantsav Formation. The deposit has a surface area of 1.5 by 3 km and is 200 meters thick. The zeolite beds are elongate and strike east-southeast and dip gently. The maximum zeolite content (60 to 90 percent) occurs adjacent to an underlying siliceous vitreous tuff. The main zeolite mineral is clinoptilolite. The deposit is large and has resources of 179.0 million tonnes grading 10 to 80 percent zeolite.

Origin and Tectonic Controls for Govi-Tamsag Metallogenic Belt

The belt is related to Aptian-Albian (Early Cretaceous) sedimentary rocks deposited in grabens and depressions that overlap the Mesozoic Eastern-Mongolian-Preargune continental-rift belt that developed on the Idermeg passive continental margin, Govi-Altai turbidite, and Mandal-Ovoo island-arc terranes. The sedimentary U deposits and occurrences formed duringt the latest stage of a late Mesozoic continental rift. The gypsum deposits and occurrences formed in continental evaporite basins.

Hartolgoi-Sulinheer Metallogenic Belt of Au-Ag Epithermal Vein, Ag-Pb Epithermal Vein, Porphyry Mo, W±Mo±Be Skarn, Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Carbonate-Hosted Hg-Sb, and Silica-Carbonate (Listvenite) Hg Deposits (Belt HS) (Southern Mongolia, Northwestern China)

This Late Jurassic through Early Cretaceous metallogenic belt is related to veins and replacements in latite and lamporphyre dikes in the Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt that intrudes and overlies the Tsagaan Uul-Guoershan and Solon terranes and the Lugyngol volcanic and sedimentary basin. The belt extends approximately 1,200 km along the southern and southeastern border of Mongolia's border with China. The major deposits are the Hartolgoi carbonate-hosted Ag-Pb, Biluut Ag-Pb vein-replacement deposits, and the Zuuntogoo Uul, Baruuntogoo Uul carbonate and hosted Sb (Au, Ag, As) occurrences, the Hotoltolgod, Barjin uul Au-Ag epithermal vein occurrences, and the Hangi Ovoo silica-carbonate Hg occurrence. The Ag-Pb vein and replacement and carbonate and hosted Ag-Pb deposits and occurrences in the Biluutiin and Ulaan Uul districts are located in the western part of the belt and were first assigned to the South Govi-Nuhetdavaa metallogenic belt (Yakovlev, 1977; Batjargal and others, 1997). Various carbonate-hosted Sb (Au, Ag, As), Au-Ag epithermal vein, and listvenite Hg occurrences are located along an east-west-trending thrust fault in the Sulinheer subuction-zone terrane and were discovered as the result of detailed geological mapping and prospecting in the last 10 years. The significant deposits are at Biluut, Harmorit, Hartolgoi, Khartolgoi, Khoit Barjin, Qiyishan, Ulaan Uul, and Zuun Togoo.

The metallogenic belt displays the following features. (1) The vein and replacement Ag-Pb, carbonate-hosted Ag-Pb, and carbonate-hosted Sb (As, Au, Ag), epithermal Au-Ag and silica-carbonate Hg deposits and occurrences all occur in the southern, border part of Mongolia, and are controlled by east-west trending thrust faults. (2) The deposits are closely related to monzonite, quartz porphyry ,and diabase stocks and dikes that intrude Late Triassic through Early Jurassic granite porphyry and granite stocks with local REE deposits. (3) The thrust fault is a part of the east-west trending Yenshan thrust zone. The western part of this metallogenic belt of Qiyishan W-Mo-W±Mo±Be skarn occurs in the western part of Inner Mongolia (Northwestern China) It trends east-west and is about 170 km long and 30 km wide. (4) The Tsagaantolgoi fault in Mongolia, which controls the Buluutiin and Ulaan Uul districts, is the western continuation of the Sulinheer thrust fault that may be a part of the Yenshan thrust zone in China (Geological and Mineral Resources Maps of China). These east-west trending thrust faults closely control the Late Mesozoic vein and replacement deposits and occurrences in the belt. The post-accretionary Late Jurassic granite that is related to the deposits in the metallogenic belt, intruded the volcanic and sedimentary units of the Archean Alashan terrane.

The main references on the geology and metallogenesis of the belt are Batjargal and others (1997), Mineral Resources (Metals) Map of China (1992), Editorial Committee of the Discovery History of Mineral deposits of China, Inner Mongolia (1996a), and Tomurtogoo and others (1999).

Khartolgoi Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (fig. 10) (Khasin, 1977; Jargalsaihan and others, 1996; D. Dorjgotov, written commun., 1990) consists of Pb-Ag veins and lenticular bodies in Proterozoic metamorphic rock intruded by Triassic granitoid. Bodies have dimensions of 100 by 400 to 2 to 29 by120 meters. Wallrock hydrothermal alteration consists of carbonate and silica alteration. Ore minerals are galena, pyrite, stibnite, arsenopyrite, and Ag minerals. Major gangue minerals are chalchedony, siderite, quartz, and calcite. The deposit is large and has an average grade of 1.8 to 13.4 percent Pb and 2.6 percent Sb. The deposit has a resource of 60,000 tonnes Pb, 30,000 tonnes Sb, and 138 tonnes Ag.

Biluut Ag-Pb Epithermal-Vein Deposit

This deposit (Yakovlev, 1977) and other occurrences in the Biluutiin district are located in the western margin of the belt in a zone with quartz veins containing galena, pyrite, and chalcopyrite. The zone occurs along a east-northeast-striking fault that cuts Silurian sandstone and is closely spatially related to quartz porphyry dikes that also contain ore minerals. Some occurrences also contain anglesite and cerussite and are hosted in Proterozoic carbonate and Silurian sedimentary rocks, and in Devonian granitoid.

Ulaan Uul District

This district (Yakovlev, 1977) occurs in south of Dalanzadgad city and contains Hartolgoi and Hormorit carbonate-hosted Ag-Pb deposits and related occurrences. The bedrock is Proterozoic marble, Carboniferous granodiorite and granite, Permian sandstone and shale, Late Triassic through Early Jurassic granite stocks, and Late Cretaceous basalt (Yakovlev, 1977). The deposits and occurrences are controlled by the east-northeast-striking Tsagaantolgoi fault that bounds the Hashaat Tsagaan Uul and Sulinheer terranes.

Hartolgoi Carbonate-Hosted Ag-Pb Deposit

The deposit (Yakovlev, 1977) is hosted in Proteozoic marble that is thrust over a Carboniferous granitoid pluton composed of gabbro, diorite, granodiorite, granosyenite, and granite. Also occurring close to the deposit are extensive Late Triassic and Early Jurassic(?) stocks and dikes of monzonite, quartz monzonite, and quartz-porphyry (Yakovlev, 1977). The deposit is mainly hosted in marble and, to a lesser degree, in monzonite and quartz porphyry. Individual bodies occur along a major north-northwest-striking, north-dipping thrust and parallel faults, and also in northwest-striking, steeply-dipping faults associated with the major thrust. Ore minerals occur mainly in thrust faults and veins in steep-dipping faults. Ore mineral assemblagess are siderite-sulfide, massive sulfide, and sulfide-magnetite. Main sulfides are pyrite, galena, and arsenopyrite. In addition to high Pb are high contents of Ag, Sb, As, Cd, Cu, and Zn. The deposit is intensely oxidized and leached on the surface. In addition to the Hartolgoi deposit, extensive Fe-oxides zones occur along the Tsagaantolgoi fault and branches.

Harmorit Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This polymetallic deposit (Khasin, 1977; Yakovlev, 1977) is hosted along a fault in Permian sandstone and shale that are intruded by a Late Triassic through Early Jurassic granite porphyry stock that also hosts a Sn vein and greisen deposit. Diabase and diabase porphyry dikes are extensive and are closely related to the polymetallic veins. Cassiterite-quartz veins and cassiterite-topoz-fluorite greisens occur in the granite porphyry stock and in adjacent, contact-metamorphosed Permian sandstone and shale. Polymetallic veins are altered to sericite, chlorite, and limonite, and contain pyrite, arsenopyrite, galena, and chalcopyrite. The veins occur in Permian shale, mostly to the southwest of the granite porphyry stock. Gangue minerals are quartz, feldspar, and calcite. The polymetallic veins, diabase, and diabase porphyry dikes intrude the granite porphyry stock and related Sn vein and greisen. Pb grade ranges from 0.1 to 11 percent at the surface. Khasin (1977) and Yakovlev (1977) interpret that the polymetallic veins are closely related to the granite-porphyry stock and related Sn vein and greisen deposits, but formed in separate stages. This study interprets that polymetallic veins are closely related to diabase and diabase porphyry dikes, and are younger than granite porphyry stock and associated Sn deposits.

Carbonate-Hosted Hg-Sb Deposits

Various carbonate-hosted Sb (Au, Ag, As) deposits and occurrences, as at Zuun Togoo Uul and Baruuntogoo Uul, are hosted in Carboniferous limestone that is thrust over Permian sedimentary rock. The major ore mineral is stibnite. The deposits consist of thin veins with stibnite, quartz, and carbonate that are as much as 10 cm wide and form a stockwork in limestone. The occurrences contain high Au, Ag, and As. Diabase dikes are widespread.

Zuun Togoo Uul Carbonate-Hosted Hg-Sb Deposit

This deposit (A. Gotovsuren and others, written commun., 1995) has a surface area of 7 km^2 and is hosted in Carboniferous limestone thrusted over Permian volcanic and sedimentary rock and serpentenitized ultramafic rock that occur along a sub-latitudinal fault zone. The rocks are intensively altered to stibnite and are cut by a quartz vein stockwork with stibnite and other sulfides. NEE-trending quartz veins and veinlets are also abundant. Limestone is intensively altered to silica. Soil samples show a complex anomaly of Sb, W, Ni, As, Cr, Ba, Ag, Mo, and Au. Grab rock and chip samples contain 0.01 to 1.0 percent and more Sb, 0.01 to 1.0 percent As, 0.001 to 0.01 percent W, 0.005 to 0.02 percent Ni, 0.07 to 0.3 percent Cr, 0.002 to 0.02 percent Co, 0.0005 to 0.001 percent Mo, 0.007 to 1.0 g/t Au and 0.3 to 1.0 g/t Ag. A complex hard rock geochemical anomaly occurs in a 1.2 km^2 area with average grade of 0.12 percent Sb, 0.19 percent As, 0.06 percent Ni, 0.14 percent Cr, and 0.94 to 1.41 percent Sb. The anomaly coincides with the Zuun Togoo uul peak. Ore minerals are stibnite, marcasite, pyrite, chromite, nickeline, native silver, native gold, and Fe oxides and various secondary minerals. The deposit is small and has a resource of 15,000 tonnes Sb and grades as much as 1.41 percent Sb.

Au-Ag Epithermal-Vein Occurrences

Various Au-Ag epithermal vein occurrences are closely related to an Early Cretaceous basalt and rhyolite sequence. The Barjin Uul occurrence occurs along the Sulinheer thrust zone and consists of silicified and brecciated andesite and chalcedony-like quartz veins that are hosted in Cretaceous andesite.

Khoit Barjin Au-Ag Epithermal-Vein Deposit

This occurrence (N. Aizawa and others, written commun., 1996) occurs in the eastern part of an Early Cretaceous siliceous, en-echelon, subvolcanic bodies that arealigned along a sublatitudinal fault zone. The Khoit Barjin hill subvolcanic body is cut by northeast-trending and sublatitudinal quartz veins that are as much as 1.0 meters thick and as much as 50 meters long. A northeast-trending quartz-vein zone contains parallel veins and contains coarse-bladed quartz that is partly fractured, brecciated, and is altered to limonite. A northnortheast-trending breccia zone occurs in siliceous volcanic rock and contains abundant disseminated fine-grained pyrite. Rock chip samples contain as much as 1.0 to -3.0 g/t Au. The average grade is as much as 3.0 g/t Au.

Qiyishan W±Mo±Be Skarn Deposit

This deposit (Editorial Committee of the Discovery History of Mineral Deposits, 1996a) consists of 71 small lensoid bodies that strike east-west and dip 50 to 65°. The largest body is 700 meters long, extends 300 to 500 meters downdip, and ranges from 80 to 150 meters wide. The bodies occur predominately in the contact-metamorphosed tuffaceous sandstone and andesite in the exocontact zone and partly in the granite intrusion. The bodies consist of veinlets and disseminations and are complicated. The main ore minerals are wolframite, scheelite, colloform Sn-minerals, molybdenite, cassiterite, lepidolite, and quartz. Rb lepidolite occurs. The deposit is closely related to a Jurassic biotite granite and granitic porphyry that was previously interpreted as a Rb-Li granite deposit. The deposit is not mined because of difficulty in ore dressing. The deposit is medium size.

Origin and Tectonic Controls for Hartolgoi-Sulinheer Metallogenic Belt

The part of the belt located in northwestern China is interpreted as having formed during generation of postaccretionary granite during subduction of Pacific Plate under the Eurasian Plate. The part of the belt in southern Mongolia is interpreted as having formed as a result of back arc extension of a late Mesozoic continental-margin arc.

Jiliaolu Metallogenic Belt of Zn-Pb (±Ag, Cu) Skarn, Cu (±Fe, Au, Ag, Mo) Skarn, Granitoid-related Au Vein, Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork, and Volcanic-Hosted Au-Base Metal Metasomatite Deposits (Belt JLL) (Northeastern China)

This Middle Jurassic through Early Cretaceous metallogenic belt is related to replacements and granitoids of the Jilin-Liaoning-East Shandong volcanic-plutonic belt that overlies and intrudes the Sino-Korean craton, Jilin-Liaoning-East Shandong terrane. The belt extends northeast from East Jilin Province to the Liaodong and Shandong Peninsulas, and is 600 km long and 100 to 200 km wide. Nearly 20 relatively large volcanic basins overlap the Jilin-Liaoning-East Shandong Archean terrane and Proterozoic-Paleozoic overlap assemblages. The host volcanic rock for the belt include calc-alkalic andesite, dacite, and rhyolite. Plutonic rocks associated with volcanic rock are mainly multiple stages of granite. The belt contains several types of large deposits. The

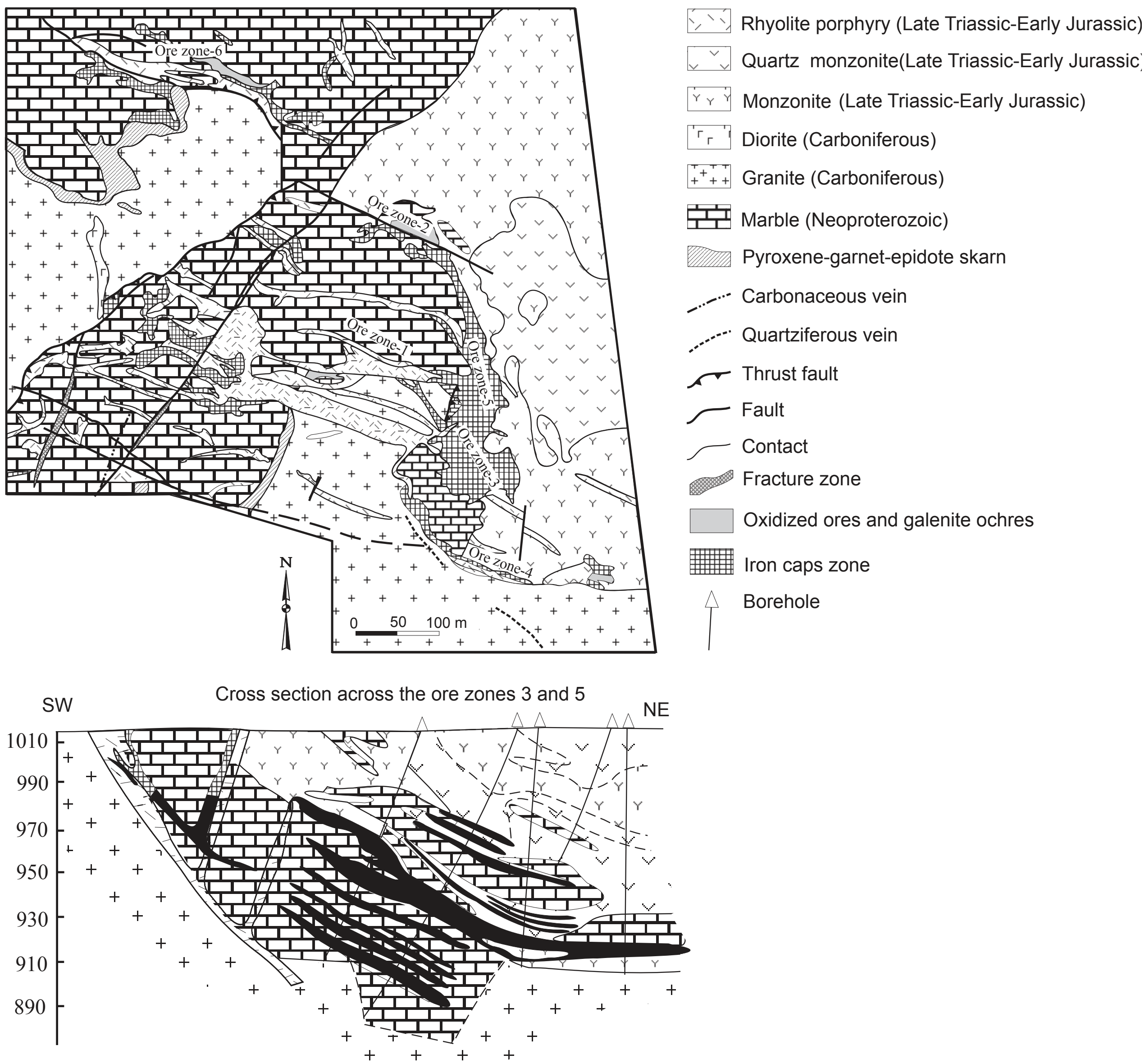


Figure 10. Generalized geologic map and schematic cross section of Khartolgoi polymetallic Pb-Zn±Cu (±Ag, Au) vein and stockwork deposit, Hartolgoi-Sulinheer metallogenic belt, Mongolia. Adapted from Marinov and others (1977).

belt is the important economic resource for Cu, Pb, Zn and Au in China. The significant deposits are at Huanren, Huatong, Ermi, Jiaojia, Liudaojiang, and Xianluwanzhi.

The main references on the geology and metallogenesis of the belt are Yao and others (1990), Rui (1994), and Lin and others (1998).

Huanren Zn-Pb (±Ag, Cu) Skarn Deposit

This deposit (Tu Guangzhi and others, 1989) occurs at the contact zone between limestone and diorite. The skarn occurs in a belt that ranges from 30 to 60 meters wide and 600 to 800 meters long in an external contact zone. The skarn forms several complicated-shaped lenses. The skarn belt and alteration is as much as 200 meters wide. The skarn extends more than 300 meters downdip. Apparent lateral and vertical zoning occurs. The lateral zonation is diorite altered to K feldspar-altered diorite, epidote-altered diorite, epidote skarn, garnet skarn, garnet-diopside skarn, Pb Zn sulfides, marble, and limestone. The vertical zonation is an upper Pb-Zn sulfide zone, a middle Cu and Zn sulfide zone,; and a lower are Fe sulfide zone. The ore minerals occur in masses and disseminations, and are mainly magnetite, hematite, pyrite, arsenopyrite, chalcopyrite, sphalerite, galena, garnet, diopside, calcite, quartz, epidote, and actinolite. The exposed area of the diorite intrusion is 12 km^2. The intrusion consists of diorite, granodiorite, and quartz diorite and is intruded by numerous mafic, intermediate, and siliceous dikes. The diorite is Cretaceous and intrudes Precambrian strata and Jurassic volcanic rock. The deposit is large and has reserves of 495,900 tonnes Zn grading 0.40 percent Zn.

Huatong Cu (±Fe, Au, Ag, Mo) Skarn Deposit

This deposit (Deng and others, 1994) occurs at the contact zone between the marble in the Paleoproterozoic Dashiqiao Formation and a giant phenocryst granite. Both magnesian and calcic skarn occurs. Sulphides occur mainly in calcic skarn but overprint both skarn types. Ore minerals are chalcopyrite, magnetite, pyrrhopyrite, and pyrite. Minor and trace minerals are ludwigite, molybdenite, scheelite, chalcocite, bornite, galena, gold, and arsenopyrite. Gangue minerals are skarn minerals, talc, wollastonite. The deposit shape is very complicated and is controlled by the shape of the intrusion, lithology of host rocks, and fissures in the host rocks. Gold occurs in both skarn types and may comprise a separate resource. The deposit is medium size.

Ermi Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (Feng, 1998) is hosted in a Late Jurassic sedimentary and volcanic sequence, and occurs in the eastern part of a quartz diorite intrusion that formed in a Mesozoic volcanic basin during the Yanshan orogeny. The deposit mainly occurs in the inner and outer contact zone of a granite porphyry intrusion, partly in the contact zone of quartz diorite intrusion, and in andesite. About 8,000 veins are recognized and are concentrated around quartz diorite and granite porphyry in an arc. The economic deposits are divided into gently-dipping and steeply dipping arcuate fractures with massive ore minerals, and steeply-dipping lenses. The ore minerals are chalcopyrite, pyrrhotite, sphalerite, marcasite, pyrite, galena, chalcocite, magnetit, and bismuthine. Gangue minerals are quartz and calcite along with minor sericite, kaolinite, and chlorite. Cu mainly occurs in chalcopyrite. The ore minerals display idiomorphic-hypidiomorphic, porphyritic, and metasomatic textures. The ore minerals occur in masses, bands, disseminations, breccia, veins, stockworks, and colloidal masses. The main ore assemblages are chalcopyrite-marcasite, Cu-bearing magnetite, tourmaline, and chalcopyrite-pyrrhotite-arsenopyrite. Main alteration minerals are silica, tourmalinie, chlorite, carbonate, pyrite, chalcopyrite, kaolinite, and sericite. Vertical and horizontal zoning occurs in the deposit. The deposit is medium size.

Jiaojia Granitoid-Related Vein Au Deposit

This deposit (Wei and Lu, 1994; Sun and others, 1995) consists of tabular zones in the Mesozoic Yanshanian Linglong granite that intrudes gneiss and amphibolite of the Archean Jiaodong group. Pyrite is the dominant ore mineral with lesser chalcopyrite, sphalerite, galena, gold, and electrum. Gold occurs in altered and fractured rock in networks and disseminations. Extensive alterations are K-feldspar, sericite, silica, beresite, and carbonate alterations. The deposit is controlled by the Jiaojia-Xincheng fracture zone and the main deposits parallels the fracture. The largest part of the deposit is as much as 800 meters long and 70 meters wide, and extends downdip more than 1,000 meters. Four mineralizing stages are recognized. The mineralizing temperatures range from 150 to 450°C and pressures range from 60 to 120 MPa. The deposit occurs in the western part of the Jiaodong Peninsula. The deposit is large and has reserves of 60 tonnes of ore grading: 5 to 8 g/t Au.

Liujiapuzhi Volcanic-Hosted Au-Base Metal Metasomatite Deposit

This deposit (Wu, 1995) is hosted in the limestone in the Neoproterozoic, Cambrian, and Ordovician Wanlong and Badaojiang Formations. The deposit occurs in various branches, dikes and veins of granite, diorite, diorite porphyry, quartz diorite porphyry, and syenite porphyry. The deposits are controlled by faults in a steeply-dipping, quartz diorite porphyry intrusion. Sulphide minerals comprise more than 50 percent deposit minerals. The ore minerals occur in masses and disseminations. The main ore minerals are pyrite, galena, sphalerite, and chalcopyrite, and minor hessite and gold. Gangue minerals are quartz and calcite. Alterations are silica, sericite, pyrite, carbonate, epidote, and zeolite. The deposit is medium size.

Origin and Tectonic Controls for Jiliaolu Metallogenic Belt

The belt is interpreted as having formed during interplate magmatism associated with extensional tectonism related to oblique subduction of the Pacific Oceanic Plate beneath Eurasian Plate. The metallogenic belt occurs in about twenty relatively large volcanic basins and east of the famous Tanlu fault zone along a series of northeast-trending regional faults. The volcanic and plutonic rocks hosting the belt are interpreted as having formed during back-arc extension (Rui, 1994). The alkalinity, REE, and lithophyle content of volcanic rock in the belt are slightly lower than those of the Daxinganling volcanic belt, but are slightly higher than those of interplate continental volcanic rock. The north-northeast-trending, strike-slip faults, such as the Tanlu fault zone that occurs along the coast, are an important control (Lin Qiang and others, 1998). The metallogenic belt contains several very important districts. The belt contains more than 200 granitoid-related vein Au deposits in a district of 23,000 km^2, some large and superlarge, that comprise one quarter of proven Au reserve in China. In addition, the belt contains Zn-Pb (±Ag, Cu) skarn and volcanic rock related polymetallic-vein deposits in the Shandong Peninsula. Debate continues about why so much Au was concentrated in a limited area (Yao and others, 1990).

Kitakami Metallogenic Belt of Cu (± Fe, Au, Mo) Skarn and Granitoid-Related Au-Vein Deposits (Belt Kit) (Japan)

This Early Cretaceous (Aptian through Albian) metallogenic belt is related to replacements in the Cretaceous and Paleogene Hiroshima granitic belt (too small to show on the summary geodynamics map) that intrudes the South Kitakami and Mino-Tamba-Chichibu terranes. The belt occurs in the Kitakami Mountains and eastern Abukuma Mountains in the eastern part of northeast Japan, trends north-south for more than 350 km, and has a maximum width of 70 km. The rocks units in the Kitakami Mountains are divided into the North Kitakami and South Kitakami provinces. The North Kitakami province consists of a Jurassic accretionary complex and is a part of the Mino-Tamba-Chichibu terrane. The South Kitakami province consists of Paleozoic granite, sedimentary rock, and andesite. These units are intruded by a Cretaceous granitoid, part of the Hiroshima granite belt. K-Ar isotopic ages of the granitoid in the Kitakami Mountains range from 120 to 110 Ma, and the granitoid forms about 25 percent of the surface exposure. The granitoids consist mainly of I-type tonalite, granodiorite, and granite. The major deposit types in the Kitakami metallogenic belt are Cu skarn and Au-Ag-vein deposits, and the major deposit is the Kamaishi Cu-Fe skarn deposit that formed during intrusion of Cretaceous granite along with the Au-Ag-vein deposits that frequently contain scheelite. Mo skarn and-vein deposits occur in the eastern margin of the North Kitakami province, although those deposits are not described in the database. Tsuboya and others (1956) previously defined the Kitakami metallogenic province and Abukuma metallogenic province; however, this study limits the Kitakami metallogenic belt to the eastern margin of the Abukuma province. The Kitakmi metallogenic belt is interpreted as the eastern extension of the Outer Zone. The major mines are at Kamaishi and Oya.

The main references on the geology and metallogenesis of the belt are Ishihara (1978), and Ishihara and others (1992).

Kamaishi Cu (±Fe, Au, Ag, Mo) Skarn Mine

This mine (fig. 11) (Ishihara and others, 1992) consists of 12 skarns bodies that occur in irregular masses. The main ore body is 660 meters long, 100 meters wide, and 450 meters deep. The main ore minerals are magnetite and chalcopyrite. Minor minerals are cubanite, pentlandite, pyrrhotite, pyrite, sphlerite, hematite, arsenopyrite, scheelite, and molybdenite. Skarn minerals are hedenbergite, actinolite, diopside, garnet, and epidote. Host rocks are Paleozoic limestone, slate, and sandstone, and Cretaceous granodiorite. The mine is related to a Cretaceous granodiorite with a K-Ar isotopic age 119 Ma. The deposit was discovered in 1727. Mining was started by the government 1874 and completed in 1993. The mine is medium size with production of 200,000 tonnes Cu and 14,000,000 tonnes Fe grading 30.9 percent Fe, and 0.63 percent Cu for copper-iron ore.

Oya Granitoid-Related Au-Vein Mine

This mine (Geological Survey of Japan, 1955; Mining and Metallurgical Institute of Japan, 1968) consists of north-south striking veins with eight main vein systems. Veins occur in an area 3 km by 1.5 km. The main vein is 700 meters long and has an average thickness of 0.3 meters. The main ore minerals are arsenopyrite, pyrrhotite, pyrite, sphalerite, chalcopyrite, native gold, galena, argentite, tetradymite, and molybdenite. Gangue minerals are mainly quartz, calcite, hedenbergite, actinolite, epidote, and sericite. Wallrocks are alteted to quartz and calcite. Host rocks are Jurassic sandstone, slate, and granodiorite. Veins are contact metamorphosed. Veins are interpreted as having formed during intrusion of Cretaceous granodiorite. The deposit is small and has prodeuced 15.6 tonnes Au and 2.8 tonnes Ag. The average grades are 20 to 30 g/t Au and 2 to 8 g/t Ag.

Origin and Tectonic Controls for Kitakami Metallogenic Belt

The belt is interpreted as having formed during intrusion of granitoids that were part of a continental-margin arc with abundant siliceous magmatism. Ishihara (1978) defined the western W-Cu province and eastern Mo-Pb-Zn province in the Kitakami Mountains. The Mo-Pb-Zn province included the Taro Kuroko-type Pb-Zn deposit that is excluded from the Kitakami belt in this study. Granitoids in the Kitakami metallogenic belt are characteristically magnetite-series (Ishihara and others, 1992).

Kondyor-Feklistov Metallogenic Belt of Zoned Mafic-Ultramafic Cr-PGE Deposits (Belt KD) (Russia, Far East)

This Early Cretaceous metallogenic belt is related to several zoned mafic-ultramafic intrusions that occur along a northwest-trending, major, buried fault that cuts the southeastern Stanovoy block of the North Asian craton and the northeastern part of Galam terrane. The belt contains the large zoned mafic-ultramafic Kondyor Cr-PGE deposit and the Chad (Mokhovoy) and Feklistov (Shantar Islands) deposit. The major deposit is at Kondyor.

The main references on the geology and metallogenesis of the belt are Marakushev and others (1990), A.I. Khanchuk, written commun (1994), and Dalrymple and others (1995).

Kondyor Zoned Mafic-Ultramafic Cr-PGE Deposit

This deposit (fig. 12) (Marakushev and others, 1990; Bakulin and others, 1999) is hosted in the Kondyor pluton and consists of two types: (1) short lenses, veins, and disseminations that are about 2 to 50 meters long, range up to a few meters thick, and occur in the central part of a dunite stock; and (2) oval-shaped, roughly equidimensional metasomatite with dimensions of about 200 by 300 meters. The first type contains PGE minerals in intergrowths with chromite and olivine, and in small inclusions. Isoferro Pt is the major PGE mineral. The second type consists of PGE minerals that form intergrowths with magnetite, pyroxene, and rarely with metasomatic phlogopite, chrome diopside, and magnetite. This type of deposit is intruded by alkalic igneous veins and dikes including nepheline syenite, lujavrite, ijolite, and urtite. In addition to isoferro Pt and tetraferro Pt, the deposit contains as much as 5 to 8 percent sulfide and As minerals. Controversy exists about the age and tectonic environment for the host mafic and ultramafic rock. The host rocks were originally interpreted as an integral part of the Neoproterozoic and older cratonal rock of the Stanovoy block of the North Asian craton. However, A.I. Khanchuk (written commun, 1994) interprets the mafic and ultramafic rock as Jurassic because the intrusions are similar in composition to other Jurassic plutons of the Ariadny igneous belt. This igneous belt is interpreted as having formed possibly immediately before Late Jurassic accretion in the region, or possibly in the mid-Cretaceous. Unpublished K-Ar isotopic ages for the zoned mafic-ultramafic intrusions in the Kondyor metallogenic belt range from 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) that may be part of the same igneous belt that hosts the Kondyor metallogenic belt. The deposit is medium size and has about 13.5 tonnes PGE produced from 1984 to 1993. Annual production of about 2.5 to 3.0 tonnes PGE has occurred since 1993. In 1999, approximately 2.9 tonnes PGE were produced.

Origin and Tectonic Controls for Kondyor-Feklistov Metallogenic Belt

The belt is interpreted as having formed during interplate intrusion of mafic-ultramafic plutons along a major fault that formed along the North Asian cratonal margin during collision and accretion of outboard terranes during the Early Cretaceous.

Kular Metallogenic Belt of Au in Shear-Zone and Quartz-Vein, Granitoid-Related Au-Vein, and Sn-W Greisen, Stockwork, and Quartz-Vein Deposits (Belt KU) (Russia, Verkhoyansk-Kolyma Region)

This Late Jurassic and Early Neocomian metallogenic belt is related to veins and replacements in the Kular-Nera terrane. The belt occurs on the northwestern flank of the Kular-Nera (slate belt) terrane, extends northeastward for 150 km, and ranges from 30 to 40 km wide. The belt is hosted in Permian through Triasssic deep-marine black slate that is intruded by granite with a $^{40}Ar/^{39}Ar$ of 103 Ma. Early studies interpreted the belt as forming in an uplifted fault-fold complex with simple box folds. Subsequent, detailed structural studies revealed a complex fold and thrust zone with numerous refolded, recumbent isoclines. The host rocks are metamorphosed to greenschist facies (muscovite-chlorite and biotite subfacies). The metamorphic Au in shear zone and quartz-vein deposits in the Solur, Ulakhan-Sis, and Magyl-Khayata districts occur along crests of antiforms formed in Permian slate. The mineral assemblage is quartz, carbonate (ankerite and calcite), chlorite, muscovite, and albite. An early pyrite-arsenopyrite assemblage is succeeded by a productive Au pyrrhotite-chalcopyrite-sphalerite-galena assemblage. The major deposits are at Emelyanovskoye, Novoe, and the Tirekhtyak district (Nagornoe, Podgornoe, and Poputnoe).

The main references on the geology and metallogenesis of the belt are Fridovsky (1996) and Parfenov and others (1999).

Emelyanovskoye Au in Shear Zone and Quartz-Vein Deposit

This deposit (Parfenov and others, 1999) consists of concordant, stratabound saddle, lenticular, and sheet veins. High density veins and veinlets form concordant stockworks. Most of the veins and veinlets exhibit parallel cleavage and some occur in S-shaped shears and fractures. Up and down-dip, the veinlets grade into concordant veins or are truncated by decollement faults. The deposits extend as much as a few hundreds of meters long, are as much as 1.5 meters thick, and consist mainly of quartz and carbonate, along with subordinate pyrite, galena, sphalerite, Au, pyrrhotite, arsenopyrite, fahl, and chalcopyrite. Gold grains are 3 to 4 mm long.

Novoe Granitoid-Related Au-Vein Deposit

This deposit (Ivensen and others, 1975) consists of steeply-dipping, cross-cutting shear zones and lenticular veins that occur in tension gashes. The shear zones strike northeast and dip northwest or southeast at 15-60°, commonly are as much as several meters thick, locally to 10 to 12 meters thick, and as much as 1.5 km long. The lenticular veins range from 0.1 to 2 meters thick and as much as 50 to 100 meters long. Major minerals are quartz, wolframite, arsenopyrite, carbonate, cassiterite, and gold. The deposit hosted in Late Permian sandstone and shale near the dome of the Central-Kular anticline. The deposit is small with as much as 0.2 to 6.8 percent $W0_3$, 0.03 to 0.16 percent Sn, and 0.5 to 5 percent As.

Tirekhtyak District (Nagornoe, Podgornoe, Poputnoe) Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (Ivensen and others, 1975) consists of veins of tourmaline-quartz and cassiterite-scheelite-quartz; and cassiterite stringers. The major minerals are beryl, pyrrhotite, arsenopyrite, muscovite, sphalerite, and galena. Veins and stringers range from 0.01-1.2 meters thick and as much as 100 meters long. Veins and stringers strike northeast and occur near the contact of the Early Cretaceous Tirekhtyak granite

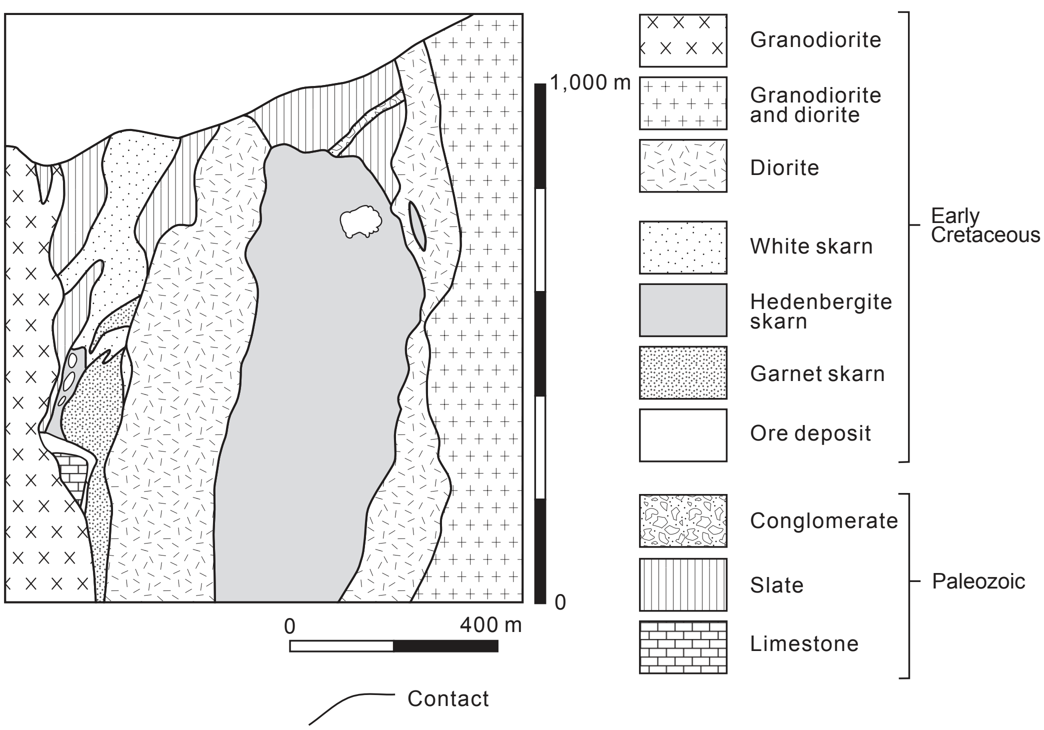


Figure 11. Schematic cross section of Kamaishi Cu (±Fe, Au, Ag, Mo) Skarn Mine, Kitakami metallogenic belt, Japan. Adapted from Kaneda and others (1978) and Nittetsu Mining Co. (1981).

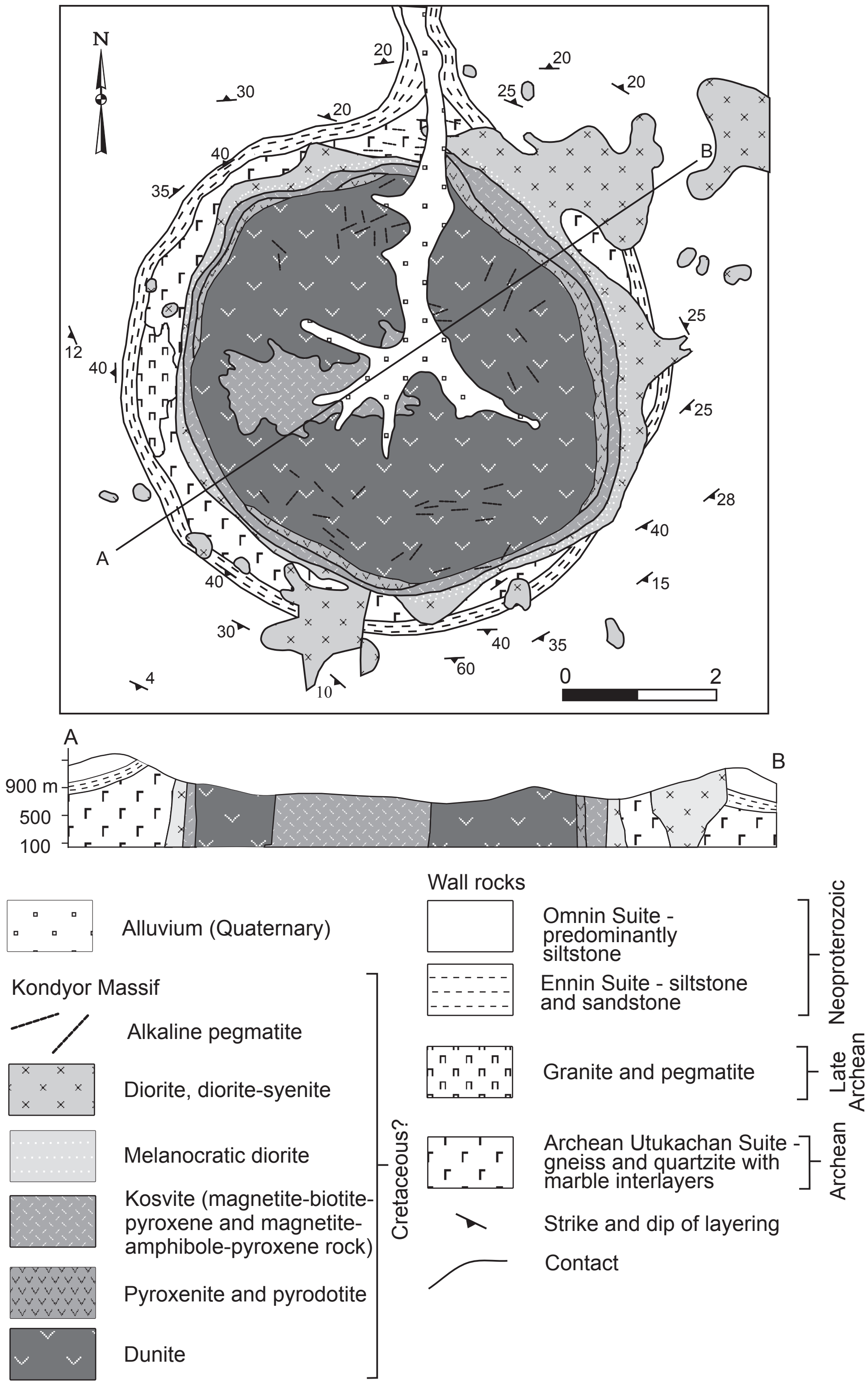


Figure 12. Generalized geologic map and schematic cross section of Kondyor zoned-mafic-ultramafic Cr-PGE deposit, Kondyor-Feklistov metallogenic belt, Russian Southeast. Adapted from G.V. Andreev, A.A. El'yanov, and A.N. Mil'to, written commun. (1974).

pluton. Veins and stringers intrude aplite dikes and granites and adjacent Triassic clastic rock that is contact metamorphosed. The deposit is small with as much as 5 percent S, 1 percent $W0_3$, 0.6 percent Pb, and 1 percent As.

Origin and Tectonic Controls for Kular Metallogenic Belt

The belt is interpreted as having formed during collision of the Kolyma-Omolon superterrane to the North Asia craton and associated regional metamorphism in Late Jurassic through early Neocomian. The belt occurs on the northwestern flank of the Kular-Nera slate belt.

Nerchinsky Metallogenic Belt of Granitoid-Related Au-Vein, W-Mo-Be Greisen, Stockwork, and Quartz-Vein, and Fluorspar-Vein Deposits (Belt NC) (Russia, Eastern Transbaikalia)

This Middle Jurassic through Early Cretaceous metallogenic belt is related to granitoids and volcanic complexes related to Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt that intrudes and overlaps the Western Stanovoy terrane, Barguzin-Vitim granitoid belt, and the Selenga and Transbaikalia sedimentary and volcanic-plutonic belts. The northeast-to east-trending belt occurs in the Chersky Range in the watershed of the Uruljunguy and Nercha Rivers and the upper Olekma River. The belt is 1,025 km long and 85 km wide. The host Mesozoic intrusions consist of coarse-, medium-, and fine-grained biotitic granite porphyry in the Amanan and Amudzhikan complexes that are intruded by numerous granite porphyry, andesite, diabase, microdiorite, pegmatite, and fine-grained granite dikes. The major deposits are at Darasun, Teremkinskoye, Talatuyskoye, Muoklokanskoye, and Usuglinskoye.

The major deposits in the belt are (1) major granitoid-related Au vein type deposits at Darasun, Teremkinskoye, and Talatuyskoye, and numerous small deposits); (2) W-Mo-Be greisen, stockwork, and quartz-vein deposits at Muoklokan W and elsewhere; and (3) fluorspar-vein deposits at Usuglinskoye, Uluntuy, and elsewhere. All deposits contain numerous components formed in multiple stages. The Au deposits occur in zoned volcanic-tectonic structures (Seminsky and others, 1987; Zorina, 1993; Zorina and others, 1989), and are related to Mesozoic subvolcanic bodies of mainly granodiorite porphyry and rare granite and diorite porphyry (Tauson and others, 1987). The vein form of deposits and a distinct relationship to local extrusive domes and volcanic basins structures is common. Also occurring in the belt are Wo-Mo hydrothermal deposits and W hubnerite-sulfide deposits in quartz veins, vein zones, and stockworks that are related to Mesozoic granitoid plutons. The fluorite deposits occur in basins filled with Late Jurassic and Early Cretaceous sedimentary and volcanic rock and occur near margins of widespread Late Jurassic granodiorite and granosyenite porphyry plutons that contain numerous Paleoproterozoic metamorphic-rock xenoliths with granitic gneiss, schist, and migmatite. The deposits consist of quartz-fluorite veins (Yakzhin, 1962; Kotov, 1995). The belt is prospective for undiscovered Au,W, fluorite, and associated deposits.

The main references on the geology and metallogenesis of the belt are Seminsky and others (1987), Zorina and others (1989), Zorina (1993), and Kotov (1995).

Darasunskoye Granitoid-Related Au-Vein Deposit

This deposit (Zvyagin and Sizikov, 1971) consists of more thanb 120 steeply-dipping quartz-sulfide veins that extend along strike for 1.0-1.2 km. The zone of veins ranges from 100 to 1,000 meters thick, and individual veins vary from 5 to 20 cm thick. A zone of wallrock marginal to the veins is about 0.6 to 1.5 meters thick and contains disseminated sulfides. The ore minerals comprise the complex Darasun sulfide-sulfosalt type with as much as 40 to 60 percent sulfides. The main ore minerals are pyrite, arsenopyrite, chalcopyrite, pyrrhotite, galena, sphalerite, Pb, Cu, Ag, Bi, As, and Sb sulfosalts, tellurides, native gold, quartz, carbonates, and tourmaline. The principal economic gold-bearing mineral assemblages are chalcopyrite-gray ore, chalcopyrite-pyrrhotite, pyrite-arsenopyrite, and sphalerite-galena. Gold occurs in arsenopyrite, pyrite, chalcopyrite, pyrrhotite, and gray ore, and is finely dispersed. The deposit ocurs along the Mongol-Okhotsk suture and is hosted in a middle and Late Cretacous granodiorite-porphyry that intrudes a volcanic dome. The porphyry is accompanied by dikes of diorite and granodiorite porphyry, and explosive breccia. The deposit occurs both in the intrusion and in the enclosing early Paleozoic gabbro, middle Paleozoic granodiorite, and in late Paleozoic and Triassic granite. Host rocks are altered to propylite. The deposit is large with grades up to 300 ppm Au and averages 6.5 ppm Au.

Muoklakanskoye W-Mo-Be Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (Sizykh and others, 1985; Skursky, 1996) consists of two subparallel zones that host 30 steeply dipping quartz-hubnerite-sulfide veins (with dimensions of 300 to 600 by 0.5 by 2.0 meters). The first zone contains a series veinlets with about 1.0 percent WO_3, as much as 1,400 ppm Ag and to 3.4 ppm Au. The second zone contains three large quartz veins and several small ones and grades 0.45 percent WO_3. The ore minerals are quartz, hubnerite, muscovite, native gold, molybdenite, sphalerite, galena, chalcopyrite, and calcite. Host rocks are altered to K-feldspar, beresite, and silica. The deposit is hosted in Archean granitic gneiss, plagiogneiss, amphibolite, and diopside quartzite along the exocontact of the Middle and Late Jurassic Dzhekdachinsky granite massif that intrudes the Archean Muoklakan block. The deposit is small and has an average grade of 0.8 percent WO_3.

Usuglinskoye Fluorspar-Vein Deposit

This deposit (Yakzhin, 1962; Kotov, 1995) is hosted in seven fault zones that strike northwest and occur in an area from 1-3 km wide. The zones contain extensive, steeply-dipping veins that extend from 800 to 3000 meters, range from 0.3-1.8 meters thick, and extend to a depth of 100 to -400 meters. The deposits occur in pillars that range from 8 to 45 meters thick. The ore minerals are fluorite and quartz (90 percent), minor kaolinite, and rare dikkite, narkite, hydromicas, barite, calcite, pyrite, apatite, rutile, sphene, calcite, and sericite. The deposits occur in masses, layers, breccia, and veinlets. The vein texture is symmetrically banded with a variable color for fluorite. The main mineral assemblage is quartz-fluorite. Sulfur grade is about about 0.12 percent with 0.01 to 0.16 percent P_2O_5. The deposit is hosted in Neoproterozoic and early Paleozoic granite and granodiorite along the northern edge of a late Mesozoic basin filled with Middle Jurassic through Early Cretaceous terrigenous, volcanic, and sedimentary rock. The deposit is medium size and has resources of 2.9 million tonnes CaF_2 grading 64 percent CaF_2.

Origin and Tectonic Controls for Nerchinsky Metallogenic Belt

The belt is interpreted as being related to magmatism along transtensional zones along transform microplate boundaries and within plate (plume) environment. The belt is related to granitoids in the Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt.

North Bureya Metallogenic Belt of Au-Ag Epithermal-Vein and Granitoid-Related Au-Vein Deposits (Belt NB) (Russia, Far East)

This Early Cretaceous metallogenic belt is related to veins and granitoids in Early Cretaceous felsic and intermediate volcanic rock in the Umlekam-Ogodzhin volcanic-plutonic belt that intrudes and overlaps the Malokhingansk terrane, Turan terrane of the Bureya superterrane, Gonzha terrane, Nora-Sukhotin-Duobaoshan terrane, and Tukuringra-Dzhagdy terrane. The host volcanic rock extends along the boundary between the Tukuringra-Dzhagdi terrane and the North Asia craton. Several poorly-explored Carlin type deposits that consist of layers of disseminated gold in jasper beds, occur in the area, but are unexplored. Numerous related placer Au mines occur in the metallogenic belt. The Au in the placer mines is interpreted as being mainly derived from Au-bearing quartz veins in Late Jurassic through Early Cretaceous sedimentary and volcanic rock. The major Au-Ag epithermal-vein deposit is Pokrovskoe and granitoid-related Au-vein deposit is at Pioneer.

The main references on the geology and metallogenesis of the belt are Mel’nikov (1984), Khomich (1990), V.D. Mel’nikov, written commun. (1993), and Khanchuk and others (1996).\

Pokrovskoe Au-Ag Epithermal-Vein Deposit

This deposit (fig. 13) (Mel’nikov, 1984; Khomich, 1990; V.D. Mel’nikov, written commun., 1993) is hosted in a sequence of Early Cretaceous andesite, dacite andesite, and tuff that overlies a Jurassic coal-bearing sequence of sandstone, siltstone, and argillite. The deposits consist of gently-dipping quartz veins and zones of hydrothermal alteration. The main alterations are propylitic (albite, sericite, calcite, chlorite, and pyrite), berezite (quartz, sericite, and hydromica), and argillite (kaolinite, montmorillonite, hydromica, carbonate, quartz, and pyrite). The largest part of the deposit is a gently-dipping zone of altered rock that occurs near the lower contact of an andesite sequence with a granodiorite porphyry sill. Hydrothermally altered rock consists of quartz (25 to 85 percent), carbonate (2 to 5 percent), hydromica (5 to 12 percent), adularia (as much as 5 percent), kaolinite (5 to 7 percent), and sulfides (less than 1 percent, mostly pyrite). Gold is fine-grained (0.0005 to 0.032 mm), is associated with quartz, and is rarely or not associated with sulfides. Silver grains (0.002 to 0.016 mm) occur in Fe-hydroxide alteration. The deposit is interpreted as having formed in the Early Cretaceous. The deposit is medium size and has reserves of 15 million tonnes grading 4.4 g/t Au and 15 g/t Ag.

Pioneer Granitoid-Related Au-Vein Deposit

This 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 and in adjacent country rock that consists of contact-metamorphosed Jurassic sandstone and siltstone. The deposit consists of veins of quartz, quartz-feldspar, quartz-tourmaline, and quartz-carbonate, and altered zones of quartz, K-feldspar, sericite, and albite. The veins and zones vary from 1 to 50 meters thick. The deposit is large, low grade, and has no visible boundaries. The extent of deposit is determined by geochemical sampling. Both gold and Au-sulfide ores occur. The Au ore consists of quartz-adularia-carbonate veins, and the Au-sulfide ore consists of quartz veins with pyrite, galena, stibinite, and Ag-sulfosalts. The deposit is small and has reserves of 17.1 tonnes Au and 20.1 tonnes Ag, and an average grade of 2.7 g/t Au and 5.2 g/t Ag.

Origin and Tectonic Controls for North Bureya Metallogenic Belt

The belt is interpreted as having formed during formation of Umlekan-Ogodzhin continental-margin arc that formed during subduction of part of ancestral the Pacific Ocean Plate. The arc is now preserved on the Bureya-Jiamusi superterrane and Badzhal collage (Khabarovsk, and Samarka terranes). This tectonic pairing is based on (1) occurrence of the subduction-zone terranes outboard (oceanward) of the Umlekan-Ogodzhin arc; (2) formation of melange structures during the Jurassic and Early Cretaceous; and (3) where not disrupted by extensive Cretaceous and Early Cenozpic movement along the Central Sihote-Aline strike-slip fault, dipping of melange structures and bounding faults toward and beneath the igneous units of the arc. Subduction is generally interpreted as ending in the Early Cretaceous when extensive sinsitral faulting occurred along the subduction zone.

North Jilin Metallogenic Belt of Zn-Pb (±Ag, Cu) Skarn, Granitoid-Related Au-Vein, Porphyry Au, Porphyry Cu (±Au), Porphyry Mo (±W, Bi), Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite, Au-Ag Epithermal-Vein, and Fluorspar-Vein Deposits (Belt NJ) (Northeastern China)

This Middle Jurassic through Early Cretaceous metallogenic belt is related to replacements and granitoids that intrude the Late Carboniferous through Permian North Margin plutonic belt of North China Platform that in turn intrudes the Laoling terrane and Zhangguangcailing superterrane in the Sino-Korea craton in the North Jilin Province. The deposit-related igneous rocks formed during multiple stages of volcanism and plutonism mainly in the Late Jurassic and Cretaceous during central and pipe-like eruptions of intermediate volcanic rock. The major Mesozoic granite intrusions in the area are Early Jurassic granite (I type) and Late Jurassic granite (A type) (Rui, 1994). The metallogenic belt is controlled by the structures along the northern margin of the Sino-Korea craton, and by northeast-, northwest-, and east-west-trending faults. Though irregular, the belt generally trends east-west, and is 500 km long and 50 km wide. The significant deposits are at Tianbaoshan, Haigou, Sanwen, Daheishan, Xiaoxinancha, and Ciweigou.

The main references on the geology and metallogenesis of the belt are Rui (1994) and Lin and others (1998).

Xiaoxinancha Porphyry Cu (±Au) Deposit

This deposit (fig. 14) (Rui, 1994) is located at the intersection of Tianshan-Jilin (Heilongjiang) east-west-trending Paleozioc accretion zone and Circum Pacific Mesozoic tectono-magmatic zone.The oldest exposed strata are the early Paleozoic Qinglong Group, that often occur as xenoliths in late Hercynian granite and diorite and consist of amphibolite, amphibolitic gneiss, biotite schist, graphite schist, andalusite state, sillimanite slate and sandy slate. Early and Late Permian strata are distributed in the adjacent region amd are composed of intermediate-siliceous tuff, volcanic breccia, lava and sandy slate. Jurassic volcanic rock can be seen in the fault basins south and northwest of the deposit. Ingneous intrusives account for more than 60 percent the deposit area, including Hercynian, Indosinian, Yanshannian and Himalayan igneous bodies. The dominant Hercynian intrusives consist of plagioclase granite, biotite-plagioclase granite, gneissic biotite granite, and diorite. The main host rock is Hercynian diorite. During early Yanshannian stage, many kinds of intrusives formed, including diorite, quartz diorite, granite, diorite porphyry, moyite, admallite and granitic porphyry. The intrusives occur as small igneous stocks or dikes of Hercynian granite and Jurassic volcanic rock. Intermediate porphyry, especially diorite porphyry (130.1 Ma) also contains Cu and Au minerals. The deposit is controlled by the intersection of northwest-and north-northeast-striking faults. There are 34 bodies in a north-northwest-trending belt with an area of 2.4 to 1.8 km^2. The bodies are composite vein type, single vein type, network type and veinlets and disseminations. Main deposit minerals are chalcopyrite, pyrite, pyrrhotite, native gold and electrum. Quartz, calcite, sericite, chlorite, epidote, actinolite, and zeolite are gangue minerals. Wallrock alterations include K-feldspar alteration, biotitization, beresite alteration, propylitic alteration and carbonate alteration. The deposit-forming temperatures are 200 to 450ºC. The deposit is large.

Tianbaoshan Zn-Pb (±Ag, Cu) Skarn Deposit

This deposit (Rui, 1994) occurs at the intersection of the the east-west-trending Tianbaoshan-Madida fault and the major northeast-striking Liang Jiang-Tianqiaoling fault. The host rocks are Cambrian and Ordovician amphibolite, chlorite schist interlayered with siliceous marble, Late Carboniferous marble interlayered with biotite slate, chert, and limestone, Late Trisssic rhyolite, andesite, and Late Jurassic mafic and intermediate volcanic rock. Several periods of igneous intrusives occur in the area: (1) early Hercynian gneissoid granite with a U-Pb zircon isochron age of 326.4 Ma; (2) late Hercynian granodiorite with a U-Pb zircon isotopic age of 245.2 Ma; (3) Indosinian porphyritic adamellite and dacite porphyry with a U-Pb zircon isotopic age of 205 Ma; and (4) Yanshannian andesitic porphyry and granite porphyry. The deposit is related to Yanshannian igneous rocks and is controlled by the intersections of northwest-, northeast-, and north-south-trending faults. The skarn occurs in the contact zone of Indosinian and Yanshanian granodioritic porphyries and marble in metavolcanic rock. The main ore minerals are magnetite, galena, sphalerite, and chalcopyrite. Explosive breccia pipe deposits occur in the western part of the Mesozoic Tianbaoshan volcanic basin. Galena, sphalerite, chalcopyrite, and pyrite are the main ore minerals, and alteration minerals are quartz, calcite,

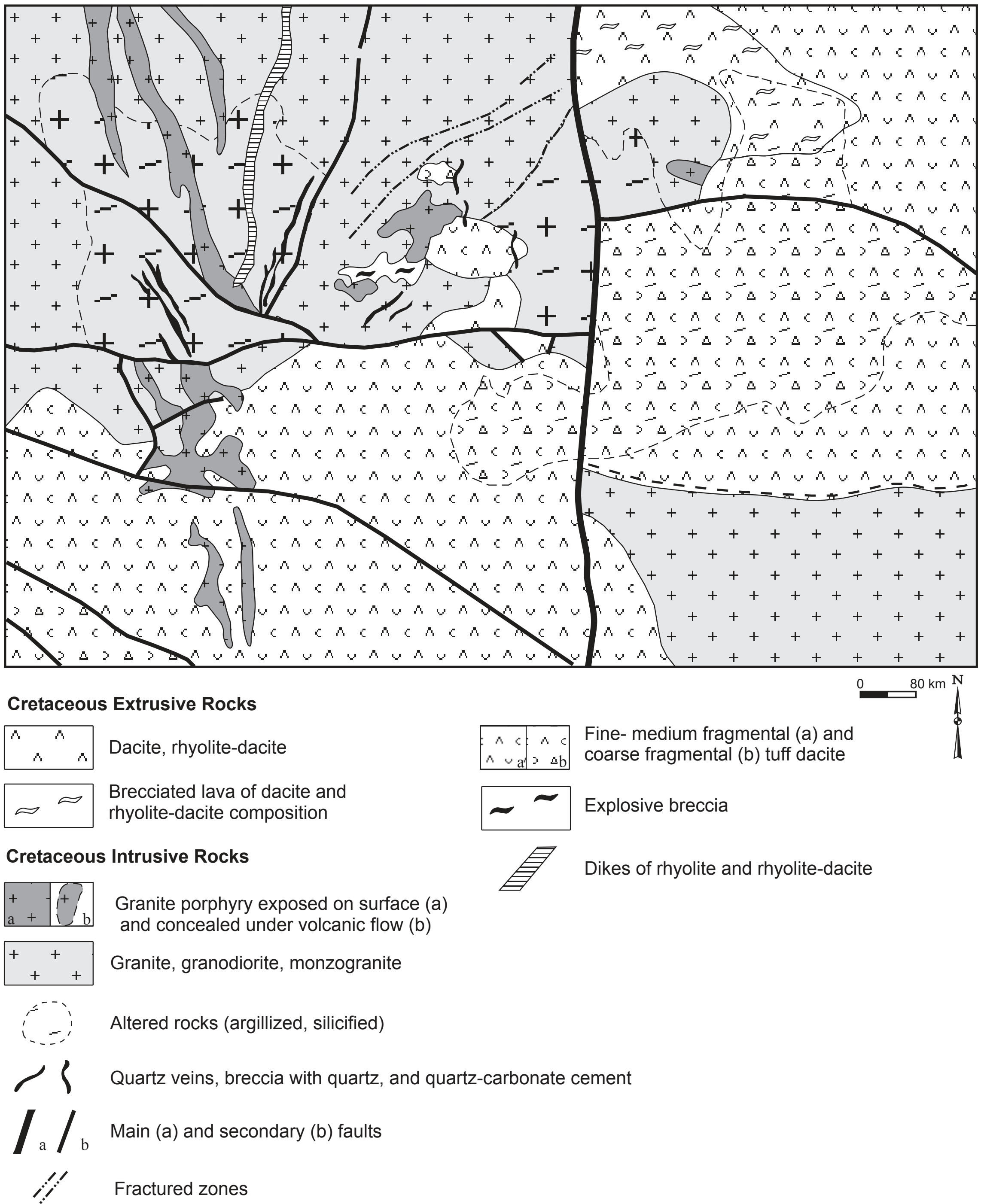


Figure 13. Generalized geologic map of Pokrovskoe Au-Ag epithermal-vein deposit, North Bureya metallogenic belt, Russian Southeast. Adapted from N.I. Novikov and others, written commun., 1987.

epidote, hydromica, and chlorite. The main sulfide depositional temperatures are 210 to 300ºC. The deposit is medium size and has reserves of 123,300 tonnes Pb and 193,900 tonnes Zn. The average grades are 0.52 percent Pb and 1.76 percent Zn.

Sanmen Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite Deposit

This deposit (Tian and Shao, 1992) consists of veins, lenses, and stockwork. The main part of the deposit is 1800 meters long. The ore minerals occur in masses, veinlets, and disseminations and consist of native silver, pyrite, galena, sphalerite, argentite, Cu and Sn sulfides, and quartz. Intense host-rock alteration consists of silica, pyrite, and beresite. The host rocks are Cambrian and Ordovician intermediate and siliceous volcanic rock, sedimentary clastic and carbonate rock that is intruded by Jurassic and Cretaceous granitoids. The deposit is controlled by north-northeast-trending faults and fracture zones. The deposit is large and has an average grade of 180 g/t Ag.

Daheishan Porphyry Mo (±W, Bi) Deposit

This deposit (Huan others, 1994) consists of veinlets and disseminations in the Yanshanian plagiogranite that intrudes the highly metamorphosed Variscan granite of the Devonian Hulan group with a K-Ar biotite isotopic age of 354 Ma. The plagiogranite forms an ellipse with a surface area of 8 km^2. Ore mineral is mainly molybdenite with minor pyrite, chalcopyrite, galena, and sphalerite. From central to outward, the important proximal alterations are silica, sericite, kaolinite alterations. The deposit occurs at the intersection between north-northeast-trending Panshi and the east-west-trending Huadian-Shuanghe structural zones that occur in the southeastern part of the Jilin Variscan fold belt near the north margin of Sino-Korean Plate. The deposit is large and has reserves of 1.09 million tonnes of ore grading 0.066 percent Mo.

Ciweigou Au-Ag Epithermal-Vein Deposit

This deposit (Xu and others, 1994; Rui, 1994) occurs along the Yanshannian intracontinental volcanic basin along the southeastern Inner Mongolia-Xinganling Hercynian fold belt. The host rocks are Late Jurassic siliceous, intermediate, and mafic volcanic rock with a Rb-Sr isochron age of 147.5 Ma. The deposit is controlled by circular and radial faults around a maar volcano that occurs at the intersection between east-west-trending major faults and northwest-trending faults. The deposit occurs in veins. Wallrocks display silica, carbonate, sericite, and propylitic alterations. The depositional temperatures range from 180 to 240°C, and pressures from 20 to 1.48 MPa. Ore minerals are pyrite, chalcopyrite, tetrahedrite, sphalerite, galena, electrum, argentite, gold, calaverite, and sylvanite. The deposit is medium size.

Origin and Tectonic Controls for North Jilin Metallogenic Belt

The belt is interpreted as being related to magmatism along transpression zones along transform microplate boundaries and within plate (plume) environment. The volcanic rocks that host part of the deposits are interpreted as having formed during lithosphere extension and are controlled at least partially by the major, north-northeast-trending Tanlu strike-slip fault system. The belt occurs in (1) the northern margin of the Archean Jilin-Liaoning-East Shandong terrane of the Sino-Korea craton; (2) plutonic rocks related to early and late Paleozoic accretions; and (3) postaccretionary Early Triassic, Late Jurassic, and Cretaceous volcanic and plutonic rocks. The deposits in the belt may have formed in multiple stages. Various authors cite different isotopic ages for the same deposit and, therefore, some deposit ages are uncertain. Some deposits probably formed during the Early Jurassic and Late Triassic (Rui, 1994), but most surely formed in the Middle Jurassic and Early Cretaceous. Lin and others (1998) suggested that the volcanism in the area continued from the Late Triassic through post Early Cretaceous with most intense activity in the Middle Jurassic and Early Cretaceous.

North Stanovoy Metallogenic Belt of Granitoid-Related Au-Vein and Au-Ag Epithermal-Vein Deposits (Belt NS) (Russia, Far East)

This Early Cretaceous metallogenic belt is related to granitoids in the Stanovoy granite belt that intrude the Tynda terrane. The deposits generally consist of quartz and quartz-carbonate veins that are spatially related to Jurassic through Early Cretaceous granite and granodiorite that are generally interpreted as having formed in a collisional setting. The one large Au-Ag epithermal-vein deposit is at Bamskoe. Also occurring in the area are numerous related placer Au mines that are some of the largest placer Au mines in the west-central part of the Russian Far East.

The main references on the geology and metallogenesis of the belt are Parfenov (1995) and Sukhov and others (2000).

Bamskoe Granitoid-Related Au-Vein Deposit

This deposit (A.V. Lozhnikov and others, written commun., 1989; Kurnik, 1992) consists of thirty-five zones of listwenite and beresite hydrothermal alteration that occur in granite and gneiss. The altered zones contain eight Au prospects with abundant veins, pods, and small quartz and quartz-carbonate veinlets. Prospects range from 140 to 960 meters long and have an average thickness of about 3 meters. The deposits are related to, and occur around the periphery of an Early Cretaceous subvolcanic rhyolite and rhyodacite stock that intrudes Neoproterozoic granite and biotite-amphibolite gneiss of the Tynda terrane.

Burindinskoe Au-Ag Epithermal-Vein Deposit

This deposit (fig. 15) (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 are as much as 200 meters long and have an average thickness of about 10 meters. The veins are hosted in an Early Cretaceous volcanic sequence overlying the Gonzhinsky terrane of the Burea-Khanka superterrane. The deposit is medium size and has reserves of 6,230 kg gold and 38,200 kg silver grading 9.5 g/t Au and 42.6 g/t Ag.

Origin and Tectonic Controls for North-Stanovoy Metallogenic Belt

The belt is interpreted as having formed during late-stage accretion of the Bureya superterrane to the south with the North Asian craton to the north, during final closure of the Mongol-Okhotsk Ocean. The lode Au and related large placer deposits occur in the southern part of the metallogenic belt, near a major fault between Precambrian gneiss of the Tynda terrane to the north and the Paleozoic rocks of the Tukuringra-Dzhagdi subduction-zone terrane to the

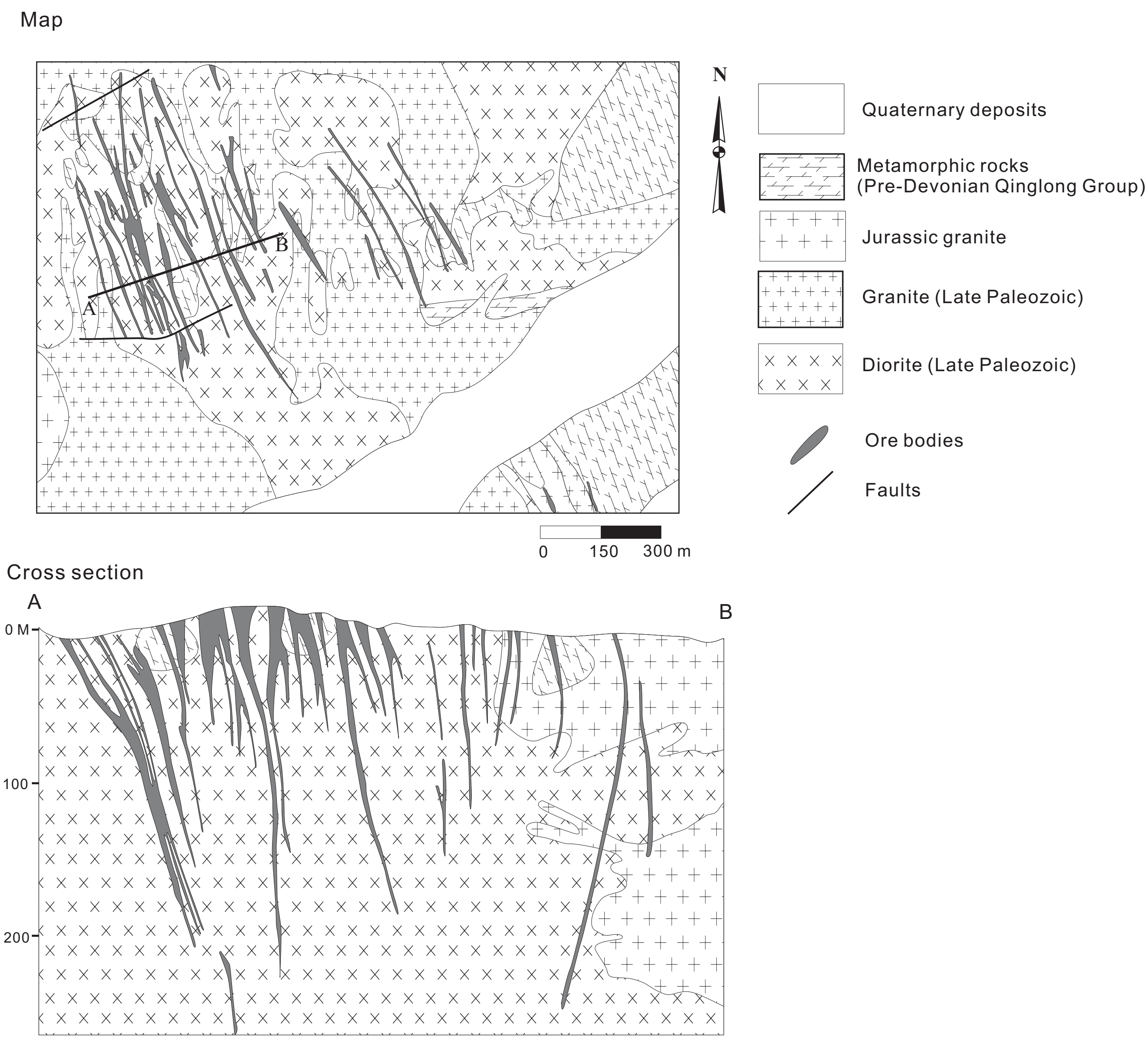


Figure 14. Generalized geologic map and schematic cross section of Xiaoxinancha porphyry Cu (±Au) deposit, North Jilin metallogenic belt, northern China. Adapted from Rui (1994).

south. The latter is metamorphosed to greenschist facies. The Paleozoic rocks contain beds of Au-bearing, pyrite-bearing graphitic shale.

Onon-Turinskiy Metallogenic Belt of Porphyry Au, Granitoid-Related Au-Vein, and Cassiterite-Sulfide-Silicate Vein and Stockwork Deposits (Belt OT) (Russia, Central Transbaikalia and Mongolia)

This Middle Jurassic through Early Cretaceous metallogenic belt is related to veins, volcanic complexes, and replacements related to Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt that overlies and intrudes the Selenga sedimentary-volcanic plutonic belt, and Ononsky terrane. The belt occurs along the Onon and Ingoda Rivers, trends east-northeast along the western boundary of the Argunsky terrane for 300 km, and ranges from 50 to 70 km wide. The Late Mesozoic Transbaikalia sedimentary-volcanic-plutonic belt consists of calc-alkaline and subalkaline volcanic rock of the Sokhondinsky and Dzhargalantuy Suites, calc-alkaline and subalkaline granitoid of the Sokhondinsky, Kyrinsky, Asakan-Shumilovsky Kharalginsky Complex, diorite and granodiorite of the Shakhtaminsky Complex, and REE granite of the Kukulbey Complex. The volcanic rock units are lava, pyroclastic, extrusive, and subvolcanic varieties that occur in volcanic domes, pluton-related domes, and basins that are controlled by longitudinal and transverse faults (Seminsky, 1980). The Mongolian part of the belt occurs in the Hentii subterrane of the Hangay-Dauria terrane adjacent to Russia, and consists of Sn-W greisen, stockwork, and quartz vein, and stockwork deposits. The belt contains a few cassiterite-wolframite-quartz and wolframite-cassiterite-beryl-quartz veins that are related to small plutons composed of biotite, two-mica, and muscovite fluorite leucogranite that is intensely altered to greisen with a K-Ar isotopic age of 146 Ma (Koval, 1998). The major deposits are at Ara-Ilinskoye, Khapcheranga, Lubavinskoye, and Tarbaldzhiskoye.

The major deposits in the Onon-Turinskiy belt occur in two districts that strike northeast and are controlled by crossing northwest-striking faults. The deposits are related to Jurassic and Cretaceous magmatism and faults that define the districts. The largest district is at Lubavinsky-Tarbaldzhey and contains the Lubavinsky granitoid-related Au-vein deposit. This deposit contains simple and saddle-like Au-quartz veins (Shubin, 1984). The Tarbaldzhey deposit with cassiterite-sulfide-silicate veins and stockwork contains feldspar-fluorite-quartz veins with cassiterite and sulfides (Ontoev, 1960). The Ara-Ilinsky porphyry Au deposit occurs in a cryptovolcanic diatreme and consists of an Au stockwork (Fogelman, 1964).

The main references on the geology and metallogenesis of the belt are Zonenshain and others (1990), Kovalenko and others (1995), Koval (1998), Gerel and others (1999), Cluer and others (2000), and Tomurtogoo (2001).

Khapcheranga Cassiterite-Sulfide-Silicate Vein and Stockwork Deposit

This deposit (fig. 16) (Gongalsky and and others, 1995; Skursky, 1996) consists of 20 extensive (to 1,100 meters) veins with thicknesses of 0.4 to 0.5 meters, in swells 1.5 to 2.0 meters in steeply-dipping shears with a northnorthwest strike, and 50 small, variably-trending veins on the southern flank of the deposit. Major minerals are cassiterite, arsenopyrite, sphalerite, pyrrhotite, and galena; less common are chalcopyrite, pyrite, stannite, ferebrite, and marcasite; minor molybdenite, lellingite, magnetite, bismutine, gray ore, and argentite; and very rare hydrothermal kavalerite, tantalite, hematite, and monazite. Nonmetalliferous minerals are quartz, muscovite, topaz, chlorite, microcline, albite, biotite, fluorite, calcite, tourmaline, and epidote. The vein occurs along southern exocontact of a stock (2 km^2 area) of Middle Jurassic granite porphyry with greisen in apical part. The veins are multistaged, and have a mineral zonation defined by the distance from the contact of the granite stock. Zone 1 has apical Sn-W greisen; zone 2 contains quartz-feldspar with arsenopyrite, pyrite, pyrrhotite, cassiterite, and sphalerite; zone 3 contains sulfate-cassiterite-chlorite with pyrrhotite and sphalerite, an economic assemblage; and zone 4 has carbonate-sphalerite-galena with cinnabar and antimonite. The enclosing rock consists of quartz-altered and chlorite-altered sandstone and shale of Early and Middle Triassic age that is sheared in a sublatitudinal anticlinal fold. The deposit is medium size and has a grade of 0.75 percent Sn, 0.3 to 25 percent Pb, 1 to 25 percent Zn, 0.01 to 0.17 percent Cd, and 11 to -600 ppm Ag. More than 10,000 tonnes of metal has been produced. The deposit is prospected to a depth of 475 meters, and it is developed to 400 meters depth.

Lubavinskoye Granitoid-Related Au-Vein Deposit

This deposit (Kitaev, 1977; Shubin, 1984) consists of saddle-shaped gold-quartz veins, mineralized dikes, and local stockworks. The veins are subdivided into extensive veins that extend some hundred meters and dip steeply, and short brecciated veins that extend tens of meters and dip gently. The former occur in shears often parallel to layering of hosting rock, whereas the latter occurs in fractures. The thickness of both types of veings ranges from a few centimeters to 1 to 5.2 meters in swells. The deposit is hosted in weakly metamorphosed sandstone and shale that is intruded by intermediate and siliceous granitoids dikes and stocks. The highest concentration of veins occurs adjacent to small granitoid stock. Gold occurs in veins in columns. The veins consist of quartz with minor (0.5 to 4.0 percent) sulphides with lesser ankerite, siderite, and barite. The primary ore minerals are gold, arsenopyrite, and pyrite with lesser galenite, sphalerite, chalcopyrite, grey ore, Pb and Sb sulfosalts, pyrrhotite, Pb, Bi, and Bi meneginite and sulfoantimonite, and local scheelite, cassiterite, molybdenite, and cinnabar. Gold occurs as free gold in quartz (70 percent), in intergrowths with sulfides, and dispersed. The ore minerals occur in breccia, layeres, and disseminations. Main alterations are beresite and silica. The deposit is located along the Mongolo-Okhotsk suture. The deposit is medium size and grades to several hundred ppm Au.

Ara-Ilinskoe Porphyry Au Deposit

This deposit (Fogelman, 1964; Shubin, 1984) consists veinlets and stockwork that are hosted in a cryptovolcanic diatreme that contains extrusive units (trachyliparites), subvolcanic bodies (dikes of quartz porphyries, diorite porphyry, and diorite stock), and explosive units (breccia with clasts of fragmented granite). All units in diatreme are altered to beresite. Gold occurs in cement of breccias as phenocrysts and in veinlets along with quartz, carbonate, and minor sulfides (3 percent). The sulfides are arsenopyrite and pyrite with lesser chalcopyrite, sphalerite, galenite, and tetrahedrite. The granite contains tourmaline. Gold is distributed irregularly; 80 percent occurs as native gold, and 20 percent occurs in sulfides. Fineness of gold is 784 to 880. The deposit occurs along the Mongolo-Okhotsk suture. The deposit is small.

Tarbaldzheiskoe Cassiterite-Sulfide-Silicate Vein and Stockwork Deposit

This deposit (Radkevich, 1947; Ontoev, 1960) consists of three stockworks and a series of veins. The largest stockwork is 350 to -400 meters wide and 400 to 800 meters long. The stockworks consists of thin subparallel veinlets with quartz, cassiterite, and arsenopyrite, and rare fluorite, topaz, muscovite, pyrite, wolframite, beryl; and bodies of explosive breccias with quartz, orthoclase, and fluorite, rare wolframite. The deposit is interpreted as being a complicated cassiterite-sulfide body that is overprinted by Sn greisen. The veins have dimensions of 50 by 600 by 0.1 to 0.5 meters, and contain assemblages of feldspar-fluorite-quartz (quartz, orthoclase, fluorite, galenite, sphalerite, arsenopyrite, and cassiterite), polymetallic (quartz, chlorite, galenite, sphalerite, chalcopyrite, cassiterite, stannine, pyrite, pyrrhotite, and arsenopyrite), and quartz (quartz, fluorite, galenite, sphalerite, native gold) composition. The veins occur in the superdomal part of a hidden Mesozoic granitoid stock that occurs along a regional fault. The host rocks are metamorphosed Middle Permian through Early Tertiary sandstone and shale on the southern side of the fault, and by Silurian through Early Devonian sedimentary rocks on the southern side that are altered to greisen, K-feldspar, silica, and sulfides. Middle Triassic through Late Jurassic quartz porphyry, lamprophyre, and porphyry dikes are widespread. The deposit contains anomalous Pb, Zn, As, Ag, W, Cu, Bi, Au, Be, Li, and CaF_2. The deposit is medium size and has an average grade of 0.75 percent Sn, 0.5 to 16 percent Pb, 1.6 to -24 percent Zn, and 0.05 to 0.3 percent WO_3.

Origin and Tectonic Controls for Onon-Turinskiy Metallogenic Belt

The belt is interpreted as being related to magmatism that formed alng transpression zones related to transform microplate

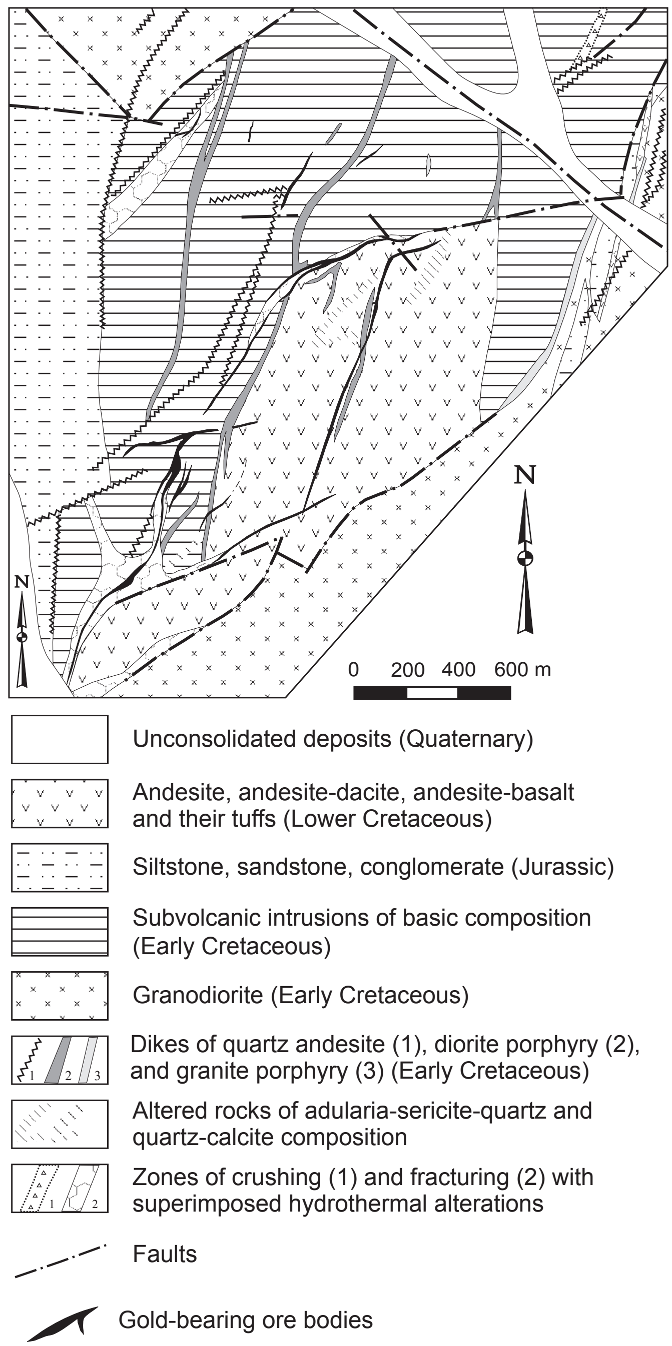


Figure 15. Generalized geologic map of Burindinskoe Au-Ag epithermal-vein deposit, North Stanovoy metallogenic belt, Russian Southeast. Adapted from N.G. Korobushkin, written commun. (1984), and V.A. Taranenko, written commun., 1991.

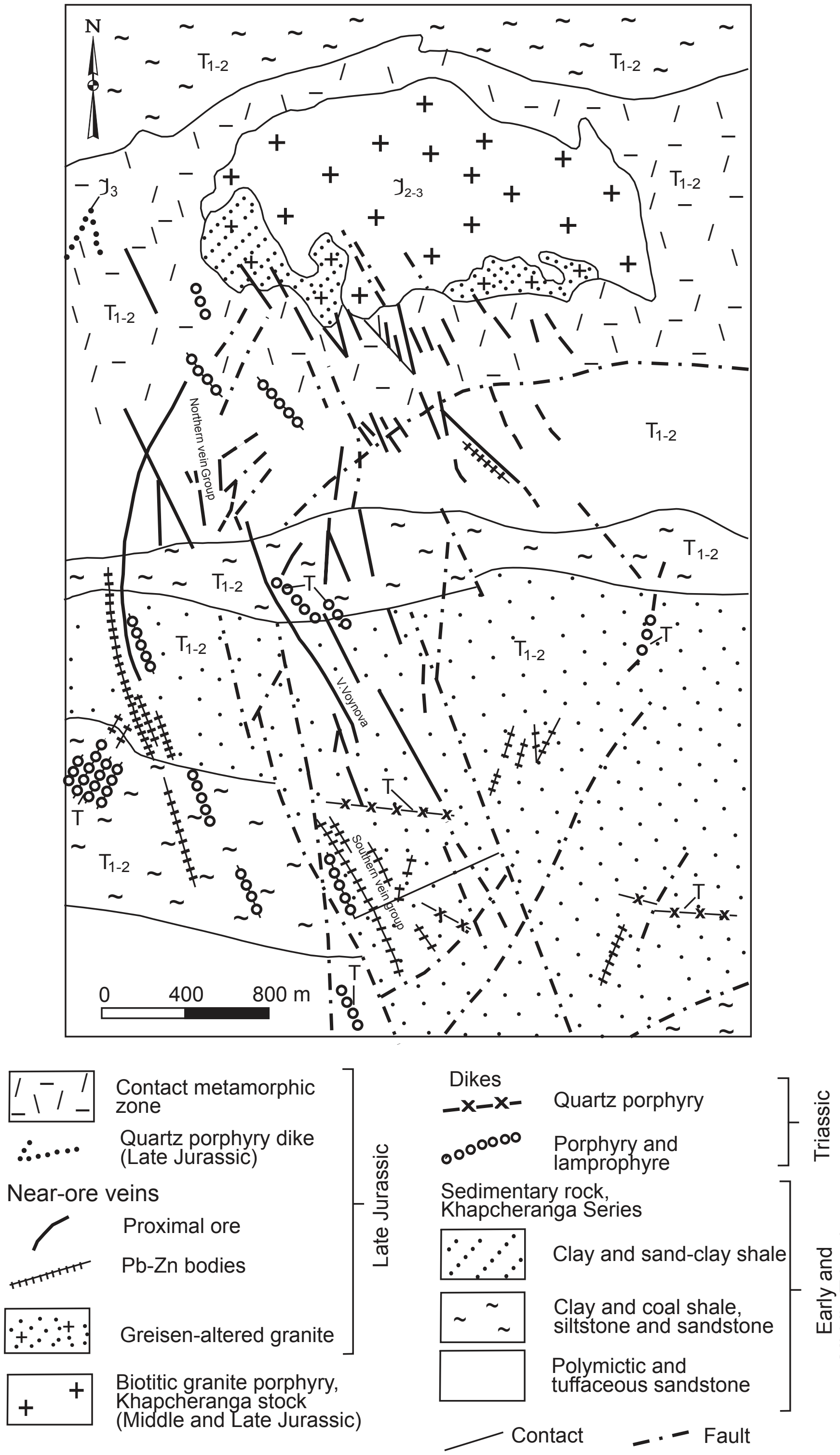


Figure 16. Generalized geologic map of Khapcheranga cassiterite-sulfide-silicate vein and stockwork deposit, Onon-Turinskiy metallogenic belt, Transbaikal, Russia. Adapted from Ontoev (1974).

boundaries and within plate (plume) environment. The belt and related host rock occurs along the submeridional Onon-Tura fault that strikes east-northeast, and companion northwest-striking faults. These major structures are associated with the tectonic origin of the intricate Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt.

Poloush Metallogenic Belt of Cassiterite-Sulfide-Silicate Vein and Stockwork, and Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposits (Belt PO) (Russia, Verkhoyansk-Kolyma Orogenic Region)

This Neocomian through Aptian (130 to 120 Ma) metallogenic belt is related to granitoids in the Northern granite belt. The metallogenic belt extends sublatitudinally for 200 km along the western margin of the Northern granite belt, is as much as 70 km wide, and crosses the northern block of the Omulevka terrane and the Polousnyy synclinorium. The Northern granite belt has $^{40}Ar/^{39}Ar$ ages of 130 to 120 Ma. In the western part of belt are the Marya-Khaya, Mamyandzhu, and Talannakh occurrences, and in the eastern part are the Egekit deposit and other occurrences. The major deposits are at Mamyandzhu, Marya-Khaya, Talannakh, and Egekit.

The main references on the geology and metallogenesis of the belt are Trunilina (1992) and Nokleberg and others (2003).

Ulakhan-Sala Cassiterite-Sulfide-Silicate Vein and Stockwork Deposit

This deposit (V. Arsky and others, written commun., 1963) consists of four quartz-tourmaline and tourmaline-chlorite-quartz veins that range from 320 to 1400 meters long and 0.2 to 3.6 meters wide. Major minerals are cassiterite, pyrrhotite, arsenopyrite, sphalerite, chalcopyrite, galena, wolframite, scheelite, and calcite. Veins are brecciated. Sn decreases with depth. The wallrocks are altered to silica and sulfides. Veins hosted in Late Jurassic sandstone and shale display minor contact metamorphism. Host rocks form monocline that strikes from north to east. The deposit is small and has an average grade of 0.84 percent Sn.

Aragochan Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (V. Shpikerman in Nokleberg and others, 1997) consists of seven sheet-like veins. Veins range from 120 to 700 meters long and 0.4 to 1.13 meters thick. Major minerals are quartz, calcite, siderite, galena, sphalerite, pyrite, and rare cassiterite. Veins hosted in Upper Jurassic sandstone and shale that dip 60 to 65° N. The deposit is small and has an average grade of 5.28 percent Pb and 3.6 percent Zn.

Origin and Tectonic Controls for Polousnyy Metallogenic Belt

The belt is interpreted as having formed during collision of the Kolyma-Omolon superterrane and the North Asian craton and associated regional metamorphism and generation of anatectic granitoids.

Samarka Metallogenic Belt of Porphyry Cu-Mo (±Au, Ag), Porphyry Mo (±W, Sn, Bi), and W±Mo±±Be Skarn Deposits (Belt SM) (Russia, Far East)

This Early to mid-Cretaceous metallogenic belt is related to replacements and S-type granitoids in the Khungari-Tatibi granitic belt that intrudes Samarka subduction-zone terrane. The belt occurs in Early to mid-Cretaceous aluminous, mainly S-type granitoids that intrude the Samarka terrane. The host granitic rocks are mainly granodiorite porphyry, granite, gabbro, and diorite. The olistostrome that host the Samarka belt consists of limestone caps of guyots that are enclosed in a matrix of highly deformed Jurassic sedimentary rock. The skarns are hosted in limestone along contacts between calcareous and alumosilicate clastic rock. The belt contains a major W±Mo±Be skarn deposit at Vostok-2, and small porphyry Cu-Mo (±Au, Ag) deposits at Khvoshchovoe, Kafen, and Malakhitovoe. The major deposits are at Malakhitovoe, Vostok-2, and Lermontovsky.

The main references on the geology and metallogenesis of the belt are Stepanov (1977), Gvozdev (1984), Rostovsky and others (1987), A.I. Khanchuk, written commun. (1997), and Nokleberg and others (1997, 2003).

Malakhitovoe Porphyry Cu-Mo (±Au, Ag) Deposit

This deposit (Petrachenko and others, 1988) occurs in a circular aureole of hydrothermally altered rock with dimensions of 200 by 200 meters. The aureole occurs over an intrusive dome. Successive mineral assemblages are (1) quartz-biotite-actinolite with pyroxene and epidote; (2) quartz-biotite-actinolite; (3) quartz-biotite-sericite (± chlorite); and (4) quartz-hydromica with carbonate. A stockwork contains the first three facies and consists of a thick network of quartz-epidote-actinolite veinlets and lenses that are as much as 2 to 3 cm thick and contain chalcopyrite, bornite, and pyrite. Heavily fractured and brecciated chert and siltstone in breccia zones were prospected by rare holes to a depth of 100 meters. Ore minerals in breccia zones are chalcopyrite, bornite, molybdenite, and pyrite, rarely pyrrhotite, cubanite, arsenopyrite, galena, and sphalerite. Carbonate veinlets with chalcopyrite also occur. The deposit occurs at the northwest margin of a volcanic-tectonic depression that contains a lower structural stage of Early Cretaceous sandstone, interlayered with siltstone and shale, that grades upwards into conglomerate and sandstone overlain by Paleogene andesite and basaltic andesite lava and lava breccia. Local intrusive rocks consist of dikes of calc-alkaline andesite porphyry that is interpreted as tongues of a dome-like subvolcanic intrusion. The deposit is small and has an average grade of 0.1 to 1.6 percent Cu in stockwork, and as much as 0.5 percent Cu in the breccia zone.

Vostok-2 W±Mo±Be Skarn Deposit

This major deposit (fig. 17) (Stepanov, 1977; Rostovsky and others, 1987) consists of skarn in veins and sheets that formed in several stages. From older to younger the stages are (1) skarn composed mainly of pyroxene, plagioclase, amphibole, and garnet; (2) greisen alteration of skarn and granitoid with formation of quartz, feldspar, and muscovite, along with lesser chlorite and biotite with scheelite and apatite, and minor arsenopyrite, pyrrhotite, and chalcopyrite; (3) scheelite and quartz; and (4) low temperature scheelite and arsenopyrite. The deposit occurs along flat to steeply-dipping contacts of granitoid plutons that intrude an olistostrome consisting of Carboniferous and Permian limestone and calcareous-shale. Successive skarn and greisen alteration of limestone preceded deposition of scheelite, gold, and apatite that are as much as a few tens of percent. A plagiogranite with an approximate K-Ar isotopic age of 110 Ma is interpreted as coeval with the deposit. The deposit is large and has an average grade of 0.65 percent W_2O_3 and 1.64 percent Cu; it has been mined since the 1980s.

Lermontovsky W±Mo±Be Skarn Deposit

This deposit (Gvozdev, 1984) consists of skarn in lenses, sheets, and nests that occur at the top contact of an Early Cretaceous granitic stock that intrudes bedded limestone. Skarn ranges from 40 to 640 meters long and 1 to 78 meters thick. The deposit formed in three stages (1) skarn (diopside, hedenbergite, hornblende, wollastonite, and garnet) replacement of limestone and of biotite hornfels derived from sandstone; (2) hydrothermal alteration of granitoid, hornfels, and skarn to greisen; and (3) deposition of sulfide minerals. Two types of greisen occur (1) quartz-albite-muscovite; and (2) scheelite-muscovite-apatite-mica-quartz. Pyrrhotite is the major sulfide, and arsenopyrite, pyrite, marcasite, and scheelite are minor. Sulfide minerals are either superimposed on scheelite greisen, or occur separately in veins. The deposit also contains Ag-telluride-bismuth (polymetallic) and Au-telluride-bismuth (pyrrhotite) zones. W occurs in all parts of the deposit, although the most abundant scheelite occurs in muscovite and lesser biotite, and in phlogopite greisen, quartz veins, and a metasomatic feldspathic rock. The host Early Cretaceous granitoid is highly aluminous, contains low alkalies and Ca, and contains elevated F and P. The deposit is large and has an average grade of 0.67 to 3 percent W_2O_3.

Origin and Tectonic Controls for Samarka Metallogenic Belt

The belt is interpreted as having formed during generation of S-type grantitoid plutons during underthrusting of the Kula oceanic ridge and formation of igneous rocks along a transform continental margin. K-Ar isotopic ages for host granitoids range from 110 to 115 Ma.

Shilkinsko-Tukuringrskiy Metallogenic Belt of Granitoid-Related Au Vein, Porphyry Au, Au Skarn, Au-Ag Epithermal-Vein, Porphyry Mo (±W, Bi), W-Mo-Be Greisen, Stockwork, and Quartz Vein, Cassiterite-Sulfide-Silicate Vein and Stockwork, Ta-Nb-REE Alkaline Metasomatite, Polymetallic (Pb, Zn ± Cu, Ba, Ag, Au) Metasomatic Carbonate-Hosted, Au-Ag Epithermal-Vein, and Fluorspar-Vein Deposits (Belt ST) (Russia, Eastern Transbaikalia)

This Middle Jurassic through Early Cretaceous metallogenic belt is related to granitoids, volcanic rocks, and replacements related to the Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt that intrudes and overlaps the West Stanovoy, Ononsky, and Argunsky terranes and adjacent units. The belt occurs in Eastern Transbaikalia along the Onon River, the Borschovochny Range, and the Shilka River. The belt extends for 1,000 km and varies from 50 to 125 km wide. The belt contains numerous major deposits at Ukonikskoye, Itakinskoye, Aleksandrovskoye, Kluchevskoye, Kariyskoye, Aprelkovskoye, Baleiskoye, Sredne-Golgotaiskoye, Fatimovskoye, Shunduinskoye, Delmachik, Andryushkinskoye, Taseyevskoye, Davendinskoye, Zhirekenskoye, Belukhinskoye, Bukukinskoye,Sherlovogorskoye; Etykinskoye, Yekaterininskoye, Kalanguyskoye, Tamenskoye, Zhetkovskoye, Kirovskoe, and Berezitovoe.

The Au, Mo, W, Sn, Pb, Ta, Nb, and F deposits are related to Middle and Late Jurassic and Early Cretaceous granitoids that occur along the Mongol-Okhotsk suture. The Au, Mo, and polymetallic deposits are related to Middle and Late Jurassic and Early Cretaceous granitoids. The Jurassic granitoids are mainly granite and granodiorite with rare granosyenite and diorite. Also occurring are granite, granodiorite, and diorite porphyry subvolcanic bodies. Associated extrusive rocks are rhyolite, dacite, latite, andesite, shoshonite, and basalt. The deposits and occurrences are commonly located in domes, dome rings, and basins and are spatially and temporally related to minor stocks, sills, and dikes of granodiorite, granite, diorite, and felsite porphyry. Vein deposits are concentrated around stocks and dikes, inside stocks, and in explosive breccias. Stocks are surrounded by zoned, decreasing temperature mineral assemblages.

Granitoid-related Au-vein deposits are dominant in the belt and consist of low-sulfide (Fatimovskoye, Shunduinskoye), medium-sulfide (Kluchevskoye, Sredne-Golgotaiskoye, Kirovskoe, Berezitovoe) and high-sulfide (Uonikskoye, Itakinskoye, Aleksandrovskoye, Karyiskoye, Aprelkovskoye) deposits. The center of the Au deposits is the intersection of the Onon fault with the main Mongol-Okhotsk suture. This area also contains low- and medium-sulfide (Sredne-Golgotaysky), Au skarn (Andryushkinskoye), porphyry Au (Delmachik), and Au-Ag epithermal-vein (Baley and Taseevsky) deposits that formed in Early Cretaceous rifting in the Baley graben. The characteristics of Au deposits evolve along the suture from the center to the northeast. Along this direction, the granitoid-related Au-vein deposits exhibit an increase of sulfides (pyrite, arsenopyrite, chalcopyrite, galena, and sphalerite), occurrence of sulfide deposits, and intense occurrence of tourmaline (Kluchevskoye) and Sb deposits (Itakinsky) to the extreme northeast. This part of belt also includes large porphyry Mo (±W, Sn, Bi) deposits (Davendinsky, Zhirekensky) and rare polymetallic (Pb, Zn±Cu, Ba, Ag, Au) metasomatic carbonate-hosted deposits (Yekaterininsky).

The belt also contains various Sn-W greisen, stockwork, and quartz vein (Belukhinsky, Bukukinsky) deposits, cassiterite-sulfide-silicate vein and stockwork deposits (Sherlovogorsky, Bolshaya Sopka, Tourmaline Otrog, Vostochny), Ta-Nb-REE alkaline metasomatite deposits (Etykinsky), and fluorine vein (Kalanguysky, Tamensky, Zhetkovsky) deposits. These deposits occur along the southwestern flank of the belt in the Onon fault that cuts the Aginsky terrane. The deposits are related to Middle and Late Jurassic granite porphyry stocks, Late Jurassic leucocratic and amazonite granite plutons, and Early Cretaceous diorite, granodiorite, and granite porphyry dikes. This area contains greisen with silica and tourmaline alteration. The belt is promising for undiscovered Au, Mo, W, Sn, Ta, Ni, and fluorite deposits.

The main references on the geology and metallogenesis of the belt are Tauson and others (1987), Zorina (1993), Spiridonov and Gnilusha (1995), Zorin and others (1998), and Zorin (1999).

Baleyskoe Au-Ag Epithermal-Vein Deposit

This deposit (fig. 18) (Petrovskaya and others, 1961; Yurgenson and Grabeklis, 1995) consists of quartz veins and zones of small veinlet and stockwork mineralization. Ore bodies are located in concentric gently-lying zones and in steeply-dipping, ruptured fractures. The former represent lenticular short and thin quartz veins, and the latter have complicated morphology. In the northern part of the deposit variably-oriented veins in granitoids form a stockwork (about 1 km^2). In places, ore pillars occur. Mineralization is penetrated by boreholes to 0.8 to 1 km depth. Ore is composed of adular, chalcedony, quartz, kaolinite, carbonate, pyrite, chalcopyrite, arsenopyrite, markasite. In places there

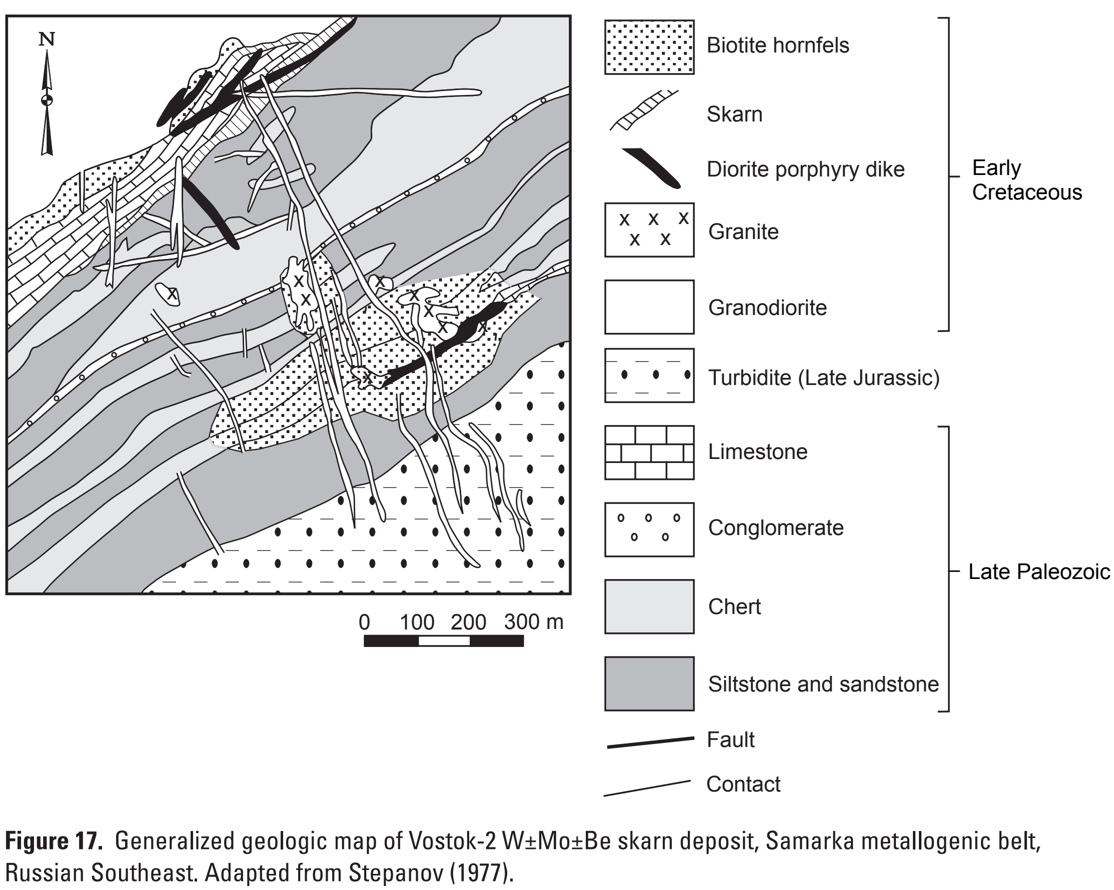


Figure 17. Generalized geologic map of Vostok-2 W±Mo±Be skarn deposit, Samarka metallogenic belt, Russian Southeast. Adapted from Stepanov (1977).

are gold-enriched stibial sulphosalts Cu, Pb, Ag, the most predominant are pyrargyrite and grey ore. Sulfides comprise 0.5 to 1.5 percent. The fineness of gold is 680 to 780, and gold contains finely dispersed silver (grading to electrum). The enclosing rocks are granodiorites, volcanics of dacite-andesite composition, conglomerate, sandstone, and aleurolite. Near-ore alterations include propilitization, beretization, and argillitization. The deposit formed during Early Cretaceous rifting and occurs in the Baley graben along the Mongol-Okhotsky suture.

Berezitovoe Polymetallic Pb-Zn±Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (A.K. Ivashchenko and A.A. Kuzin, written commun., 1982; Vakh, 1989) consists of massive Pb-Zn sulfides that occur in a lenticular, northwest-striking, steeply-dipping (75 to 85°) zone that is as much as 1,000 meters long and 100 to 160 meters thick. The deposit hosted in Early Proterozoic gneissic granite. The sulfides are metamorphosed and galena-sphalerite aggregates contain younger andradite and gahnite (zinc spinel). Host muscovite-quartz-potassium feldspar rock also contains metamorphic garnet. Adjacent Mesozoic igneous rocks are not metamorphosed, indicating preMesozoic mineralization. The deposit occurs in narrow, northeast-trending fracture zones. Gold mineralization is later than polymetallic-sulfide mineralization. Thin Au-bearing zones, associated with quartz-sericite altered rock, occur beyond the polymetallic-sulfide deposit in gneissic granite. The deposit is medium size and contains an estimated 42.3 tonnes Au, 201.0 tonnes Ag, 131.0 thousand tonnes Zn, and 80 thousand tonnes Pb. The average grade is 3.3 g/t Au, 14.3 g/t Ag, 0.93 percent Zn , 0.57 percent Pb. The deposit contains an estimated 42.3 tonnes Au, 201.0 tonnes Ag, 131,000 tonnes Zn, and 80,000 tonnes Pb.

Kalanguyskoye Fluorspar-Vein Deposit

This deposit (Kormilitsyn, 1973; Ivanov, 1974) consists of a series of fluorspar veins and zones of crushing with three commercial deposits. 80 percent resources occur in one vein with dimensions of 1300 by 0.7 to 3.6 by 600 meters. The vein contains three ore pillars with swells about 15 to 20 meters thick. The major ore minerals are fluorite, quartz, and pyrite (2 to 10 percent). Minor ore minerals are kaolinite, gearksutite, and marcasite, and rare ore minerals are galena, molybdenite, arsenopyrite, calcite, galluasite, and sphalerite. At depth sulfides increase to 15 to 25 percent and fluorite decreases from 80 to 45 percent. The upper parts of the veins exhibit a symmetric-zonal structure and are brecciated. Yellow-honey fluorite is most common, with lesser porcelaneous fluorite and violet and green fluorite. The deposit contains kidney-shaped, concretionary and boulder types of ores and is interpreted as an epithermal sulfide-quartz-fluorite deposit type. The vein occurs in a large, steeply-dipping fault zone with submeridional strike and is hosted in Late Jurassic sandstone and shale. The adjacent host rocks are altered to kaolinite or silica to a depth of 10 to 20 meters. The deposit is large and has resources of 6.3 million tonnes fluorspar grading 60 percent CaF_2.

Ukonikskoe Granitoid-Related Au-Vein Deposit

This deposit (Fedchuk and Lukin, 1995) consists of two zones that range from 300 to 1.5 km long and contain quartz-carbonate-sulfide veins, lenses, and streaks, and disseminations. The zones vary from 0.15 to 4.5 meters thick, extend 300 to 400 meters downdip, and from 40 to 220 meters along strike, with an average of 80 to 100 meters. The zones occur in gneiss and schist that altered into quartz-sericite metasomatite and beresite near the bodies. Grades range from 10 to 40 percent sulfides with an average of about 30 percent. The main ore minerals are quartz, carbonates, pyrite, arsenopyrite, galena, sphalerite, and native gold. Secondary minerals are chalcopyrite, bismuth, bismuthin, and silver. Two varieties of gold occur (1) finely dispersed gold in pyrite and arsenopyrite of quartz-pyrite and pyrite-arsenopyrite-quartz bodies; and (2) native (free) gold in polymetallic sulfides. Gold particles range from 0.5 to 200 mm, and the fraction of coarse gold is as much as 5 percent. Formation of the deposit is linked with numerous (about 45 per 1 km^2) dikes of mafic, intermediate, and siliceous porphyry granitoids. The deposit is medium size and has a range of 1 to 170 ppm Au.

Zhirekenskoye Porphyry Mo (±W, Sn, Bi) Deposit

This deposit (Pokalov, 1978; Sotnikov and others, 1995) consists of an isometric stockwork (with surface dimensions of 1,200 by 100 meters) with a central pipe-like body (120 by 60 meters) of explosive breccia that extends to a depth of 600 meters. Ore minerals occur in disseminations, veinlets, and breccia, and occur in a quartz-K-feldsparr-molybdenite assemblage with varying amounts of chalcopyrite, rare molybdenite, scheelite, magnetite, arsenopyrite, fluorite, and tourmaline. Also occurring are younger, thin veinlets of quartz, pyrite, sphalerite, galena, chalcopyrite, pyrrhotite, grey ore, bornite, and chalcocite with molybdenite, pyrite and charlcopyrite comprising about 90 to 95 percent and occurring in equal amounts. The deposit also contains as much as 5 to 20 ppm Te, 20 to 900 ppm Se, 10 to 80 ppm Re, and 380 ppb PGE. The upper part of the deposit contains as much as 0.008 to 0.4 percent WO_3. The deposit occurs adjacent to a zone of intersecting shears and late Mesozoic granite-porphyry dikes that occur along the margin of a Middle and Late Jurassic granite porphyry stock with a surface area of 8 km^2. The host rocks are intensely altered to K-feldspar, argillite, and sericite. The deposit is large and has an annual production of 2.4

million tonnes of ore grading 0.08 percent Mo, and 0.03 to 0.15 percent Cu.

Origin and Tectonic Controls for Shilkinsko-Tukuringrskiy Metallogenic Belt

The belt is interpreted as being related to magmatism along transextension zones along transform microplate boundaries and within plate (plume) environment. The belt occurs in basins with continental sedimentary rocks and alkaline magmatic plutonic and volcanic rocks that occur along the Mongol-Okhotsk suture that separates various terranes and the North Asian and the Sino-Korean cratons.

South Verkhoyansk Metallogenic Belt of Au in Shear-Zone and Quartz-Vein, Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein, Stockwork, Granitoid-Related Au Vein, Cu (±Fe, Au, Ag, Mo) Skarn W-Mo-Be Greisen, Stockwork, and Quartz Vein, and Au-Ag Epithermal-Vein Deposits (Belt SV) (Russia, Verkhoyansk-Kolyma Region)

This Aptian through Late Cretaceous metallogenic belt is related to veins related to Early Cretaceous granitoids in the South Verkhoyansk granite belt (Late Jurassic through mid-Cretaceous) that intrude the Verkhoyansk fold and thrust

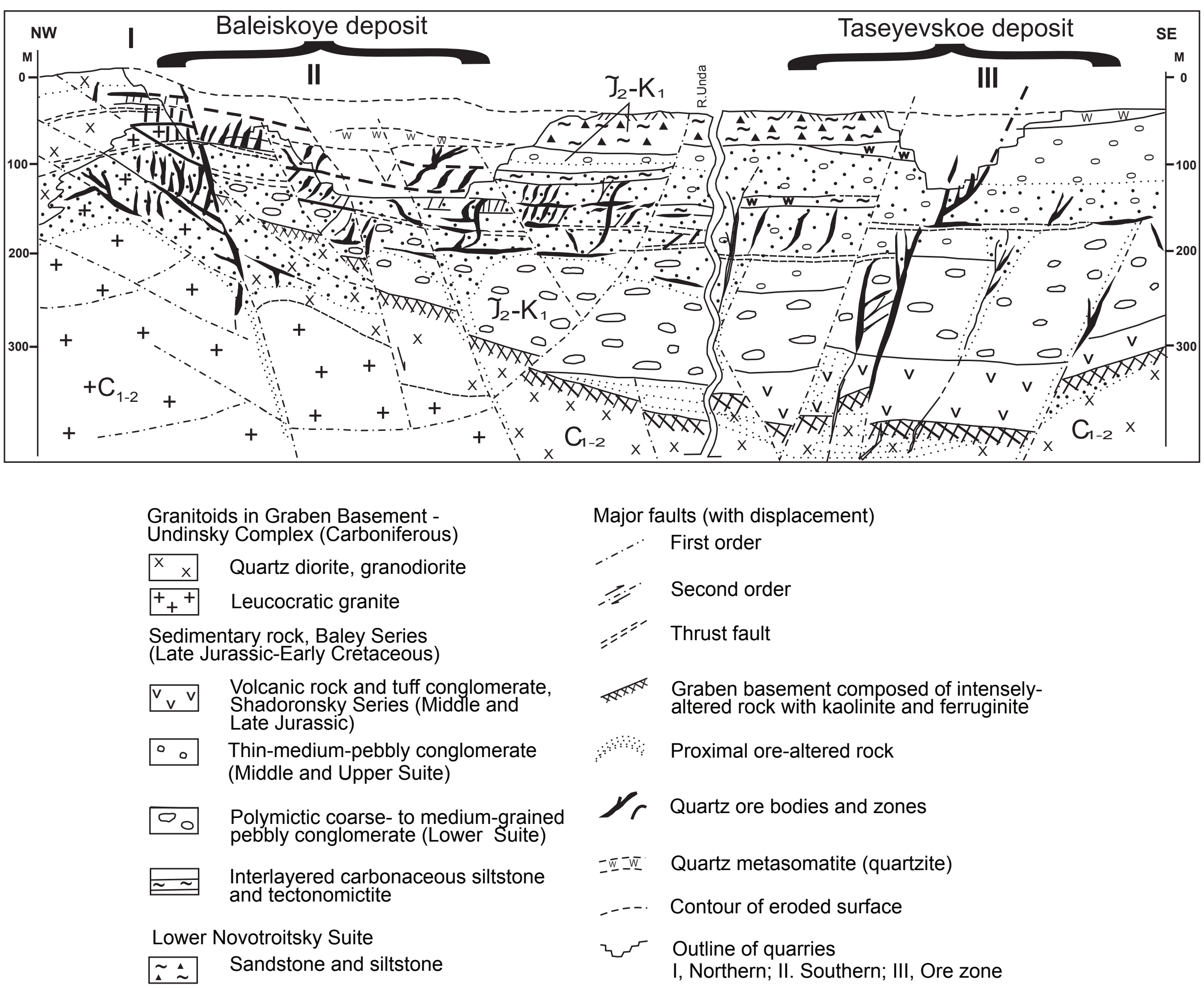


Figure 18. Schematic cross section of Baleyskoe Au-Ag epithermal-vein deposit, Shilkinsko-Tukuringrskiy metallogenic belt, Transbaikal. Adapted from Seminsky and others (2002).

belt in the North Asian cratonal margin. The metallogenic belt occurs in the central part of the South Verkhoyansk synclinorium and is bounded to the west by the Minorsk-Kiderikinsk fault and to the east by the Yudoma fault. The belt extends longitudinally for about 300 km from the Yudoma River in the south to the East Khandyga River in the north. The belt is hosted in Late Carboniferous through Middle Jurassic clastic rock that are deformed into folds that have gentle crests and smoothly undulating hinges. In the northern part of the belt are northeast-striking strike-slip faults (Suntar system) with horizontal displacements of as much as 10 km and vertical displacements ranging as much as 1 km. Related magmatic rocks consist of large polyphase plutons (Tarbagannakh, Uemlyakh, and others), stocks, dikes, and subvolcanic bodies. The belt contains Au in shear zones, quartz veins, and crush zones (Nezhdaninka deposit), Au-REE deposits that occur in and above the apices of granitoid plutons (Levo-Dybinsk district), and polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork deposits (Upper-Menkeche deposit). The major deposits are at Nezhdaninka, Upper-Menkeche, and Levo-Dybinsk.

The main references on the geology and metallogenesis of the belt are Indolev and Nevoisa (1974), Gamyanin and others (1985), Bortnikov and others (1998), and Nokleberg and others (2003).

Nezhdaninka Au in Shear Zone and Quartz-Vein Deposit

This deposit (fig. 19) (Gamyanin and others, 1985; Benevolsky and others, 1992) consists of disseminated gold that occurs in (1) steeply-dipping shear zones as much as 40 meters thick and 5.4 km long; (2) related tension-gash quartz veins that are as much as 200 meters long and 1.2 meters thick; and (3) quartz lenses in shear zones. The vein minerals are quartz, carbonate, arsenopyrite, galena, sphalerite, scheelite, sericite, albite, chalcopyrite, tetrahedrite, Pb and Cu sulfosalts, stibnite, and gold. Wallrocks display silica, sulfide, and sericite alteration. Quartz Ag polymetallic deposits cross-cut and postdate feathered quartz-veins. The deposit occurs along a major fault that cuts the core of a doubly-plunging anticline in Late Carboniferous through Early Permian sandstone and shale. The deposit extends more than 1,000 meters vertically and is explored by boreholes and seven levels of adits. The deposit is large and has proven reserves of 475 tonnes Au, and estimated resources of more than 500 tonnes Au. The average minimum grade is 5 g/t Au, as much as 6,748 g/t Au, and as much as 8,300 g/t Ag.

Upper Menkeche Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (V. Korostelev, written commun., 1963; Indolev and Nevoisa, 1974) consists of abundant Ag polymetallic sulfide lenses and veins that occur in a linear, steeply-dipping northeast-trending fault zone in Late Permian sandstone, siltstone, and shale. The fault zone is about 10 km long and 1 km wide. The sulfide bodies occur mostly parallel to the fault zone, dip steeply, range from hundred of meters to 3.5 km long, and from 1 to 10 meters (average 3 meters) thick. The main ore minerals are galena, sphalerite, pyrrhotite, arsenopyrite, and pyrite. Lesser ore minerals are cassiterite, chalcopyrite, magnetite, owyheeite, tetrahedrite, diaphorite, boulangerite, native silver, and gold. Gangue minerals are quartz, siderite, ankerite, and calcite. Three sulfide assemblages and stages of deposit formation are (1) sphalerite-quartz-siderite; (2) sulphoantimonite-galena; and (3) sulfide-carbonate. Regional metamorphism occurred between stages 2 and 3. The fault zone occurs along the dome of a plunging brachyform anticline. Part of deposit occurs within the contact metamorphic aureole of a Late Cretaceous granitoid intrusion that forms stocks and numerous dikes of granite-porphyry and granodiorite-porphyry. Lamprophyre and diabase dikes are widespread. The deposit is medium size and has an average grade of 2.7 to 11 percent Pb, 3.9 to 7.0 percent Zn, and 138 to 332 g/t Ag.

Origin and Tectonic Controls for South Verkhoyansk Metallogenic Belt

The belt is interpreted as having formed during accretion of the Okhotsk terrane to the North Asian craton and resultant deformation of the southern Verkhoyansk fold and thrust belt. The belt occurs in the Minorsk-Kiderikinsk zone of highly deformed Late Carboniferous and Permian rock in the western South Verkhoyansk synclinorium. Au-quartz veins are relatively older than large granitic plutons that intrude the South Verkhoyansk synclinorium which have ^{40}Ar-^{39}Ar isotopic ages of 123 to 120 Ma.

Taebaegsan Metallogenic Belt of Fe Skarn, Fe-Zn Skarn, Zn-Pb (Ag, Cu, W) Skarn, W±Mo±Be Skarn, Au in Shear-Zone and Quartz-Vein, and REE-Li Pegmatite Deposits (Belt TA) (South Korea)

This Middle Jurassic through Early Cretaceous metallogenic belt is related to the Middle Jurassic through Early Cretaceous granitoids in the Jurassic Daebo granite that consists of biotite granite, two-mica granite, granophyre, and felsic and quartz porphyry. The Daebo granite intrudes the Yeongnam Metamorphic Complex and Great Limestone Group that is part of Sino-Korean craton, Yeongnam granulite-paragneiss terrane. The Yeongnam Metamorphic Complex consists mainly of metasedimentary rocks, quartzite and amphibolite and quartz-injection biotite gneiss, and the Cambrian and Ordovician Great Limestone Group that consists of the Pungchon Limestone, Hwajo Formation, Dongjom Quartzite, and Dumugol and Maggol Limestone. The major deposits are at Dongnam, Kangwon, Seojom, Susuk, Soonkyong, Yomisan (Sinyemi), Sangdong, and Wondong.

The metallogenic belt also contains polymetallic (Pb, Zn, Ag) carbonate-hosted metasomatite at Uirim-Samwon, Au skarn at Chulam, Sn-W greisen, stockwork, and a quartz-vein deposit at Soonkyong. These deposits are also interpreted herein as being related to the Jurassic Daebo granite.

The main references on the geology and metallogenesis of the belt are Seo and others (1983), Moon (1987), and Hwang, 1997).

Dongnam Fe-Zn Skarn Deposit

This deposit (fig. 20) (Seo and others, 1983) consists of contact metasomatic and porphyry Mo or disseminated molybdenum including stockwork-type ore deposits. The host rocks in the deposit are Cambrian slate (Myobong Formation) and Ordovician limestone (Poongchon and Hwajeol Formation), Jurassic(?) granitic rock, and Quaternary alluvium deposits. The diorite and quartz porphyry units includes diorite-tonalite, granite, and monzodiorite-granodiorite, quartz monzonite-granite, K-rich diorite, and potassic granite. The deposit occurs in fissure filling, contact metasomatic, hydrothemal replacement, and supergene enrichment and include iron, galena, sphalerite, manganese, and molybodenum ore deposits. Diorite and quartz porphyry contains anomalous Mo, Zn, Pb, Zr, and Fe. Ore minerals are mainly magnetite, hematite, Mn oxide, Mn carbonate, galena, sphalerite, and molybdenite. Accessory minerals are pyrite, pyrrhotite, arsenopyrite, chalcopyrite, limonite, scheelite, and fluorite. Skarn minerals are mainly garnet, epidote, and chlorite, and minor secondary calcite and quartz. Garnet is associated with magnetite, epidote, chlorite, and molybdenite. The deposit is medium size and has an average grade of 21.47 to 39.46 percent Fe, and 1 to 7 percent Pb+Zn. Reserves are 1,724,732 tonnes of ore.

Kangwon Fe skarn Deposit

This deposit (Kim and Oh, 1968) consists of Fe contact and selective replacement bodies in calcareous beds in Precambrian metasedimentary rock that consists of biotite paragneiss, amphibole schist, limestone, and quartzite in thin beds. Feldspar porphyry and granite porphyry intrude metasedimentary rock. The general strike of eastern body is NS-N 10° E and the dip is 70-80° NW; the western body trends N 40° E with a dip of 25-30° NW. The length and width of the eastern body is 130-80 meters and 10-6 meters, and the western is 100 meters and 8 meters. The average grade of each body is: Eastern body–29.8 to 35.49 percent Fe, 0.56 to 1.93 percent S, and 0.02 to 0.06 percent P; Western body–49.03 percent Fe, 5.61 percent S, and 0.01 percent P. The deposit is small and has an average grade of 38.44 percent Fe and reserves of 581,000 tonnes Fe.

Susuk Fe Skarn Deposit

This deposit (Chi, 1963) consists of magnetite and pyrite or pyrrhotite skarn in Precambrian amphibolite that is altered to serpentine or silica by regional metamorphism and hydrothermal fluids. The amphibolite is interlayered with quartzite and quartz-biotite gneiss. These rocks are intruded by granophyre, and felsite and quartz porphyry of suspected Mesozoic age. The

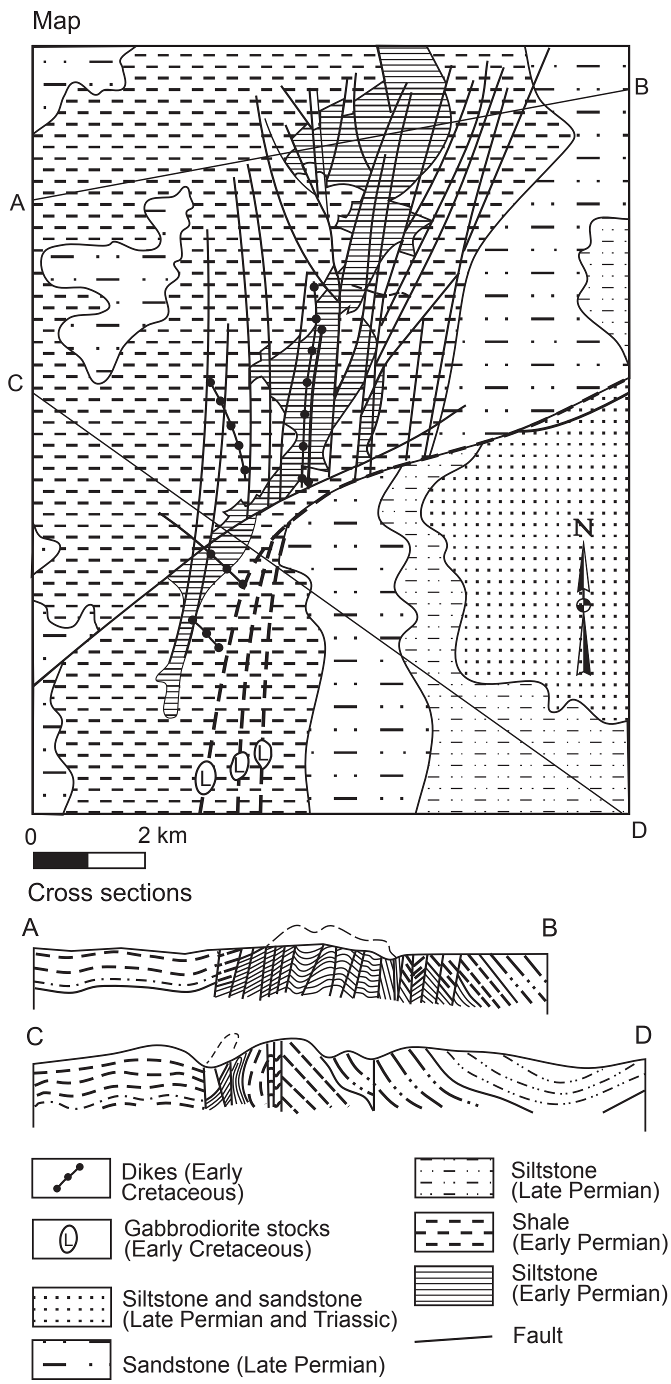


Figure 19. Generalized geologic map and schematic cross section of Nezhdaninka Au in shear zone and quartz-vein deposit, South Verkhoyansk metallogenic belt, Yakutia, Russia. Adapted from Shour (1985).

granophyre is interpreted as the deposit-related igneous body. Limonite occurs on weathered bedrock but is not economic. The deposit contains low-grade zones with 30 to 35 percent Fe and locally as much as 50 percent Fe with higher sulfide content. The deposit is small and has resources of 717,400 tonnes Fe, and reserves of 164,000 tonnes Fe grading 30 to 50 percent Fe.

Yomisan (Sinyemi) Fe-Zn Skarn Deposit

This deposit (Kim and others, 1965) consists of the West body, the East body, and the Magnetite body. The West body is layered, and the East body is a small lens with high grade that occurs along breccia and fault zone. The Magnetite body forms as a contact metasomatic unit in breccia and as massive skarn in limestone. The host rocks are the Maggol Limestone of the Ordovician Choseon System that is unconformably overlain by the Late Carboniferous Hongjeom Formation. Igneous intrusions of suspected Mesozoic age intrude the sedimentary rocks. The average grade of the West ore body is 5.38 percent Zn. Reserves are are as much as about 490,000 tonnes. The Magnetite body has estimated reserves of 100,000 tonnes grading 26.16 percent Fe. The deposit is small and has reserves of 590,000 tonnes of ore and an average grade of 5.38 percent Zn, and 26.16 percent Fe.

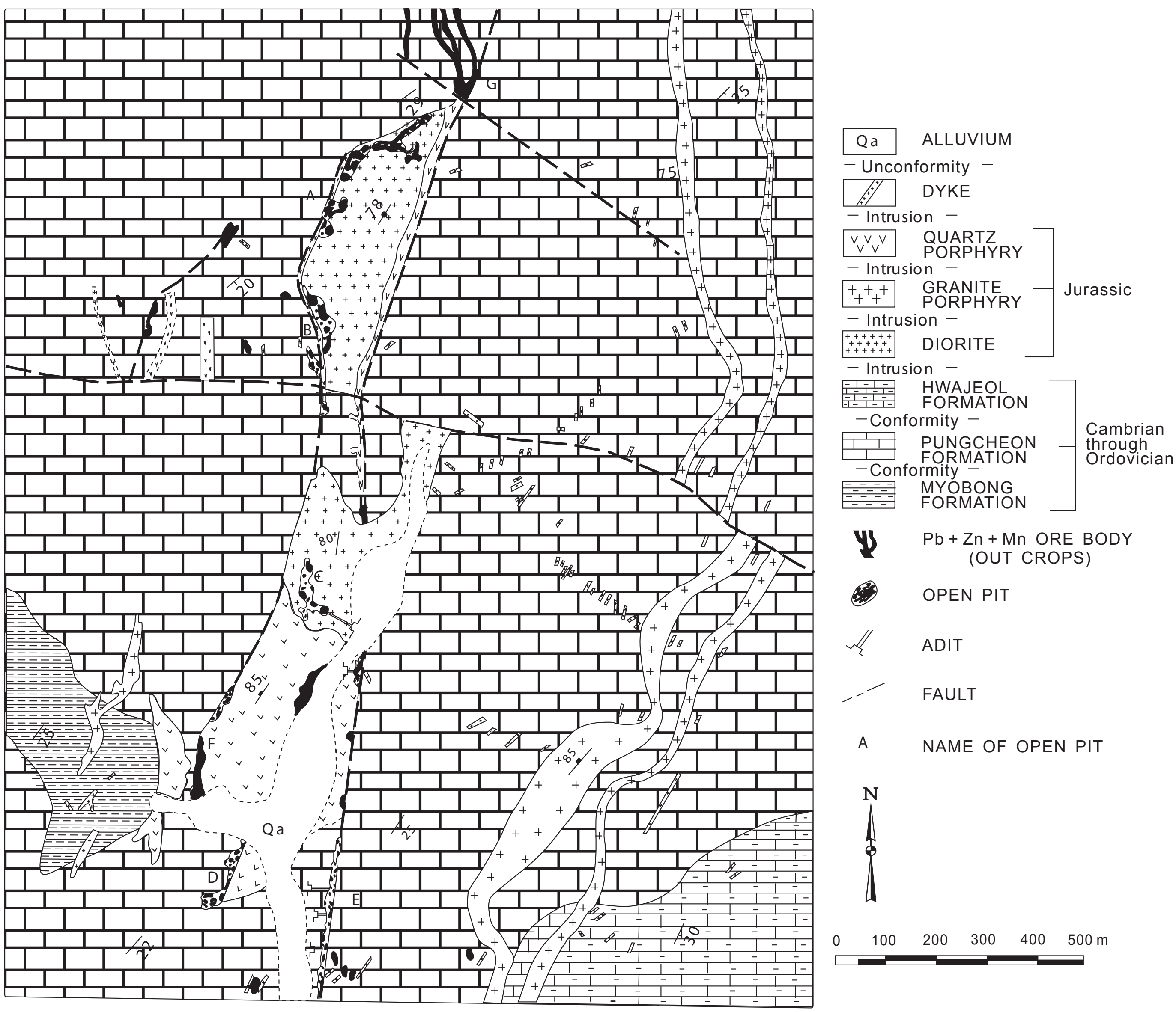


Figure 20. Generalized geologic map of Dongnam Fe-Zn skarn deposit, Taebaegsan metallogenic belt, Korea. Adapted from Seo and others (1983).

Wondong W±Mo±Be Skarn Deposit

This deposit (Hwang, 1997) consists of three types of skarn ore bodies. The skarns occur in Carboniferous-Permian formations and in a lesser Cambrrian and Ordovician formations which are intruded by rhyolite. The Weondong thrust fault occurs in the central part of the mine. A north-soutn-trending fault system cuts an east-west-trending thrust. The Pb+Zn, scheelite and iron (magnetite) ore bodies are present. Twenty-one ore bodies having the cut-off grade of WO_3 of 0.10 percent have been found. The deposit consists of upper and lower ore bodies. The upper Pb-Zn ore body is 1.15 meters thick and has an average grade of 0.56 percent Pb, 3.76 percent Zn, 0.13 percent Cu, 1.03 percent As, 260 ppm Cd, and 25 ppm Ag. The lower ore body is 0.25 meters thick and has an average grade of 0.36 percent Pb, 4.53 percent Zn, 0.42 percent As, 620 ppm Cd, and 60ppm Ag. The Fe-ore body is as much as 3.0 meters thick and has an average grade of 38 percent Fe. Fe mineralization is always associated with scheelite. Scheelite skarn, lead-zinc, magnetite deposits occur in Cambrian limestone formations and have an average grade of 0.48 percent WO_3 and are 2.80 meters thick (for three ore bodies). Stockworks and veinlets of the porphyry Co-Mo deposit occur in rhyolite and have an average grade of 0.51 percent Cu and minor molybdenite. The 15 ore bodies total 23.8 meters thick. The deposit is small and has an average grade of 0.10-0.40 percent WO_3, 0.36 to 0.56 percent Pb, 3.76 to 4.53 percent Zn, and 38 percent Fe.

Sangdong W±Mo±Be Skarn Deposit

This deposit (Moon, 1987) consists of W-Mo minerals that occur in bedded limestone in the Cambrian Myobong Slate Formation. The common skarn minerals are Ca-garnet and clinopyroxene. Abundant quartz veins in the W-Mo skarn indicate that W and Mo were transported in a silicate-rich fluid. A syncline interpreted as being related to emplacement of granitoids includes hidden skarn bodies that may occur along its northern limb. The deposit, which consists of both skarn and quartz veins, is interpreted as having formed over a long period during the Jurassic and Cretaceous. The deposit is large and has an average grade of 77.86 percent WO_3 and 6.49 percent MoS_2.

Seojom Au in Shear Zone and Quartz-Vein Deposit

This deposit (fig. 21) (Hwang and Kim, 1963) consists of veins following a fault zone in the Ochon-dong formation. The Ochon-dong formation consists of sedimentary rock of the lower formation of the Shilla series, Kyongsang system, that is overlain comformably by Shinyangdong formation. These rock formations are intruded by andesite extrusive stocks and younger quartz porphyry. The source of the veins may be the andesite porphyry stocks and quartz porphyry. Several veins are distinctively developed in the mine property. The most promising vein has an average width of 20 cm. The deposit is small and has an average grade of 2.7 g/t Au, 2000 g/t Ag, 18 percent Pb, and 9 percent Zn, resources of 26,150 tonnes, and reserves of 5,150 tonnes.

Origin and Tectonic Controls for Taebaegsan Metallogenic Belt

The belt is interpreted as having formed during intrusion of granitoids associated with Late Jurassic through Early Cretaceous Daebo granite that intruded during the Daebo orogeny. Granite consists of biotite granite, feldspar porphyry, and granite porphyry that intrude Precambrian metasedimentary rocks. The skarn deposits formed during contact metasomatism of calcareous layers in metasedimentary rock.

Tompo Metallogenic Belt of W±Mo±Be Skarn and Sn-W Greisen, Stockwork, and Quartz-Vein Deposits (Belt TO) (Russia, Verkhoyansk-Kolyma Region)

This Neocomian(?) metallogenic belt is related to replacements in the Transverse granite belt that intrudes the southeastern part of the Verkhoyansk fold and thrust belt. The belt is about 30 km long, 20 km wide, and occurs the east of the southern termination of the Verkhoyansk metallogenic belt that occurs along a sublatitudinal zone of high-angle faults, with probable strike-slip components, that crosscut Permian through Middle Jurassic sandstone and shale that occur in sublatitudinal folds. The major granitoid plutons, with surface areas of less than 2 km^2, occur at Sosukchan and Erikag. Associated with the granitoid plutons are granitoid-dike swarms and contact metamorphism. The belt major deposits are the Agylky Cu-W±Mo±Be skarn deposit, the largest in the belt, and the Erikag and Dzhuptagan cassiterite-silicate-sulfate deposits.

The main references on the geology and metallogenesis of the belt are Shour (1985) and Parfenov and others (1999).

Agylky Cu-W±Mo±Be Skarn Deposit

This deposit (Flerov and others, 1974) consists of pyroxene-garnet-scheelite skarn that occurs in layers of metamsomatized limestone in contact metamorphosed Early Triassic argillite and siltstone. Layers are as much as 3 to 5 meters thick. Three successive metasomatic mineral assemblages occur (1) scheelite-quartz; (2) sulfide; and (3) calcite. Most W occurs in scheelite and, rarely, in wolframite. Main sulfide minerals are pyrrhotite and chalcopyrite. Subordinate minerals are pyrite, arsenopyrite, stannite, sphalerite, galena, native bismuth, and bismuthine. Contact metamorphosed argillite does not contain ore minerals. The deposit occurs on limbs of a brachyform anticline in the thermal aureole of an unexposed granitoid intrusion with numerous apophyses of

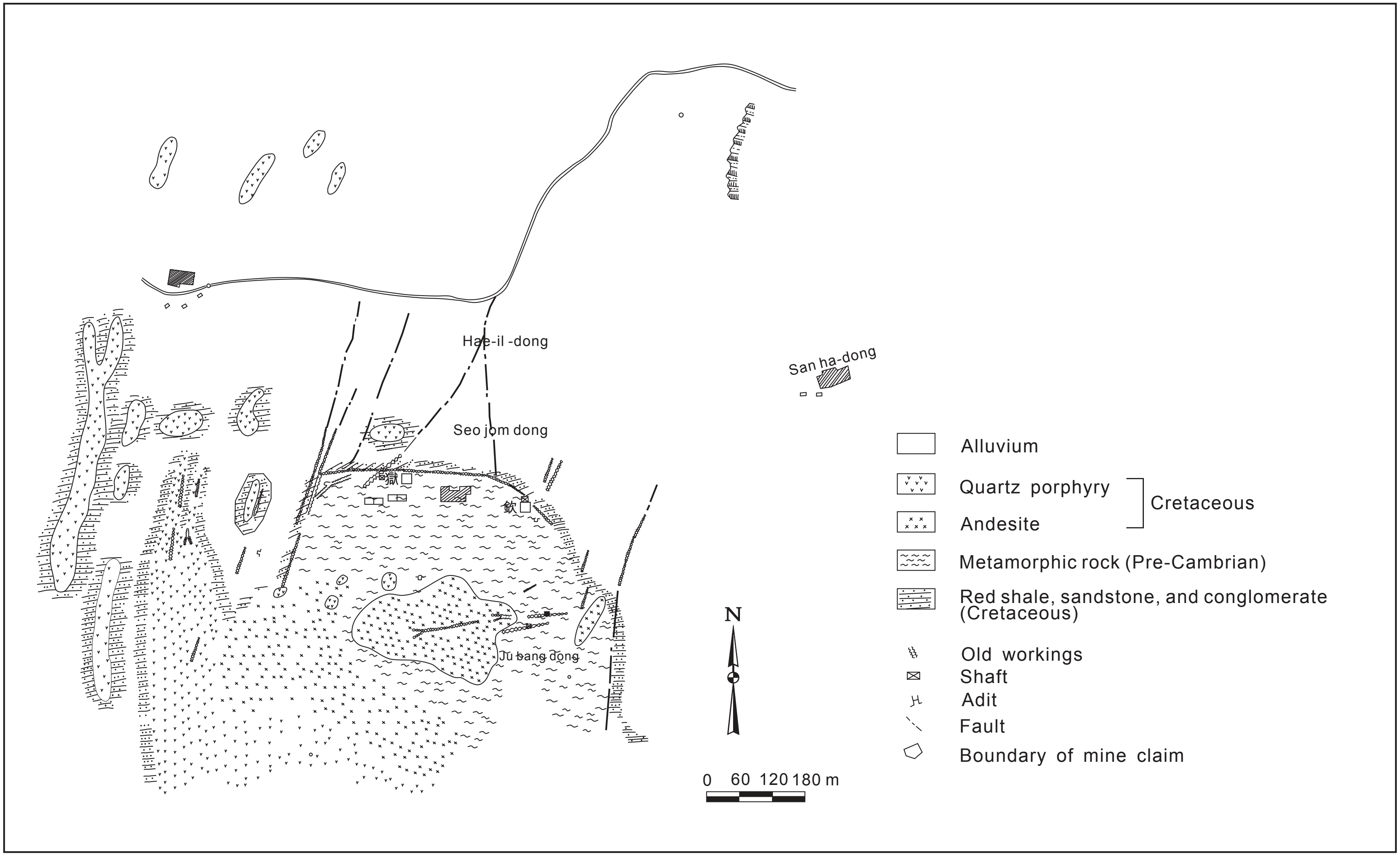


Figure 21. Generalized geologic map of Seojom Au in shear zone and quartz-vein deposit, Taebaegsan metallogenic belt, Korea. Adapted from Hwang and Kim (1963).

granodiorite porphyry dikes. The deposit dips 20 to 35° on anticline limbs. The deposit is medium size.

Erikag Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (Flerov and others, 1974) consists of sulfide-quartz veins and stringers in a zone that occurs parallel to bedding. Veins and stringers extend in an east-west-trending band that dips steeply south. Major minerals are quartz, pyrite, and stannite. Subordinate minerals are arsenopyrite, cassiterite, bismuthine, bismuth, chalcopyrite, and sphalerite, and minor pyrargyrite and tetrahedrite. Wallrocks exhibit intense chlorite, sericite, and tourmaline alteration. The deposit is hosted in steeply-dipping, contact metamorphosed sandstone and shale in the contact aureole of the Erikag granodiorite pluton that has a K-Ar isotopic age of 130 to 125 Ma.

Origin and Tectonic Controls for Tompo Metallogenic Belt

The belt is interpreted as having formed during collision of the Kolyma-Omolon superterrane and the North Asian craton and associated regional metamorphism and generation of anatectic granitoids in the Transverse granite belt. The belt occurs along sublatitudinal high-angle, probable strike-slip faults that cut Permian through Middle Jurassic sandstone and shale.

Verkhne-Ingodinsky Metallogenic Belt of Cassiterite-Sulfide-Silicate Vein and Stockwork Deposits (Belt VI) (Russia, Central Transbaikalia)

This Middle Jurassic through Early Cretaceous metallogenic belt is related to veins, volcanic complexes, and replacements related to Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt that overlies and intrudes the Hangay-Dauria terrane and Selenga sedimentary-volcanic plutonic belt. The belt extends for 175 km, varies from 25 to 50 km wide, and trends northeast. The Late Mesozoic Trans-Baikalian-Daxinganling belt is composed of calc-alkaline and subalkaline volcanic rock of Sokhondinsky and Dzhargalantuy Suites, and calc-alkaline and subalkaline granitoids of the Sokhondinsky, Kyrinsky, Asakan-Shumilovsky, and Kharalginsky. The granite porphyries in these suites host the Sn-W deposits (Ingodinsky and Sokhondinsky deposits). The major deposits are at Ingodinskoye and Levo-Ingodinskoye.

Large cassiterite-sulfide-silicate vein and stockwork deposits occur at Ingodinskoye and Levo-Ingodinskoye. Small deposits occur at Novoye, Sokhondinskoye, Uljurtuoye, Perevalonoye, Ozernoye and, Bukukunskoye. The deposits are controlled by the Ingodinsky fault. The deposits are hosted in brecciated hornfels and siltstone. The deposits consist of (1) a thick network of veins and veinlets filled with cassiterite, arsenopyrite, chalcopyrite, quartz, fluorite, topaz, and muscovite (as at the Ingodinskoye and Levo-Ingodinsoye deposits); (2) pipes of granite porphyry with quartz-cassiterite veins and veinlets; (3) scattered, disseminated pyrite, arsenopyrite, cassiterite, and scheelite; and (4) local areas of a gradation from granite porphyries into veins (Sokhondinskoye deposit). The deposits range from 200 meters to 1 km wide.

The main reference on the geology and metallogenesis of the belt is Semenjuk and Donenko (1964).

Origin and Tectonic Controls for Verkhne-Ingodinsky Metallogenic Belt

The belt is interpreted as being related to magmatism that occurred along transpressional zones related to transform microplate boundaries and within plate (plume) environment. The belt is prospective for undiscovered Sn, W, and As deposits.

Verkhoyansk Metallogenic Belt of Au in Shear Zone and Quartz Vein Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Sn-W Greisen, Stockwork, and Quartz-Vein, and Au in Black Shale Deposits (Belt VK) (Russia, Verkhoyansk-Kolyma orogenic region)

This Late Jurassic through Early Neocomian metallogenic belt is related to veins and replacements in the Verkhoyansk fold and thrust belt (unit NSV). The age of the belt is interpreted as late Late Jurassic and Early Neocomian. The Verkhoyansk belt extends as a narrow (as much as 100 km) band for 1200 km along the western margin of the northern and central sectors of the Verkhoyansk fold and thrust belt. It is made largely of Carboniferous and Permian clastic rocks metamorphosed at greenschist facies. Metamorphism is thought to be related to thrust zones, regional metamorphism or to unexposed granitoid plutons. Initially, the Au deposits were interpreted as being associated with greenschist facies metamorphism. Later, the Au content was found to be low in higher-grade rocks of the biotite subfaces, and that the best Au values were in the muscovite-chlorite subfacies. Metamorphism consists of flow cleavage, recrystallization blastic and thorny structures of the rocks, and by the presence of metamorphogenic quartz, muscovite, and albite. The main deposits of the belt are concordant veins complicated by cross veinlets clustering into stockworks in sandstone beds. The major Au-shear zone deposit is at Djandi.

The main references on the geology and metallogenesis of the belt are Ivensen and others (1975) and Parfenov and others (1999).

Djandi Au in Shear Zone and Quartz-Vein Deposit

This deposit consists of stockworks, veins, and mineralized breccias controlled by sublongitudinal high-angle faults. The stockworks are as much as 900 meters long and 100 meters wide and averaging 20 meters). Concordant and cross-cutting veins are present, and are as much as 80 meters long and 3 meters wide. The veins and stockworks are associated with mineralized breccias. The highest Au values occur in the stockworks is as much as 4.3 g/t. Ag content of the stockworks is as much as 1 g/t. Fineness of Au is 700 to 900 and gold occurs in grains as much as 2 to 3 mm in size. The structure of the deposit area is determined by linear overturned folds and thrusts. Flow cleavage is clearly defined is parallel to thrusts.

The main references on the geology and metallogenesis of the belt are Prokopiev and others (2001) and Fridovsky and Prokopiev (2002).

Kuolanda Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (Ivensen and others, 1975; V. Tseidler, written commun., 1985) consists of a breccia with abundant veins and stringers of massive and disseminated galena and sphalerite that are hosted in Early Carboniferous siltstone and sandstone. The main ore mineral is sphalerite with lesser galena and chalcopyrite. Subordinate minerals are siderite, arsenopyrite, glaucodot, pyrite, melnikovite, pyrrhotite, and native silver. Veins are divided into sulfide and quartz-sulfide types. Some veins are as much as 20 meters long and 0.2 to 0.3 meters thick. Vein zones are as much as as much as 280 meters long and from 1.5 to 10 meters wide. The deposit occurs along the axis of an anticline. The deposit is large and has reserves of 15,000 tonnes Pb and 120,000 tonnes Zn. Average grades are 20 to 30 percent Zn, 2 percent Pb, 1.3 percent Cu, and as much as 953 g/t Ag.

Imtandzha Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (Ivensen and Proschenko, 1961; Indolev and Nevoisa, 1974) occurs in a fissure zone that is as much as 500 meters wide, 2 km long, and occurs along the axis of an anticline. Intruding the sedimentary rock are granodiorite porphyry dikes that are associated with the deposit. The dikes cut polymetallic veins and in turn are cut by Sn-sulfide veins. Early-stage Ag-polymetallic veins are mostly conformable. Later-stage veins are mostly cross-cutting, but are less common. Veins range from 0.01 to 0.85 meters thick. Major ore minerals are galena, sphalerite, and siderite. Lesser vein minerals are quartz, tetrahedrite, pyrite, arsenopyrite, and boulangerite. Later-stage veins contain quartz, chlorite, pyrite, arsenopyrite, galena, cassiterite, tourmaline, and stannite and range from 0.1 to 0.6 meters thick. Stringers range from 2 to 3 meters thick and are as much as 1 km long.

Mangazeika 2 Au in Black Shale Deposit

This deposit (fig. 22) (Indolev and Nevoisa, 1974; Kostin and others, 1997) consists of high-angle veins that have a variable dip and strike, and thin or branch into closely-spaced veinlets. The veins are as much as tens of centimeters to 2 to 2.5 meters thick (in swells) and extend from a few meters to tens of meters to 700 to 1,000 meters long. Stock-like swells in veins are as much as 25 to 30 meters thick. Crush zones and closely spaced vein systems also occur. The deposit is discontinous in an area 3 km across and 19 km long and is hosted in Late Carboniferous and Early Permian clastic rock. The deposit contains native Ag, Sb Ag minerals, animikite, allargentum, acanthite, Pb-acanthite, Cu-acanthite, Ag_2S-Cu_2S sulfide series, galena, sphalerite, chalcopyrite, stannite, pyrite, arsenopyrite, bismuthinite, and stibinite. Also occurring are sulfosalts, including fahl, pyrargyrite, miargyrite, diaphorite, owyheeite, polybasite, stephanite, canfieldite, freieslebenite, geocronite, bournonite, boulangerite, gustavite, and Ag-Bi-sulfotelluride. The deposit is interpreted as having formed during Devonian rifting. Metals are interpreted as having been leached from Devonian basalt by sea water that circulated along faults. The deposit is large.

Nikolaevskoe and Otkrytoe Au in Shear-Zone and 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, that are hosted in Early Permian sandstone beds. The veins occur in anticlinal hinges, are as much as 1 km long, and range from 0.2 to 1 meters thick, and are sometimes as much as 10 meters thick. Sulfides comprise as much as 5 percent of the veins. The Au quartz-vein deposits are not economic, but are the source for the placer Au mines of the Verkhoyansk district.

Origin and Tectonic Controls for Verkhoyansk Metallogenic Belt

The belt is interpreted as having formed during collision of the Kolyma-Omolon superterrane and the North Asian craton and associated regional metamorphism during the Late Jurassic through early Neocomian. The belt is hosted mainly in Carboniferous and Permian clastic rocks that are metamorphosed to greenschist facies. Metamorphism is interpreted as being related to thrust zones, regional metamorphism, and (or) unexposed granitoid plutons

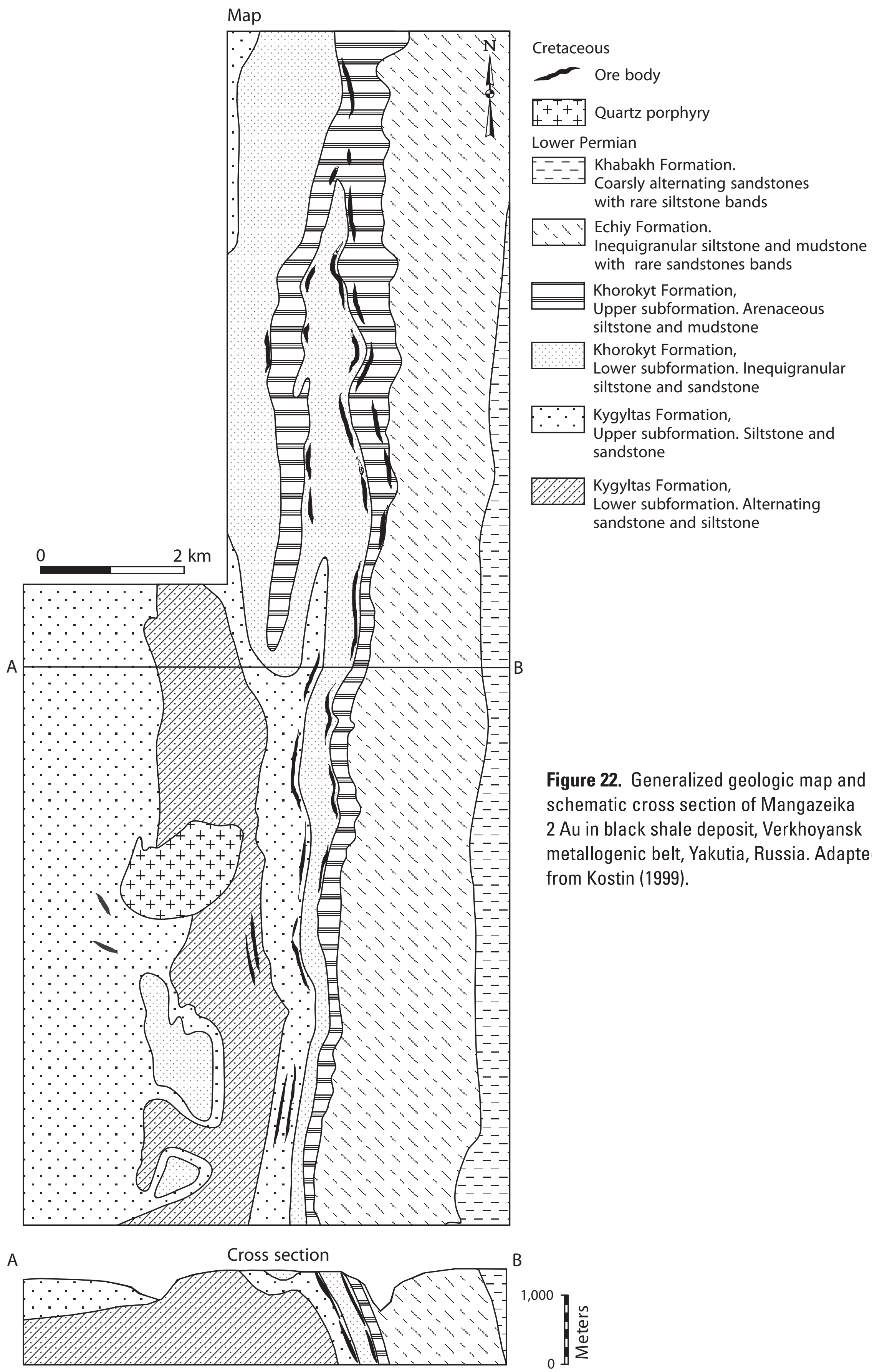


Figure 22. Generalized geologic map and schematic cross section of Mangazeika 2 Au in black shale deposit, Verkhoyansk metallogenic belt, Yakutia, Russia. Adapted from Kostin (1999).

Yana-Adycha Metallogenic Belt of Cassiterite-Sulfide-Silicate Vein and Stockwork and Sn-W Greisen, Stockwork, and Quartz-Vein Deposits (Belt YA) (Russia, Verkhoyansk-Kolyma Region)

This mid-Cretaceous (130 to 123 Ma) metallogenic belt is related to replacements in the Transverse granite belt. The host Transverse granite belt radiates from the southwestern warp of the Kolyma-Omolon superterrane boundary and crosscuts at a high angle older folds and faults of the Verkhoyansk fold and thrust belt. The belt contains the Ege-Khaya, Tirekhtyakh, and Derbeke-Nel'gese districts, each of which is hoted in part of the Transverse granite belt that bears the same name. The districts strike northeast for 150 to 200 km and range from 10 to 30 km wide. Each district contains several tens of Sn deposits and various occurrences. The major deposits are cassiterite-sulfide-silicate vein and stockwork at Ege-Khaya, Ilin-Tas, and Burgochan deposits, and a Sn-W greisen, stockwork, and quartz-vein deposit at Kester.

The main references on the geology and metallogenesis of the belt are Flerov (1974), Shour (1985), Trunilina and others (1985); Parfenov and others (1999), and Nokleberg and others (2003).

Ege-Khaya Cassiterite-Sulfide-Silicate Vein and Stockwork Deposit

This deposit (Flerov, 1974; V. Spomnor and others, written commun., 1985; Shour, 1985) consists of shear zones, stringers, and less common veins that occur in zones that range from 0.7 to 4 meters thick, extend for as much as 1 km long, dip steeply, and extend downdip for about 500 meters. Host rocks are weakly contact metamorphosed Late Triassic shale and interbedded sandstone. Major minerals are quartz, chlorite, cassiterite, sphalerite, pyrrhotite, pyrite, marcasite, siderite, and calcite. Subordinate minerals are arsenopyrite, galena, stannite, chalcopyrite, wolframite, bismuth, tourmaline, and albite. Sulfides are predominant at depth. Wallrocks exhibit chlorite, silica, and sulfide alteration. Average grades are 0.1 to 3 percent Sn and 0.1 to 3 percent Zn. Limited production has occurred. The deposit is medium size.

Kester Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (Flerov, 1974; V. Spomnor and others, written commun., 1985; Shour, 1985) consists of greisen with major minerals of quartz, muscovite, albite, K feldspar, molybdenite, zinnwaldite, tourmaline, topaz, amblygonite, apatite, cassiterite, wolframite, and tantaloniobate, and lesser stannite, arsenopyrite, and Pb sulfosalts. Host granite exhibits intense greisen alteration for occurrence of local tourmaline and sulfides. The deposit is irregularly shaped and occurs along the margin of a stock of subalkalic alaskite granite that intrudes the Arga-Ynnakhai granodiorite pluton. The deposit is 80 by 1,200 meters in plan view and extends to a depth of 60 meters. The deposit is small and is partly mined. Average grades are 0.3 percent Sn, and as much as 0.5 percent Nb_2O_5, and 0.35 percent Li_20.

Origin and Tectonic Controls for Yana-Adycha Metallogenic Belt

The belt is interpreted as having formed during collision of the Kolyma-Omolon superterrane and the North Asian craton and occurrence of associated regional metamorphism and generation of anatectic granitoids to form the Transverse granite belt.

Yanshan Metallogenic Belt of Cu (±Fe, Au, Ag, Mo) Skarn, W±Mo±Be Skarn, Porphyry Mo (±W, Bi), Granitoid-Related Au Vein, Polymetallic Pb-Zn±Cu (±Ag, Au) Vein and Stockwork, and Au-Ag Epithermal-Vein Deposits (Belt YS) (Northeast and North China)

This Middle Jurassic through Early Cretaceous metallogenic belt is related to veins, replacements, and small granitoids in the northeastern part of the Sino-Korean craton. The belt occurs in the Yanshan Mountains in North Hebei Province and in an eastern continuation in the West Liaoning Province. The volcanic-plutonic belt consists of Early Jurassic basalt and andesite, Middle Jurassic andesite, dacite, and trachyandesite, Late Jurassic rhyolite and pyroclastic rock, and Early Cretaceous andesite and rhyolite. Most of the volcanic rocks in the belt are calc-alkaline and or alkaline. Plutonic rocks in the belt consist of monzogranite, granodiorite, granite, K-feldspar granite, granite porphyry, and quartz porphyry and are mostly calc-alkaline. The metallogenic belt trends east-west and is about 600 km long and 200 to 250 km wide. The belt forms a shield-shaped area consisting of northeast and north-northeast-trending zones and districts. The belt contains numerous large and superlarge deposits of various types and is one of the most economic regions in North China. The significant deposits in the belt are at Shouwangfen, Yangjiazhangzi, Jinchangouliang, Xiaosigou, Dazhuangke, Caijiaying, and Niujuan.

The main references on the geology and metallogenesis of the belt are Huan (1991), Shi (1994), Deng and others (1996), Lin and others (1998), and Wu and Sun (1999).

Shouwangfen Cu (±Fe, Au, Ag, Mo) Skarn Deposit

This deposit (Xu, Qidong and others, 1993) occurs at the contact zone of the Mesozoic granodiorite and the Neoproterozoic dolomite of the Wumishan Formation. The deposits are lenticular and lensoid in skarn and are stratiform shaped in metasomatized dolomite. Seven skarn zones occur along the contact (1) granodiorite zone, (2) altered granodiorite zone, (3) garnet-epidote-vesuvianite skarn zone, (4) diopside zone, (5) magnetite-humite-diopside skarn zone, (5) wollastonite skarn zone, and (7) serpentinized dolomite zone. The main ore minerals are molybdenite, pyrrhotite, pyrite, sphalerite, galena, chalcopyrite, magnetite, hematite, and scheelite. The ore minerals comprise five types (1) magnetite, (2) pyrite-bearing magnetite, (3) pyrrhotite and Co-bearing chalcopyrite, (4) pyrite-bearing chalcopyrite, and (5) veined chalcopyrite. The ore minerals occur in masses, disseminations, veins, and veinlets, and display idiomorphic, xenomorphic, crashing, colloid textures. Four skarn stages are recognized (1) a scapolite stage with scapolite, wollastonite, vesuvianite, garnet and diopside; (2) a magnetite stage with magnetite, humite, phlogopite, sericite, tremolite, and actinolite; (3) a quartz-sulphide stage with sulphides, chlorite, and sericite; and (4) a carbonate stage with calcite and fluorite. The deposit is medium size and has reserves of 155,300 tonnes Cu grading 0.65 percent Cu.

Yangjiazhangzi W±Mo±Be Skarn Deposit

This deposit (Huan and others, 1994) consists of tabular skarns that occur along the contact zone between the coarse-grained Hongluoshan granite (with a K-Ar isotopic age of 186 to 178 Ma) and Middle Cambrian through Middle Ordovician limestone. The deposit is 500 meters long, 220 meters wide, and extends 600 meters downdip. The main skarn body, is 300 to 800 meters long, 3 to 10 meters thick, and extends 200 to 350 meters downdip. The ore minerals are mainly molybdenite and pyrite, with lesser sphalerite, galena, and chalcopyrite. Molybdenum occurs in disseminations, veinlets, and networks. Skarn is an important alteration and skarn exhibits late-stage pyrite, chlorite, carbonate, and silica alterations. Molybdenum deposition is closely related to silica alteration. Like the Lanjiagou porphyry Mo deposit, this deposit also occurs in the Proterozoic Yanshan Basin zone along the northern edge of the Sino-Korean Plate. The deposit is medium size and has reserves of 32,145 tonnes Mo grading 0.141 percent Mo.

Jinchanggouliang Granitoid-Related Au-Vein Deposit

This deposit (Zhang and others, 1994) occurs in the northwestern outer contact zone of a Mesozoic granodiorite stock. More than 50 Au-bearing altered zones occur in gneiss and amphibolite of the Archean Xiaotazhigou Formation. The zones are generally several hundred meters long and 1 to 5 meters wide and are mostly trend northwest and dip steeply southwest or northeast. The deposit occurs discontinously in these altered zones in layers or lenses. The ore minerals occur mainly in masses and dense disseminations and consist mainly of pyrite, quartz, sericite, chalcopyrite, sphalerite, and galena. Sulphur isotopes of ores are narrowly concentrated around 0. Homogenization temperatures for fluid inclusions in quartz range from 250 to 370°C. A K-Ar isotopic age for a related dike is about 120 Ma. The deposit is large and has reserves of 17.67 tonnes Au grading 13.09 g/t Au.

Caijiaying Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (fig. 23) (Zhang, 1990; Quan, 1994) consists of swarms of dense veins that range from 300 to 1,000 meters long, 1 to 18 meters thick, and extend 400 to 500 meters downdip. The ore minerals occur in masses and disseminations and are sphalerite, galena, pyrite, arsenopyrite, magnetite, hematite, gold, siliver, and electrum, and minor molybdenite, chalcopyrite, and bornite. The gangue minerals are sericite, quartz, and chlorite and sparse barite and calcite. Host rocks contain chlorite, sericite, silica, pyrite, and carbonate alterations. Early chlorite alteration was replaced by later sericite alteration. Adjacent to the deposit, the host rocks display successive wide zones of sericite and chlorite alteration. Fluid inclusion temperatures range from 200 to 350º C. The host rocks for the deposit are fine-grained amphibole gneiss derived from Paleoproterozoic volcanic and sedimentary rocks that are metamorphosed to amphibolite facies. The host rocks occur along a limb of an overturned fold and the deposit is controlled by faults. The deposit is related to a Jurassic and Cretaceous granite porphyry and quartz porphyry dikes and Late Jurassic volcanic rock and is a Mesozoic magmatic hydrothermal system. The deposit is large and has reserves of 1.44 million tonnes Zn grading 4.26 percent Zn and 2.73 percent Pb.

Dazhuangke Porphyry Mo (±W, Bi) Deposit

This deposit (Huan and others, 1994) consists of veins and stockworks in explosive breccia pipes. The main part of the deposit occurs in a pipe that is 350 to 400 meters long and 40 to 90 meters thick. Ore minerals occur in disseminations and veinlets. The main ore mineral is molybdenite with minor magnetite, pyrite, chalcopyrite, sphalerite, and scheelite. Gangue minerals consitute the breccia and are mainly plagioclase, K feldspar, quartz, biotite, fluorite, and sericite. Host rocks are altered to K feldspar, biotitie, silica, pyrite, beresite, zeolite, and propylite. The deposit is related to a Jurassic quartz diorite and quartz monzonite (with a K-Ar isotopicage of 168 to 146 Ma.) and is controlled by east-west-trending fault zones. The deposit is medium size, and the average grade is 0.10 percent Mo.

Niujuan Au-Ag Epithermal-Vein Deposit

This Ag deposit (Liu and Zhang, 1997) is hosted in metamorphic rock of the Proterozoic Hongqiyingzhi Group and the Late Jurassic volcanic rock that are intruded by the medium- to coarse-grained Gangou granite, fine-grained Dongta granite, and Yushugoumen quartz diorite. The granitoids have a U-Pb zircon isotopic age of 245.1 Ma. The main deposit occurs in veins in siliceous breccia controlled by faults. The breccias are very complicated and contain fragments of various granite, quartz veins, feldspar, and quartz. The breccia cement is chalcedony. The deposit exhibits seven stages (1) sericite, (2) siliceous rock (chalcedonite), (3) suphide, (4) pyrite-quartz, (5) purple fluorite, (6) white fluorite, and (7) kaolinite. The second stage is the most important. The main ore minerals are sericite, chlorite, pyrite, quartz, adularia, galena, sphalerite, arsenopyrite, marcasite, chacopyrite, magnetite, native silver, Ag tetrahedrite, fluorite, kaolinite, and quartz. The deposit-forming temperatures range from 220 to 350°C and pressures range from about 12.6 to 26.0 Mpa. These data suggest a hot spring origin. The deposit is medium size and has an average grade of 281 g/t Ag.

Origin and Tectonic Controls for Yanshan Metallogenic Belt

The belt is interpreted as having formed during interplate magmatism associated with extensional tectonism related to oblique subduction of the Pacific Oceanic Plate beneath the Eurasian Plate. Related volcanism and plutonism is interpreted as extending from the Late Triassic through the Early Cretaceous. The Au deposits in the belt are herein interpreted as being related to a separate alkaline igneous complex. Some Early Jurassic deposits may occur in the belt, but most of the belt is interpreted as having formed during the Middle Jurassic and Early Cretaceous (Shi, 1994). The metallogenic zones and districts in the metallogenic belt are apparently controlled by the north-northeast and east-west trending major faults. As for other Middle Jurassic and Early Cretaceous metallogenic belts in this region, some authors discuss the origin of the Mesozoic magmatism as related to deep lithosphere processes (Deng and others, 1996; Lin and others, 1998; Wu and Sun, 1999).

Major Cenomanian through Campanian (96 to 72 Ma) Metallogenic Belts

Badzhal-Komsomolsk Metallogenic Belt of Sn-W Greisen, Stockwork, and Quartz-Vein, Cassiterite-Sulfide-Silicate Vein and Stockwork, Cu (±Fe, Au, Ag, Mo) Skarn, and Porphyry Mo (±W, Sn, Bi) Deposits (Belt BK) (Russia, Far East)

This Late Cretaceous metallogenic belt is related to veins and replacements in the Khingan-Okhotsk volcanic-plutonic

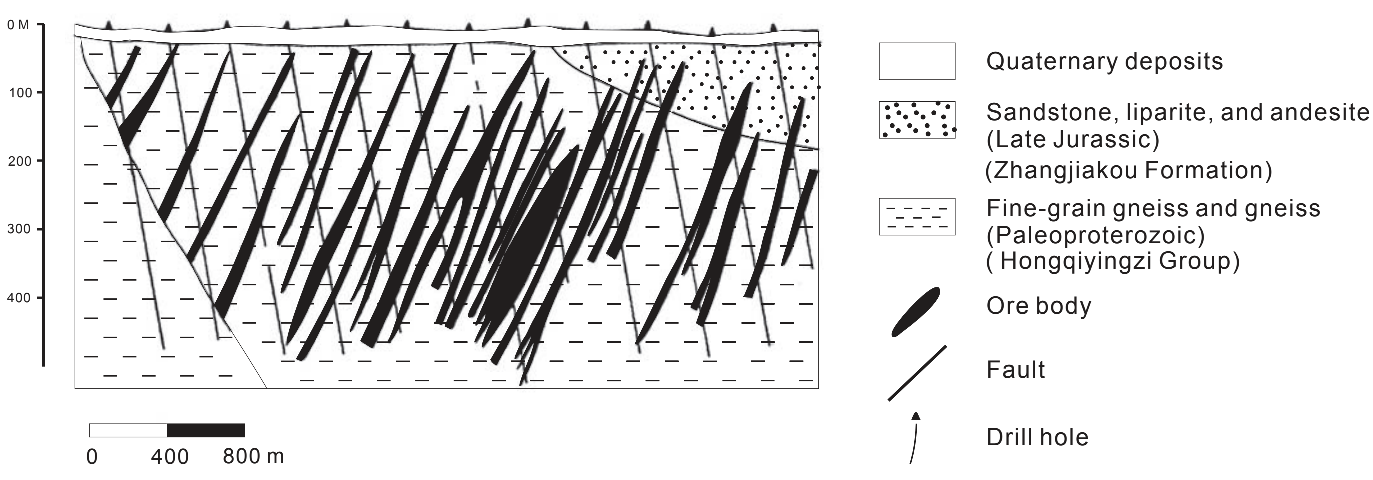


Figure 23. Schematic cross section of Caijiaying polymetallic Pb-Zn±Cu (±Ag, Au) vein and stockwork deposit, Yanshan-2 metallogenic belt, northern China. Adapted from Quan (1994).

belt. The major deposits are at Pravourmiyskoe, Solnechnoe, Festivalnoe, and Sobolinoye.

The main references on the geology and metallogenesis of the belt are Ognyanov (1986), Nokleberg and others (2003), Lebedev and others (1994), and Rodionov (2000).

Solnechnoe Sn-W Greisen, Stockwork, and Quartz-Vein Mine

This mine (fig. 24) (Ognyanov, 1986) consists of numerous highly-altered quartz-tourmaline zone apophyses that occur along, and are related to a long north-south-striking, left-lateral, strike-slip fault. The zone ranges varies from 0.5 to 15 meters thick, is 800 meters long, and extends deep more than 500 meters deep. Five vertically-zoned mineral assemblages occur, 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 a K-Ar isotopic age of 86 to 75 Ma. The deposit is medium size and has an average grade of 0.56 percent Sn, 0.05 percent W, and 0.1 percent Cu. The deposit has been mined since 1960s and is mostly exhausted.

Sobolinoye Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (G.E. Usanov, written commun., 1987; Onikhimovsky and Belomestnykh, 1996) occurs in the northern part of Amusk volcanic basin in a fault-bounded district that covers an area of 5.4 km^2. The deposit is bounded by the Leningradskiy thrust that dips west at a low angle (48°) and contains mylonite tectonic breccias. Along the thrust, folded Jurassic flysh is overthrust by Late Cretaceous andesite, dacite, and rhyolite. Units along the thrust are intruded by Late Cretaceous diorite and quartz-diorite stock and dikes. Sedimentary, volcanic, and intrusive rocks are cut by generally steeply-dipping (60 to 80°) fracture zones that occur in or near the thrust in feathering, strike-slip faults. The deposit contains about ten fracture zones quartz-tourmaline, quartz-sericite, and quartz-chlorite. Zones range as much as 1.1 km long and are about 3 to 7 meters thick, with some as much as 60 meters thick. The deposit contains Sn, W, Cu, Bi, Ag, and economic In. Quartz-tourmaline forms an older mineral assemblage that grades upward into (1) quartz-cassiterite with arsenopyrite; (2) quartz-pyrrhotite-chalcopyrite with stannite, fluorite, and magnetite; (3) quartz-galena-sphalerite; and (4) quartz-fluorite-calcite. Host rocks are generally altered to quartz-sericite and quartz-chlorite alteration in the upper parts of the deposit. The deposit is large and has an average grade of 0.3-0.7 percent Sn, 0.53 percent Cu, 0.06 percent WO_3, and 0.014 percent Bi.

Pravourmiskoe Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (fig. 25) (Ognyanov, 1986) consists of disseminations and veins that occur in a linear area more than 1,500 meters long and 5 to 25 meters thick that extends several hundred meters 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. The deposit contains Sn, W, and Cu; Bi, Pb, and Sb. Gangue-mineral assemblages are quartz-siderophyllite (zwitters) with quartz-topaz greisen. The deposit occurs along an east-west-trending thrust fault with small offset, and is hosted in, and is genetically related to Late Cretaceous felsic volcanic rock that overlie the large, shallow, granite and leucogranite complex of the Verkhneurmiisky batholith with K-Ar isotopic ages of 85 to 75 Ma. The granite has a Rb-Sr isochron age of 95 to 83 Ma and an initial Sr ratio of 0.703 to 0.708. The deposit is medium size and has an average grade of 0.1 to 5 percent Sn, 0.05 percent $W0_3$, and 0.5 percent Cu.

Origin and Tectonic Controls for Badzhal-Komsomolsk Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along the Khingan transform continental-margin arc that is related to oblique subduction of ancestral Pacific Ocean Plate. The Khingan-Okhotsk volcanic-plutonic belt, that hosts the metallogenic belt, is divided into two main sequences (1) Berriasian through Cenomanian calc-alkalic andesite and minor tholeiitic basalt, with coeval gabbro, diorite, and granodiorite; and (2) Late Cretaceous (mainly preSenonian) K-rich felsic volcanic rock, tuff, and ignimbrite, and coeval subvolcanic intrusive and granitoids plutons. The Cretaceous granitoids include granite, leucogranite, and composite gabbro, diorite, granodiorite that are coeval and comagmatic with volcanic rock. Both suites exhibit high K contents. The Khingan-Okhotsk belt overlies the Turan and Malokhingask terranes of the Bureya continental-margin arc superterrane and the Badzhal and Ulban subduction-zone terranes.

Chelasin Metallogenic Belt of Sn-B (Fe) Skarn (ludwigite), Granitoid-Related Au Vein, Cu (±Fe, Au, Ag, Mo) Skarn, Porphyry Cu-Mo (±Au, Ag), and Porphyry Cu (±Au) Deposits (Belt CH) (Russia, Far East)

This Late Cretaceous through Paleocene metallogenic belt is related to replacements and granitoids that are part of the Okhotsk-Chukotka volcanic-plutonic belt that intrudes and overlies North Asian craton and Uda volcanic-plutonic belt. The belt contains several types of granitoid-related deposits. The main deposit is at Chelasin.

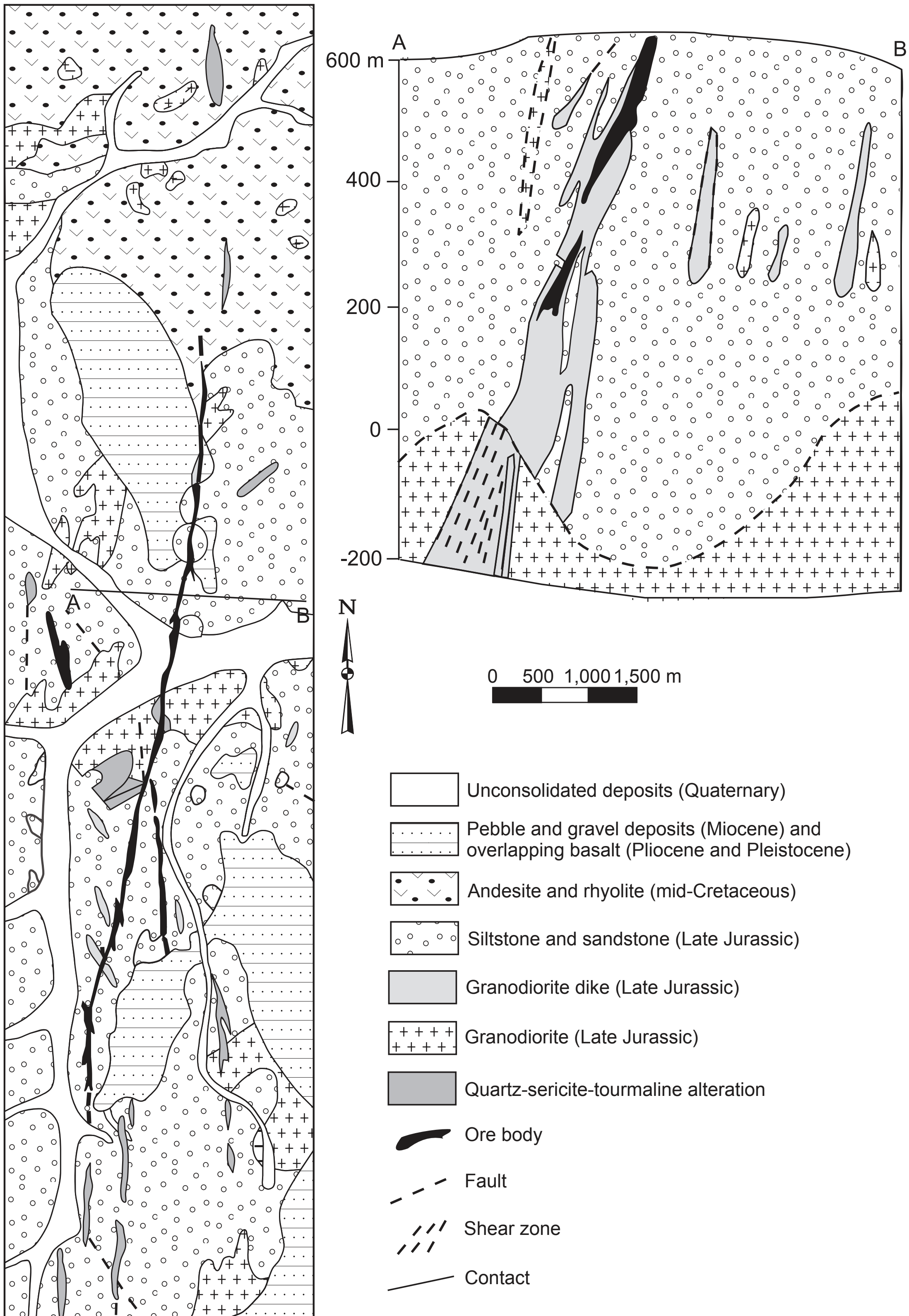


Figure 24. Generalized geologic map and schematic cross section of Solnechnoe Sn-W greisen, stockwork, and quartz-vein mine, Badzhal-Komsomolsk metallogenic belt, Russian Southeast. Adapted from Ognyanov (1986).

The main reference on the geology and metallogenesis of the belt is S.M. Rodionov, A.A. Cherepanov, and E.V. Kurbatov, written commun. (1994).

Chelasin Porphyry Cu (±Au) Deposit

This deposit (S.M. Rodionov, A.A. Cherepanov, and E.V. Kurbatov, written commun., 1994) consists of 42 stockwork zones and some quartz-sulfide veins. The zones occur in a single tract that extends about 2.5 km. One zone was dissected by three trenches, varies from 10 to 28 meters thick, and extends more than 700 meters according to geophysical data. The zone splits into several branches at the flanks. The host rocks consist of dacite and andesite flows and numerous dikes of rhyolite, andesite, diorite porphyry, and granodiorite that display silica and propylitic alteration. A K-Ar isotopic age for the altered rock is 67 to 64 Ma years. The deposit is unexplored. Average grades are 1.0 to 9.4 percent Cu, and as much as 10.0 g/t Au, 1,119.0 g/t Ag, 3.0 percent Pb, and 3.0 percent Zn.

Origin and Tectonic Controls for Chalasin Metallogenic Belt

The belt is herein interpreted as having formed during generation of granitoids along an active continental-margin arc consisting of the Albian through Late Cretaceous Okhotsk-Chukotka volcanic-plutonic belt.

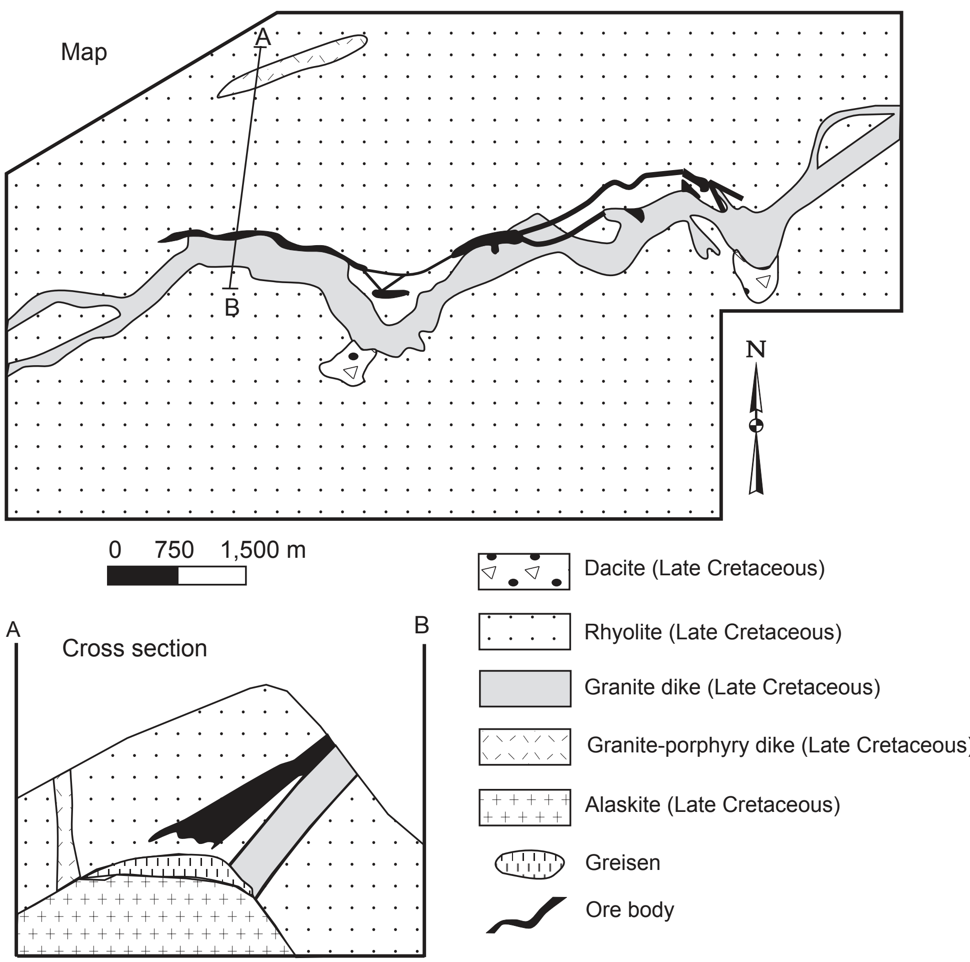


Figure 25. Generalized geologic map and schematic cross section of Pravourmiskoe Sn-W greisen, stockwork, and quartz-vein deposit, Badzhal-Komsomolsk metallogenic belt, Russian Southeast. Adapted from Ognyanov (1986).

Central Polousny Metallogenic Belt of Cassiterite-Sulfide-Silicate Vein and Stockwork and Sn-W Greisen, Stockwork, and Quartz-Vein Deposits (Belt CP) (Russia, Verkhoyansk-Kolyma Region)

This Aptian through Late Cretaceous metallogenic belt is related to veins and replacements related to the Northern granite belt that intrudes the Polousny-Debin subduction-zone terrane. The metallogenic belt covers an area of 450 by 150 km in the central part of the Polousny synclinorium that contains complexely-deformed Jurassic flysch that is intruded by granitoids in the western part of the Northern granite belt. The granitoids have $^{40}Ar/^{39}Ar$ isotopic ages of 130 to 120 Ma. The deposits are related to a Late Cretaceous REE and similar subalkali granitoids that occur in small stock-like bodies. The belt contains large Sn deposits as at Deputatskoye deposit, which is the largest in Russia. The major deposits are at Deputatskoye, Odinokoye, and Polyarnoe.

The main references on the geology and metallogenesis of the belt are Flerov and others (1971, 1979), Indolev and Nevoisa (1974), and Nokleberg and others (2003).

Deputatskoe Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (Flerov, 1974) contains about 150 separate bodies in shear zones, veins, and linear stockworks. The deposit ranges as much as 18 meters thick and 1,400 meters long. The major 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 main part of the deposit is explored to depths of more than 350 meters by adits and drillholes. The wallrocks are altered to silica, tourmaline, chlorite, and less commonly to greisen and sulfides. The deposit is hosted in contact metamorphosed Middle Jurassic shale and in an unexposed granite stock that is penetrated by drilling at 377 meters depth. The stock has a K-Ar isotopic age of 108 Ma. Widespread are predeposit, coeval, and postdeposit mafic, intermediate, and felsic dikes. Abundant polymetallic veins occur in felsic and intermediate dikes. The deposit is large and has an average grade of 0.3 to 0.7 Sn and locally as much as 10 percent Sn.

Origin and Tectonic Controls for Central Polousnyy Metallogenic Belt

The belt is interpreted as having formed during postaccretionary extension related to initiation of opening of the Eurasia Basin. The belt is associated with REE and subalkali granitoids that occur in small stocks in the western sector of the Northern granite belt. The deposits are related to Late Cretaceous REE and compositionally similar subalkali granitoids in small stocks that intrude the Polousnyi-Debin subuction zone terrane that consists of complexely deformed Jurassic flysch.

Chokhchur-Chekurdakh Metallogenic Belt of Cassiterite-Sulfide-Silicate Vein and Stockwork Deposits (Belt CC) (Russia, Verkhoyansk-Kolyma Region)

This Aptian through Late Cretaceous metallogenic belt is related to veins and replacements in the Jurassic Svyatoi Nos volcanic belt. The belt extends longitudinally for 250 km and occurs in a discontinuous chain of small uplifts in Cenozoic deposits of the Primorsk lowlands. The uplifts consist of horizontal Late Jurassic volcanic and sedimentary rock that is intruded by granodiorite, amphibole-biotite granite, and subalkali granite. The granitoids have $^{40}Ar/^{39}Ar$ isotopic ages of 106 to 105 Ma and are classified as intraplate formations that intruded during extension. Small fields of Late Cretaceous dacite and rhyolite are associated with subvolcanic bodies that contain Sn deposits. The metallogenic belt is characterized by cassiterite-silicate-sulfide deposits in the northern part and by cassiterite-quartz deposits in the southern part. Also occurring are polymetallic and Sb deposits also occur. The major deposits are at Churpunya and Chokurdakh.

The main reference on the geology and metallogenesis of the belt is Parfenov and others (1999).

Churpunya Cassiterite-Sulfide-Silicate Vein and Stockwork Deposit

This deposit (Zelenova, 1990; Drobot and others, 1993) is the best known in the metallogenic zone and is hosted in Late Cretaceous volcanic and plutonic rocks. At the base of the section are stratabound tuff, lahar breccia, and andesite lava that grade upward into lava breccia, tuff, and tuffaceous sandstone. These units are overlain by lavas of rhyolite and dacite and are intruded by explosive breccia veins and a rhyodacite that form the core of a paleovolcano. The deposit is associated with intrusion of steeply dipping, subvolcanic, dacite dikes that contain intense quartz-tourmaline metasomatite, intrusion of rhyolite dikes and formation of Sn deposits. The deposit consists of veins, crush zones, veinlets, and disseminations, and it occurs along extensive shear zones that strike sublatitudinally. The deposit contains a productive cassiterite-quartz stage, a pyrrhotite-chalcopyrite (sulfide) stage, and a final sulfosalt-carbonate stage. Most of the Sn reserves (about 90 percent) are in a central zone. Associated ore minerals are wolframite and Bi minerals. A general facies-stage zonation consists of occurrence of the sulfide stage in the central zone. At depth in the western section are areas of voluminous disseminated Cu-Sn minerals and quartz that are not explored. Associated with hypergene alteration of the sulfide minerals is formation of secondary sulfide zones with rich chalcocite.

Origin and Tectonic Controls for Chokhchur-Chekurdakh Metallogenic Belt

The belt is interpreted as having formed during postaccretionary extension related to initiation of the opening of the Eurasia Basin. The belt occurs along the Yana fault and is hosted in granodiorite, amphibole-biotite granite, and subalkali granite that form part of Svyatoy Nos magmatic arc. Geochemical analyses indicate intraplate formation of granitoids during extension.

Eckyuchu-Billyakh Metallogenic Belt of Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork, Clastic-Sediment-Hosted Sb-Au, Hg-Sb-W Vein and Stockwork, Ag-Sb Vein, and Au-Ag Epithermal-Vein Deposits (Belt EB) (Russia, Verkhoyansk-Kolyma Region)

This Aptian through Late Cretaceous metallogenic belt is related to veins and replacements related to the Transverse granite belt that intrudes the Verkhoyansk fold and thrust belt in the North Asian cratonal margin. The metallogenic belt occurs in the central, deeply-subsided part of the fold and thrust belt in the Sartang synclinorium, extends longitudinally for 350 km, and is as much as 150 km wide. The belt is hosted in Permian, Triassic, and Early to Middle Jurassic marine clastic rocks that are deformed into large, simple, linear folds that trend longitudinally. The clastic rocks are intruded by granitoid stocks and dikes of various composition that generally occur at the terminations of the Transverse granitoid belt. Along the western margin of the metallogenic belt is the Khoboyatu-Echiy granite pluton with a $^{40}Ar/^{39}Ar$ isotopic age of 97 Ma. The metallogenic belt contains mainly epithermal deposits that are younger than the granitoids and adjacent contact-metamorphic rocks. The major deposits are at Prognoz, Billyakh, Zvyozdochka, Mugurus, and Betyugen.

The main references on the geology and metallogenesis of the belt are Indolev and others (1980), Shour (1985), Gamyanin and others (1998), and Parfenov and others (1999).

Prognoz Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (E. Vladimirtseva, written commun., 1985; Alekseenko and others, 1991) consists of long and thin sulfide-carbonate veins in Triassic clastic rock. The major ore minerals are siderite, galena, pyrargyrite, owyheeite, various Ag minerals, and sphalerite and in granite porphyry dike. The deposit is a large world-class deposit and has average grades of 3 percent Pb, 1 percent Zn, and as much as 600 g/t Ag, and probable resource of more than 2,000 tonnes Ag.

Zvyozdochka Clastic Sediment-Hosted Hg±Sb Deposit

This deposit (Maslennikov, 1977; Klimov, 1979; V. Maslennikov, written commun., 1985; Shour, 1985) is hosted in intercalated Triassic sandstone and siltstone that is deformed into small folds that strike roughly north-south. The deposit is 0.2 to 11 meters thick, dips west at 70 to 75°, and occurs along a fault that cuts an anticlinal axis. The margin of the deposit is not distinct and is defined by geochemical channel sampling. The major host lithology is sandstone along the western limb of an anticline. Cinnabar is the major ore mineral and native Hg occurs at depths greater than 100 meters. Other minor ore minerals are metacinnabarite, pyrite, maracasite, galena, sphalerite, chalcopyrite, and arsenopyrite, and rare stibnite, Au, and Ag. Gangue minerals are quartz, ankerite, calcite, dickite, and kaolinite. Wallrocks exhibit intense silica, dickite, and carbon alterations. The deposit is medium size and it has an average grade of 1.5 to 1.95 percent Hg, and it has reserves of 3,712 tonnes Hg.

Origin and Tectonic Controls for Eckyuchu-Billyakh Metallogenic Belt

The belt is interpreted as having formed during postaccretionary extension related to initiation of opening of the Eurasia Basin. The belt hosted in granitoid stocks and dikes of various compositions that occur at the terminations of the Transverse granitoid belt. The metallogenic belt occurs in the central, subsided part of the Verkhoyansk fold and thrust belt along the margins of the Sartang synclinorium. The granitoids intrude Permian, Triassic, and Early to Middle Jurassic marine clastic rock. The granitoids have $^{40}Ar/^{39}Ar$ isotopic ages that are older than 120 Ma. Near the western margin of the metallogenic belt is the Khoboyatu-Echiy granite pluton with a $^{40}Ar/^{39}Ar$ isotopic age of 97 Ma.

Ezop-Yam-Alin Metallogenic Belt of W-Mo-Be Greisen, Stockwork, and Quartz Vein, Sn-W Greisen, Stockwork, and Quartz Vein, Cassiterite-Sulfide-Silicate Vein and Stockwork, and Porphyry Mo (±W, Sn, Bi) Deposits (Belt EY) (Russia, Far East)

This Late Cretaceous metallogenic belt is related to veins and replacements associated with the Khingan-Okhotsk volcanic-plutonic belt. The deposits occur mainly along the contacts large granite and leucogranite intrusions. K-Ar isotopic ages indicate the Sn deposits and related Sn granite formed between 100 to 75 Ma. The major deposits are at Ippatinskoe, Olgakanskoe, and Shirotnoe.

The main references on the geology and metallogenesis of the belt are Vrublevsky and others (1988), Nokleberg and others (2003), Nechaev and others (1996), and Sengor and Natal'in (1996).

Ippatinskoe Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (Ognyanov, 1986) consists of veins and selvages in the northern part of a large granitic body. Sixty-five veins are recognized. The veins range from 2 cm to 2 meters wide, extend as much as 290 meters along strike, and are prospected to a depth of 100 meters. The veins occur in a north-south-trending zone that is 3,000 meters long and as much as 300 meters wide. Ore minerals are cassiterite, wolframite, and arsenopyrite, and rare chalcopyrite, pyrite, scheelite, sphalerite, and molybdenite, and very rare bismuthinite and beryl. Gangue minerals are quartz, muscovite, feldspar, fluorite, and rare tourmaline. The deposit contains minor Cu, Ph, Sb, Pb, and Au. The deposit is related to a fine-grained leucogranite with a K-Ar isotopic age of 90 7 to 5 Ma. The deposit is small and has average grades of 0.31 percent Sn and 0.19 percent WO_3 in the 6 largest veins.

Lednikovy-Sarmaka W-Mo-Be Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (A.I. Bukhanchenko, written commun., 1988) occurs in an apical portion of a Late Cretaceous granite pluton and granite-porphyry dikes that intrudes sandstone and siltstone. The deposit consists of a linear stockwork that is as much as 2 km long and about 300 meters wide. The stockwork is composed of quartz and fluorite-topaz-quartz veins and veinlets that vary from 1.0 to 30.0 cm thick and that occur in an altered zone that contains greisen, chlorite-quartz, and sericite-chlorite-quartz metasomatite. The major minerals are quartz, muscovite, wolframite, arsenopyrite, pyrite, and chalcopyrite. The ore minerals comprise 5 to 40 percent of the veins. The deposit is large and has resources of 41,000 tonnes WO_3 and 28,000 tonnes Cu. The average grades are 0.37 percent (0.31 to 0.43 percent) WO_3, and 0.18 percent (0.14 to 0.21 percent) Cu.

Origin and Tectonic Controls for Ezop-Yam-Alin Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along the Khingan transform continental-margin arc consisting of the the Khingan-Okhotsk volcanic-plutonic belt. The arc is tectonically linked to oblique subduction of ancestral Pacific Ocean Plate. Fragments of this plate are interpreted as occurring in tectonically interwoven units of the Amur River (AM), Khabarovsk (KB) (younger Early Cretaceous part), and Kiselevka-Manoma subduction-zone terranes. This tectonic linkage is based on (1) occurrence of subduction-zone terranes outboard (oceanward) of, and parallel to, the various parts of the Khinghan arc; (2) formation of melange structures during the Early and Middle Cretaceous; and (3) where not disrupted by extensive Cretaceous movement along the Central Sihote-Aline strike-slip fault, dipping of melange structures and bounding faults toward and beneath the igneous units of the arc. Formation of the Khingan-Okhotsk magmatic arc is related to subduction that is generally interpreted as having ended in the late mid-Cretaceous when oblique subduction changed into sinistral-slip faulting along the outboard margin of the arc.

Gyeongnam Metallogenic Belt of Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork, Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite, Fe Skarn, W-Mo-Be Greisen, Stockwork, and Quartz Vein, Porphyry Mo (±W, Sn, Bi), Cu-Ag Vein, Au in Shear Zone, and Quartz-Vein Deposits (Belt GN) (South Korea)

This metallogenic belt is hosted in Yeongnam Metamorphic Complex (part of Sino-Korean craton, Yeongnam granulite-paragneiss terrane), Gyeongsang Supergroup, and the Late Cretaceous Bulgugsa Granite. The age range of the belt is interpreted as being Cenomanian through Campanian (96 to 75 Ma). The Yeongnam metamorphic complex consists of leucogranite gneiss, hornblende plagioclase gneiss, biotite gneiss and schist of Wonnam Formation. The Gyeongsang Supergroup consists of shale and sandstone of the Hadong and Sindong Groups and volcanic rock of Yucheon Group that are intruded by Late Cretaceous Bulgugsa biotite granite, granodiorite, anorthosite, porphyry, and felsic and quartz porphyry dikes. The major deposits are at Cheolma, Gwymyeong, Mulkum, Kuryong, Ulsan, Goseong, Tongyoung, and Haman-Gunbuk.

The main references on the geology and metallogenesis of the belt are Hwang and Kim (1962), Park (1963), Hwang (1963), Kim and Kim (1977), and Park and others (1988).

Cheolma Au in Shear Zone and Quartz-vein deposit

This deposit (Hwang and others, 1989) consists of gold-bearing quartz veins following fault shear zones, joints, and fractures. Host rocks are Cretaceous andesitic rocks, lapilli tuffs, rhyolitic tuffs and felsophyre intruded by Cretaceous granodiorite, hornblende granite, biotite granite and aplite. Veins trend N20-40°W, dip 70-85°NE, and range in length and width 65 to 130 meters and 1.0 to 1.5 meters, respectively. Ore minerals are chalcopyrite, galena, sphalerite, pyrite, pyrrhotite and magnetite. The deposit is small and has resources of 98,700 tonnes grading 0.5 to 1.3 g/tAu, 2 to 30 g/t Ag, and 0.5 to 3.01 percent Cu.

Goseong Cu-Ag Vein Mine

This mine (Park and others 1988) is hosted in Cretaceous greenish grey shale and sandstone of the Jindong Formation and rhyolite tuff of Yucheon group that are intruded by late Cretaceous granodiorite. The deposit occurs along fissures and a fault-shear zone. The ore minerals consist of arsenopyrite, pyrite, sphalerite, chalcopyrite and galena. The mine is small and it has produced 6,900 tonnes of ore from 1929 to 1964 grading 2.6 to 10.0 percent Cu, 1.2 to 10 g/t Au and 65 to 300 g/t Ag.

Gwymyeong Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite Deposit

This deposit (Hwang and others, 1989) is hosted by Cretaceous tuffaceous rock and Late Cretaceous andesite and diorite. The deposit occurs along fissures and shear zones in andesite and diorite. The width, length, and depth of veins are 0.3 to 1 meters, 60 to 120 meters, and 90 to 200 meters, respectively. Ore minerals are chalcopyrite, galena, and sphalerite. The deposit is small with reserves of 6,080 tonnes of ore grading 6.8 percent Pb, 9.2 percent Zn, 1.3 percent Cu, 1.1 g/t Au, and 94.83g /t Ag.

Haman-Gunpuk Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite Deposit

This deposit (Kim and Kim, 1977) is hosted in light-gray chert of the Cretaceous Jindong Formation. The deposit consists of fissure-filling hydrothermal veins composed of Cu sulfide, specularite, and tourmaline. Sixteen veins crop out at the surface. Drilling reveals that the C and M veins are economic. The C vein is 0.1 to 1.2 meters wide, 130 meters long, and 120 meters deep, and has reserves of 34,920 tonnes grading 0.89 percent Cu. The M vein is 0.5 to 3.3 meters wide, 160 meters long, and 75 meters deep, and has reserves of 77,992 tonnes of ore grading 0.83 percent Cu. The deposit is medium size and has reserves of 112,912 tonnes of ore grading 0.86 percent Cu.

Kuryong Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite Mine

This mine (fig. 26) (Park, 1963; Kim and Oh, 1966) is hosted in a Cretaceous granite porphyry that intrudes widespread limestone of unknown age. Associated with the granite porphyry is a succession of intrusive andesite, agglomerate, pyroxene andesite, masanite, quartz-feldspar porphyry, and altered andesite. The intrusive andesite is partly covered by the agglomerate that forms an extrusive phase. The pyroxene andesite forms a bedded flow. The deposit is mainly sulfide veins and propylitic, hydrothermal alteration zones. Quartz monzonite intrudes both the andesite and the altered andesitic. Quartz-feldspar porphyry occurs only in drill cores. The altered zone occurs in both andesite and agglomerate. The alteration is contemporaneous with, or postdates a quartz monzonite intrusion. Propylitically-altered rocks are green-grey, weathered to light grey, and contain a fine-grained pyrite in disseminations. Chlorite, epidote, sericite, kaoline, calcite, quartz, and pyrite are extensively developed in the propylitic zone. The intensity of alteration and pyrite content increases with proximity to veins. The deposit is small amd has resources of 413,280 tonnes of ore grading 41.6 percent Fe, 0.11 percent S, and 0.04 percent P.

Mulkum Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite Mine

This mine is (Hwang and Kim, 1962) hosted in a Cretaceous feldspar porphyry that was intruded by an extensive Late Cretaceous biotite granite. The deposit consists of a magnetite metasomatite that occurs in fissure fillings. The ore minerals are magnetite, pyrite, chalcopyrite, galena, and sphalerite. The average width of veins ranges from 1 to 6 meters, and the average length ranges from 44 to 250 meters. The average depth ranges from 70 to 150 meters. The deposit is small a nd has reserves of 1,741,875 tonnes of ore. The average grades are 60 percent Fe, 13.61 percent SiO_2, 0.12 percent S, 0.26 percent P, and 0.006 percent TiO_2.

Tongyoung Cu-Ag Vein Mine

This mine (Park and others 1988) is hosted in the Cretaceous andesite and andesitic tuff breccia of the Yucheon group that are intruded by a Late Cretaceous quartz porphyry and diabase. The veins occur along fissures and shear zones in andesite, andesite tuff breccia, and quartz porphyry. The ore minerals are chalcopyrite, pyrite, galena, sphalerite, electrum, and argentite. The deposit is small and has a production of 5,000 tonnes of ore grading 0.3 to 5.5 g/t Au, 15 to 366 g/t Ag, and 0.2 to 1.2 percent Cu.

Ulsan Fe Skarn Mine

This mine (Hwang, 1963) is hosted in limestone and serpentine of unknown age and Cretaceous slate, hornfels, and biotite granite. The Fe skarn occurs along the bedding limestone, or on the contact zone between limestone and serpentinite. The ore minerals are magnetite, chalcopyrite, sphalerite, galena, pyrrhotite, and arsenopyrite. Drilling revealed several deposits that have a lenticular shape and vary from 170 to 180 meters long and are 140 meters wide and 80 meters deep. The deposit is medium size and has reserves of 1,708,400 tonnes of ore grading 43 percent Fe and 0.02 percent Pb.

Origin and Tectonic Controls for Gyeongnam Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids during the Late Cretaceous through Early Tertiary Bulgugsa orogeny. The deposits occur along the fissures and shear zones and formed during intrusion of Bulgugsa granite (biotite granite, granodiorite, and quartz-porphyry).

Gyeongpuk Metallogenic Belt of Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork, W-Mo-Be Greisen, Stockwork, and Quartz-Vein, Sn-W Greisen, Stockwork, and Quartz Vein, Fe Skarn, and Polymetaliic Ni Vein Deposits (Belt GP) (South Korea)

This metallogenic belt is hosted in the Yeongnam Metamorphic Complex, Gyeongsang Supergroup, Yeongnam granulite-paragneiss terrane, that is part of the Sino-Korean

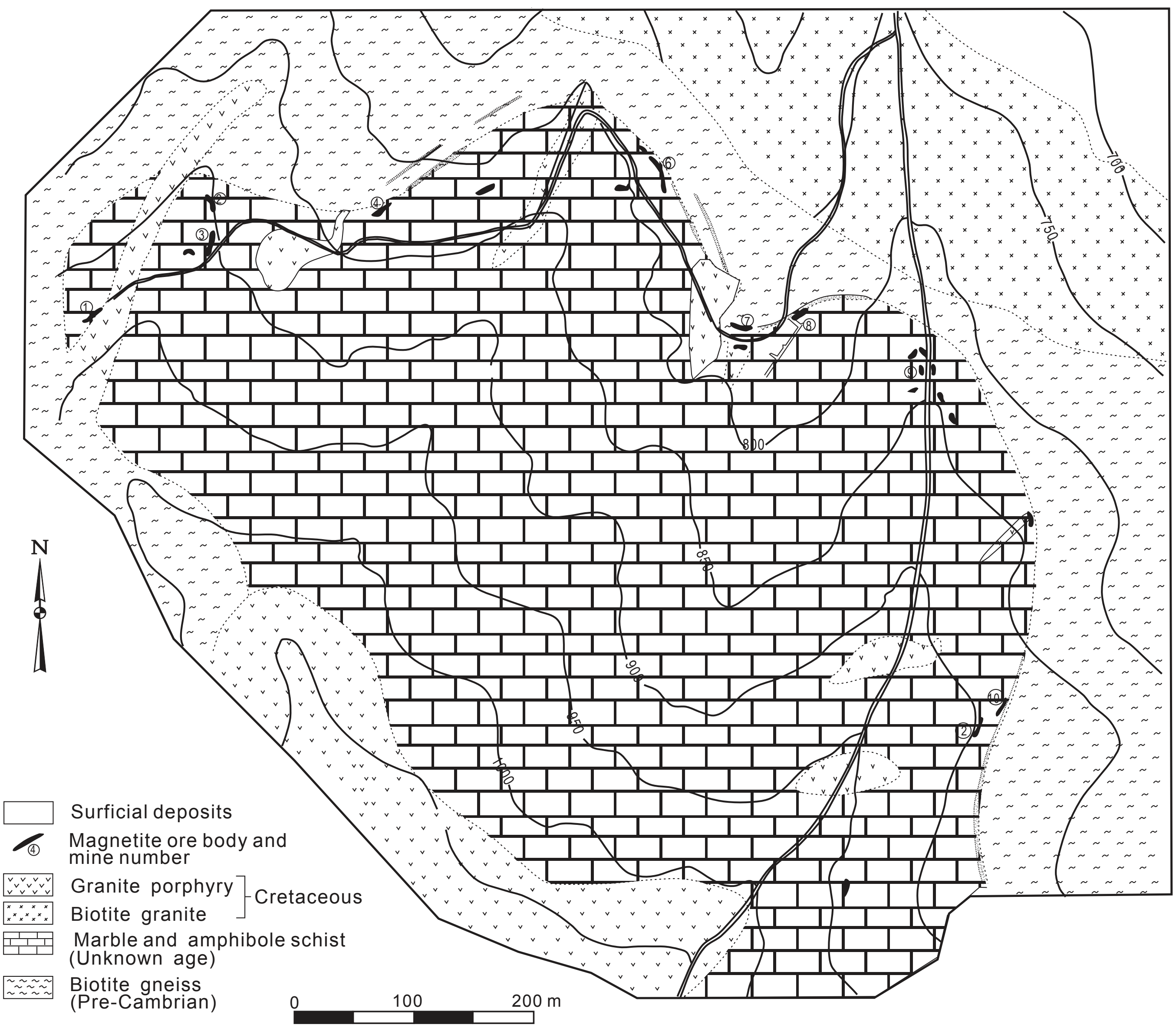


Figure 26. Generalized geologic map of Kuryong polymetallic (Pb, Zn±Cu, Ba, Ag, Au) volcanic-hosted metasomatite mine, Gyeongnam metallogenic belt, Korea. Adapted from Park (1963).

craton, and in the Late Cretaceous Bulgugsa Granite. The age range of the belt is interpreted as Cenomanian through Campanian (96 to 75 Ma). The Yeongnam Metamorphic Complex consists of leucogranite gneiss, hornblende plagioclase gneiss, and biotite gneiss and schist of the Wonnam Formation. The Gyeongsang Supergroup consists of shale and sandstone of Hadong and Sindong Group and volcanic rock of Yucheon Group. The Bulgugsa Granite consists of biotite granite, granodiorite, anorthosite, porphyry, and felsic and quartz porphyry dikes. The major deposits are at Darak, Kyeongju, Chilgok, and Wangpiri.

The main references on the geology and metallogenesis of the belt are Cho and Lee (1966), Park and others (1969), and Kim and Shin (1966).

Chilgok Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (Koo and Kim, 1966) is hosted mainly in hornblende granite of the Cretaceous Bulgugsa granite series that intrudes older sedimentary rock of the Sindong Group. The deposit is controlled by joints and faults that mainly strike N 40° W and dip 75 to 85° northeast. The fissures are filled by quartz with ore minerals of mainly galena, sphalerite, and pyrite, lesser chalcopyrite and arsenopyrite, and rare pyrrhotite. The deposit is small and has resources of 3,000 to possibly 5,900 tonnes, and reserves of 5,300 tonnes of ore. Grades are 0.9 to 5.5 g/t Au, 154.4 to 280.8 g/t Ag, 3.9 to 8.83 percent Pb, and 4.1-7.08 percent Zn.

Darak Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (Cho and Lee, 1966) is hosted in Precambrian granite gneiss and Cretaceous biotite granite and granodiorite that are intruded by Late Cretaceous porphyry, felsite and quartz porphyry dikes. The deposit consists of sulfide veins in hydrothermal fissure fillings in granite gneiss, granodiorite, and biotite granite. The main vein strikes N 50-60° W, dips 70 to 90° southwest, and averages 70 cm wide. The average grades are 3.57 percent Pb and 3.72 percent Zn. The ore minerals are galena, sphalerite, pyrite, pyrrhotite, and chalcopyrite. Gangue minerals are quartz, feldspar, calcite, chlorite, sericite, and fluorite. The deposit is small and has resources of 85,720 tonnes of ore. The average grades are 3.01 percent Pb, 4.41 percent Zn, 1.63 g/t Au, and 41.23 g/t Ag.

Kyeongju W-Mo-Be Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (Park and others, 1969) is hosted in Cretaceous shale and sandstone of the Hadong group and volcanic rock of Yucheon group that are intruded by the Late Cretaceous Bulgugso biotite granite. The deposit consists mainly of disseminated molybdenite in leucogranite that forms the margin of a granite stock, and partly in extrusive breccia, and in quartz veins in granite. The deposit is medium size and has resources of 260,000 tonnes of ore grading 0.2 to 0.3 percent Mo.

Samkwang Polymetaliic Ni Vein Deposit

This unusual, multistage deposit (Kim, 1982) consists of Ni sulfide minerals in amphibolite bodies that are part of a Precambrian assemblage of granitic gneiss, banded gneiss, and siliceous dikes that are intruded by Cretaceous biotite granite, lamprophyre dikes, quartz veins, and pegmatitic quartz veins. The amphibolite consists of coarse-grained Ni sulfide minerals in fine- to medium-grained ultramafic rock. The deposit occurs in the top parts of amphibolite near the surface and grades downwards into barren or very low-grade parts. The major ore minerals are pyrrhotite with subordinate pentlandite, chalcopyrite, and pyrite that occur in disseminations, predominantly in the upper, subsurface part of the amphibolite. Three stages of mineralization occurred (1) magmatic segregation with formation of disseminated Ni sulfide minerals; (2) deuteric or hydrothermal alteration associated with Cretaceous plutonism with alteration of rock forming minerals; and (3) remobilization of sulfides, mainly pyrrhotite with pentlandite. The ore minerals are pyrrhotite, pentlandite, chalcopyrite, and pyrite. Gangue minerals are plagioclase, sericite, tremolite-actinolite, talc, chlorite, calcite, and quartz. Areas with sulfides vary from 5 to 8 meters thick and 45 to 50 meters long. The deposit is small and has reserves of 17,820 tonnes of ore grading 0.57 percent Ni.

Wangpiri Sn-W Greisen, Stockwork, and Quartz-Vein Mine

The mine (Kim and Shin, 1966) is hosted in Precambrian metasedimentary rock in the Wonnam and Yulri Series and in the Cretaceous Bunchon granite gneiss, granite, and granite. The deposit is hosted in granitic pegmatite that intrudes the contact between granite and the Yulri Series. The veins are mostly concordant with schistosity in phyllite, mica schist, and micaceous metasandstone; they strike north-south to N 60° E and dip 30 to 80° northwest. The deposit consists of cassiterite pegmatite veins with banded structure of alternating quartz and feldspar zones that range from 2 to 22 mm wide. Local homogeneous and coarse granular textures occur. The main ore mineral is cassiterite along with quartz, microcline, perthite, plagioclase, sericite, and muscovite and sparse tourmaline. The mine consist of small lenses, pipes, or large veins that range from 0.3 to 15 meters wide and 5 to 150 meters long. Fine cassiterite grains occur occasionally. Cassiterite is generally concentrated in quartz-rich zones in the homogeneous pegmatite vein, and also is disseminated in muscovite-rich zones on the hanging wall in fine grains; it occurs rarely in feldspar-rich zones. Average width of the veins is 1.24 meters. The deposit is small and has an average grade of 0.45 percent Sn.

Origin and Tectonic Controls for Gyeongpuk Metallogenic Belt

The belt is interpreted as having formed during generation of the Bulgugsa Granite during the Late Cretaceous through Early Tertiary Bulgugsa orogeny. The Bulgugsa Granite consists of biotite granite, granodiorite, porphyry, and felsic and quartz porphyry. The belt is hosted in the Yeongnam Metamorphic Complex, Gyeongsang Supergroup, Yeongnam granulite-paragneiss terrane, that is part of the Sino-Korean craton, and in the Late Cretaceous Bulgugsa Granite.

Hidaka Metallogenic Belt of Cyprus Cu-Zn Massive Sulfide and Besshi Cu-Zn-Ag Massive Sulfide Deposits (Belt HD) (Japan, Hokkaido)

This Middle Cretaceous through Eocene metallogenic belt is related to stratiform units in the Hidaka belt of the Shimanto subuction zone terrane. The belt occurs in the central part of the Hokkaido island, trends north-south for more than 350 km, and ranges from 20 to 70 km wide. The belt is hosted in a Cretaceous and Paleogene subduction-zone complex. The northern Hidaka belt contains mainly clastic rocks, and the southern Hidaka belt contains the Hidaka Metamorphic Rock. Saito (1958) defined this belt as the Main Central Hokkaido belt, and Tsuboya and others (1956) used the name Hidaka metallogenic province to refer to an area that contained the Kamuikotan metallogenic belt of present study. Saito and others (1967) used the name Central Hokkaido metallogenic province with a definition similar to that used for the Hidaka metallogenic province. The Hidaka metallogenic belt contains at least ten, very minor Cyprus type massive sulfide deposits (Saito, 1958). The major deposits are the Besshi Cu-Zn-Ag and Shimokawa Cu-Zn-Ag massive sulfide deposits.

The main references on the geology and metallogenesis of the belt are Saito and others (1967) and Miyashita and others (1997).

Besshi Cu-Zn-Ag Massive Sulfide Deposit

This deposit (Suyari and others, 1991; Watanabe and others, 1998) consists of four srtratiform ore bodies. The Main Motoyama body extends 1,600 meters along strike and 2,000 meters down dip, and has dimensions of 3,000 by 11,000 meters. Average thickness is 2.4 meters with a maximum thickness of 15 meters. The main ore minerals are pyrite, chalcopyrite, bornite, and magnetite. Gangue minerals are chlorite, hornblende, glaucophane, and quartz. The deposit hosted in pelitic schist of the Cretaceous Sambagawa Metamorphic Rocks that may be correlative to the Shimato belt of similar units. Mafic schist and piedmontite schist occur in the ore zone. Geochemistry indicates that the mafic schist is derived from basalt that formed in an oceanic intraplate or in constructive plate margins. The age of peak of metamorphism is 110 Ma according to Rb-Sr and K-Ar isotopic studies. The deposit was discovered in 1690, is large with a grade of 1.0 to 1.8 percent Cu, 0.1 to 1.4 percent Zn, 11.9 to 40 percent S, 0.3 to 0.7g/t Au, 7 to 20 g/t Ag. The deposit has produced 706,000 tonnes Cu and has reserves of 8 million tones of ore.

Shimokawa Cu-Zn-Ag Massive Sulfide Deposit

This deposit (Kato and others, 1990) consists of of seven sulfide bodies that occur along the same stratigraphic horizon. The horizon strikes north-south, and dips 50 to 60^{o} east. The sulfide bodies occur along a 1,800-meters-long zone. Average thickness of the bodies is 5.2 meters, with a maximum of 30 meters. The main ore minerals are pyrite, chalcopyrite, pyrrhotite, sphalerite, and magnetite. Minor ore minerals are cubanite, valleriite, cobalt-bearing pentlandite, and cobaltite. Gangue minerals are quartz, chlorite, sericite, and cabonate minerals. The deposit occurs between tholeiitic pillow basalt and slate of the Cretaceous Hidaka Group. Tholeiitic rocks show geochemical similarity to mid-ocean ridge basalt or marginal basin basalt. Host rocks are altered from zeolite to amphibolite facies. The deposit is medium size and has an average grade of 2.3 percent Cu, 0.8 percent Zn, 0.22 percentCo, and 20.3 percent S. 6,800,000 tonnes of ore was produced from 1941 to 1982.

Origin and Tectonic Controls for Hidaka Metallogenic Belt

The belt is interpreted as having formed in basalt generated along the Kula-Pacific ridge. Subsequently, the host rocks and deposits were structurally incorporated into the Shimanto subuction zone terrane. The basalt associated with the deposits has geochemical characteristics of N-type MORB (Miyashita and others, 1997). The ages of basalt are interpreted as mid-Cretaceous through Eocene. The basalt occurs in clastic sedimentary rock, suggesting occurrence of a spreading ridge near a subduction zone (Miyashita and others, 1997). The deposits in the belt are interpreted as having formed during this magmatism along the Kula-Pacific ridge that was being subducted under the East Asia continental margin.

Inner Zone Southwest Japan Metallogenic Belt of Zn-Pb (Ag, Cu, W) Skarn, W-Mo-Be Greisen, Stockwork, and Quartz Vein, W±Mo±Be skarn, Cu (±Fe, Au, Ag, Mo) Skarn, Porphyry Mo (±W, Sn, Bi), Polymetallic Pb-Zn ±Cu (± Ag, Au) Vein and Stockwork, Fluorspar Vein, and Metamorphic Graphite Deposits (Belt ISJ) (Japan)

This Cretaceous through Paleogene metallogenic belt is related to veins and replacements in Nohi rhyolitic volcanic belt and Hiroshima granitic belt that overlie and intrude the Hida, Sangun-Hidagaien-Kurosegawa, Akiyoshi-Maizuru, and Mino-Tamba-Chichibu terranes (some units are too small to show on the summary geodynamics map). The metallogenic belt occurs in the western part of Honshu Island and northern Kyushu Island, trends east-northeast to west-southwest for more than 1,000 km, and is as much as 150 km wide. The belt contains numerous skarn deposits (Kamioka Tochibara deposit) and polymetallic veins (Ikuno deposit). Tsuboya and others (1956) used the name Inner Zone Southwest Japan metallogenic province; however, the Ikuno and Akenobe deposits were excluded because they were interpreted as being Neogene at that time. The Ikuno and Akenobe deposits are included in the Inner Zone Southwest Japan metallogenic belt.

The main references on the geology and metallogenesis of the belt are Tsuboya and others (1956), Ishihara (1978), and Ishihara and others (1992).

Kamioka Mozumi Zn-Pb (Ag, Cu, W) Skarn Mine

This mine (fig. 27) (Sato and Akiyama, 1980) consists of more than 18 skarn bodies that occur in masses, stratiform layers, and veins. The Main ore body is 300 meters long, 400 meters wide, and 10 meters thick. The main ore minerals are sphalerite, galena, chalcopyrite, magnetite, pyrite, and pyrrhotite with minor molybdenite and scheelite. The skarn minerals are hedenbergite, actinolite, diopside, garnet, wollastonite, and epidote. The skarn is clinopyroxene skarn that is replaced by garnet or by magnetite, calcite, and quartz. Replacements are likely related to deposition of Zn-Pb sulfides. Host rocks are crystalline limestone, diopside gneiss, amphibole gneiss, and amphibolite of the Hida Metamorphic Rock. K-Ar age for sericite from the Kamioka Tchibora and Kamioka Mozumi deposits are 63.8 to 67.5 Ma and a K-Ar age isotopic for hastingsite from skarn near the Kamioka Tchibora deposit is 63.3±1.6 Ma. These ages suggest mineralization during the Late Cretaceous through Paleogene. Mineralization is related to the quartz porphyry or granite intrusion. The deposit was discovered in 1589, is medium size and has produced 815,000 tonnes Zn, 52,000 tonnes Pb, and 190 tonnes Ag. The average grades are 7.9 percent Zn, 2.68 percent Pb, and 31 g/t Ag.

Bandojima Cu (±Fe, Au, Ag, Mo) Skarn Mine

This mine (Geological Survey of Japan, 1956; Mining and Metallurgical Institute of Japan, 1965) consists of nine skarn bodies that occur in masses and sheets. The main ore body is 150 meters long, 85 meters wide, and 4 meters thick. The main ore minerals are sphalerite, galena, chalcopyrite, and pyrrhotite. Skarn minerals are garnet and epidote. Host rocks are crystaline limestone, calcareous shale, and chert of the Hida Metamorphic Rock. Mineralization is related to intrusion of Mesozoic quartz diorite that occurs under the deposit. The small deposit was found before 1900. The deposit has produced 1,723 tonnes Zn, 1,464 tonnes Pb, and 105 tonnes Cu from 1952 to 1961 grading 10 to 15 percent Pb, 5 to 7 percent Zn, and 1 to 2 percent Cu. The mine contains reserves of 600,000 tonnes of ore.

Kamioka Tochibora Zn-Pb (Ag, Cu, W) Skarn Mine

This mine (Sato and Uchiumi, 1990) consists of more than 34 skarn bodies with local massive ore. The main ore body is 250 meters long, 500 meters wide, and 60 meters thick. The main ore minerals are sphalerite, galena, chalcopyrite, matildite, magnetite, pyrite, and hematite. The minor minerals are molybdenite native silver, argentite, and scheerlite. Skarn minerals are hedenbergite, actinolite, diopside, garnet, wollastonite, and epidote. Host rocks are crystaline limestone, diopside gneiss, amphibole gneiss, and amphibolite of the Hida metamorphic rock. The K-Ar ages of sericites from Kamioka Tchibora and Kamioka Mozumi deposits are 63.8 to 67.5 Ma. A K-Ar age of hastingsite from skarn near the Kamioka Tchibora deposit is 63.3±1.6 Ma. These ages suggest mineralization occurred during the Late Cretaceous through Paleogene. The mineralization may be related to the quartz porphyry. The deposit was discovered in 1580.

Ikuno Polymetallic Pb-Zn ±Cu (± Ag, Au) Vein and Stockwork Mine

This mine (Ministry of International Trade and Industry 1988) consists of more than 50 northwest and north-south striking polymetalic veins. The main vein is 1,900 meters long and and has an average width of 1.4 meters. Veins occur in an area 8 km (east-west) by 6 km (north-south). The host rocks are rhyolite, andesite, and associated pyroclastic rock, and minor sedimentary rocks of Cretaceous-Paleogene Ikuno Group. A zonal distribution of metals occurs. From the center of the deposit to margin are Cu, Cu-Zn, Zn, Pb-Zn, and Au-Ag assemblages. Sn and Sn-W zones also occur. Ore minerals are pyrargyrite, stephanite, native silver, native gold, and scheelite. Rare Se-bering benjaminite and matildite occur. Gangue minerals are quartz, calcite, fluorite, chlorite, siderite, and feldspar. The wallrocks are altered to quartz, chlorite, and sericite. A K-Ar isotopic age for adularia from the vein is 65.6±2.0 Ma and 63.0±1.9 Ma. The deposit was discovered in 807 and the mine closed in 1972. The mine is medium size with production of 47,000 tonnes Cu, 92,000 tonnes Zn, 19,000 tonnes Pb, 1,500 tonnes Sn grading 0.3 g/t Au, 60 g/t Ag, 1.4 percent Cu, 5 percent Zn, 0.8 percent Sn, and 1.5 percent Pb.

Otani W-Mo-Be Greisen, Stockwork, and Quartz-Vein Mine

This mine (Shibata and Ishihara, 1974) consists of northeast striking veins. The Main vein is 700 meters long and has an average thickness of 1.5 meters. The host rock is Cretaceous granodiorite. The main ore minerals are scheelite, cassiterite, chalcopyrite, arsenopyrite, pyrite, pyrrhotite, sphalerite, and stannite. Gangue minerals are mainly quartz, calcite, muscovite, and fluorite. Greisen alteration occurs in the wallrocks. The deposit formed during intrusion of Cretaceous granite. K-Ar isotopic age of muscovite from the vein is 91 Ma. The deposit was found in 1912, and the mine closed in 1983. The mine is medium size and has a production of 776,000 tonnes of ore (from 1951 to 1971) and has an average grade of 0.46 percent WO_3, 0.26 percent Cu, and 0.11 percent Sn.

Origin and Tectonic Controls for Inner Zone Southwest Japan Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along the East Asia magmatic arc related to subduction of the Kula and Pacific Ocean plates. The deposits in the belt are interpreted as having formed during siliceous granitoid magmatism. Granitoids in the Inner Zone of Southwest Japan are classified into three belts, from south to north, the Ryoke, Sanyo, and Sanin belts. Granitoids in the Ryoke and Sanyo belts are typically ilmenite-series, and those in the Sanin belt are magnetite-series (Ishihara and others, 1992). Ages of granitoids from the Ryoke and Sanyo belts are Cretaceous, however, ages of the Sanin belt granitoids are mostly Paleogene. The deposits are not related to granitoids of the Ryoke belt. Granitoids in the Sanyo belt host W-Sn-Cu skarn or veins deposits. Ishihara (1978) defined a W-Sn-Cu metallogenic province for this belt. Mo-Pb-Zn deposits characterize the Sanin belt, and were defined as a Mo-Pb-Zn metallogenic province by Ishihara (1978). The Inner Zone Southwest Japan metallogenic belt is thereby divided into two units–the southern W-Sn-Cu Sanyo belt and the Mo-Pb-Zn Sanin belt.

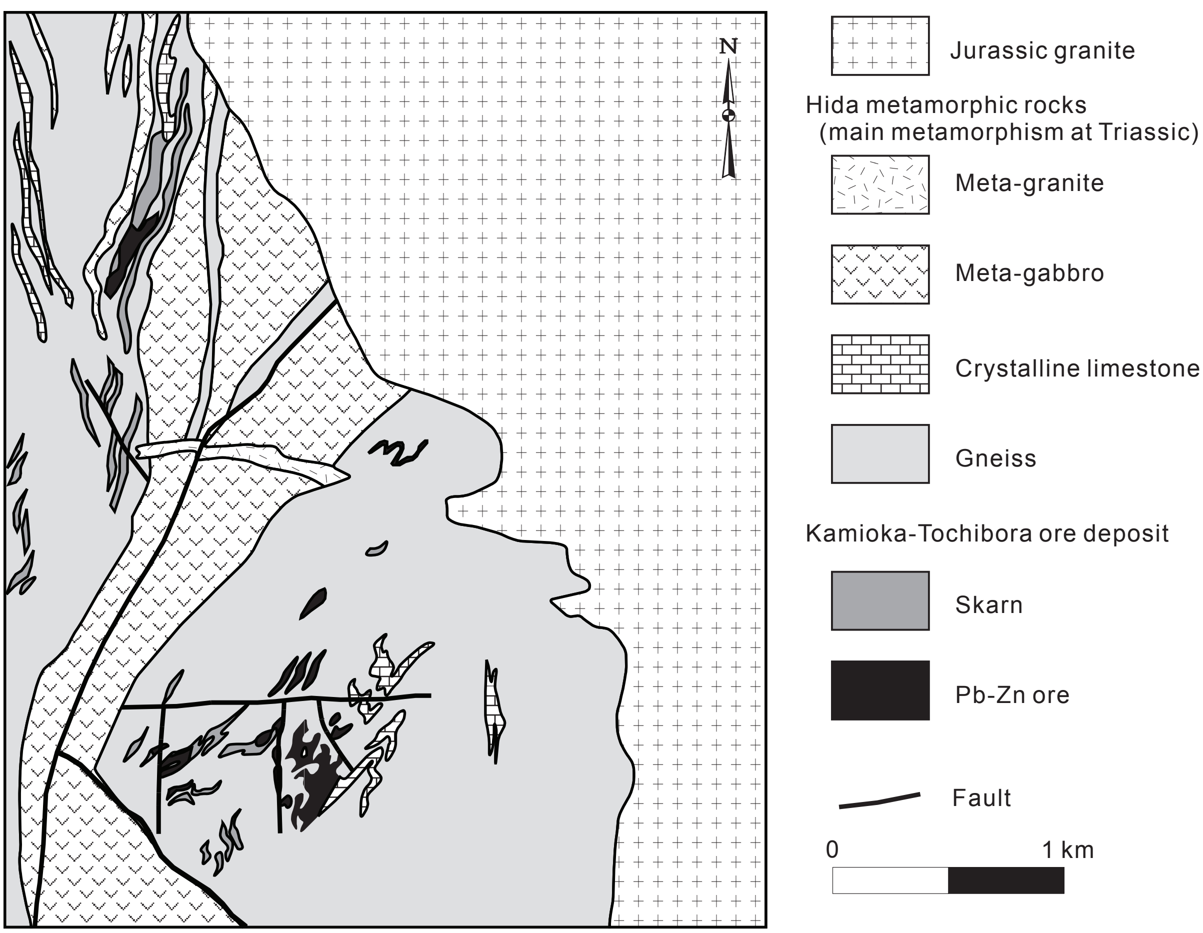


Figure 27. Generalized geologic map of Kamioka Mozumi Zn-Pb (Ag, Cu, W) skarn mine, Inner Zone Southwest metallogenic belt, Japan. Adapted from Kunugiza (1999).

Khandyga Metallogenic Belt of Ag-Sb Vein, Carbonate-Hosted As-Au Metasomatite, Clastic-Sediment-Hosted Sb-Au, and Clastic Sediment-Hosted Hg±Sb Deposits (Belt KA) (Russia, Verkhoyansk-Kolyma Region)

This Aptian through Late Cretaceous metallogenic belt is related to veins and replacements in the southern Verkhoyansk fold and thrust belt in the North Asian cratonal margin. The metallogenic belt extends longitudinally for 250 km and is as much as 30 km wide. The belt occurs (1) along the Sette-Daban tectonic zone that contains early to middle Paleozoic carbonate rock; (2) in the adjacent, eastern Kylakh tectonic zone that contains Riphean clastic and carbonate rock; and (3) in an area of periclinal closure containing Carboniferous, Permian, and Triassic marine clastic rock. The major deposits are at Senduchen, Khamamyt, Svetloe, and Khachakchan.

The main references on the geology and metallogenesis of the belt are Ozerova and others (1990) and Nokleberg and others (2003).

Senduchen Clastic-Sediment-Hosted Sb-Au Deposit

This deposit (V. Korostelev, written commun., 1963) consists of quartz-carbonate veins composed of orpiment, stibnite, realgar, arsenopyrite, sphalerite, enargite, chalcopyrite, and jamesonite. Individual orpiment concretions are as much as 10 tonnes. The veins intrude dark-gray Silurian limestone, are as much as 3.5 meters thick, and occur in a fault zone that cuts an anticline. The deposit is small and has an average grade of 10 to 58 percent As and 2.9 percent Sb.

Seikimyan Clastic Sediment-Hosted Hg±Sb Deposits

This deposit (Klimov, 1979; E. Vladimirtseva, written commun., 1987) consists of stringers and disseminations with quartz, dickite, cinnabar, calcite, and pyrite, and rare galena, sphalerite, and arsenopyrite. The deposit hosted in feathered shear and breccia zones in sandstone and has dimensions of 0.4 to 7 by 50 to 200 meters. The deposit occurs on northeastern limb of an anticline formed in Late Triassic sandstone and siltstone. The deposit is bounded by faults that occur parallel to the major, regional Bryungadin fault. The average grades are as much as 0.1 to 0.5 percent Hg.

Origin and Tectonic Controls for Khandyga Metallogenic Belt

The belt is interpreted as having formed during postaccretionary extension related to initiation of opening of the Eurasia Basin. The belt occurs in veins and replacements in the southern Verkhoyansk fold and thrust along the Sette-Daban tectonic zone.

Kukhtuy-Uliya Metallogenic Belt of Au-Ag Epithermal Vein, Porphyry Mo (±W, Sn, Bi), Porphyry Sn, and Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite Deposits (Belt KU) (Russia, Far East)

This Late Cretaceous through Paleocene metallogenic belt is related to veins that are associated with the Okhotsk-Chukotka volcanic-plutonic belt that intrudes and overlies the Okhotsk terrane. The metallogenic belt occurs in the Uliya volcanic zone of Okhotsk-Chukotka volcanic-plutonic belt and in the overlapped Okhotsk cratonal terrane. The metallogenic belt contains several Au deposits and occurrences. The main deposits are at Khakandzha and Yurievka.

The main references on the geology and metallogenesis of the belt are Moiseenko and Eirish (1996) and Onikhimovsky and Belomestnykh (1996).

Khakandzha Au-Ag Epithermal-Vein Deposit

This deposit (Onikhimovkiy and Belomestnykh, 1996) occurs in the Uliya volcanic zone that overlaps the Okhotsk terrane, and it is hosted in a large domal volcanic-plutonic structure that overlies a Late Triassic clastic sequence. The lower part of the volcanic-plutonic structure is andesite and the upper part is dacite and rhyolite. The volcanic rocks are intruded by a Late Cretaceous brecciated latite sill and granosyenite porphyry dikes, and by Paleocene basalt, diabase, and andesite dikes. The deposit consists of a gently dipping (15 to 30^{o} SW) zone of breccia and silica alteration that ranges from 7 to 52 meters thick. The zone is cut by numerous branching veins and veinlets of quartz and quartz-adularia that contain the Au-Ag minerals. The ore is low-sulfide (0.5 to 3.0 percent), and the main ore minerals are native gold, pyrite, galena, sphalerite, chalcopyrite, electrum, and native silver. Gangue minerals are quartz, adularia, rodhochrosite, rhodonite, and calcite. Gold fineness ranges from 532 to 774. The deposit contains 0.1 to 1,806 g/t Au (average of 8 to 10 g/t Au) and 0.1 to 32,676 g/t Ag (average of 350 to 600 g/t Ag). The Au/Ag ratio is 1:44. A high Mn content is typical for the deposit.

Yurievka Au-Ag Epithermal-Vein Deposit

This deposit (Onikhimovkiy and Belomestnykh, 1996) is hosted in the Uliya volcanic zone that consisits of Late Cretaceous andesite, basalt, dacite, rhiolite, and dacite. The deposit occurs along a tectonic zone that strikes sublatitudinally and dips steeply. The host rocks are altered to propilite. Gold ores are high-sulfide. The average grades is about 10 to 25 g/t Au, and the deposit contains about 7.1 tonnes of gold.

Origin and Tectonic Controls for Kukhtuy-Uliya Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along an active continental-margin arc consisting of the Albian through Late Cretaceous Okhotsk-Chukotka volcanic-plutonic belt.

Luzhkinsky Metallogenic Belt of Sn-W Greisen, Stockwork, and Quartz-Vein, Cassiterite-Sulfide-Silicate Vein and Stockwork, W-Mo-Be Greisen, Stockwork, and Quartz-Vein, Porphyry Sn, Porphyry Cu (±Au), Porphyry Cu-Mo (±Au, Ag), and Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposits (Belt LZ) (Far East Russia)

This mid-Cretaceous through early Tertiary metallogenic belt is related to veins, replacements, and granitoids in the East Sikhote-Alin volcanic-plutonic belt that overlies and intrudes Zhuravlevsk-Amur River terrane. The significant deposits in the belt are cassiterite-silicate-sulfide vein and porphyry Sn deposits (Yantarnoe), and Sn-W greisen, stockwork, and quartz-vein deposits (Tigrinoe and Zabytoe). The Sn deposits are interpreted as having formed in the mid-Cretaceous through early Tertiary between 100 and 50 Ma. Also in the same area are younger, generally uneconomic Sn-W greisen, stockwork, and quartz vein occurrences with K-Ar isotopic ages of 60 to 50 Ma. In addition to Sn deposits, the northern Luzhkinsky metallogenic belt contains sparse small porphyry Cu (±Au) deposits (Verkhnezolotoe) that are hosted in Senomanian and Turonian monzodiorite in the northwestern part of the metallogenic belt near the Samarka subduction-zone terrane that contains abundant oceanic rocks. The porphyry Cu (±Au) deposits are coeval with the Sn deposits of the Luzhkinsky metallogenic belt, but presumably reflect the anomalous Cu-rich composition of the Samarka terrane.

The main references on the geology and metallogenesis of the belt are Rodionov (1988) Ruchkin and others (1986), Gerasimov and others (1990), Korostelev and others (1990), Gonevchuk and Gonevchuk (1991), Nokleberg and others (2003), and Gonevchuk and others (1998).

Tigrinoe Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (fig. 28) (Korostelev and others, 1990; Gonevchuk and Gonevchuk, 1991) is complex and consists of (1) a greisen along the contact of a Li-F granite pluton; (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 that range from 3 to 100 cm thick and are hosted in metasedimentary rock adjacent to the granite intrusion; and (3) a sulfide-cassiterite breccia pipe that contains rock fragments of the stockwork and greisen cemented by quartz and lesser carbonate, fluorite, and sulfides. Three stages occur (1) early stage with quartz-molybdenite-bismuthinite; (2) middle stage of REE greisen with wolframite-cassiterite with high contents of Sc, Ni, and Ta; and (3) late stage with hydrothermal quartz-fluorite-carbonate-sulfide veins. In, Cd, Ag, and Se are enriched in sulfides in the two last stages. K-Ar isotopic age of the lithium-fluorine granite is 90 Ma ± 5 percent. A Rb-Sr isochron age for the Li-F granite is 86±6 Ma with an initial Sr ratio of 0.7093. A Rb-Sr age for the greisen is 73±18 Ma with an initial Sr ratio of 0.7105. The deposit is medium size and has an average grade of 0.14 percent Sn and 0.045 percent WO_3.

Vysokogorskoe Cassiterite-Sulfide-Silicate Vein and Stockwork Deposit

This deposit (fig. 29) (Litavrina and Kosenko, 1978; Ryabchenko, 1983) consists of quartz-chlorite-cassiterite, quartz-sulfide-cassiterite and sulfide-cassiterite veins,and fracture zones in Early Cretaceous olistostrome partially overlain by Late Cretaceous felsic volcanic rock. Sn minerals are related to the areas of quartz-tourmaline alteration about 5 to 6 meters thick. Average thickness of veins and zones is 1.2 to 1.4 meters, with lengths of 400 to 500 meters. The deposit extends to a depth of 700 meters. In addition to cassiterite, deposit contains chalcopyrite, arsenopyrite, and pyrrhotite, and rare galena and sphalerite. Sulfosalts of Bi and Ag are common. The deposit is medium size has a grade of 1.0 percent Sn. The deposit has been mined from the 1960s to present, and it is the largest mine in Kavalerova area.

Zimnee Sn-W Greisen, Stockwork, and Quartz-Vein Deposit

This deposit (fig. 30) (P.G. Korostelev and others, written commun., 1980; Nazarova, 1983) consists of breccia, breccia- and fracture-filling veins, zones of closely spaced veinlets, and pockets that occur in fracture zones. These structures are as much as 1,200 meters long, are extensive down dip, and vary from several tenths of a meter to several tens of meters wide. The deposit occurs near a granodiorite body and consists mainly of pyrrhotite, pyrite, arsenopyrite, sphalerite, stannite, and cassiterite. Far from the granodiorite, and in the upper part of veins, the deposit is mostly galena with fine-grained cassiterite. Near the granodiorite, the deposit consists of breccia-bearing fragments of Sn-sulfide minerals that are cemented by a quartz-mica (greisen) aggregate with arsenopyrite and cassiterite. The K-Ar age of altered rocks related to the Sn-polymetallic deposits is 75 Ma. The K-Ar isotopic age of the greisen and granodiorite is approximately 50 Ma. The deposit is regionally metamorphosed and deformed. The deposit is small and has an average grades of 0.1 to 3.0 percent Cu, 3.18 percent Pb, 0.59 percent Sn, and 4.09 percent Zn.

Arsenyevsky Sn-W Greisen, Stockwork, and Quartz-Vein Mine

This mine (fig. 31)((Rub and others, 1974; Radkevich and others, 1980) consists of a series of parallel, steeply-dipping quartz veins that extend as much as 1000 meters along strike and 600 to 700 meters downdip. The deposit is closely controlled by moderate- to steeply-dipping rhyolite dikes with a K-Ar isotopic age of 60 Ma. The ore-mineral assemblage is vertically zoned. From the top

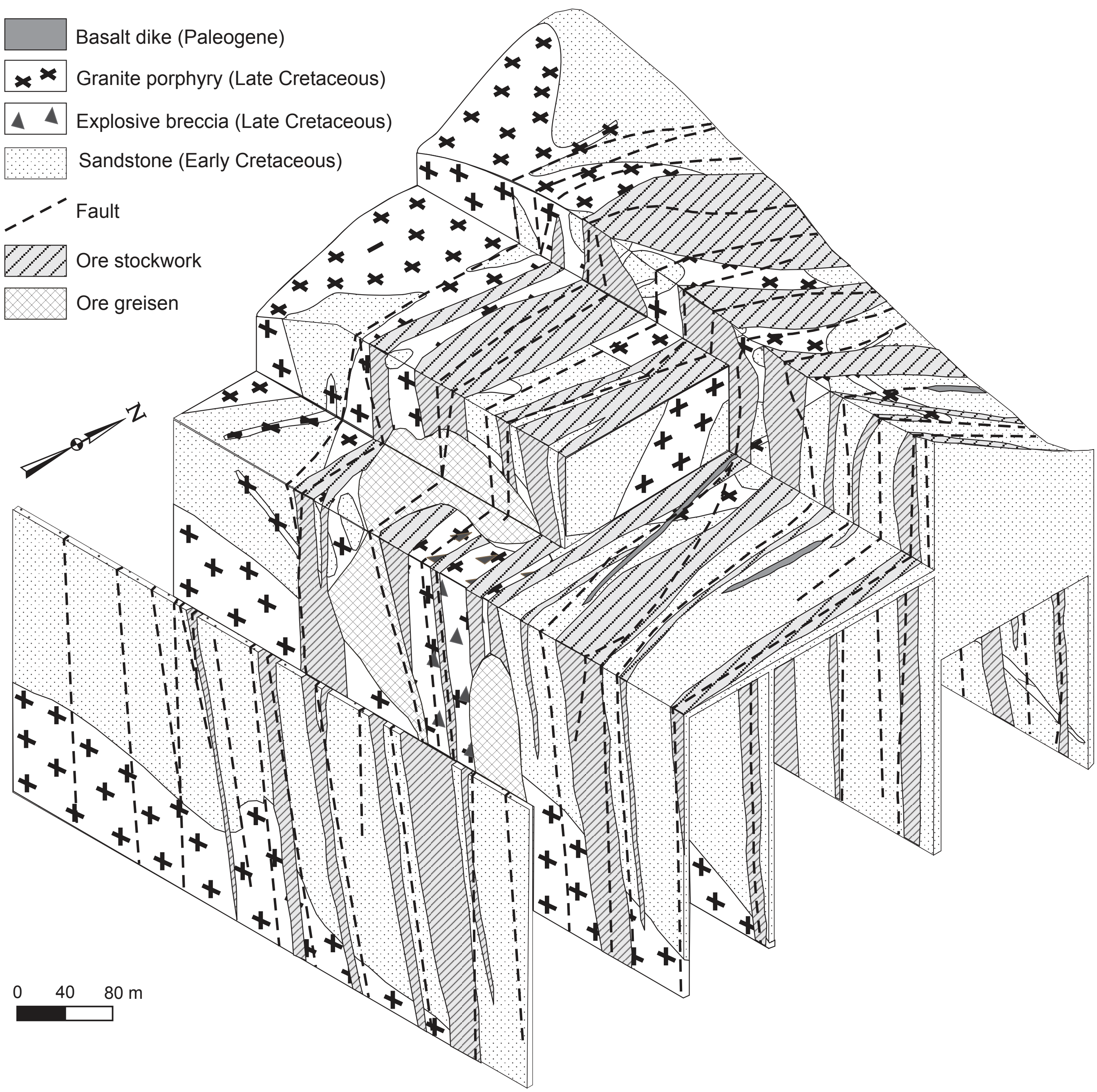


Figure 28. Generalized oblique-view geologic map and cross sections of Tigrinoe Sn-W greisen, stockwork, and quartz-vein deposit, Luzhkinsky metallogenic belt, Russian Southeast. Adapted from Gonevchuk and others (1998) and S.M., Rodionov (written commun., this study).

downwards, the assemblages are (1) quartz-cassiterite; (2) quartz-arsenopyrite-pyrrhotite; (3) polymetallic; and (4) arsenopyrite-pyrrhotite. The rhyolite exhibits quartz-sericite alteration. Local miarolithic cavities are filled with cassiterite. The deposit is medium size and has an average grade of 2 to 3 percent Sn, and locally as much as 20 to 25 percent Sn. The deposit also contains from 0.1 to 0.5 percent WO_3, 1 to 2 percent Pb and Zn , and a few hundred ppm Ag. The deposit has been mined since the 1970s.

Yantarnoe Porphyry Sn Deposit

This deposit (Rodionov, 1988) consists of veinlets and disseminations of cassiterite and sulfide minerals in a pipe-like body of volcanic breccia composed of trachyandesite and rhyolite. These units intrude Early Cretaceous clastic sedimentary rock. The older part of the deposit is in rhyolite in the pipe-like body that contains pyrite and chalcopyrite. The younger and major part of the deposit formed after intrusion of the explosive breccia and consists of metasomatic quartz-chlorite, quartz-sericite, and quartz-chlorite-sericite alterations that contain a sulfide-free cassiterite-chlorite-quartz assemblage and a Sn-polymetallic assemblage rich in galena, sphalerite, and chalcopyrite. The host igneous rocks are spatially related to Paleocene volcanic vents with K-Ar isotopic ages of about 65 Ma. The deposit is small and has an average grade of 0.1 to 2.17 percent Cu, 0.03 to 1.02 percent Pb, 7.3 percent Sn, and 0.7 to 2.22 percent Zn.

Origin and Tectonic Controls for Luzhkinsky Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids in the back-arc part of the the East-Sikhote-Aline continental-margin arc that is tectonically linked to oblique subduction of the ancestral Pacific Ocean Plate. Like the Sergeevka-Taukha and Kema metallogenic belts, the coeval Luzhkinsky metallogenic belt is hosted in the East Sikhote-Alin volcanic-plutonic belt. The differences between the coeval metallogenic belts are interpreted as being the result of the igneous rocks that host these metallogenic belts intruding different bedrock. The Sergeevka-Taukha metallogenic belt contains mainly B skarn, Zn-Pb (±Ag, Cu) skarn, and Pb-Zn polymetallic-vein deposits. The belt is hosted in, or near igneous rocks that intrude the Taukha subduction-zone terrane that contains a complex assemblage of abundant Paleozoic and early Mesozoic oceanic rocks, and lesser Jurassic and Early Cretaceous turbidite deposits. In contrast, the Kema metallogenic belt contains mainly Ag-Au epithermal deposits and is hosted in or near granitoids that intrude the Cretaceous island arc rocks of the Kema terrane. In contrast, the Luzhkinsky belt is related to a granitoid that intrudes the southern Zuravlevksk-Tumnin turbidite basin terrane. Additional controls for the Luzhkinsky metallogenic belt are (1) the turbidite deposits in the Zuravlevksk-Tumnin terrane which are enriched in Sn; and (2) the Luzhinsky belt, which occurs in the back-arc part of the East Sikhote-Alin igneous belt where magnetite-series granitoids are predominate.

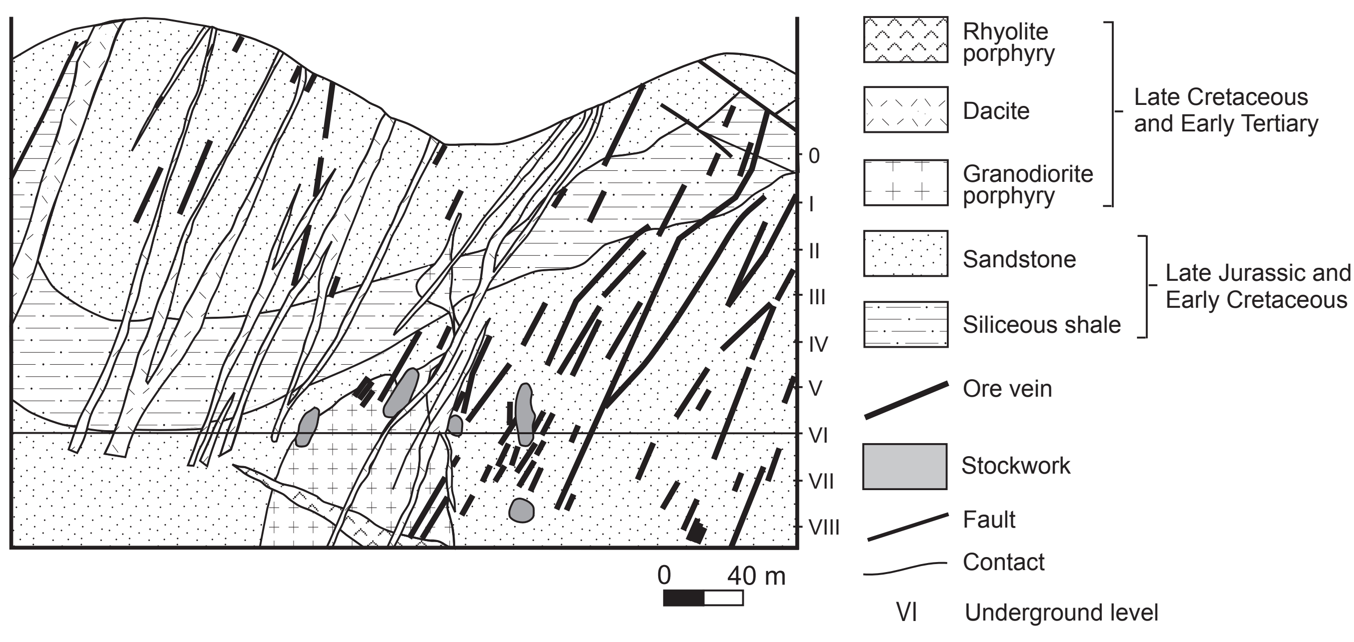


Figure 29. Schematic cross section of Vysokogorskoe cassiterite-sulfide-silicate vein and stockwork deposit, Luzhkinsky metallogenic belt, Russian Southeast. Adapted from Gonevchuk and others (1998).

Malo-Khingan Metallogenic Belt of Porphyry Sn and Rhyolite-Hosted Sn Deposits (Belt MK) (Russia, Far East)

This Late Cretaceous metallogenic belt is related to granitoids in the Khingan-Okhotsk volcanic-plutonic belt. The intrusive rocks of the Khingan-Okhotsk belt in this area are dominantly granite and are comagmatic with the volcanic rock. The granitoids are interpreted as being subduction-related, calc-alkalic igneous rocks, and they include both S-and I-type granite. The major deposit is at Khingan.

The main references on the geology and metallogenesis of the belt are Ognyanov (1986), Vrublevsky and others (1988), Natal'in (1991, 1993), Nokleberg and others (2003), Nechaev and others (1996), Sengor and Natal'in (1996), and Gonevchuk and others (1998).

Khingan Porphyry Sn Mine

This deposit (fig. 32) (Ognyanov, 1986) occurs in a pipe-shaped, hydrothermal explosion breccia that intrudes felsic volcanic rock. The deposit occurs in 15 areas in a zone that ranges from 10 to 50 meters across, varies from 100 to 400 to 500 meters long, and occurs at depth in a symmetrical breccia zone that is about 250 to 300 meters wide. The zone extends to depths of more than 1,200 meters. At the upper levels, the breccia is replaced by chlorite, and at the depths of 700 to 800 meters, the breccia is replaced by quartz-muscovite (sericite)-topaz greisen. Most of the district consists of quartz, fluorite, and cassiterite with subordinate arsenopyrite, marcasite, loellingite, chalcopyrite, and Bi-minerals. The deposit is interpreted as being probably genetically related to a subalkaline potassium granite that has a K-Ar isotopic

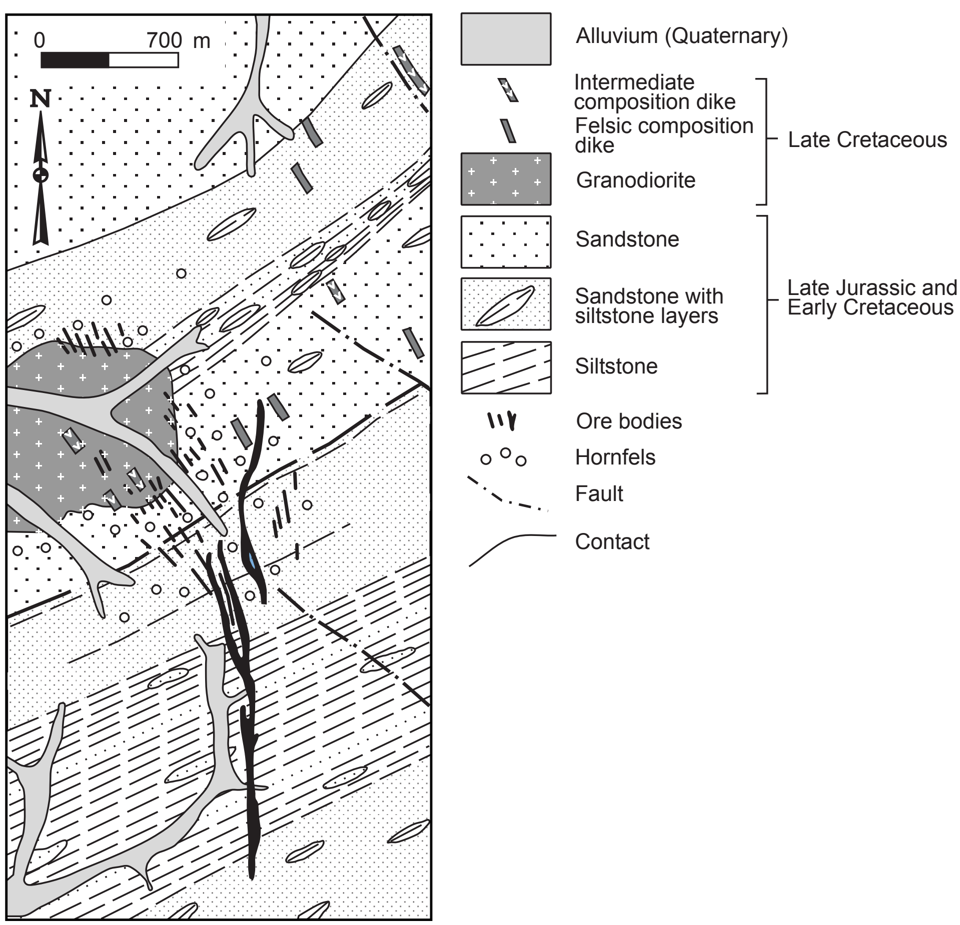


Figure 30. Generalized geologic map of Zimnee Sn-W greisen, stockwork, and quartz-vein deposit, Luzhkinsky metallogenic belt, Russian Southeast. Adapted from A.N. Ivakin and V.V. Orlovsky, written commun., 1978.

age of 90 to 80 Ma, a Rb-Sr whole-rock isochron age of 78 Ma, and an initial Sr isotopic ratio of 0.7123. The deposit has been mined since the 1960s, is medium size, and averages 0.6 to 0.7 percent Sn.

Origin and Tectonic Controls for Malo-Khingan Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along the Khingan transform continental-margin arc consisting of the Khingan-Okhotsk volcanic-plutonic belt that is tectonically related to oblique subduction of the ancestral Pacific Ocean Plate. The southwest part of Khingan-Okhotsk volcanic-plutonic belt occurs in a postaccretionary Cretaceous volcanic-tectonic basin in the eastern Bureya continental-margin arc superterrane. The basin is filled with mid-Cretaceous, intermediate volcanic rock and overlying Late Cretaceous tuff and rhyolite lava that range from 1.5 to 3.0 km thick. The basin overlies a Proterozoic metamorphic rock of the Bureya superterrane.

The Khingan-Okhotsk belt is part of the Khingan continental-margin arc that is interpreted as having formed from oblique subduction of the ancestral Pacific Ocean Plate. Fragments of this plate are interpreted as having occurred in tectonically interwoven units of the Amur River, Khabarovsk (younger Early Cretaceous part), and Kiselevka-Manoma subduction-zone terranes. This tectonic linkage of the arc to the subduction units is based on: (1) occurrence of subduction-zone terranes outboard (oceanward) of, and parallel to the various parts of the Khinghan arc; (2) the formation of melange structures during the Early and mid-Cretaceous; and (3) where not disrupted by extensive Cretaceous movement, the dipping of melange structures and bounding faults toward and beneath the igneous units of the arc. Formation of the Khingan arc and related subduction is generally interpreted as having ended in the late mid-Cretaceous when oblique subduction changed into sinistral-slip faulting along the outboard margin of the arc.

Pilda-Limuri Metallogenic Belt of Sn-W Greisen, Stockwork, and Quartz-Vein, W-Mo-Be Greisen, Stockwork, and Quartz-Vein, Ag-Sb Vein, Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork, and Granitoid-Related Au-Vein Deposits (Belt PL) (Russia, Far East)

This Late Cretaceous metallogenic belt is related to veins, replacements, and granitoids related to the Evur zone of the Khingan-Okhotsk volcanic-plutonic belt. The belt occurs at the junction area of the Amgun, Zhuravlevsk-Amur, and Samarka terranes. Several small deposits of different types occur in the belt. The belt contains small deposits at Agnie-Afanasievskoye, Dyapp, and Uchaminskoye.

The main reference on the geology and metallogenesis of the belt is Moiseenko and Eirish (1996).

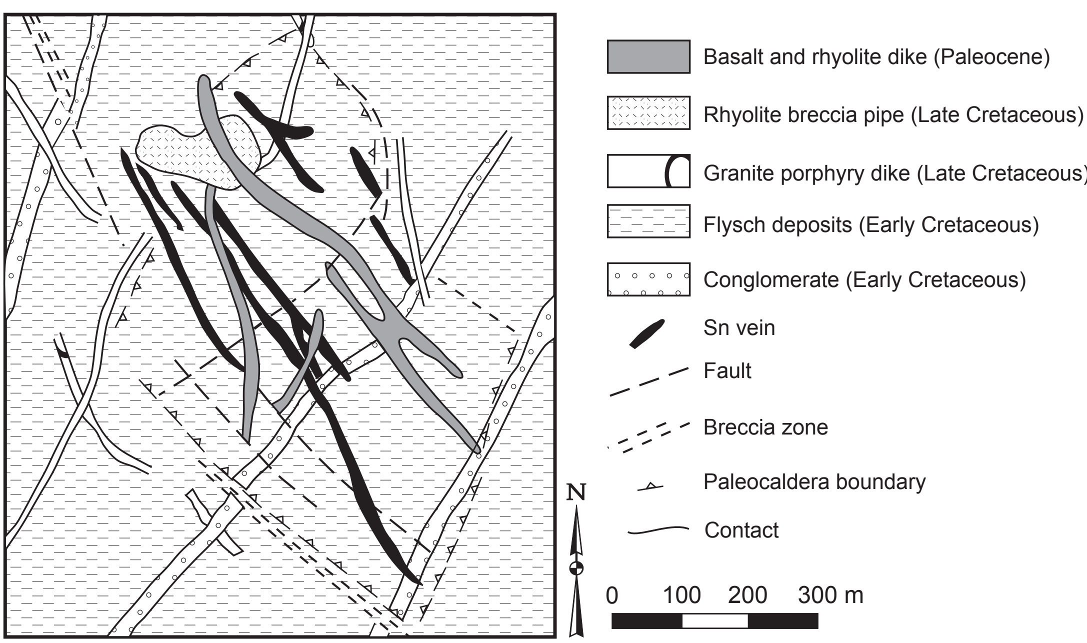


Figure 31. Generalized geologic map of Arsenyevsky Sn-W greisen, stockwork, and quartz vein mine deposit, Luzhkinsky metallogenic belt, Russian Southeast. Adapted from Ratkin (1995).

Agnie-Afanasievskoye Granitoid-Related Au Vein Mine

This mine (Moiseenko and Eirish, 1996) occurs in a vein system that ranges up 0.5 km wide and as much as 1.0 km long. The system occurs in an anticline formed in Early Cretaceous sandstone and siltstone. Several diorite dikes occur along joints that cross host rock bedding. Veins range from 200 to 700 meters long and 5 to 10 cm wide, strike northeast, and dip moderately. The veins contain mainly quartz, carbonate, feldspar, chlorite, and sericite with as much as 1 percent ore minerals. The ore minerals are pyrite, arsenopyrite, antimonite, chalcopyrite, sphalerite, chalcocite, and gold, and rare cassiterite, wolframite, sheelite, and molybdenite. Pyrite is dominant and forms disseminations and thin veinlets in quartz. The amount of arsenopyrite is less than pyrite and occurs in high-grade zones. Gold grains range from 1 to 6 mm and occur in bunches, thin veinlets, and rare octahedron crystals in fractured quartz. Gold fineness is 790.

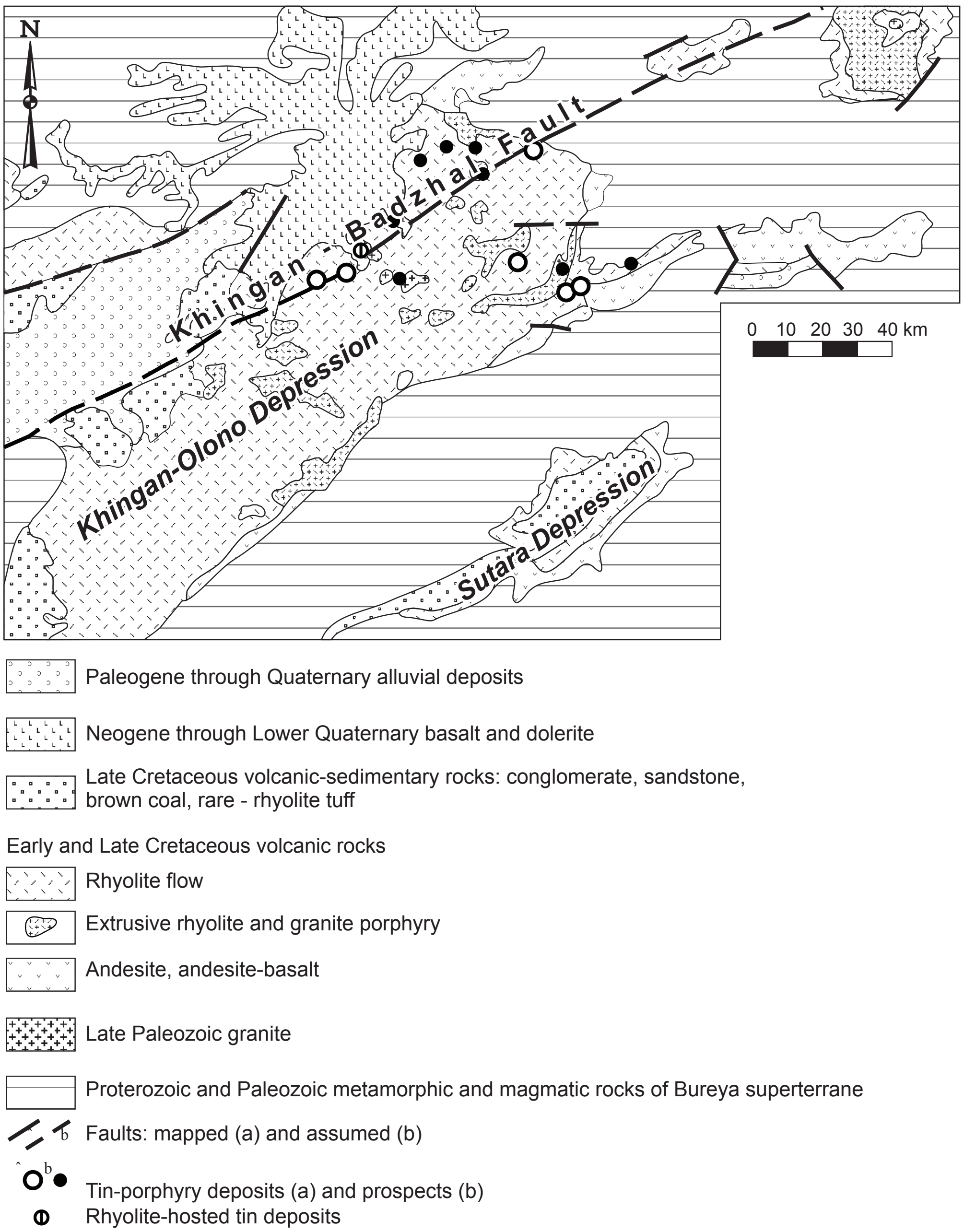


Figure 32. Generalized geologic map of Khingan porphyry Sn mine, Malo-Khingan metallogenic belt, Russian Southeast. Adapted from N.P. Emel'yanov, written commun. (1964).

Host rocks are altered near the quartz veins and contain as much as 2 to 4 g/t Au. The deposit is small and produced 12 tonnes Au. The average grades is about 25 g/t Au, with a maximum grade 1 to 2 kg/t Au. The deposit was mined from 1936 to 1962.

Dyappe Au-Sb Vein Deposit

This deposit (Moiseenko and Eirish, 1996) consists of low sulfide quartz veins and lesser vein breccia with pyrite, arsenopyrite, antimonite, magnetite, and gold. Pyrite contains from 40 to 50 g/t to 1.5 kg/t Au . Ore gold is fine-grained from 0.01 to 0.1 mm to 1.2 mm. Au fineness is 600 to 650. Ore contains Te. Several veins, dipping 65 to 85° SE, are prospected. Veins and breccia range from a 4 to 45 cm thick and from 30 to 800 meters long. The deposit occurs in the exo- and endocontact zone of diorite stock that intrudes Late Cretaceous black shale. The deposit is small. Primary ore grades as much as 5 to 6 g/t Au, and the oxidation zone grades as much as 200 to 300 g/t Au. The deposit was mined for Au from 1935 to1938 and from 1941 to 1942 for Sb.

Uchaminskoye Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Deposit

This deposit (fig. 33) (V. Kochubey, written commun., 1955; Moiseenko and Eirish, 1996) occurs in folded Early Cretaceous sandstone and siltstone that is intruded by a Late Cretaceous granite porphyry stock and lamprophyre dikes. The deposit occurs in a linear zone of fractured sedimentary rock that is about 1.5 km wide and 0.8 to 30.0 meters thick. The zone contains linear stockworks and several quartz-sulfide veins that range from 1.5 to 3.0 meters thick. Veins and veinlets consist of fine-grained quartz and sulfides including pyrite, pyrrhotite, and arsenopyrite. The deposit is small and has an average grade of 7.0 to 12.2 g/t Au, 30 to 70 g/t Ag, 0.5 to 1.0 percent Pb, and 0.03 to 0.5 percent Sn.

Origin and Tectonic Controls for Pilda-Limuri Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along the Khingan transform continental-margin arc that is related to oblique subduction of ancestral Pacific Ocean Plate.

Preddzhugdzhursky Metallogenic Belt of Porphyry Cu-Mo (±Au, Ag), Porphyry Cu (±Au), and Au-Ag Epithermal Vein Granitoid-Related Au-Vein, and Cu (±Fe, Au, Ag, Mo) Skarn Deposits (Belt PD) (Russia, Far East)

This Late Cretaceous through Paleocene metallogenic belt is related to granitoids in the Preddzhugdzhur volcanic zone of the Okhotsk-Chukotka volcanic-plutonic belt that intrudes and overlies the Batomga composite terrane of the East Aldan superterrane, the Dzugdzur anorthosite belt, and the Ulkan plutonic belt. Numerous deposit types occur in the belt and almost all of them are poorly studied. The best studied deposit is at Avlayakan.

The main reference on the geology and metallogenesis of the belt is Moiseenko and Eirish (1996).

Avlayakan Au-Ag Epithermal-Vein Deposit

This deposit (Moiseenko and Eirish, 1996) occurs along the southern flank of Dzhugdzhur district and is hosted in Late Cretaceous dacite, rhyolite, and andesite that overlie Precambrian gabbro and anorthosite. The deposit consists of quartz and quartz-carbonate veins that occur in several sublongitudinal zones. Two zones are well explored. The Central zone varies from 5 to 40 meters thick, is about 3 km long, and consists of quartz and quartz-carbonate veins and veinlets with disseminated gold. Hosted volcanic rocks are altered as much as chlorite, sericite, hydromica, and quartz propilite. The average gold content for two intersections is 34.5 and 72.5 g/t Au. The Northeastern zone occurs 450 meters north of the Central zone, ranges from 50 to 120 meters thick, is 3 km long, and consists of numerous branching quartz veins and breccias with minor sulfides. The average grade is about 10.8 g/t Au for one intersection. The average for the whole deposit is 18.2 g/t Au and 38.1 g/t Ag. The Au:Ag ratio is 1:2 to 4. The deposit is small.

Origin and Tectonic Controls for Preddzhugdzhursky Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along an active continental-margin arc consisting of the Albian through Late Cretaceous Okhotsk-Chukotka volcanic-plutonic belt.

Selennyakh Metallogenic Belt of Carbonate-hosted Au-Sb-Hg, Volcanic-Hosted Hg, Au-Ag Epithermal Vein, and Ag-Sb Vein Deposits (Belt SE) (Russia, Verkhoyansk-Kolyma Rgion)

This Aptian through Late Cretaceous metallogenic belt is related to veins and replacements in the Omulevka passive continental-margin terrane of the Kolyma-Omolon superterrane and adjacent terranes. The belt contains carbonate and hosted Au-Sb-Hg (Gal Khaya, Pologoye, and Arbat deposits), volcanic-hosted Hg (Dogdo deposit), and Ag-Sb vein (Kysylga deposit) deposits. The Selennyakh metallogenic belt was previously named the Uyandina-Yasachnaya Hg ore belt (Obolenskiy and Obolenskaya, 1968; Indolev and others, 1980). The belt is 80 km wide, extends for 200 km. The veins and replacements are mainly in Late Jurassic volcanic rock of the

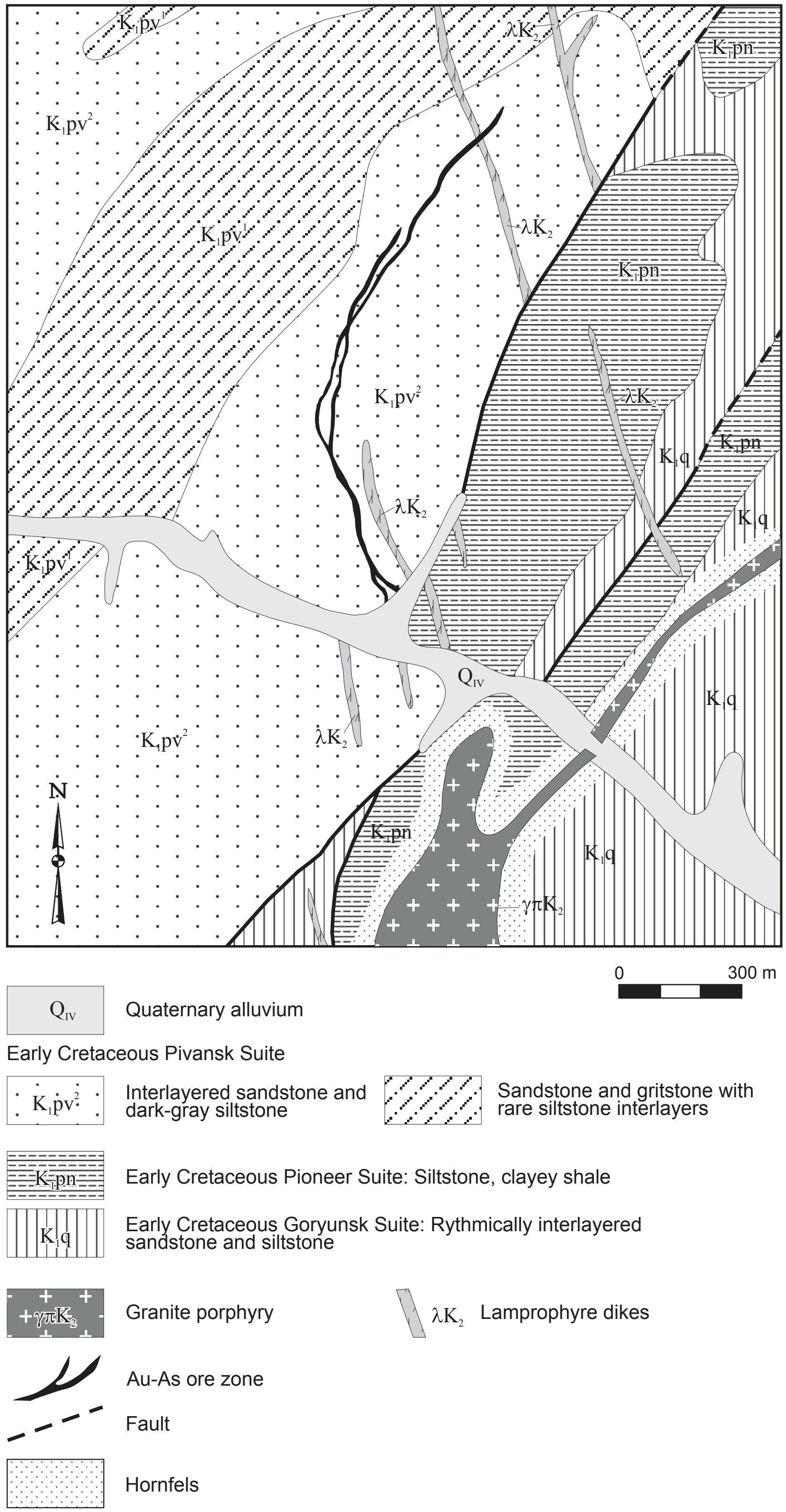


Figure 33. Generalized geologic map of Uchaminskoye polymetallic Pb-Zn±Cu (±Ag, Au) vein and stockwork deposit, Pilda-Limuri metallogenic belt, Russian Southeast. Adapted from L.V. Eyrish, written commun., 1976.

Uyandina-Yasachnaya volcanic belt that unconformably overlies the Omulevka terrane. In the northwestern part of the belt is the Sakyndzha ore district (Au-Hg-Sb) and to the southeast is the Dogdo (Hg-Au-Ag) ore district. In other areas of the belt are numerous Hg-Au occurrences.

The main references on the geology and metallogenesis of the belt are Obolenskiy and Obolenskaya (1968), Indolev and others (1980), Shoshin and Vishnevskiy (1984), Parfenov and others (1999), and Nokleberg and others (2003).

Kysylga Ag-Sb Vein Deposit

This deposit (Shoshin and Vishnevskiy, 1984; E. Vladimirtseva, written commun., 1985; Nekrasov and others, 1987; Gamyanin and Goryachev, 1988.) consists of veins in a zone that varies from 0.60 to 1.25 meters thick and as much as 400 meters long. The veins consist of gangue quartz and calcite with about 1 to 5 percent arsenopyrite, pyrite, Ag-tetrahedrite, pyrrhotite, sphalerite, galena, chalcopyrite, boulangerite, Ag-jamesonite, and Au (fineness of 638). The veins strike roughly east-west to northeast and dip steeply south. The veins exhibit brecciaiated or, less commonly, comb and massive structures, and often grade into stringers. The deposit occurs along feathered fissures in a northwest-striking major fault that cuts Late Triassic sandstone and siltstone. Host rocks are folding and are intensely contact metamorphosed adjacent to a granitic intrusive. Wallrocks exhibit sericite, chlorite, and feldspar alteration. The average grade is 3.0 to 84.5 g/t Au, 1 to 37 g/t Ag; 0.01 to 0.1 As; 0.01 to 0.04 percent Sb, 0.002 percent Sn, and 0.03 percent Pb.

Origin and Tectonic Controls for Selennyakh Metalogenic Belt

The belt is interpreted as having formed during postaccretionary extension related to initiation of the opening of the Eurasia Basin. The belt extends northwest along the Omulevka terrane, which is composed of early and middle Paleozoic carbonate rock that is unconformably overlain by Late Jurassic volcanic and sedimentary rocks of the Uyandina-Yasachnaya volcanic belt.

Sergeevka-Taukha Metallogenic Belt of Granitoid-Related Au Vein, Boron (datolite) Skarn, Zn-Pb (±Ag, Cu) Skarn, Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork, Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite, Au-Ag Epithermal-Vein, and Porphyry Cu (±Au) Deposits (Belt ST) (Russia, Far East)

This Late Cretaceous and early Tertiary metallogenic belt is related to veins and granitoids related to East Sikhote-Alin volcanic-plutonic belt that overlies and intrudes Sergeevka, Samarka, and Taukha terranes. The belt includes several deposit types.

The main references on the geology and metallogenesis of the belt are Efimova and others (1978), Garbuzov and others (1987), Ratkin and others (1990, 1991), Ratkin and Watson (1993), Ishihara and others (1992), Vasilenko and Valuy (1998), and Nokleberg and others (2003).

Progress Granitoid-Related Au-Vein Deposit

This deposit (A.N. Rodionov, written commun., 1991) consists of sulfide-poor veins and small veinlets that contain pyrite, arsenopyrite, quartz, and Au. In addition the deposit contains poorly mineralized fracture zones, mylonite zones, and zones of metasomatically-altered carbonate and chlorite-sericite rock. The deposit occurs in, or near a Late Cretaceous granitoid pluton and dikes that intrude Cambrian granitic and gabbro rocks of the Sergeevka complex. The deposit is also the source for local placer Au mines. The deposit is medium size and has an average grade of 5.89 g/t Au.

Askold Granitoid-Related Au-Vein Deposit

This deposit (M.I. Efimova and others, written commun., 1971; Efimova and others, 1978) consists of a Au-quartz vein stockwork in a Mesozoic granite that is altered to greisen and that intrudes Paleozoic volcanic and sedimentary rock. A K-Ar muscovite age for alteration associated with the vein is 83.2 Ma. The deposit is prospected to depths of more than 100 meters. The deposit is medium size and has an average grade of 5.9 to 7.6 g/t Au.

Dalnegorsk Boron (datolite) Skarn Mine

This major, world-class boron mine (fig. 34) (Ratkin, 1991; Ratkin and Watson, 1993; P. Layer, V. Ivanov, and T. Bundtzen, written commun., 1994) occurs in a thick skarn formed in a large, upturned olistolith of bedded Triassic limestone that is enclosed in Early Cretaceous clastic sedimentary rock. The skarn extends to a depth of approximately 1 km, where it is intruded by a granite pluton. 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 an approximate K-Ar isotopic age of 70 Ma). The first-stage skarn consists of grossular-wollastonite skarn, is concentrically zoned, and consists of 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. An Ar-Ar isotopic age for orthoclase in the second stage skarn assemblage is 57 Ma. The silicate mineralogy of the first-stage skarn is similar to Zn-Pb (±Ag, Cu) skarn deposits in the belt. B isotopic studies indicate a magmatic source for boron. The Dalnegorsk open-pit mine at the deposit is explored to a depth of 1 km. The deposit is very large and had been mined from the 1970s to the present. The deposit produces more than 90 percent of all borate in Russia.

Nikolaevskoe Zn-Pb (±Ag, Cu) Skarn Mine

This mine (Garbuzov and others, 1987; V.V. Ratkin in Nokleberg and others, 1997) is hosted in a giant olistolith of Triassic limestone that is part of an Early Cretaceous accretionary complex. The skarn occurs along the contacts of limestone with hosting siltstone and sandstone, and with overlying felsic volcanic rock of a Late Cretaceous through Paleogene postaccretionary sequence. Small skarn bodies also occur in limestone blocks in the volcanic rock that were faulted from the underlying basement. The ore minerals are dominantly galena and sphalerite that replace an older hedenbergite skarn near the surface, and, at depth, replace a garnet-hedenbergite skarn. Subordinate ore minerals are chalcopyrite, arsenopyrite, pyrite, pyrrhotite, fluorite, and

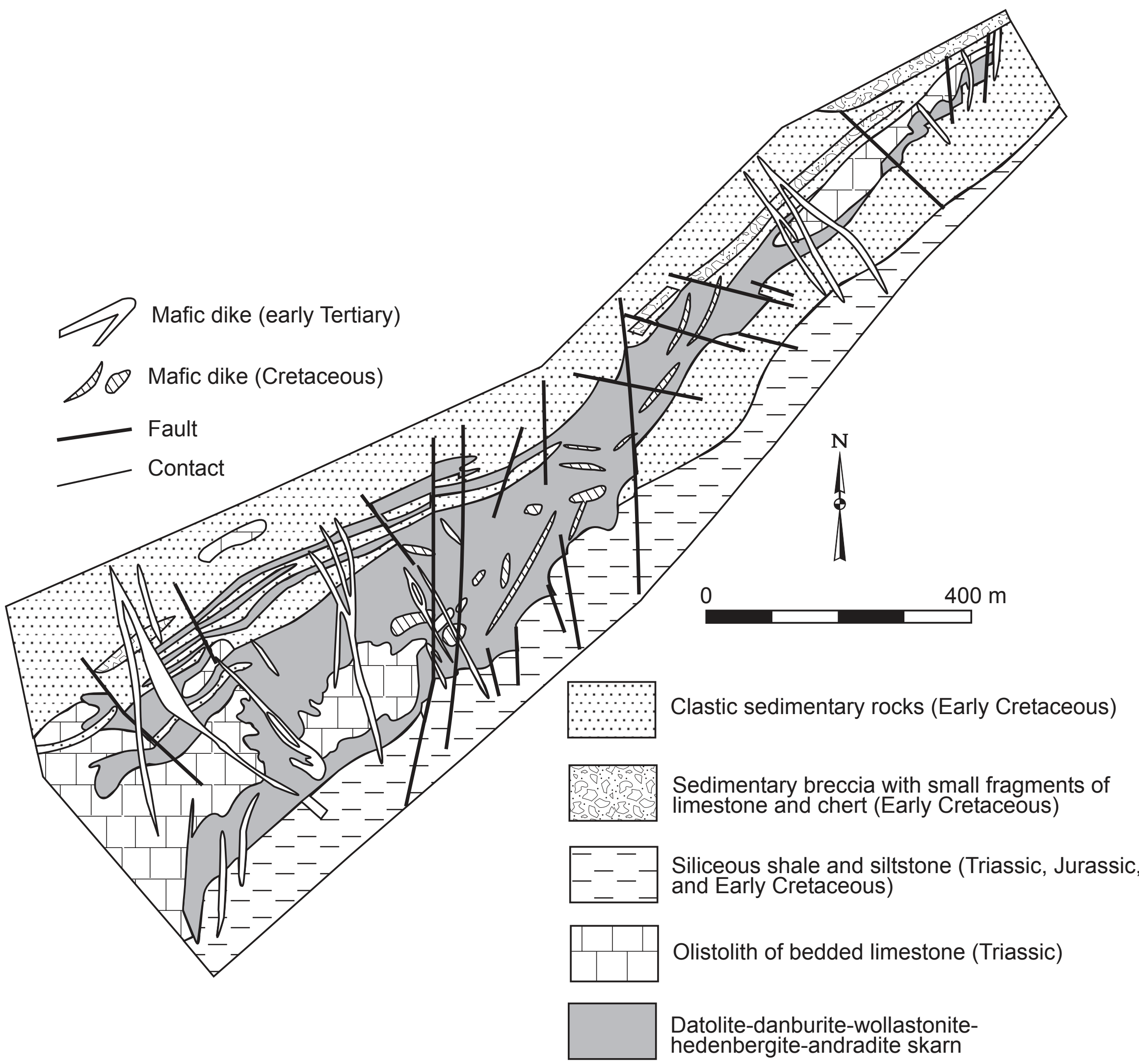


Figure 34. Generalized geologic map of Dalnegorsk boron (datolite) skarn mine, Sergeevka-Taukha metallogenic belt, Russian Southeast. Adapted from Ratkin (1991).

Ag-sulfosalts. The K-Ar age of deposits ranges from 80 to 60 Ma. Average grades are 62 g/t Ag, 1.5 to 8.7 percent Pb, and 1.36 to 10.5 percent Zn. The deposit has been mined from the 1970s to the present.

Partizanskoe Zn-Pb (±Ag, Cu) Skarn Mine

This mine (Ratkin and others, 1991) consists of numerous, small, steeply-dipping skarn bodies that occur at the contact of a Triassic limestone olistolith surrounded by Early Cretaceous clastic rock. The deposits merge and form a single skarn body about 400 meters below the surface and pinch out at a depth of approximately 600 meters. The skarn assemblages are vertically zoned, and higher temperature assemblages occur deeper. Massive, densely disseminated Ag-Pb-Zn sulfides (with a Pb/Zn ratio of about 1.0) occur above a quartz-calcite aggregate in the upper part of the deposit. Massive, densely-disseminated Pb-Zn sulfides (with a Pb/Zn ratio of about 0.8) are associated with Mn hedenbergite skarn and occur in the middle part of the deposit. Disseminated Zn sulfides (with a Pb/Zn ratio of about 0.5) occur 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, and 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 deposits is bracketed between 80 to 60 Ma by basalt dikes that intrude the deposit at the contact of olistolith, and by the lower part of the overlying volcanic strata that are intruded by deposit. The deposit consists of four or more related ore bodies that occur along an about 5 km strike length, including the Soviet 2, Partizansk East, Partizansk West, and Svetliyotvod bodies. The underground workings have a total length of about 11 km. The deposit is medium size, and the average grades are 67.6 g/t Ag, 1.5 to 3 percent Pb, and 0.6 to 4 Zn percent. The deposit has been mined from the 1950s to present.

Krasnogorskoye Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite Deposit

This deposit (fig. 35) (Ratkin and others, 1990) consists of steeply-dipping quartz-sulfide veins that extend as much as several hundred meters long along strike and range from 0.2 to 1.5 meters thick. The veins intrude Late Cretaceous tuff. Sphalerite, cassiterite, and galena are the dominant ore minerals, and the margins of veins contain pyrite-marcasite-pyrrhotite with lesser Sb-Ag-sulfosalts. In the deeper level of the deposit, galena contains as much as several percent Ag and Bi in matildite. The volcanic rock adjacent to the polymetallic veins is 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 a Late Cretaceous and Paleocene volcanic vent. The vent breccia also contains disseminated sphalerite, galena, and cassiterite. The veins formed immediately after deposits of the vent breccia, which has an approximate K-Ar isotopic age of 65 Ma. The deposit is medium size, and the average grades are 62 g/t Ag, 5 percent Pb, 0.26 percent Sn, and 6.77 percent Zn.

Origin and Tectonic Controls for Sergeevka-Taukha Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along the East-Sikhote-Aline continental-margin arc related to subduction of the ancestral Pacific Ocean Plate. This belt is hosted in, or near igneous rocks that intrude the Taukha subduction-zone terrane that contains a complex assemblage of abundant Paleozoic and early Mesozoic oceanic rocks and lesser Jurassic and Early Cretaceous turbidite deposits.

Taryn Metallogenic Belt of Clastic-Sediment-Hosted Sb-Au Deposits (Belt TAR) (Russia, Verkhoyansk-Kolyma Region)

This Aptian through Late Cretaceous metallogenic belt is related to veins and replacements in the Kular-Nera continental-margin turbidite terrane and Verkhoyansk fold and thrust belt in the North Asian cratonal margin. The belt extends northwest for 500 km along most of the Kular-Neta terrane. The belt contains numerous major Sb-Au deposits at Tan, Maltan, Kinyas'-Yuryakh, Sarylakh, Kyunkugur, Kim, El'gi-Tonor, Tobychan, Lower Tordocha, Kekhtey, Kemyustakh, Byindzha, Aulachan, Dzholakag, Nitkan, Uzlovoye, Burgavliyskoye, Sentachan, and Markovskoye, and lesser Ag and Ag-Sb polymetallic deposits at Kupol'noye and Dichek. The major deposits are at Sarylakh, Senatachan, and Kupol'noe.

The main references on the geology and metallogenesis of the belt are Berger (1978, 1986), Indolev and others (1980), V.V. Maslennikov, written commun. (1985), Shour (1985), and Gamyanin and Goryachev (1988).

Senatachan Clastic-Sediment-Hosted Sb-Au Deposit

This deposit (fig. 36) (Berger, 1978; Zharikov, 1978; Indolev and others, 1980; Maslennikov, written commun., 1985; Shour, 1985) consists of two rod-like veins that range from 85 to 200 meters long and 0.2 to 3.1 meters thick. The veins occur in shear zones that strike northwest, dip 60 to 80° NW and extend to a depth of 600 meters or more. The main ore minerals are stibnite and quartz, with lesser ankerite, muscovite, pyrite, arsenopyrite, dickite, and hydromica, and rare sphalerite, Au, chalcostibnite, berthierite, tetrahedrite, zinkenite, jamesonite, aurostibnite, and chalcopyrite. Wallrocks exhibit quartz, carbonate, hydromica and dickite alteration. Disseminated pyrite and stibnite occur in aureoles around the deposit. The deposit is hosted in Late Triassic (Norian and Rhaetian) clastic rock that is deformed into northwest-trending, gently-plunging folds. The deposit occurs along the northwest-trending Adycha-Taryn fault and is conformable to folding. The average grade is 3.2 to 40.3 percent Sb with as much as 30 percent Sb and 50 g/t Au. The deposit is medium size, has been mined, and has reserves of 100,000 tonnes of Sb.

Origin and Tectonic Controls for Taryn Metallogenic Belt

The belt is interpreted as having formed during postaccretionary extension related to initiation of the opening of the Eurasia Basin.

Tumnin-Anyui Metallogenic Belt of Porphyry Sn, Cassiterite-Sulfide-Silicate Vein and Stockwork, and Au-Ag Epithermal-Vein Deposits (Belt TA) (Russia, Far East)

This Late Cretaceous through Paleocene metallogenic belt is related to veins and granitoids in the perivolcanic zone of the East Sikhote-Alin volcanic-plutonic belt that overlies and intrudes the Kema, Luzhkinsky, and Samarka terranes. The major deposits are at Mopau and Tumninskoye.

The main references on the geology and metallogenesis of the belt are Moiseenko and Eirish (1996) and Nokleberg and others (2003).

Mopau Porphyry Sn Deposit

This deposit (Finashin, 1959; Usenko and Chebotarev, 1973) is the most important deposit of the belt and consists

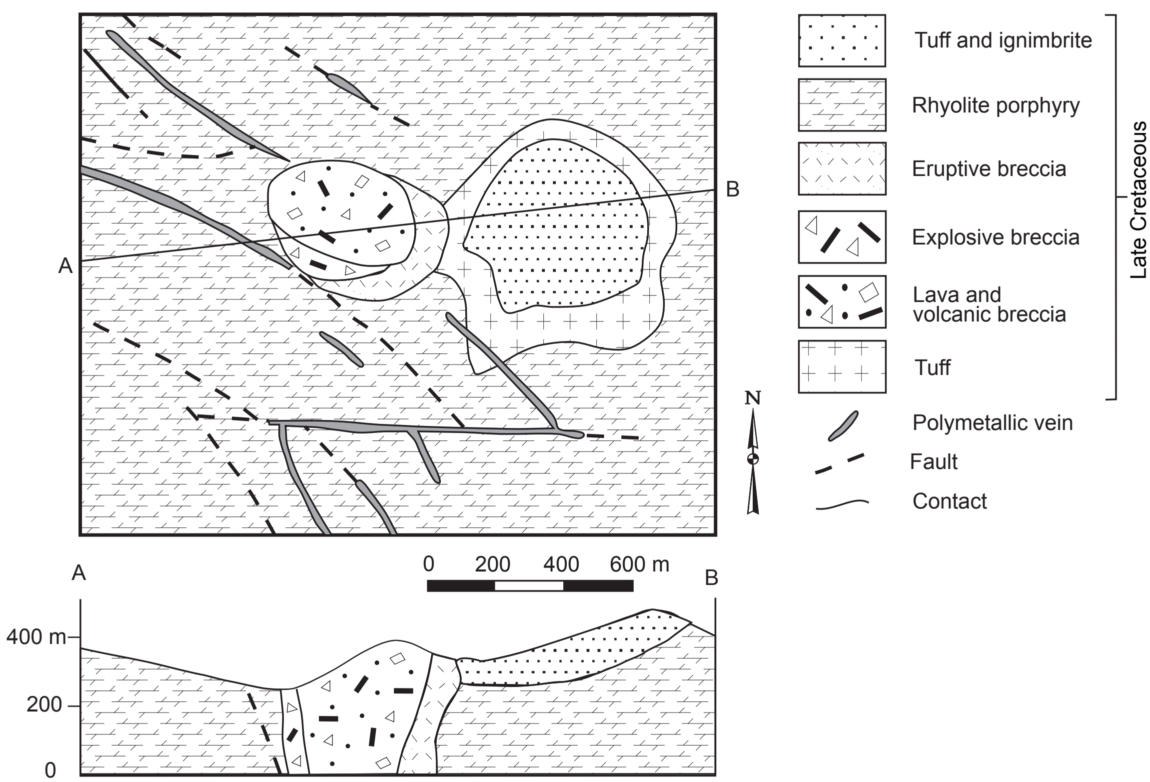


Figure 35. Generalized geologic map and schematic cross section of Krasnogorskoye polymetallic (Pb, Zn±Cu, Ba, Ag, Au) volcanic-hosted metasomatite deposit, Sergeevka-Taukha metallogenic belt, Russian Southeast. Adapted from Ratkin and others (1990).

of lenticular zones in quartz-sericite rock. The zones contain abundant quartz-cassiterite, cassiterite-quartz-feldspar, quartz-cassiterite-chlorite, and quartz-cassiterite-arsenopyrite-chlorite veinlets. The veinlets range from paper-thin to 0.5 cm thick and, locally, as much as 10 cm thick. Where closely-spaced, the veinlets form an intricate stockwork as much as 100 meters across with high Sn content. The zones are more than 400 meters long and several tens of meters thick. Some zones occur at contacts with diabase porphyry dikes. The deposit extends to depths of more than 200 meters, is sulfide poor, and is easily concentrated. The deposit is hosted in a group of closely-spaced volcanic vents composed of rhyodacite breccia that is intruded by felsite porphyry intrusions and quartz porphyry dikes. The deposit is related to a major felsic pluton. The age of the deposit

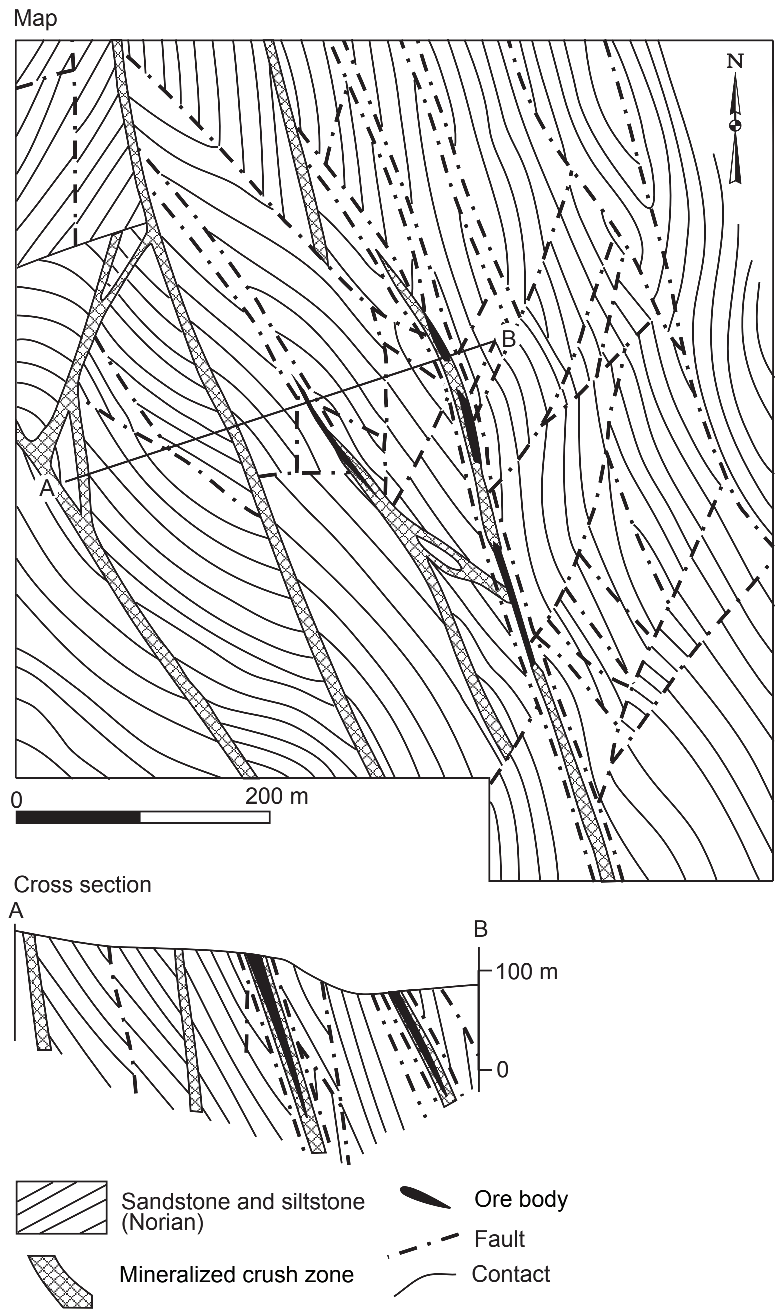


Figure 36. Generalized geologic map and schematic cross section of Senatachan clastic-sediment-hosted Sb-Au deposit, Taryn metallogenic belt, Yakutia, Russia. Adapted from Shour (1985).

interpreted as being Late Cretaceous through Paleogene. The deposit is small and has an average grade of 0.3 percent Sn.

Tumninskoye Au-Ag Epithermal-Vein Mine

This mine (Moiseenko and Eirish, 1996) occurs in the northern part of Samarka terrane. The deposit consists of low sulfide Au-quartz veins that parallel, or rarely crossut strike in wallrocks. Isolated granite porphyry dikes also contain Au. The Au-quartz veins range from about 200 to 500 meters long and from 0.2 to 6.0 meters wide (locally as much as 19 meter)s. The veins are predominantly (90 to 95 percent) composed by quartz. The ore minerals are arsenopyrite, galena, sphalerite, chalcopyrite, pyrrhotite, gold, and wolframite. The gangue minerals are quartz, by calcite, albite, adularia, sericite, and chlorite. Gangue quartz locally contains numerous host-rock fragments. The deposit is hosted in Early Cretaceous sandstone and siltstone in the Oyemku anticline that trends north-northeast. The core of the anticline consists of siltstone, and the flanks are consists of sandstone and interlayered siltstone. The main Au veins and rare dikes of granite porphyry, diorite porphyry, spessartite, and malchite occur along steeply-dipping (50 to 60^o) bedding faults. Bedding faults are widespread. The deposit is small and has produced 576 kg of Au from 1962 to 1966.

Origin and Tectonic Controls for Tumnin-Anyui Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along the East-Sikhote-Aline continental-margin arc related to subduction of the ancestral Pacific Ocean Plate.

Upper Uydoma Metallogenic Belt of Cassiterite-Sulfide-Silicate Vein and Stockwork, Polymetallic Pb-Zn±Cu (±Ag, Au) Vein and Stockwork, Sn-W Greisen, Stockwork, and Quartz-Vein, and Porphyry Mo (±W, Sn, Bi) Deposits (Belt UY) (Russia, Verkhoyansk-Kolyma Region)

This Late Cretaceous metallogenic belt is related to veins and replacements that are part of the Okhotsk-Chukotka volcanic-plutonic belt that intrudes and overlies the Verkhoyansk fold and thrust belt in the North Asian cratonal margin. The metallogenic belt occurs along the western margin of the Okhotsk-Chukotka volcanic-plutonic belt on the eastern limb of the South-Verkhoyansk synclinorium, extends for 200 km, and is as much as 60 km wide. The igneous rocks cut Permian and Triassic clastic rock that is deformed into folds that trend north to northeast. Typical are small fields of Late Cretaceous horizontal, volcanic and subvolcanic bodies of rhyolite and dacite. The Late Cretaceous igneous bodies and deposits are controlled by longitudinal, northwest-, and northeast-striking faults. Various Pb, Zn, Sn, Ag, Au, W, and Sb deposits are widespread and most prevalent are low-sulfide cassiterite-silicate and argentiferous Sn polymetallic deposits (galena-pyrrhotite-sphalerite). The major deposits are at Khoron, Khaardakh, Kutinskoye, and Djatonskoye.

The main references on the geology and metallogenesis of the belt are Flerov (1974), Andrianov and others (1984), Parfenov and others (2001), and Nokleberg and others (2003).

Khoron Cassiterite-Sulfide-Silicate Vein and Stockwork Deposit

This deposit (Andriyanov and others, 1984) occurs on the northeastern side of the metallogenic belt at the intersection of the Khoron and the Pravonitkansk faults. The deposit is hosted in Permian sandstone and siltstone that are simply folded. The sedimentary rocks are intruded by preore dikes and a granodiorite porphyry stock. The deposit occurs in crush zones and veins that are as much as 100 meters long and from 1 to 1.5 meters wide. The vertical span is 500 meters. The principal minerals are quartz, tourmaline, and muscovite, and local chlorite and pyrrhotite. Accessory minerals are actinolite, axinite, galena, Fe disulfide, sphalerite, cassiterite, chalcopyrite, stannite, and Bi minerals. Minor minerals are stibinite, Ag minerals, teallite, native Bi and gold. The deposit formed in five phases (1) quartz-tourmaline, (2) cassiterite-quartz with arsenopyrite, (3) greisen, (4) quartz-sulfide, and (5) quartz-carbonate. Most cassiterite formed in the second phase. The deposit is large and has an average grade of 1.17 percent Sn.

Origin and Tectonic Controls for Upper Udoma Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along an active continental-margin arc consisting of the Albian through Late Cretaceous Okhotsk-Chukotka volcanic-plutonic belt. Late Cretaceous magmatism and deposits of the belt are controlled by longitudinal, northwest, and northeast faults.

Major Maastrichtian through Oligocene (72 to 24 Ma) Metallogenic Belts

Kema Metallogenic Belt of Ag-Au Epithermal-Vein, Porphyry Cu-Mo (±Au, Ag), Porphyry Cu (±Au), and Porphyry Mo (±W, Sn, Bi) Deposits (Belt KM) (Russia, Far East)

This early Tertiary metallogenic belt is related to veins in the East Sikhote-Alin volcanic-plutonic belt that intrudes and overlies the Kema island-arc terrane. The Ag epithermal-vein deposits, as at Tayoznoe, occur in Early Cretaceous clastic and volcaniclastic rocks and in overlying Late Cretaceous and Paleogene, subalkalic, postaccretionary volcanic rock. Rare Pb-Zn polymetallic-vein deposits occur, but are not economic. The epithermal-vein deposits generally occur mostly in or near Danian (early Paleocene) and Paleocene volcanic rock; however, a few occur in granodiorite plutons. Porphyry Cu-Mo (±Au, Ag) deposits in the metallogenic belt occur mainly in the northern part of the belt. These deposits generally consist of disseminations and veinlets in, and near intrusive rocks and coeval volcanic rock that often contain anomalous Pb, Zn, W, Au, and Ag in addition to Cu and Mo. The porphyry Cu-Mo deposits occur in Late Cretaceous through Paleogene granitic and diorite intrusions. A porphyry Cu (±Au) deposit also occurs in the southern part of the belt. The major Au-Ag epithermal-vein deposits are at Burmatovskoe, Glinyanoe, Salyut, Sukhoe, Tayozhnoe, Verkhnezolotoe, and Yagodnoe. Porphyry Cu (±Au) deposits are at Nesterovskoe and Nochnoe, a porphyry Cu-Mo (±Au, Ag) deposit is at Sukhoi Creek, and a porphyry Mo (±W, Bi) deposit is at Moinskoe.

The main references on the geology and metallogenesis of the belt are Orlovsky and others (1988), Petrachenko and others (1988), Khomich and others (1989), Pakhomova and others (1997), and Nokleberg and others (2003).

Glinyanoe Ag-Au Epithermal-Vein Deposit

This deposit (A.N. Rodionov, written commun., 1986) consists of adularia-quartz, sericite-chlorite-quartz, and carbonate and chlorite-quartz veins and zones that contain pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, argentite, acanthite, Ag-tellurides, and native gold and silver. The veins and zones occur in altered, silicified volcanic rock that overlie Late Cretaceous (Santonian) felsic volcanic rock. The deposit as occurring 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 being Late Cretaceous through Paleogene. The deposit is small and has an average grade of 8.3 g/t Au and 122 g/t Ag.

Sukhoi Creek Porphyry Cu-Mo (±Au, Ag) Deposit

This deposit (Petrachenko and others, 1988) consists of stockworks and an associated altered zone that are several hundred meters across. Polymetallic ore is dominant. The ore minerals are chalcopyrite, molybdenite, sphalerite, galena, cassiterite, scheelite, and pyrite, with significant Au and Ag. The deposit occurs in Early Cretaceous sedimentary rock that is overlain by Late Cretaceous volcanic rock and crosscut by deposit-hosting granitic intrusions with a K-Ar isotopic age of 73 Ma. The deposit is related to several granodiorite and granite stocks that 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. 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. Host siltstone and sandstone are altered to orthoclase-actinolite-chlorite hornfels, and the felsic extrusive rocks are altered to quartz and phyllite. The deposit is small and grades as much as 0.2 percent Cu and 0.01 percent Mo.

Tayozhnoe 1 Ag-Au Epithermal-Vein Mine

This mine (A.N. Rodionov and others, written commun., 1976; Ratkin and others, 1991) consists of steeply-dipping quartz veins that occur along northwest to north-south fractures that intrude Early Cretaceous sandstone. The veins vary from 100 to 500 meters long and 0.5 to 2 meters thick, and also occur beneath a contact between sandstone and an overlying 50-m-thick section of Late Cretaceous felsic volcanic rock. The ore minerals occur in veins, and in metasomatic zones along the subhorizontal contact, and between veins and overlying volcanic rock. The major Ag minerals are Ag sulfosalts and sulfides. Pyrite and arsenopyrite are rare and formed before Ag minerals. In the upper part of veins, Ag occurs in tetrahedrite, freibergite, stephanite, pyrargyrite, and polybasite. At middle depths, Ag occurs mainly in acanthite and stephanite, along with arsenopyrite and allargentum. Acanthite is dominant at depth. The deposit is medium size and has an average grade of 50 to 2000 g/t Ag and 1 g/t Au. The deposit has been mined since the 1980s.

Verkhnezolotoe Porphyry Cu (±Au) Deposit

This deposit (Orlovsky and others, 1988) occurs at the northwest margin of a caldera that contains dikes of calc-alkaline andesite porphyry that is interpreted as tongues of a dome-like subvolcanic intrusion. A stockwork occurs in a circular aureole of hydrothermally altered rock with a surface extent of 200 m^2 over the intrusive dome. Successive alterations are (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 contains the first three alterations and consists of a thick network of quartz-epidote-actinolite veinlets and lenses as much as 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 that extend to 100 meters depth. The ore minerals in the breccia zones are chalcopyrite and bornite. Molybdenite and pyrite, and rare pyrrhotite, cubanite, arsenopyrite, galena, and sphalerite also occur. Carbonate and chalcopyrite veinlets also occur. The richest ore is associated with Sn, Cu, and local W tungsten minerals. A zone of oxidized ore as much as 20 to 30 meters thick caps the deposit. The deposit is small and has an average grade of 3 g/t Au, 86 g/t Ag, 0.35-2.27 percent Cu, 0.69 percent Pb, and 0.26 percent Sn.

Origin and Tectonic Controls for Kema Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along a continental-margin arc related to subduction of the ancestral Pacific Ocean Plate. The granitoids hosting the belt are part of the Late Cretaceous and early Tertiary East Sikhote-Alin volcanic-plutonic belt. This belt consists chiefly of five major units (1) Early Cenomanian rhyolite and dacite,; (2) Cenomanian basalt and andesite, (3) thick Turonian through Santonian ignimbrite sequences, (4) Maastrichtian basalt and andesite, and (5) Maastrichtian through Danian (early Paleocene) rhyolite. The East Sikhote-Alin belt also contains coeval, mainly intermediate-composition granitoid plutons that in the frontal (eastern) part of the belt are predominantly Early Cretaceous magnetite-series granitoids. The East-Sikhote-Alin belt is correlative with the Okhotsk-Chukotka volcanic-plutonic belt on strike to the north in the Russian Northeast, and it is tectonically linked to the Aniva, Hidaka, and Nabilsky subuction zone and subduction-zone terranes.

Lower Amur Metallogenic Belt of Au-Ag Epithermal-Vein, Epithermal Quartz-Alunite, Porphyry Au, Porphyry Cu (±Au), Sn-W Greisen, Stockwork, and Quartz-Vein Deposits (Belt LA) (Russia, Far East)

This Late Cretaceous and Paleocene metallogenic belt is related to veins in the East Sikhote-Alin volcanic-plutonic belt that intrudes or overlies the Amur River and Kiselyovka-Manoma subduction-zone terranes. The Au-Ag epithermal-vein deposits, as at Mnogovershinnoe, range from medium to large and are generally hosted in Paleocene alkaline granitoids that are closely related to coeval andesite to dacite volcanic rock. A few Au-Ag epithermal-vein deposits are related to Eocene and Oligocene volcanism. The Au-Ag epithermal-vein deposits, as at Belaya Gora and Bukhtyanskoe, are closely associated with rhyolite and trachyrhyolite flows and vent rocks that are commonly hydrothermally-altered to siliceous and adularia phases. Au is either disseminated throughout the hydrothermally-altered rock or is concentrated in small quartz veins. The adularia phases also locally contain Au. Placer Au deposits, as at Kolchanskoe, Ulskoe, and Oemku, are derived from Au-Ag epithermal-vein deposits. In addition to the Au-Ag epithermal-vein deposits, the Lower Amur metallogenic belt contains a few, small porphyry Cu (±Au) deposits that are all hosted in or near Paleogene alkaline granitoids. The major Au-Ag epithermal-vein deposits are at Belaya Gora, Bukhtyanskoe, and Mnogovershinnoe; a porphyry Cu (±Au) deposit is at Tyrskoe; and a major and large quartz-alunite deposit is at Iskinskoe.

The main references on the geology and metallogenesis of the belt are Mel’nikov (1978), Zalishchak and others (1978), Ivanov and others (1989), Khomich and others (1989), and Nokleberg and others (2003).

Mnogovershinnoe Au-Ag Epithermal-Vein Deposit

This large deposit (Zalishchak and others, 1978; Ivanov and others, 1989) consists of hydrothermally altered, adularia-sericite-quartz vein zones that are as much as 800 meters long and contain a series of adularia-quartz veins and veinlets. Some deposits consist of rhodonite-carbonate veins, and lenses of skarn and sulfides. The ore minerals are pyrite, marcasite, gold, argentite, Au-and Ag-tellurides, galena, sphalerite, chalcopyrite, and freibergite. The ore minerals comprise as much as 1 percent veins and the Au:Ag ratio is 1:1. The deposit is hosted in Paleocene andesite and dacite that are genetically related to a multiphase intrusion of highly alkaline granitoids. K-Ar isotopic studies indicate a deposit age of 69 to 49 Ma. During formation of local Au-bearing skarn, that is related to intrusion of Paleogene subalkaline granite, Au was remobilized. The deposit is medium size.

Belaya Gora Au-Ag Epithermal-Vein Deposit

The deposit (fig. 37) (Mel’nikov, 1978) consists of disseminations and stockworks that occur in extrusive bodies of subalkalic rhyolite and dacite, and in explosive breccia of an Eocene-Oligocene igneous complex. Alteration minerals are quartz (50 to 90 percent), 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 gold-quartz and Au-sulfosalts-sulfide-quartz. Gold distribution is highly irregular, and the deposits have gradational boundaries. The deposit is medium-size.

Iskinskoe Epithermal Quartz-Alunite Deposit

The deposit (Onikhimovkiy and Belomestnykh, 1996) is hosted in intensively altered Tertiary dacite and rhyolite. The deposit consists of a metasomatic body of quartz-alunite surrounded by a concentric zone of quartz-sericite alteration, and an outer zone of propylitic alteration. The deposit is 2.3 km long, 1.2 km wide, and as much as 360 meters deep. The ore minerals are 29.4 to 32.0 percent alunite; 60.0 to 66.0 percent quartz; 2.0 percent halloysite; 1.5 to 5.0 percent Fe oxides; 1.5 to 1.6 percent kaolinite; and as much as 2.0 percent beudantite. Rare minerals are pyrite, diaspore, andalusite, dickite, montmorillonite, and kaolinite. Pure alunite occurs in descrete masses ranging as much as 8 to 10 cm in diameter. The deposit is large and has reserves of 336,581,000 tonnes alunite ore and has an average grade of 26.1 percent alunite.

Origin and Tectonic Controls for Lower Amur Metallogenic Belt

The belt is interpreted as having formed during generation of granitoids along a continental-margin arc related to subduction of the ancestral Pacific Ocean Plate. The granitoids hosting the belt are part of the Late Cretaceous and early Tertiary East Sikhote-Alin volcanic-plutonic belt. This belt consists chiefly of five major units (1) Early Cenomanian rhyolite and dacite, (2) Cenomanian basalt and andesite, (3) thick Turonian through Santonian ignimbrite sequences, (4) Maastrichtian basalt and andesite, and (5) Maastrichtian through Danian (early Paleocene) rhyolite. The East Sikhote-Alin belt also contains coeval, mainly intermediate-composition granitoid plutons that. in the frontal (eastern) part of the belt. are predominantly Early Cretaceous magnetite-series granitoids. The East-Sikhote-Alin belt is correlative with the Okhotsk-Chukotka volcanic-plutonic belt on strike to the north in the Russian Northeast, and it is tectonically linked to the Aniva, Hidaka, and Nabilsky subuction zone and subduction-zone terranes.

Popigay Metallogenic Belt of Impact Diamond Occurrences (Belt PP) (Russia, Northern North Asian Craton)

This Eocene metallogenic belt is related to an astrobleme or impact ring structure developed on Early Precambrian crystalline basement and Phanerozoic sedimentary rock of the North Asian craton. The age of the belt is interpreted as being Eocene. The belt occurs in the Popigay ring structure.

The main references on the geology and metallogenesis of the belt are Masaitis and others (1975, 1998).

Popigay Impact Diamond Deposit

This deposit (Masaitis and others, 1975, 1998) occurs in an impact structures that is about 80 km in diameter on the northeastern margin of the Anabar shield. The ring structure forms a round basin with a floor that is 200 to 300 meters lower relative to the surrounding plateau. The basin contains a specific rock complex, including volcanic-like rock. Masaitis and others (1975, 1998) identified an impactite with varying amounts of glass that chemically corresponds to (1) andesite and dacite rock and mineral fragments, (2) explosive allogenic breccia that fell in or beyond the limits of the crater after the explosion, and (3) authigenic breccia formed from brecciated material at the bottom of the crater and that underwent high-grade shock metamorphism with melting and formation of pseudotachylite. The impactite is classified as a massive lava-like tagamite and glassy-clastic suevite. The tagamite and impact glasses have an $^{40}Ar/^{39}Ar$ isotopic age of 35.7±0.2 Ma. Diamond occurs in graphite gneiss and tagamite that formed during shock metamorphism (Masaitis and others, 1998). Diamond crystals range from 0.05 to 2.0 mm in diameter. Adjacent placer deposits contain diamonds as big as 8 to 10 mm. The most abundant diamonds are yellow; colourless, transparent, grey, and black crystals are rare. Diamonds from the gneiss retain morphological and structural features inherited from crystalline graphite. Common are tabular crystals with a characteristic striation of basal planes due to repeated twinning, parallel intergrowths, irregular intergrowths, and aggregates.

Origin and Tectonic Controls for Popigay Metallogenic Belt

The belt is hosted in the Popigay ring structure for which two origins are proposed, either meteoritic impact, or cryptovolcanic eruption. The most popular idea is meteoritic origin (Masaitis and others, 1975, 1998) with structure forming from the impact of a giant meteorite. Supporting the meteoric idea are numerous indications of shock metamorphism and partial melting of Early Precambrian crystalline rock. The cryptovolcanic hypothesis suggests explosion during a volcanic eruption with the ring structure being the stage of kimberlite formation, both alnoite kimberlite and carbonatite, and cryptoexplosion.

Major Miocene through Quaternary (24 Tto 0 Ma) Metallogenic Belts

Hokuriku-Sanin Metallogenic Belt of Au-Ag Epithermal-Vein, Polymetallic Pb-Zn ± Cu (± Ag, Au) Vein and Stockwork, Ag-Sb vein, and Clastic-Sediment-Hosted U Deposits (Belt HS) (Japan)

This Miocene to Pleistocene metallogenic belt is related to veins and replacements in the Japan Cenozoic sedimentary basin that overlies and intrudes the Hiroshima granitic plutonic belt and the Akiyoshi-Maizuru and Mino-Tamba-Chichibu terranes. The belt occurs in the western part of Honshu and northern Kyushu Islands, trends east-northeast to west-southwest for more than 900 km, and is as much as 50 km or more wide. The belt occurs in northern part of the Inner Zone of southwestern Japan and contains Au-Ag epithermal-vein deposits (Omori) and polymetallic-vein deposits (Taishu).

The deposits are associated with siliceous and intermediate magmatism. Tsuboya and others (1956) used the names Toyama, Noto, and Shimane provinces for the Hokuriku-Sanin metallogenic belts. A small number of the Kuroko-type deposits occur in the belt, but they are not described in the mineral deposit database. Ishihara (1978) defined this belt as a Ag-Cu-Pb-Zn province. The belt was originally interpreted as Miocene; however, new K-Ar isotopic ages for the Omori Au-Ag deposit suggest the deposits continued to form into the Pleistocene (Sakoda and others, 2000).

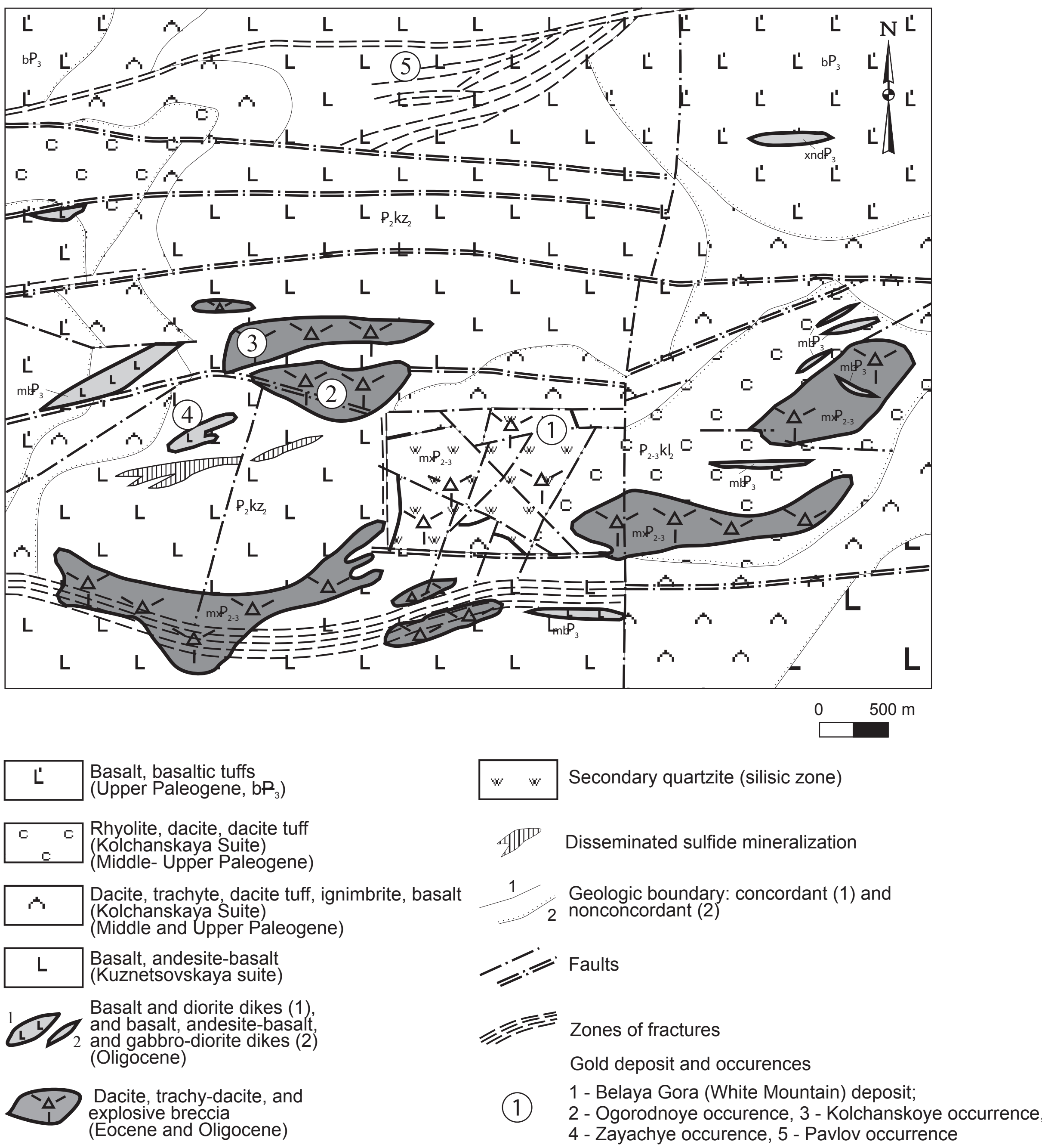


Figure 37. Generalized geologic map of Belaya Gora Au-Ag epithermal-vein deposit, Lower Amur metallogenic belt, Russian Southeast. Adapted from E.P. Khokhlov, written commun., 1978.

The main references on the geology and metallogenesis of the belt are Ishihara (1978) and Sakoda and others (2000).

Omori Au-Ag Epithermal-Vein Mine

This mine (fig. 38) (Mining and Materials Processing Institute of Japan, 1994b; Sakoda and others, 2000) consists of seven main northeast striking veins. The Main vein is 400 meters long and 0.5 meters wide. The veins occur in an area that 0.5 km side (east-west) by 0.7 km long (north-south). The host rocks are Miocene dacite. The ore minerals are argentite, chalcopyrite, pyrite, galena, sphalerite, siderite, and hematite. Gangue minerals are quartz, barite, and chalcedony. Wallrocks are altered to quartz and chlorite. A K-Ar sericite age for the alteration zone is 1.07±0.04 Ma. A stockwork with disseminated silver occurs 1 km east of the Main vein. Mining started from 1309 and stopped in 1923. The deposit was also known as the Iwami silver deposit, and it was one of the biggest silver mines in Japan. The mine is small and it produced 1.4 tonnes of Au, 65.7 tonnes of Ag, and 6,300 tonnes of Cu (from 1891 to 1919). The average grades are 1,000 to 2,000 g/t Ag.

Taishu Polymetallic Pb-Zn ± Cu (± Ag, Au) Vein and Stockwork Mine

This mine (Karakida and others, 1992) consists of three main north-south and northeast striking vein systems. The Main vein is 2,200 meters long and 2 meters thick. The host rocks are Paleogene sandstone and shale. The deposit formed during intrusion of a Miocene granitoid that occurs 5 km south. The granitoid consists of fine- to medium-grained monzogranite, granodiorite, and local quartz diorite. The average K-Ar biotite age for the granite is 16.1±0.8 Ma. The main ore minerals are sphalerite, galena, pyrrhotite, arsenopyrite, and chalcopyrite. Gangue minerals are calcite and quartz. Wallrocks are altered to chlorite, calcite, sericite, and lesser quartz. The deposit was discovered in 674 and the mine closed in 1973. The mine is medium size and produced 230,000 tonnes of Zn, and 139,000 tonnes of Pb from 5 million tonnes of ore. The average grade is 6.4 percent Zn, and 2.9 percent Pb.

Origin and Tectonic Controls for Hokuriku-Sanin Metallogenic Belt

The belt is interpreted as having formed along an island arc during back-arc rifting or along the axial part of an island arc that was related to subduction of Philippine Sea Plate. The deposits are associated with siliceous through intermediate magmatism in a back-arc rift or in an island arc.

Kyushu Metallogenic Belt of Au-Ag Epithermal-Vein Deposits (Belt KY) (Japan)

This Pliocene to Quaternary metallogenic belt is related to veins and replacements in the Quaternary Japan volcanic belt and Japan Cenozoic sedimentary basin that overlies and intrudes the Akiyoshi-Maizuru, Shimanto, and Mino-Tamba-Chichibu terranes. The belt occurs in central and southern Kyushu Island, trends northeast to southwest for more than 400 km, and ranges from 50 to 100 km wide. The belt extends south along the Ryukyu Island arc. The belt contains a large number of Au-Ag epithermal-vein deposits (Taio and Hishikari). The Satsuma metallogenic province was defined by Iwasaki (1912) and Watanabe (1923) and is similar to the Kyushu belt. However, the Satsuma province contains Sado and other Au-Ag deposit in other areas of Japan. Tsuboya and others (1956) used the name Kyushu Au-Ag epithermal vein metallogenic province that is similar to the Kyushu metallogenic belt, but excluded sulfur and limonite deposits related to recent volcanoes.

The deposits in the Kyushu metallogenic belt occur mainly in the Central and Southern Kyushu districts. The Central Kyushu district contains the Taio metallogenic district, and the southern Kyushu district contains the Kushikino metallogenic district of Kinoshita (1961). The Central Kyushu district is closely related to the Beppu-Shimabara graben that trends northeast-southwest, extends for 100 km long, and is as much as 40 km wide. The Beppu-Shimabara graben is an early Pliocene volcano-tectonic basin. Au-Ag deposits in the area range from 3.5 to 2.7 Ma (Ministry of International Trade and Industry, 1999). Although, some Au-Ag epithermal-vein deposits are Quaternary, most deposits formed in the Pliocene. The Pliocene Au-Ag deposits occur along the northern side of the graben, whereas the Quaternary deposits occur in the graben (Izawa and Urashima, 1989).

The Southern Kyushu district is subdivided into two areas, the northern Hokusatsu and southern Nansatsu areas. Typical low sulfidation Au-Ag epithermal-vein deposits (Hishikari and Kushikino) occur in the Hokusatu area. High sulfidation type epithermal Au deposits occur in the Nansatsu area. The Kushikino deposit in the Hokusatsu area, and high sulfidation-type epithermal-Au deposits in the Nansatsu area formed in the Pliocene (Ministry of International Trade and Industry, 2000a, b). These deposits occur along the western side of the district. The Hishikari, Fuke, and other low sulfidation Au-Ag epithermal-vein deposits in the Hokusatsu area formed in the Quaternary along the eastern side of the district. Migration of mineralizing centers from the western backarc side to the eastern volcanic front side occurs with with younger volcanic units (Izawa and Urashima, 1989). Most Au-Ag deposits range from Pliocene to Quaternary in the Southern Kyushu district. Host rocks are generally andesite; however, veins in the deep portion of the Hishikari deposit occur in the underlying Shimanto Group. The Kyushu metallogenic belt also contains minor sulfur and limonite deposits in Quaternary volcanoes (Kinoshita, 1961). The Kuju sulfur deposit occurs in the Kuju volcano, and the Iojima deposit occurs on the small Iojima Island south of Kyushu Island. Limonite deposits occur in the Aso volcano. However, these deposits are small and not significant, and they are not listed in the mineral-deposit database. The Kagoshima graben, which formed during Quaternary volcanism, occurs in the eastern Southern Kyushu district.

The main references on the geology and metallogenesis of the belt are Iwasaki (1912), Watanabe (1923), Tsuboya and others (1956), Kinoshita (1961), and Ministry of International Trade and Industry (2000a,b).

Hishikari Au-Ag Epithermal-Vein Deposit

This deposit (fig. 39) (Ibaraki and Suzuki, 1989; Naito, 1993; Izawa and others, 1989; Sekine and others, 1998) consists of northeast-striking veins. Three main vein systems are Honko, Yamada, and Sanjin. Veins occur in an area 2.5 km (east-west) by 0.8 km (north-south). Veins in Honko range from 1 to 3 meters wide with a maximum strike length of 400 meters. Maximum width of the vein is 13 meters. Host rock is preMiocene Shimanto Supergroup and Quaternary andesite. Ore minerals are electrum, pyrite, chalcopyrite, marcasite, spahlerite, galena, and stibnite. The Au/Ag ratio is high, typically about 2 and

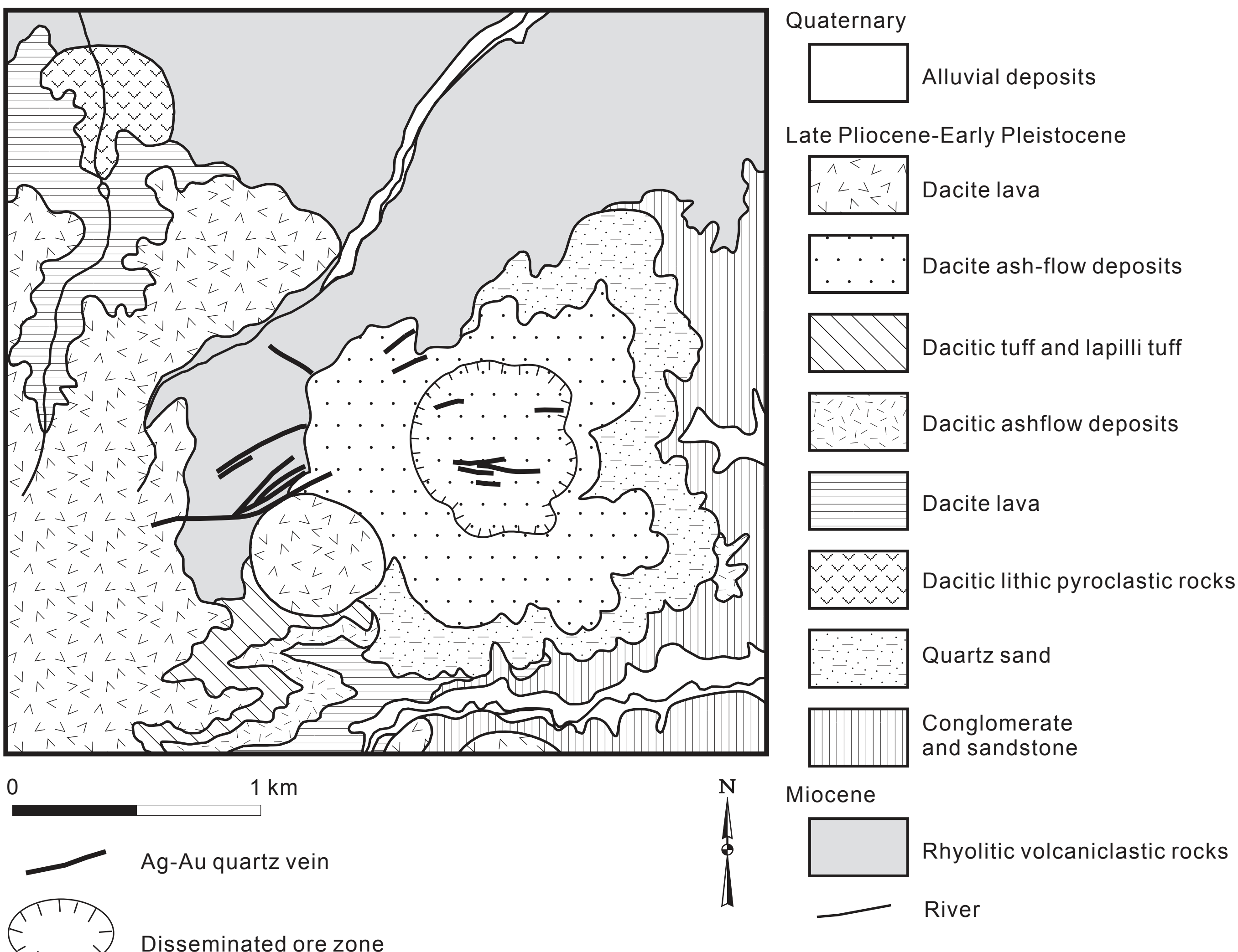


Figure 38. Generalized geologic map of Omori Au-Ag epithermal-vein mine, Hokuriku-Sanin metallogenic belt, Japan. Adapted from Kano and others (2001).

the average Ag grade is about 100 g/t. Gangue minerals are quartz, adularia, smectite, kaolinite, sericite, chlorite, and calcite. About 20 percent of gangue is adulaia. Grain size of electrum is about 10 microns. Wallrocks show zonal alteration from the center outwards to the chlorite-sericite zone, interstratified clay mineral zone, quartz smectite zone, and cristobalite smectite zone. K-Ar isotopic ages of adularia range from 0.78±0.07 Ma to 1.05±0.07 Ma. The deposit was discovered in 1981. The deposit is medium size and has an average grade of 46 g/t Au and resources of 250 tonnes of Au.

Kushikino Au-Ag Epithermal-Vein Mine

This mine (Karakida and others, 1992) consists of northeast-striking veins. The Main vein is 2,600 meters long and ranges from 3 to 50 meters wide. The veins occur in a area 3 km (east-west) by 2.5 km (north-south). The host rocks are Miocene andesite and andesite tuff. The ore minerals are electrum, native silver, argentite, pyrargyrite, stibnite, naumannite, hessite, and stephanite. Gangue minerals are quartz, adularia, sericite, and calcite. Wallrocks are altered to quartz, pyrite, chlorite, calcite, sericite, and kaolinite. A K-Ar isotopic age is 4.0±0.3 Ma. Mining started in the 1600s. The mine is medium size and produced 54.7 tonnes of Au and 497 tonnes of Ag from 8,270,000 tonnes of ore. The average grades are 6.6 g/t Au and 60 g/t Ag.

Taio Au-Ag Epithermal-Vein Mine

This mine (Mining and Materials Processing Institute of Japan, 1989; Karakida and others, 1992) consists of two main vein systems that strike east-northeast and northwest and dip north. The veins occur in an area 3 km (east-west) by 2 km (north-south). The Main vein is 1,750 meters long and 2.5 meters thick Host rocks are altered Miocene andesite. The main ore minerals are native gold, argentite, miargyrite, chalcopyrite, pyrite, galena, and sphalerite. Gangue minerals are mainly quartz, calcite, adularia, and rhodonite. Wallrocks are altered to quartz, chlorite, sericite, montmorillonite, and kaolinite. A K-Ar adularia age for the vein is 3.6 Ma. The deposit was discovered in 1894. The mine closed in 1970. The mine is medium size and produced 37 tonnes of Au and 160 tonnes of Ag from from 5,870,000 tonnes of ore. The average grades are 6.3 g/t Au and 27 g/t Ag.

Origin and Tectonic Controls for Kyushu Metallogenic Belt

This belt is interpreted as having formed during hydrothermal activitiy along a Pliocene and Quaternary island arc during back-arc rifting or along the axial part of an island arc that was related to subduction of Philippine Sea Plate.

Northeast Hokkaido Metallogenic Belt of Au-Ag Epithermal Vein, Volcanic-Hosted Hg, Hg-Sb-W Vein and Stockwork, and Clastic Sediment-Hosted Hg±Sb Deposits (Belt NH) (Japan, Hokkaido)

This Miocene to Quaternary metallogenic belt is related to veins and replacements in the Quaternary Japan volcanic belt and in the Japan Cenozoic sedimentary basin that overlies and intrudes the Hidaka zone of the Shimanto accretionarry wedge terrane. The metallogenic belt occurs in northeastern Hokkaido island in an area that is 250 km by 130 km and extends to the east of the study area. Saito (1958) defined five districts in the Northeast Hokkaido belt. The Kitami metallogenic province of Urashima (1961) is similar to this belt, but excludes Quaternary deposits. Saito and others (1967) defined a Northeast Hokkaido metallogenic province for Neogene deposits in the area, and Yahata and others (1988) named the Northeast Hokkaido metallogenic province of Quaternary epithermal-vein deposits. Most of deposits of the metallogenic belt occur in the Monbetsu-Kamishihoro Graben that ranges from 10 to 60 km wide and trends for 120 km north-south in the middle of the belt. The Kitami district of Saito (1958) covers the graben. The Utoro and Ohmu districts of Saito (1958) occur in the northwestern Northeast Hokkaido metallogenic belt and include the Motokura Pb-Zn-Cu deposit and some gold deposits. Au epithermal deposits also occur near the Quaternary volcanic front. Limonite and sulfur deposits are associated with the volcano, but they are not described in the mineral deposit database. Ages of epithermal deposits vary from 14.4 Ma to 0.3 Ma, and tend to young southward (Yahata and others, 1999). The ages of deposits indicate two stages of deposits in the belt, an early stage (14.4 to 11.2 Ma) and a late stage (8.1 to 0.3 Ma). The belt contains Au-Ag epithermal-vein deposits (Konomai), volcanic-hosted Hg deposits (Itomuka), and Pb+Zn+Cu veins (Saito).

The main references on the geology and metallogenesis of the belt are Saito (1958), Urashima (1961), Saito and others (1967), and Yahata and others (1988).

Konomai Au-Ag Epithermal-Vein Mine

This mine (fig. 40) (Kato and others, 1990; Mining and Materials Processing Institute of Japan, 1990; Maeda, 1990) consists of of east-west and northeast striking quartz veins. More than 18 veins occur in an area 15 by 5 km. One typical vein is 10 meters thick and 2,100 meters long. The veins consist mainly of quartz, chalcedony, calcite, and adularia. The main ore minerals are native gold, native silver, argentite, and miargyrite. Minor ore minerals are chalcopyrite, galena, and sphalerite. The veins are hosted in Miocene rhyolitic tuff, mudstone and altered andesite. A K-Ar age isotope age for adularia from the vein is 12.9 ± 0.4 Ma. The deposit was discovered in 1915 and the mine closed in 1973. The deposit is medium size and produced 11,486,000 tonnes of ore, 73.2 tonnes of Au, and 1,240 tonnes of Ag from 1917 to 1973. The average grade is 6.4 g/t Au and 108 g/t Ag.

Itomuka Volcanic-Hosted Hg Mine

This mine (Saito and others, 1967) consists of disseminated and vein ore bodies that occur along faults. The ore bodies occur in a area 3 km east-west by 1.5 km north-south. A typical ore body has an average thickness of 6 meters and length of 140 meters. The main ore minerals are native mercury and cinnabar. Quartz, calcite, pyrite, and marcasite also occur. The deposit is hosted in altered Miocene andesite. Miocene rhyolite occurs near the deposit and is part of the host-rock sequence. The deposit was discovered in 1936, and was the largest Hg mine in Japan. The mine is medium size and it produced 3,300 tonnes Hg grading 0.35 percent Hg.

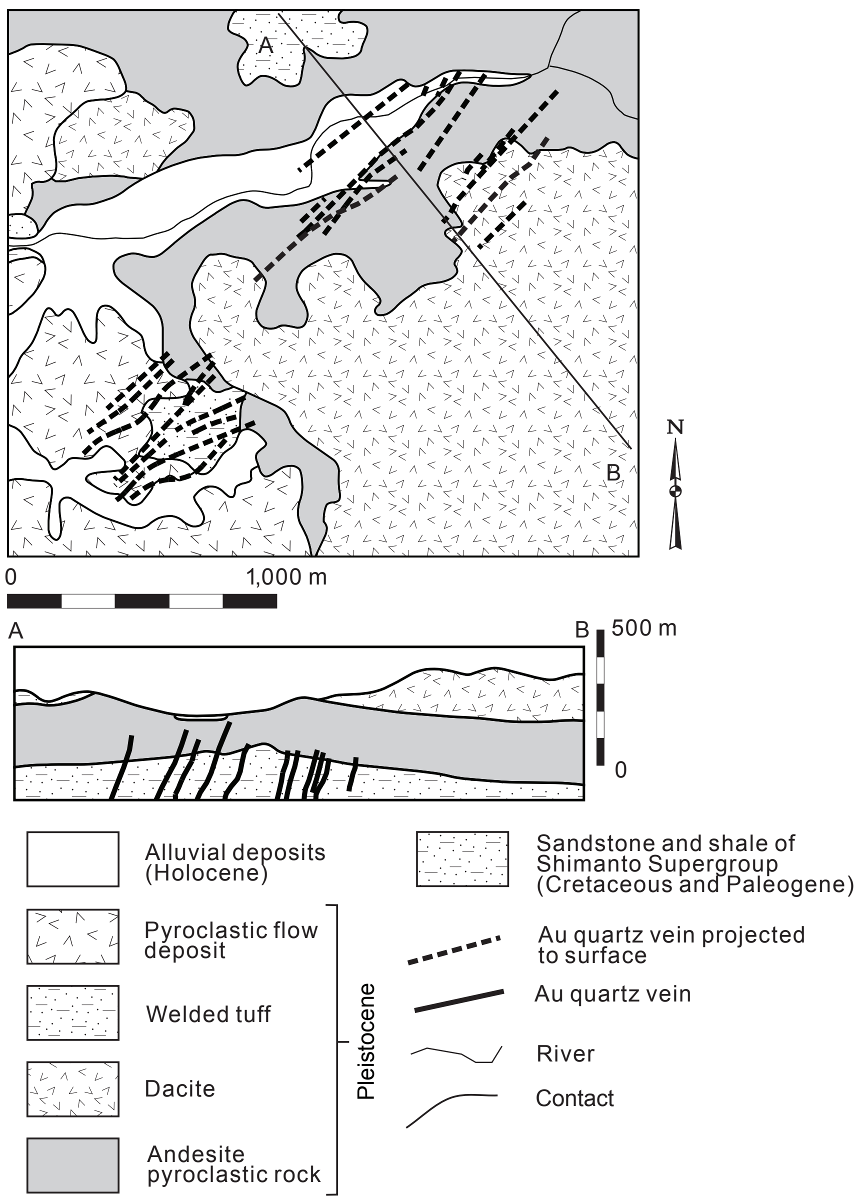


Figure 39. Generalized geologic map and schematic cross section of Hishikari Au-Ag epithermal-vein deposit, Kyushu metallogenic belt, Japan. Adapted from Naito and others (1993).

Ryushoden Hg-Sb-W Vein and Stockwork Mine

This mine (Mining and Metallurgical Institute of Japan, 1968; Kato and others, 1990) consists of dissemination that occur along faults. Pyrite, cinnabar, and calcite veins occur in the disseminated zone. The main ore mineral is cinnabar, and minor ore minerals are native mercury and pyrite. Gangue mineals are quartz, chlorite, and calcite. The deposit is hosted in Miocene sandstone. Rhyolite is present southwest of the deposit and may be related to the deposit. The deposit is medium size and it produced 880 tonnes of Hg (from 1947-1974). The average grade is 0.27 percent Hg.

Origin and Tectonic Controls for Northeast Hokkaido metallogenic belt

This belt is interpreted as having formed along an island arc related to subduction of the Pacific Plate beneath eastern Hok-

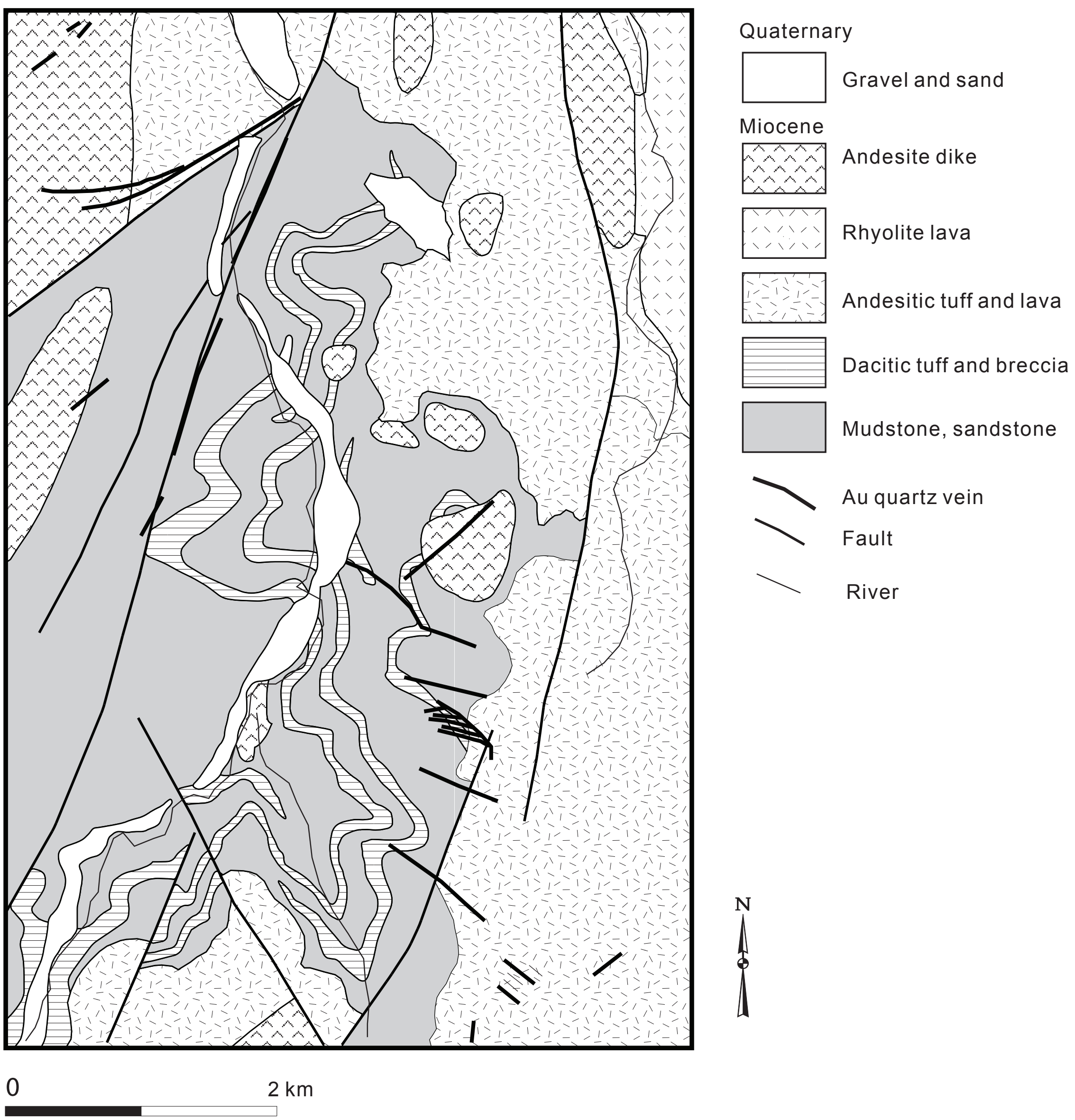


Figure 40. Generalized geologic map of Konomai Au-Ag epithermal vein mine, Northeast Hokkaido metallogenic belt, Japan. Adapted from Yahata and others (1988).

kaido Island. The deposits formed during Miocene and Quaternary island arc volcanism and related hydrothermal activity.

Northeast Japan Metallogenic Belt of Volcanogenic Zn-Pb-Cu Massive Sulfide (Kuroko, Altai types), Au-Ag Epithermal-Vein, Sulfur-Sulfide (S, FeS2), Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) Volcanic-Hosted Metasomatite, Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork, Mn vein, Volcanogenic-Sedimentary Mn, Chemical-Sedimentary Fe-Mn, and Limonite from Spring Water Deposits (Belt NJ) (Japan)

This Miocene to Quaternary belt is related to layers and veins in the Quaternary Japan volcanic belt and Japan Cenozoic sedimentary basin that overlie and intrude the Hiroshima granitic plutonic belt, and the Mino-Tamba-Chichibu and South Kitakami terranes. The metallogenic belt occurs in the western part of northeastern Honshu and southwestern Hokkaido Islands, trends north-south for more than 1,300 km, and varies from 100 to 150 km wide. The belt extends into the Izu-Bonin island arc. Most of the associated deposits occur in Miocene volcanic rock in the Neogene sedimentary basin. The volcanic rock is mostly altered and is generally described as the Green Tuff. The southwestern margin of the belt in Honshu Island is bounded by the Itoigawa-Shizuoka tectonic line.

The belt contains a large number of Kuroko deposits (Kosaka, Shakanai), Au-Ag epithermal-vein deposits (Sado), polymetallic-vein deposits (Hosokura), and sulfur-sulfide (S, FeS_2) deposits. Iwasaki (1912) used the name Kosaka metallogenic province that covers most of the Northeast Japan metallogenic belt of this study. Watanabe (1923) also used the name Kosaka metallogenic province, and he slightly modified the definition to the Ikuno-Kosaka metallogenic province. Tsuboya and others (1956) used the name Hokkaido-Northeast Japan Green Tuff metallogenic province with four provinces (1) Nemuro-Shiretoko province (in eastern Hokkaido Island), (2) Kitami province (in northeastern Hokkaido Island), (3) Inner Zone of Northeast Japan province, and (4) Fossa Magna province (major graben in central Honshu Island). The Northeast Japan metallogenic belt of this study contains the Inner Zone of Northeast Japan province and the Fossa Magna province. Ishihara (1978) classified three metallogenic provinces in an area that is similar to this belt on the basis of metals in the deposits (1) the Mn Au-Ag-Cu-Pb-Zn province in southwestern Hokkaido Island, (2) the Au-Ag-Cu-Pb-Zn province in northern Honshu Island, and (3) and the Ag-Pb-Zn province for central Japan. Many Kuroko-type deposits occur in the Hokuroku area in Akita Prefecture, northern Honshu. These deposits formed in the middle Miocene around 13 Ma. Available K-Ar ages of-vein deposits suggest two stages of ore formation (1) an early stage (15 to 10 Ma), and (2) a late stage (8 to 2 Ma). Sulfur-sulfide (S, FeS_2) and limonite deposits formed along with Quaternary volcanoes. Tsuboya and others (1956) defined a separate Pleistocene-Holocene metallogenic province around the volcanoes that is included herein in the Northeast Japan metallogenic belt.

The main references on the geology and metallogenesis of the belt are Iwasaki (1912), Watanabe (1923), Tsuboya and others (1956), and Ishihara (1978).

Ashio Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork Mine

This mine (Shibata and Ishihara, 1974; Omori and others, 1986) consists of northeast, east-northeast, and east-west striking veins. Eight main vein systems occur. Each vein system consists of 100 to 300 veins. About 1,400 veins were mined. The main vein is 2,100 meters long and 0.2 meters thick. The host rock is Miocene rhyolite (Ashio Rhyolite) that occurs as a slightly elongated circular shape (4.4 by 3.3 km) on the surface and is funnel-shaped. Most of veins occur in the rhyolite. At depth the deposit extends into a Mesozoic accretionary complex. The main ore minerals are chalcopyrite, arsenopyrie, and pyrite. Minor ore minerals are bornite, chalcocite, covellite, pyrrhotite, sphalerite, galena, wolframite, cassiterite, stannite, bismuthinite, and native gold. Gangue minerals are mainly quartz, calcite, fluorite, and apatite. A zonal distribution of ore minerals occurs a central zone with Sn-W-Bi-Cu, an intermediate zone with Cu-As-Zn, and a marginal zone with Zn-Pb-Cu-As. Massive replacement ore bodies also occur with ore minerals similar to the veins. Wallrocks are altered to quartz, sericite, chlorite, and calcite. Quartz-sericite-calcite alteration is the most common. A K-Ar isotopic age for altered tuff is 14.8±1.1 Ma. The deposit was discovered in 1550, mining started around 1,600 for Au, and the mine closed in 1973. The deposit is medium size and it produced about 800,000 tonnes of Cu, 4.5 tonnes of Au, 600 tonnes of Ag, and 22,000 tonnes of Zn. The average grade is 20 to 30 percent Cu.

Gumma Limonite Mine

This mine (Geological Survey of Japan, 1954) occurs in the eastern foothill of Ksatsu-Shirane volcano above tuff breccia and andesite. The deposit is more than 10 meters thick, and it occurs along an old valley for 2,200 meters and is several tens to 200 meters wide. The deposit formed by precipitation in the valley from a mineral spring from the Ksatsu-Shirane volcano. The ore mineral is limonite that is generally porous and reddish brown or dark brown. Jarosite occurs mainly in the upstream part of the deposit. At the upper part of the deposit, the mineral spring is still active. The deposit is small and it produced 850,000 tonnes of ore from 1950 to 1955, and has resources of about 2,000,000 tonnes. The average grade is 49 percent Fe.

Horobetsu Sulfur-Sulfide (S, FeS_2) Mine

This mine (Saito and others, 1967) consists of three ore connected bodies. The ore bodies are about 300 meters long, 150 meters wide, and 10 to 20 meters thick. The host rock is Pliocene andesite lava. The ore minerals are native sulfur and pyrite. One ore body consists of pyrite that occurs above the sulfur-ore body. The deposit is surrounded by alteration zones, including opal, allunite, and kalonite. The deposit was discovered in 1902, is small, and produced 1,571,000 tonnes of ore grading 39.7 percent S.

Hosokura Au-Ag Epithermal-Vein Mine

This mine (Takahashi and Suga, 1974) consists of 13 main vein systems that strike east-west, north-south, and northwest. The veins occur in a 4 km by 5 km area. The main vein is 2,200 meters long and 1.3 meters thick. The main ore minerals are sphalerite, galena, chalcopyrite, tetrahedrite, pyrargyrite, stibnite, pyrite, marcasite, pyrrhotite, magnetite, hematite, chalcocite, covellite, native copper, and native silver. Gangue minerals are mainly quartz, chlorite, sericite, kaolin, calcite, montmorillonite, and fluorite. Wallrocks are latered to quartz, K-feldspar, albitized plagioclase, chlorite, sericite, kaolin, montmorillonite, and calcite. The host rocks are Miocene altered andesite and tuff. A K-Ar adularia age for the vein is 5.8±0.2 Ma and for adularia from the host dacite is 9.7 U_20_5 Ma. The deposit was discovered in the early 800s and the mine closed in 1987. The deposit is medium size and it produced 26,000,000 tonnes of ore, 775,000 tonnes of Zn, 280,000 tonnes of Pb, 400 tonnes of Ag, 1 tonne of Au, and 9,500 tonnes of Cu. The average grades are 4.12 percent Zn, 1.59 percent Pb, 0.05 percent Cu, 0.2 g/t Au, and 40 g/t Ag.

Kinjo Volcanogenic-Sedimentary Mn Mine

This mine (Saito and others, 1967) consists of a horizontal stratiform-ore body. Maximum thickness is 3 meters. The deposit extends 120 meters north-south and 100 meters east-west. The ore body occurs between a lower greenish Miocene tuff breccia and an upper hornblende dacite and mudstone. Mn minerals were deposited in the Miocene. The ore minerals are psilomelane and pyrolusite. Gangue minerals are quartz and calcite. The deposit was discovered in 1952. The mine closed in 1961. The deposit is small and it produced 2,289 tonnes of MnO_2 (from 1953 to 1955) and 4,699 tonnes of Mn (from 1955 to 1958). The average grade is 53.79 percent MnO_2.

Kosaka Volcanogenic Zn-Pb-Cu Massive Sulfide (Kuroko, Altai types) Mine

This mine (Oshima and others, 1974; Hashiguchi, 1983; Nakajima, 1989) consists of three main ore bodies, Motoyama, Uchinotai, and Uwamuki. The Motoyama ore body is 600 meters long by 250 meters wide and 30 meters thick. The Uchinotai ore body is 700 meters long by 400 meters wide and 20 meters thick. The kuroko deposit is divided into three types of ores–kuroko, yellow, and siliceous ores. The main ore minerals of the kuroko are chalcopyrite, pyrite, galena, sphalerite, and tennantite. The main ore minerals of the yellow and siliceous ores are pyrite, chalcopyrite, sphalerite, bornite, chalcocite, and covellite. Minor minerals are quartz and barite. Barite is enriched at the top of the kuroko deposit. The host rocks are Miocene rhyolite and rhyolitic tuff. The Motoyama ore body was discovered in 1861 and the Uchinotai ore body was discovered 1959. The deposit is medium size and it produced 510,000 tonnes of Cu, 520,000 tonnes of Zn, 150,000 tonnes of Pb, and has reserves of 30 million tonnes. The average grades are 8.48 percent Zn, 2.84 percent Pb, 2.59 percent Cu, 1.15 g/t Au, and 184.7 g/t Ag.

Shakanai Volcanogenic Zn-Pb-Cu Massive Sulfide (Kuroko, Altai type) Deposit

This deposit (fig. 41) (Ohtagaki and others, 1974; Tanimura and others 1983; Nakajima, 1989) consists of eleven main bodies. The bodies are located in area of 4 km long and 2 km wide, with a depth of 200 meters. The main deposit minerals of the kuroko (black ore) are chalcopyrite, pyrite, galena, sphalerite, tetrahedrite and tennantite. The main deposit minerals of the yellow and siliceous ores are pyrite, chalcopyrite, and a small amount of sphalerite and galena. Siliceous and gypsum ore occurs below the unit of black ore and yellow ore. Minor minerals are quartz and barite. Host rock is Miocene rhyolite, rhyolite tuff and mudstone. Matsuki, Takadate, Takadate South deposits occur several hundred meters W of the Shakanai deposit. The deposit was discovered in 1961 and the mine closed in 1987. The deposit is medium size and has an average grade of 3.3 percent Zn, 2.15 percent Cu, 0.9 percent Pb, 0.35 g/t Au, and 77 g/t Ag. The deposit has produced 320,000 tonnes of Zn, 130,000 tonnes of Cu, 670,000 tonnes of Pb, and has reserves of 30 million tonnes.

Sado Au-Ag Epithermal-Vein Mine

This mine (fig. 42) (Mining and Materials Processing Institute of Japan, 1994a) consists of seven main east-west striking veins. The main vein is 2,100 meters long and 6 meters wide. Host rocks are Miocene dacite tuff, andesitic tuff, and mudstone. The main ore minerals are native gold, argentite, pyrargyrite, pyroustite, miargyrite, chalcopyrite, tetrahedrite, pyrite, galena, and sphalerite. Gangue minerals are mainly quartz, chalcedony, calcite, barite, adularia, rhodochrosite, gypsum, and sericite. Wallrocks are altered to chlorite, albite, sericite, quartz, and pyrite. K-Ar adularia ages for the vein are 134±0.5 Ma and 14.5±0.5 Ma. The deposit was discovered in 1601 and the mine closed in 1989. The deposit is medium size and it produced 78 tonnes of Au, 2,330 tonnes of Ag, 5,400 tonnes of Cu, and 15,300,000 tonnes of ore. The average grades are 1 to 5 g/t Au, 30 to 100 g/t Ag, and 0.1 to 0.3 percent Cu.

Toyoha Au-Ag Epithermal-Vein Mine

This mine (Mining and Metallurgical Institute of Japan, 1968; Kuwahara and others, 1983; Kato and others, 1990) consists of east-west and northwest striking veins. About 50 veins are present an area 2 km east-west by 3 km north-south. The veins have a maximum thickness of 4 meters and are about 1,300 meters long. The main ore minerals are sphalerite, galena, pyrite, and rhodochrosite. Minor ore minerals are chalcopyrite, hematite, pyrrhotite, stibnite, and marcasite. Indium minerals are found in the ore. The gangue minerals are quartz and small amounts of chlorite and calcite. Wallrocks altered to quartz, chlorite, and sericite. The deposit was one of the largest mines in Japan. The deposit is hosted in Miocene pyroclastic rocks. The K-Ar age of sericite in the vein is 2.2 Ma. The deposit is medium size and has an average grade of 9.6 percent Zn, 3.4 percent Pb, and 179g/t Ag. The mine produced 12 million tonnes of ore with 1,400 tonnes of Ag, 300,000 tonnes of Pb, and 780,000 tonnes of Zn. Reserves of 13 millon tonnes of ore grade 7.0 percent Zn, 2.1 percent Pb, and 124g/t Ag.

Origin and Tectonic Controls for Northeast Japan Metallogenic Belt

The volcanogenic massive sulfide deposits are interpreted as having formed in back-arc region of an island arc related to subduction of the Pacific Plate beneath eastern Hokkaido Island. Pliocene Au-Ag epithermal-vein deposits on Izu Peninsula formed in the Izu-Bonin island arc that accreted to Honshu Island before the formation of the deposits. Sulfur-sulfide and limonite deposits formed in the active island arc. Island arc magmatism is related to subduction of Pacific Plate.

Outer Zone Southwest Japan Metallogenic Belt of Sn Skarn, Sn-W Greisen, Stockwork, and Quartz Vein, Polymetallic Pb-Zn ± Cu (±Ag, Au) Vein and Stockwork, Au-Ag Epithermal-Vein, Volcanic-Hosted Hg, Ag-Sb Vein, Zn-Pb (±Ag, Cu, W) Skarn, W-Mo-Be Greisen, Stockwork, and Quartz Vein, Hg-Sb-W Vein and Stockwork, Cassiterite-Sulfide-Silicate Vein and Stockwork, and Clastic-Sediment-Hosted Sb-Au Deposits (Belt OS) (Japan)

This middle Miocene metallogenic belt is related to veins and replacements in the Japan Cenozoic sedimentary basin that overlies the Hiroshima granitic plutonic belt, Sambagawa, Shimanto, and Mino-Tamba-Chichibu terranes. The belt occurs in the outer zone of the Southwestern Japan, trends roughly northeast-southwest for more than 1,000 km, and

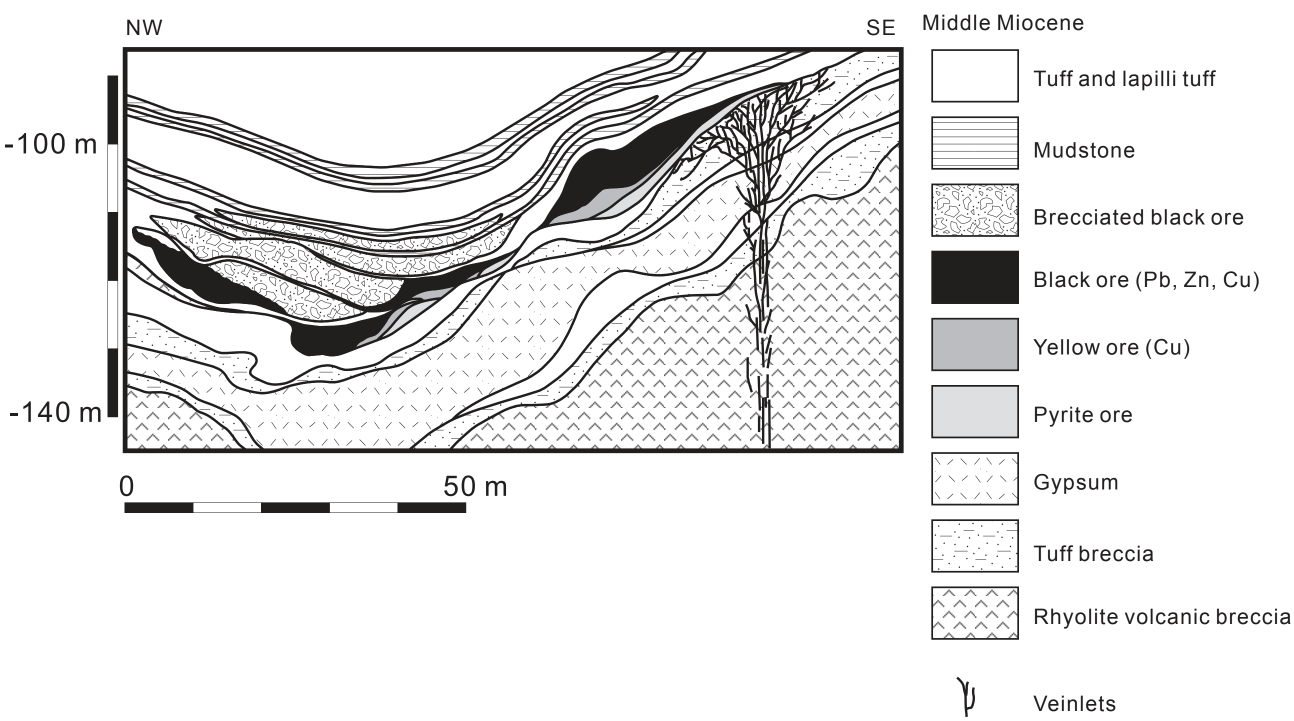


Figure 41. Schematic cross section of Shakanai Volcanogenic Zn-Pb-Cu massive sulfide (Kuroko, Altai type) deposit, Northeast Japan metallogenic belt, Japan. Adapted from Kajiwara (1970).

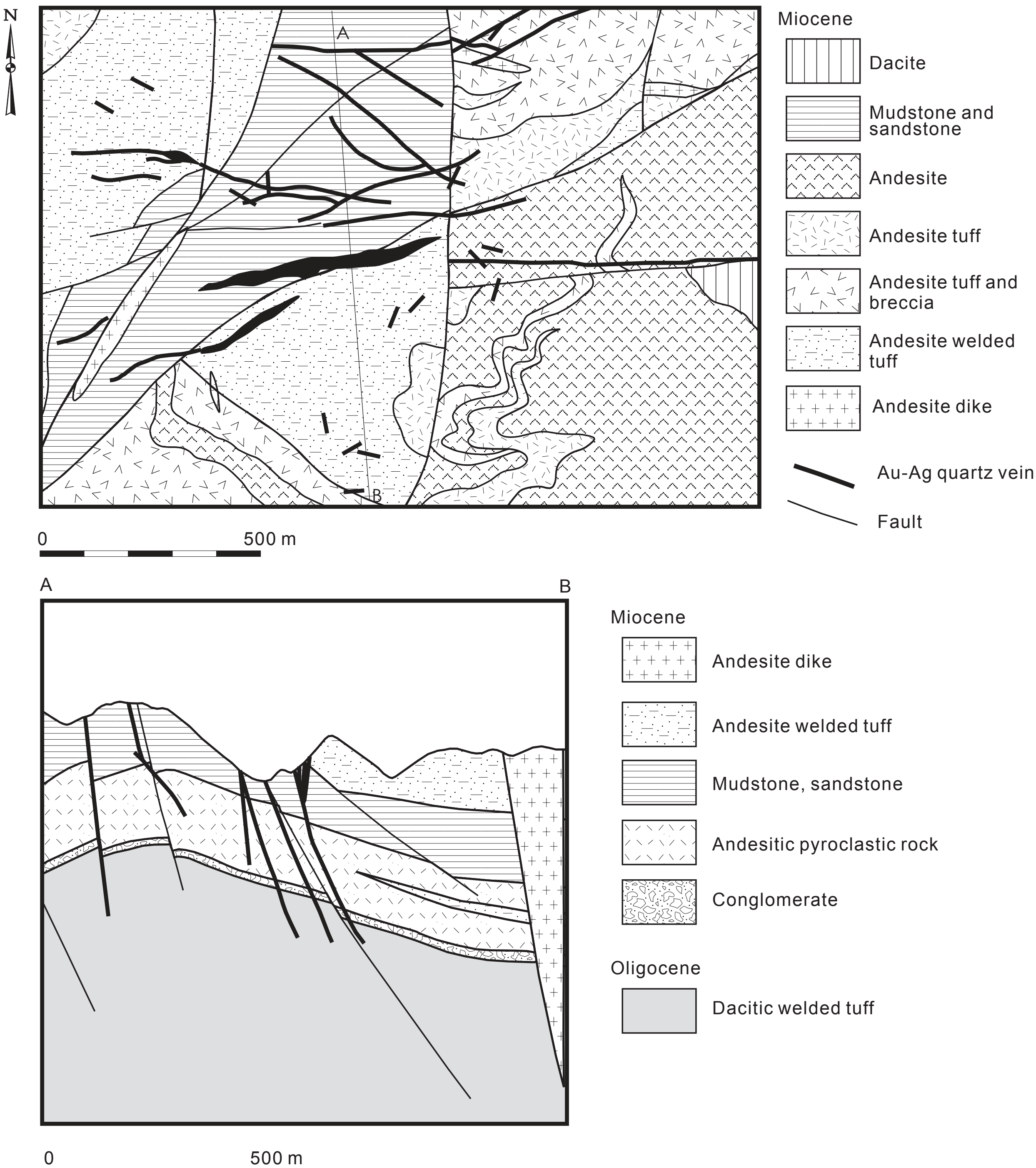


Figure 42. Generalized geologic map and schematic cross section of Sado Au-Ag epithermal vein mine, Northeast Japan metallogenic belt, Japan. Adapted from Ministry of International Trade and Industry (MITI) (1989).

varies from 50 to 150 km wide. The belt extends south along the Ryukyu island arc. Most of deposits occur south of Median tectonic line (MTL), but some Hg and Sb deposits occur north of the MTL. The metallogenic belt extends east of the Itoigawa-Shizuoka tectonic line to the Chichibu deposit.

The deposits are formed during mainly siliceous Miocene magmatism around the igneous bodies. The siliceous igneous rocks are scattered in mainly four areas (1) the Kii Peninsula (Kumano siliceous igneous rocks) on Honshu Island, (2) the Okueyama-Osuzuyama area on central Kyushu Island, and (3) the Osumi Peninsula on southern Kyushu and Yakushima Islands. The siliceous igneous rocks range from 15.5 to 13 Ma. The associated granitoids are mainly ilmenite-series. S-type granitoids occur in the southern part of the belt, and I-type granitoids occur in the northern part of the belt. The granitoids are interpreted as occurring along a forearc. The occurrence of siliceous igneous activity in the forearc is unusual. The igneous rock related to the Hg deposit is interpreted as being a member of the Miocene Setouchi volcanic rock that consists of high-Mg andesite. Tsuboya and others (1956) used the name Outer Zone Southwest Japan siliceous igneous rock metallogenic province, and Ishihara (1978) used the name Sn-W-Cu-As-Sb province for this metallogenic belt.

The main references on the geology and metallogenesis of the belt are Tsuboya and others (1956) and Ishihara (1978).

Chichibu Zn-Pb (±Ag, Cu, W) Skarn Mine

This mine (Mining and Materials Processing Institute of Japan, 1994a) consists of four ore bodies. The main ore body is 350 meters wide, 600 meters long, and 40 meters thick. The skarn occurs along the margin of a quartz-diorite and averages 30 to 50 meters wide. The ore bodies occur between limestone and skarn. The skarn was formed during intrusion of Miocene quartz-diorite and quartz-diorite porphyry. The granitoids have I-type characteristics. The main ore minerals are native gold, native silver, sphalerite, galena, magnetite, chalcopyrite, pyrite, pyrrhotite, arsenopyrite, and limonite. The gangue minerals are hedenbergite, garnet, epidote, and diopside, quartz, and calcite. Host rocks are Paleozoic limestone and mudstone. K-Ar biotite ages from the quartz-diorite are 5.87±0.37 and 6.59±0.27 Ma. The age of the ore deposit formation is interpreted to be 6.6 Ma. The deposit was discovered in 1205 and the mine closed in 1978. The mine is medium size and it produced 16.3 tonnes of Au, 72 tonnes of Ag, 100,000 tonnes of Zn, 7,000 tonnes of Pb, and 440,000 tonnes of Fe and has resources of 8 million tonnes. The average grades are 5 g/t Au, 60 g/t Ag, 5.5 percent Zn, 0.45 percent Pb, and 27.2 percent Fe.

Kishu Au-Ag Epithermal-Vein Mine

This mine (Mining and Metallurgical Institute of Japan, 1968; Mining and Materials Processing Institute of Japan, 1994b) consists of 24 east-west striking vein systems. The veins occur in an area 3 km (east-west) by 5 km (north-south). The main vein is 1,800 meters long and 0.5 meters thick. The host rocks are Shimanto Supergroup and Miocene sandstone. The main ore minerals are native gold, argentite, chalcopyrite, pyrite, sphalerite, galena, pyrrhotite, cassiterite, and wolframite. Gangue minerals are mainly quartz, calcite, chlorite, fluorite, sericite, and adularia. Wallrocks are altered mainly to chlorite. The deposit is associated with Miocene Kumano siliceous igneous rocks. The mine is medium siz-eand has produced 0.6 tonnes of Au, 153 tonnes of Ag, and 93,000 tonnes of Cu from 9,400,000 tonnes of ore. The average grades are 0.2 g/t Au, 26 g/t Ag, and 1.4 percent Cu.

Obira Cassiterite-Sulfide-Silicate Vein and Stockwork Mine

This mine (Mining and Metallurgical Institute of Japan, 1965; Karakida and others, 1992) consists of four main northeast striking veins. The main vein is 1,400 long and 1.5 meters thick. The host rocks are slate of Chichibu Group and Miocene granite porphyry and granite. The deposit formed during intrusion of Miocene granite. The ore minerals are cassiterite, arsenopyrite, pyrite, pyrhotite, and wolframite, molybdenite, chalcopyrite, and sphalerite. Gangue minerals are quartz, tourmaline, and fluorite. The deposit was discovered in 1574. The mine is medium size and has produced 800,000 tonnes of Sn ore and 5,000 tonnes of Sn. The average grades are 1.2 percent Sn, 1.56 percent Cu, and 11.2 percent As.

Yamatosuigin Hg-Sb-W Vein and Stockwork Mine

This mine (Geological Survey of Japan, 1955; Mining and Metallurgical Institute of Japan, 1968) consists of six northwest striking veins. The Main vein is 400 meters long, 500 meters wide, and extends 440 meters downdip. The host rocks are Cretaceous biotite granite of the Ryoke belt. The ore minerals are cinnabar, native marcury, realgar, and pyrite. Gangue minerals are quartz, chalcedony, sericite, calcite, and adularia. Wallrocks are altered to kaolinite, montmorillonite, and sericite. The deposit formed during Miocene igneous activity. The mine is medium size and has prooduced 645 tonnes of Hg grading 0.5 percent Hg.

Origin and Tectonic Controls for Outer Zone Southwest Japan Metallogenic Belt

The belt is interpreted as having formed along an island arc during back-arc rifting or along the axial part of an island arc that was related to subduction of the Philippine Sea Plate.

Late Jurassic through Early Cretaceous Tectonic and Metallogenic Model

Major Tectonic and Metallogenic Events

For the Late Jurassic through Early Cretaceous (154 to 96 Ma), the major metallogenic and tectonic events were (figs. 3, 43, tables 1, 2): (1) final closure of the Mongol-Okhotsk Ocean with resultant displacement of collisional processes eastward; (2) formation of collisional Stanovoy granite belt that is composed predominantly of granodiorite, granite, and granosyenite along the southern margin of the Aldan-Stanovoy shield of the North Asian craton and westward into the eastern Transbaikalia region; (3) continued formation of the Transbaikal volcano-plutonic belt and associated metallogenic belts along the axis of the closed Mongol-Okhotsk Ocean in a transpressional fault setting; (4) continued formation of transpressional fault zones along the axis of the closed Mongol-Okhotsk Ocean and formation of associated metallogenic belts; (5) postcollisional transform faulting along within-plate transpression zones in northeast China and formation of associated metallogenic belts; (6) accretion of the Kolyma superterrane and Okhotsk cratonal terrane against the Verkhoyansk (North Asian) cratonal margin and formation of collision-related granitoids and volcanic units, veins, and associated metallogenic belts; (7) formation of the Oloy continental-margin arc along the outboard edge of the accreted Kolyma-Omolon superterrane; (8) continued formation of the Uda-Murgal continental-margin arc and associated metallogenic belts; (9) beginning of underthrusting of the Kula oceanic ridge and formation of bimodal igneous rocks along the Khingan transform continental margin in the Russian Far East; and (10) in oceanic settings, but now preserved as tectonic fragments in subduction-zone terranes, formation of oceanic lithosphere and assocated metallogenic belts.

The major Middle Jurassic through Early Cretaceous metallogenic belts in Northeast Asia are shown on figure 3. The tectonic setting of each metallogenic belt is shown on figure 43.

Metallogenic Belts and Tectonic Origins

Metallogenic Belts Related to Trans-Baikalian-Daxinganling Transpressional Arc

Ten metallogenic belts are hosted in the major Late Jurassic through Early Cretaceous Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt that overlaps terranes that were previously accreted to the southern margin (present-day coordinates) of the North Asian craton (figs. 3, 43). The host rocks and metallogenic belts are interpreted as having formed during interplate extensional tectonism along the Trans-Baikalian-Daxinganling transpressional arc that formed along the major Mongol-Okhotsk suture that cuts previously-accreted terranes south of the southern margin (present-day coordinates) of the North Asian craton and cratonal margin. Displacement along the suture and arc formation occurred after the closing of the Mongol-Okhotsk Ocean. The belts contain a wide variety of siliceous igneous-rock related deposits. The host rocks and metallogenic belts occur along interplate extensional faults that are coeval with generation of subalkaline to alkaline volcanism and related sedimentation along northeast and east-west regional faults.

The Daxinganling belt (DX, figs. 3, 43) contains Zn-Pb (±Ag, Cu) skarn, Sn skarn, cassiterite-sulfide-silicate vein and stockwork, polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork, peralkaline granitoid-related Nb-Zr-REE, and Au-Ag epithermal-vein deposits that are hosted in veins, replacements, and granitoids.

The Dzid-Selenginskiy belt (DS, figs. 3, 43) contains W-Mo-Be greisen, stockwork, and quartz vein; granitoid-related Au vein; Au skarn, porphyry Mo (±W, Bi); fluorspar vein; and magmatic and metasomatic apatite deposits.

The East Mongolian-Priargunskiy-Deerbugan belt (EM, figs. 3, 43) contains polymetallic (Pb, Zn, Ag) carbonate-hosted metasomatite; Zn-Pb (±Ag, Cu, W) skarn; Au skarn; polymetallic (Pb, Zn±Cu, Ba, Ag, Au) volcanic-hosted metasomatite; volcanic-hosted Au-base-metal metasomatite; W-Mo-Be greisen, stockwork, and quartz vein; porphyry Cu-Mo (±Au, Ag); porphyry Mo (±W, Bi); granitoid-related Au vein; carbonate-hosted As-Au metasomatite; Au-Ag epithermal vein; sedimentary siderite Fe; Sn-W greisen, stockwork, and quartz vein; carbonate-hosted Hg-Sb; fluorspar vein; and volcanic-hosted U deposits.

The Govi-Tamsag belt (GT, figs. 3, 43) contains sediment-hosted U, evaporite sedimentary gypsum, sedimentary celestite, and volcanic-hosted zeolite deposits.

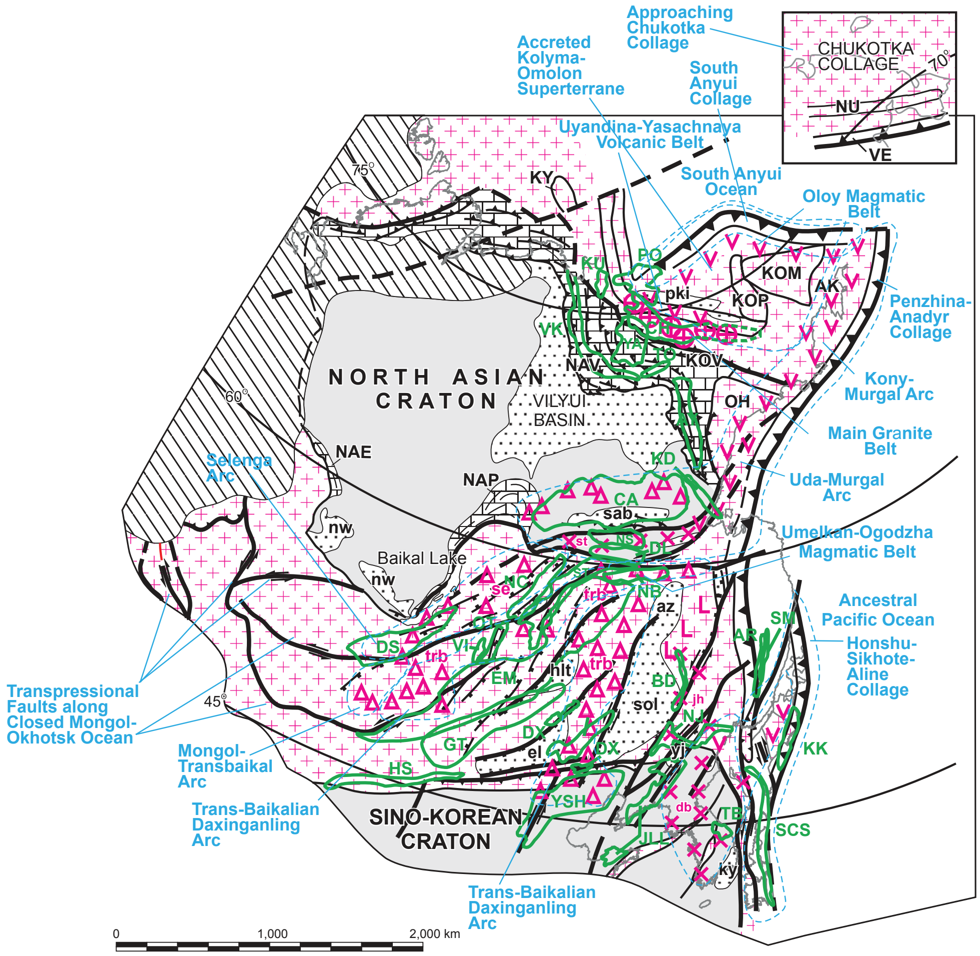
The Hartolgoi-Sulinheer belt (HS, figs. 3, 43) contains Au-Ag epithermal vein, Ag-Pb epithermal vein, porphyry Mo, W±Mo±Be skarn, polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork, carbonate-hosted Ag-Pb, carbonate-hosted Hg-Sb, and silica-carbonate (listvenite) Hg deposits.

The Nerchinsky belt (NC, figs. 3, 43) contains granitoid-related Au vein; W-Mo-Be greisen, stockwork, and quartz vein; and fluorspar-vein deposits.

The Onon-Turinskiy belt (OT, figs. 3, 43) contains granitoid-related Au vein, porphyry Au, and cassiterite-sulfide-silicate vein and stockwork deposits.

The Shilkinsko-Tukuringrskiy belt (ST, figs. 3, 43) contains granitoid-related Au vein, porphyry Au; Au skarn; Au-Ag epithermal vein; porphyry Mo (±W, Bi); W-Mo-Be greisen, stockwork, and quartz vein; cassiterite-sulfide-silicate vein and stockwork; Ta-Nb-REE alkaline metasomatite; polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork; Au-Ag epithermal vein; and fluorite-vein deposits.

And the Verkhne-Ingodinsky belt (VI, figs. 3, 43) contains cassiterite-sulfide-silicate vein and stockwork deposits.



GEOLOGIC UNITS

North Asian Craton Margin

NAE - East Angara
NAP - Patom-Baikal
NAV - Verkhoyansk

Intracontinental Sedimentary Basins

az - Amur-Zeya sedimentary basin (Late Jurassic to Quaternary)
el - Erlian sedimentary basin (Jurassic through Quaternary)
hlt - Hailar-Tamsag sedimentary basin (Late Jurassic and Cretaceous)
ky - Kyongsang sedimentary basin (Early Cretaceous)
nw - Western Siberia sedimentary basins (Mesozoic and Cenozoic)
pki - Ilin'-Tas back-arc basin (Late Jurassic)
sab - South Aldan sedimentary basin (Jurassic)
sol - Songliao sedimentary basin (Jurassic through early Tertiary)

Terranes and Superterranes

AK - Avekov terrane
KY - Kotel'nyi terrane (Passive continental margin) (Late Neoproterozoic through Late Triassic)
KOM - Kolyma-Omolon superterrane
KOP - Prikolyma terrane
KOV - Omulevka terrane (Passive continental margin) (late Neoproterozoic through Triassic)
NU - Nutesyn terrane
OH - Okhotsk terrane
VE - Velmay terrane

Overlap Continental-Margin Arcs and Granite Belts

db - Daebo granite belt (Early to Late Jurassic)
jh - Jihei volcanic and plutonic belt (Mesozoic)
se - Selenga sedimentary-volcanic plutonic belt (Permian through Jurassic)
st - Stanovoy granite belt (Jurassic and Early Cretaceous)
trb - Trans-Baikalian-Daxinganling sedimentary-volcanic-plutonic belt (Middle Jurassic through Early Cretaceous)

METALLOGENIC BELTS

AR - Ariadny
AY - Allakh-Yun'
BD - Bindong
CA - Chara-Aldan
CH - Chybagalakh
DL - Djeltulaksky
DS - Dzid-Selenginskiy
DX - Daxinganling
EM - East Mongolian-Priargunskiy-Deerbugan
GT - Govi-Tamsag
HS - Hartolgoi-Sulinheer
JLL - Jiliaolu
KD - Kondyor-Feklistov
KK - Kitakami
KU - Kular
NB - North Bureya
NC - Nerchinsky
NJ - North Jilin
NS - North Stanovoy
OT - Onon-Turinskiy
PO - Polousny
SCS - Sambagawa-Chichibu-Shimanto
SM - Samarka
ST - Shilkinsko-Tukuringrskiy
TB - Taebaegsan
TO - Tompo
VI - Verkhne-Ingodinsky
VK - Verkhoyansk
YA - Yana-Adycha
YSH - Yanshan

Figure 43. Middle Jurassic through Early Cretaceous (145 Ma) metallogenic and tectonic model for Northeast Asia. Adapted from Parfenov and others (this volume).

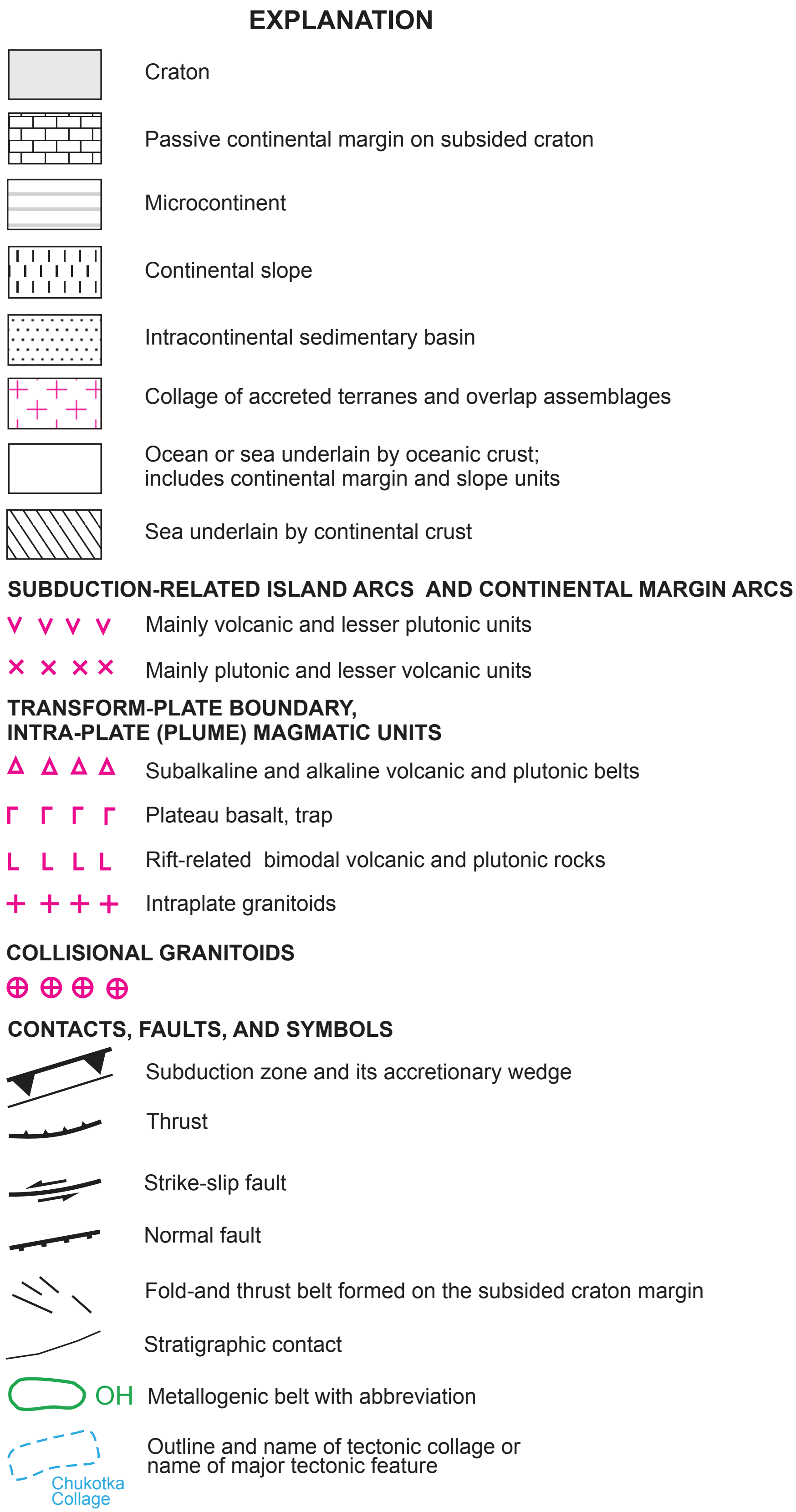


Figure 43.—Continued.

Metallogenic Belts Related to Accretion of the Kolyma-Omolon Superterrane and Okhotsk Terrane

Eight metallogenic belts possess geologic units favorable for a wide variety of Au-vein deposits and collisional granite-related deposits. The ages of the veins and associated granites range from Late Jurassic through Aptian. The belts and deposits are hosted in veins and granitoids (such as the South Verkhoyansk, Main, and Northern granite belts) that intrude the Verkhoyansk (North Asian) cratonal margin and (or) the margin of the adjacent Kolyma-Omolon superterrane. The host rocks and metallogenic belts are interpreted as having formed during collision and accretion of the Kolyma-Omolon superterrane to the North Asian cratonal margin, or immediately before the accretion of the Okhotsk terrane to the North Asian cratonal margin, with resultant regional metamorphism and generation of anatectic granitoids and related hydrothermal fluids.

The Allakh-Yun belt (AY, figs. 3, 43) contains Au in shear zone and quartz vein and Cu (±Fe, Au, Ag, Mo) skarn deposits that are hosted in veins in the Verkhoyansk (North Asian) cratonal margin.

The Chybagalakh belt (CH, figs. 3, 43) contains cassiterite-sulfide-silicate vein and stockwork, Sn-B (Fe) skarn (ludwigite), and granitoid-related Au-vein deposits that are hosted in veins and replacements in the Main granite belt that intrudes the southern margin of the Kolyma-Omolon superterrane.

The Kular belt (KU, figs. 3, 43) contains Au in shear zone and quartz vein, granitoid-related Au Vein, and Sn-W greisen, stockwork, and quartz-vein deposits that are hosted in veins in the Kular-Nera terrane, part of the Verkhoyansk-Kolyma collage.

The Polousny belt (PO, figs. 3, 43) contains cassiterite-sulfide-silicate vein and stockwork and polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork deposits that are hosted in granitoids related to the Northern granite belt that intrudes the Kolyma-Omolon superterrane and adjacent units.

The South Verkhoyansk belt (SV, figs. 3, 43) contains Au in shear zone and quartz vein, polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork; granitoid-related Au vein; W-Mo-Be greisen, stockwork, and quartz vein; and Au-Ag epithermal-vein deposits that are hosted in veins related to Early Cretaceous granitoids in South Verkhoyansk granite belt (Late Jurassic through mid-Cretaceous) intruding the Verkhoyansk (North Asian) cratonal margin.

The Tompo belt (TO, figs. 3, 43) contains W±Mo±Be skarn and Sn-W greisen, stockwork, and quartz-vein deposits that are hosted in replacements in the Northern and Transverse granite belts along northwestern margin of the Kolyma-Omolon superterrane.

The Verkhoyansk belt (VK, figs. 3, 43) contains Au in shear zone and quartz vein, polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork; Sn-W greisen, stockwork, and quartz vein; and Au in black shale deposits that are hosted in veins and replacements in the Verkhoyansk (North Asian) cratonal margin.

The Yana-Adycha belt (YA, figs. 3, 43) contains cassiterite-sulfide-silicate vein and stockwork and Sn-W greisen, stockwork, and quartz-vein deposits that are hosted in replacements in the Transverse granite belt along the northwestern margin of the Kolyma-Omolon superterrane.

Metallogenic Belts Related to Uda-Stanovoy Continental-Margin Arc

Three metallogenic belts contain granitoid-related deposits that formed during intrusion of granitoids of the Jurassic through Early Cretaceous Stanovoy granite belt that was part of the Uda-Stanovoy continental-margin arc. The arc is interpreted as having formed during subduction and closure of the Mongol-Okhotsk Ocean beneath the North Asian craton to the north (present-day coordinates).

The Chara-Aldan belt (CA, figs. 3, 43) contains Au potassium metasomatite, Au skarn, U-Au, and Au in shear-zone and quartz-vein deposits.

The Djeltulaksky belt (DL, figs. 3, 43) contains granitoid-related Au-vein deposits.

The North Stanovoy belt (NS, figs. 3, 43) contains granitoid-related Au-vein and Au-Ag epithermal-vein deposits.

Metallogenic Belts Related to Transpression

Four metallogenic belts possess geologic units favorable for a wide variety of transpressional granitoid-related deposits (figs. 3, 43). The granitoids and veins intrude either overlap assemblages on the Sino-Korean craton or the Samarka subduction-zone terrane (part of Honshu-Sikhote-Alin collage). The metallogenic belts are interpreted as having formed during intrusion of granitoids along transpressional zones along micro plate boundaries, underthrusting of the Kula oceanic ridge, and formation of bimodal igneous rocks along a transform continental margin, or during interplate magmatism associated with extensional tectonism related to oblique subduction of the Pacific Oceanic Plate beneath the Eurasian Plate.

The Jiliaolu belt (JLL, figs. 3, 43) contains Zn-Pb (±Ag, Cu) skarn, Cu (±Fe, Au, Ag, Mo) skarn, granitoid-related Au vein, polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork, and volcanic-hosted Au-base metal metasomatite deposits that are hosted in replacements and granitoids related to the Jilin-Liaoning-East Shandong volcanic-plutonic belt that overlies and intrudes Sino-Korean craton–Jilin-Liaoning-East Shandong terrane. The belt interpreted as having formed during interplate magmatism associated with extensional tectonism related to oblique subduction of the Pacific Oceanic Plate beneath the Eurasian Plate.

The North Jilin belt (NJ, figs. 3, 43) contains Zn-Pb (±Ag, Cu) skarn, granitoid-related Au vein, porphyry Cu

(±Au), porphyry Mo (±W, Bi), polymetallic (Pb, Zn±Cu, Ba, Ag, Au) volcanic-hosted metasomatite, Au-Ag epithermal vein, and fluorspar-vein deposits that are hosted in replacements and granitoids intruding the North Margin Plutonic belt that overlies the North China Platform, the Laoling terrane, part of the Wundurmiao collage, and the Zhangguangcailing superterrane. The belt is interpreted as being related to magmatism along transpression zones along transform microplate boundaries and within plate (plume) environment.

The Samarka belt (SM, figs. 3, 43) contains porphyry Cu-Mo (±Au, Ag), porphyry Mo (±W, Sn, Bi), and W±Mo±Be skarn deposits that are hosted in replacements and granitoids in the Khungari-Tatibi granite belt that intrudes the Samarka terrane, part of Honshu-Sikhote-Alin collage. The belt is interpreted as having formed during generation of S-type grantitoid plutons during underthrusting of the Kula oceanic ridge and formation of bimodal igneous rocks along a transform continental margin.

The Yanshan belt (YS, figs. 3, 43) contains Cu (±Fe, Au, Ag, Mo) skarn, W±Mo±Be skarn, porphyry Mo (±W, Bi), granitoid-related Au vein, polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork, and Au-Ag epithermal-vein deposits that are hosted in veins, replacements, and granitoids related to the Yanliao volcanic and sedimentary basin and plutonic belt that overlies and intrudes the Sino-Korean craton, including the West Liaoning-Hebei-Shanxi terrane, and adjacent units. The belt is interpreted as having formed during interplate magmatism associated with extensional tectonism related to oblique subduction of the Pacific Oceanic Plate beneath the Eurasian Plate.

Unique Metallogenic Belts

Six unique metallogenic belts formed during this time span (figs.3, 43). (1) The Ariadny belt (AR, figs. 3, 43), with mafic-ultramafic rock-related deposits is hosted in Middle Jurassic and Early Cretaceous plutons intruding the Samarka subduction-zone terrane, part of the Honshu-Sikhote-Alin collage. The belt is interpreted as having formed during generation of ultramafic and gabbroic plutons during underthrusting of the Kula oceanic ridge and formation of bimodal igneous rocks along a transform continental margin. (2) The Bingdong belt (BD, figs. 3, 43) contains Zn-Pb (±Ag, Cu) skarn, W±Mo±Be skarn, and Fe skarn deposits that are hosted in replacements related to small Late Jurassic through Early Cretaceous granitoids in the Mesozoic Jihei volcanic and plutonic belt that intrudes and overlies the Zhangguangcailing superterrane and is interpreted as having formed during interplate extensional tectonism and generation of sub-alkaline to alkaline volcanism and related sedimentation along northeast and east-west regional faults. (3) The Kitakami belt (KK, figs. 3, 43), with Cu skarn and granitoid-related Au deposits is hosted in the Early Cretaceous part (with isotopic ages of 120 to 110 Ma) of the Hiroshima granite belt and is interpreted as having formed during intrusion of granitoids associated with a continental-margin arc and siliceous magmatism. (4) The Kondyor-Feklistov belt (KD, figs. 3, 43), with zoned mafic-ultramafic Cr-PGE deposits, is hosted in mafic-ultramafic intrusions and is interpreted as having formed during intrusion of mafic-ultramafic plutons along a deep-seated fault that formed along the North Asian cratonal margin during collision and accretion of outboard terranes. (5) The North Bureya belt (NB, figs. 3, 43), with Au-Ag epithermal-vein and granitoid-related Au-vein deposits, is hosted in the Umlekam-Ogodzhin volcanic-plutonic belt. The belt is interpreted as having formed during formation of Umlekan-Ogodzhin continental-margin arc that formed during subduction of part of ancestral Pacific Ocean Plate. (6) The Taebaegsan belt (TB, figs. 3, 43), with a wide assortment of granitoid-related deposits, is hosted in the Daebo granite and is interpreted as having formed during intrusion of granitoids associated with the Late Jurassic through Early Cretaceous Daebo granite. The granitioids are interpreted as being part of a continental-margin arc that was linked to subduction of the ancestral Pacific Ocean Plate.

Cenomanian through Campanian Tectonic and Metallogenic Model

Major Tectonic and Metallogenic Events

For the Cenomanian through Campanian (96 to 72 Ma), the major metallogenic and tectonic events were (figs. 4, 44, tables 1, 2) (1) formation of granitoids and associated metallogenic belts along the Khingan transform continental margin that formed in response to oblique subduction of ancestral Pacific Ocean Plate in the Russian Far East; (2) after accretion of the Kolyma-Omolon superterrane and Okhotsk terrane and accretion of the Koryak collage (composed of Late Jurassic and Early Cretaceous island arc and tectonically-linked subduction-zone terranes) in the Late Jurassic and Early Cretaceous, outboard stepping of subduction and formation of the major Late Cretaceous and early Tertiary Okhotsk-Chukotka continental-margin arc and associated metallogenic belts; (3) after accretion of the Bureya-Jiamusi superterrane and Sino-Korean craton in the Late Jurassic through Early Cretaceous and accretion of outboard terranes, outboard stepping of subduction and formation of the East Sikote-Alin continental-margin arc (containing the East Sikote-Alin volcanic-plutonic belt) and associated metallogenic belts; (4) formation of major back-arc basins in the Russian Northeast behind the Okhotsk-Chukotka continental-margin arc and in northern China behind the East Sikhote-Alin continental-margin arc. (5) late-stage continuation of transpressional fault zones along the axis of the closed Mongol-Okhotsk Ocean and formation of associated metallogenic belts; (6) postcollisional transform faulting along within-plate transpression zones in northeast China and formation of associated metallogenic belts; (7) in the late part of this time span, in the area of the East Sikhote-Alin fault, formation of a major continental-margin transform-fault system in the Russian Southeast along with generation of granitic and volcanic rocks and associated metallogenic belts; (8) rifting and formation of the Eurasian Basin and formation of the Arctic Ocean and associated metallogenic belts; and (9) accretion into the area of Japan of the Honshu-Sikhote-Alin collage that is composed of mainly island-arc, continental-margin turbidite (flysch), and subduction-zone terranes.

The major Cenomanian through Campanian metallogenic belts in Northeast Asia are portrayed on figure 4. The tectonic setting of each metallogenic belt is portrayed on figure 44.

Metallogenic Belts and Tectonic Origins

Metallogenic Belts Related to Okhotsk-Chukotka and East Sikhote-Alin Continental-Margin Arcs

Seven metallogenic belts are hosted in the Okhotsk-Chukotka and East Sikhote-Alin continental-margin arcs (figs. 4, 44) that formed in response to subduction of the ancestral Pacific Ocean Plate. The belts are the Chelasin, Kukhtuy-Uliya, Luzhkinsky, Preddzhugdzhursky, Sergeevka-Taukha, Tumnin-Anyui, and Upper Uydoma belts that contain a wide variety of granitoid-related deposits. The ages of the hosting granites and associated veins range from mid-Cretaceous through Paleocene. The major host rock units are the Okhotsk-Chukotka volcanic-plutonic belt and the East Sikhote-Alin volcanic-plutonic belt. Both units are major overlap assemblages in the Russian Far East and are interpreted as being part of an extensive, nearly coeval, and colinear continental-margin arcs that overlie the North Asian craton and cratonal margin and previously accreted terranes to the west (present-day coordinates).

The Chelasin belt (CH, figs. 4, 44) contains Sn-B (Fe) skarn (ludwigite), granitoid-related Au vein, Cu (±Fe, Au, Ag, Mo) skarn, and porphyry Cu (±Au) deposits that are hosted in the Okhotsk-Chukotka volcanic-plutonic belt.

The Kukhtuy-Uliya belt (KU, figs. 4, 44) contains Au-Ag epithermal vein, porphyry Mo (±W, Sn, Bi), porphyry Sn, and polymetallic (Pb, Zn±Cu, Ba, Ag, Au) volcanic-hosted metasomatite deposits that are hosted in the Okhotsk-Chukotka volcanic-plutonic belt.

The Luzhkinsky belt (LZ, figs. 4, 44) contains Sn-W greisen, stockwork, and quartz vein; Cassiterite-sulfide-silicate vein and stockwork; W-Mo-Be greisen, stockwork, and quartz vein; porphyry Sn; porphyry Cu (±Au); porphyry Cu-Mo (±Au, Ag); and polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork deposits that are hosted in the Okhotsk-Chukotka volcanic-plutonic belt.

The Preddzhugdzhursky belt (PD, figs. 4, 44) contains porphyry Cu-Mo (±Au, Ag), porphyry Cu (±Au), Au-Ag epithermal vein, granitoid-related Au vein, and Cu (±Fe, Au, Ag, Mo) skarn deposits that are hosted in the Okhotsk-Chukotka volcanic-plutonic belt.

The Sergeevka-Taukha belt (ST, figs. 4, 44) contains granitoid-related Au vein, boron (datolite) skarn, Zn-Pb (±Ag, Cu) skarn, polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork, Au-Ag epithermal vein, and porphyry Cu (±Au) deposits that are hosted in the East-Silhote Alin volcanic-plutonic belt.

The Tumnin-Anyui belt (TA, figs. 4, 44) contains porphyry Sn, cassiterite-sulfide-silicate vein and stockwork, and Au-Ag epithermal-vein deposits that are hosted in the East-Silhote Alin volcanic-plutonic belt.

The Upper Uydoma belt (TA, figs. 4, 44) contains cassiterite-sulfide-silicate vein and stockwork; polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork; Sn-W greisen, stockwork, and quartz vein; and porphyry Mo (±W, Sn, Bi) deposits that are hosted in the East-Silhote Alin volcanic-plutonic belt.

Metallogenic Belts Related to Khingan Transform Continental-Margin Arc

Four major metallogenic belts are hosted in granitioids of the Khingan-Okhotsk volcanic-plutonic belt that is interpreted as having formed during the generation of granitoids along the Khingan transform continental-margin arc. The belts are Badzhal-Komsomolsk, Ezop-Yam-Alin, Malo-Khingan, and Pilda-Limuri. The isotopic ages for the granitoids hosting or associated with the deposits range from 100 to 75 Ma. The arc is interpreted as having formed during oblique subduction of the ancestral Pacific Ocean Plate and formation of the Early Cretaceous Zhuravlevsk-Amur River and Kiselevka-Manoma subduction-zone terranes, part of the Honshu-Sikhote-Alin collage.

The Badzhal-Komsomolsk belt (BK, figs. 4, 44) contains Sn-W greisen, stockwork, and quartz vein; cassiterite-sulfide-silicate vein and stockwork; Cu (±Fe, Au, Ag, Mo) skarn; and porphyry Mo (±W, Sn, Bi) deposits.

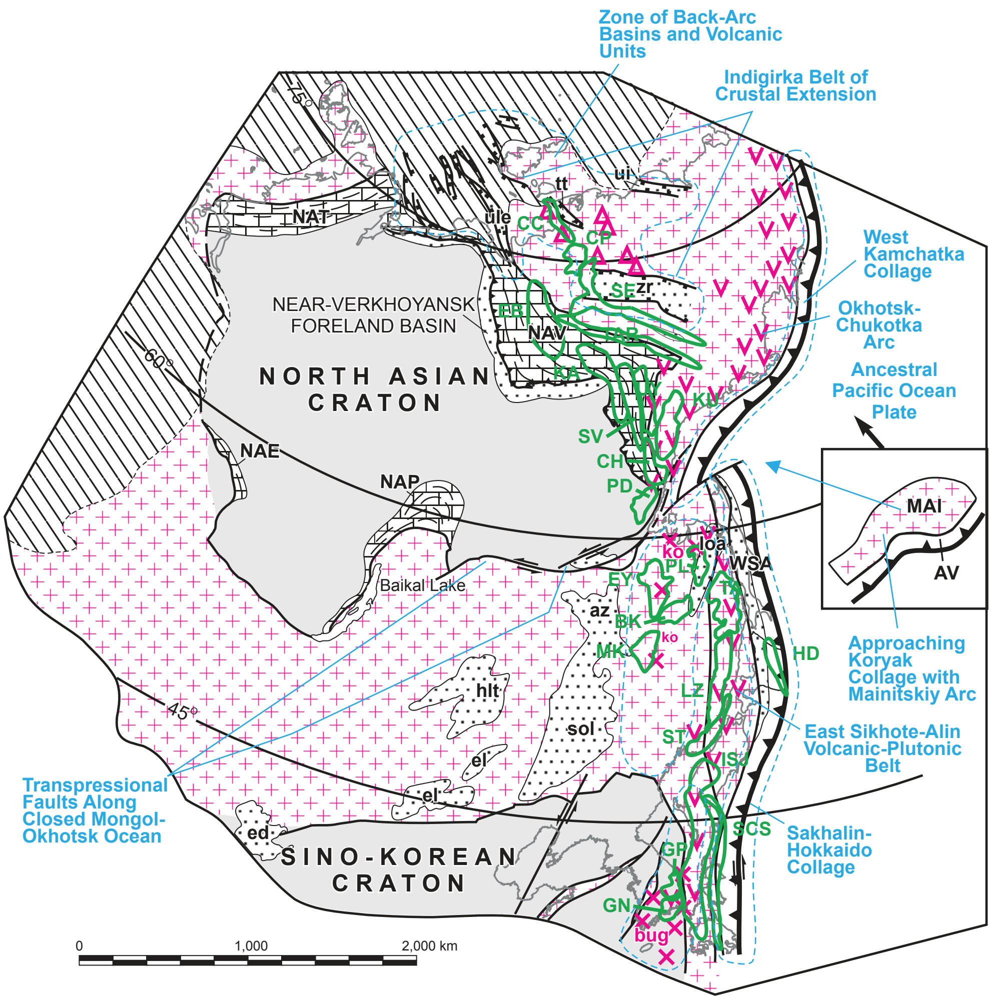
The Ezop-Yam-Alin belt (EY, figs. 4, 44) contains W-Mo-Be greisen, stockwork, and quartz vein; Sn-W greisen, stockwork, and quartz vein; cassiterite-sulfide-silicate vein and stockwork; and porphyry Mo (±W, Sn, Bi) deposits.

The Malo-Khingan belt (MK, figs. 4, 44) contains porphyry Sn and rhyolite-hosted Sn deposits.

The Pilda-Limuri belt (PL, figs. 4, 44) contains Sn-W greisen, stockwork, and quartz vein; W-Mo-Be greisen, stockwork, and quartz vein; Ag-Sb vein; polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork; and granitoid-related Au-vein deposits.

Metallogenic Belts Related to Opening of the Eurasia Basin

Five metallogenic belts are interpreted as having formed during extension related to the formation of the Eurasia Basin during initial opening of the Arctic Ocean. The extension resulted in the formation of the Indigirka belt of crustal extension (fig. 44). The belts contain a variety of vein, replacement, and granitoid-related deposits and include the Central Polousny, Chokhchur-Chekurdakh, Eckyuchu-Billyakh,



GEOLOGIC UNITS

North Asian Craton Margin

NAE - East Angara
NAP - Patom-Baikal
NAT - South-Taimyr
NAV - Verkhoyansk

Intracontinental Sedimentary Basins

az - Amur-Zeya sedimentary basin (Late Jurassic to Quaternary)
ed - Erduosi sedimentary basin (Triassic through Cretaceous)
el - Erlian sedimentary basin (Jurassic through Quaternary)
hlt - Hailar-Tamsag sedimentary basin (Late Jurassic and Cretaceous)
loa - Lower Amur overlap assemblage (Late early and early Late Cretaceous)
sol - Songliao sedimentary basin (Jurassic through early Tertiary)
tt - Tastakh Basin
ui -Ust-Indigirka Basin
ule - Ust-Lena Basin
zr - Zyryanka sedimentary basin (Late Jurassic through Cenozoic)

Terranes

AV - Alkatvaam terrane
MAI - Mainitskiy terrane
WSA - West Sakhalin terrane (Accretionary wedge, type A) (Cretaceous)

Overlap Continental-Margin Arcs and Granite Belts

ko - Khingan-Okhotsk volcanic-plutonic belt (Cretaceous)
bug - Bulgugsa granite (Late Cretaceous

METALLOGENIC BELTS

BK - Badzhal-Komsomolsk
CC - Chokhchur-Chekurdakh
CH - Chelasin
CP - Central Polousny
EB - Eckyuchu-Billyakh
EY - Ezop-Yam-Alin
GN - Gyeongnam
GP - Gyeongpuk
HD - Hidaka
ISJ - Inner Zone Southwest Japan
KA - Khandyga
KU - Kukhtuy-Uliya
LZ - Luzhkinsky
MK - Malo-Khingan
PD - Preddzhugdzhursky
PL - Pilda-Limuri
SCS - Sambagawa-Chichibu-Shimanto
SE - Selennyakh
ST - Sergeevka-Taukha
SV - South Verkhoyansk
TA - Tumnin-Anyuy
TAR - Taryn
UY - Upper Uydoma

Figure 44. Cenomanian through Companian (87 Ma) metallogenic and tectonic model for Northeast Asia. Adapted from Parfenov and others (this volume).

Khandyga, and Selennyakh belts. The isotopic ages for the-vein deposits range from 120 to 97 Ma (Aptian through Late Cretaceous). The belts and deposits are hosted in units that intrude the Northern and Transverse granite belts, the Svyatoi Nos volcanic belt, and the Uyandina-Yasachnaya volcanic belt that intrude or overlie the Verkhoyansk (North Asian) cratonal margin and outboard accreted terranes.

The Central Polousny belt (CP, figs. 4, 44) contains cassiterite-sulfide-silicate vein and stockwork, and Sn-W greisen, stockwork, and quartz-vein deposits that are hosted in Veins and replacements in the Northern granite belt along the northwestern margin of the Kolyma-Omolon superterrane.

The Chokhchur-Chekurdakh belt (CC, figs. 4, 44) contains cassiterite-sulfide-silicate vein and stockwork deposits that are hosted in veins and replacements in the Svyatoi Nos volcanic belt that occurs along southern margin of the Kolyma-Omolon superterrane.

The Eckyuchu-Billyakh belt (EB, figs. 4, 44) contains polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork; clastic-sediment-hosted Sb-Au; Hg-Sb-W vein and stockwork; Ag-Sb vein; and Au-Ag epithermal-vein deposits that are hosted in veins and replacements related to the Transverse granite belt that intrudes the Verkhoyansk (North Asian) cratonal margin.

The Khandyga belt (EB, figs. 4, 44) contains Ag-Sb vein, carbonate-hosted As-Au metasomatite, clastic-sediment-hosted Sb-Au, and clastic sediment-hosted Hg±Sb deposits that are hosted in veins and replacements in the Verkhoyansk (North Asian) cratonal margin.

The Selennyakh belt (EB, figs. 4, 44) contains Carbonate-hosted Hg-Sb, volcanic-hosted Hg, and Ag-Sb-vein deposits that are hosted in veins and replacements in the Uyandina-Yasachnaya volcanic belt along the southern margin of the Kolyma-Omolon superterrane.

Unique Metallogenic Belts

Four unique metallogenic belts formed during this time span.

(1) The Gyeongpuk belt (GP, figs. 4, 44) and the Gyeongnam belt (GN, figs. 4, 44) (with polymetallic Pb-Zn vein and stockwork, Au in shear zone and quartz vein; porphyry Mo; W-Mo-Be greisen, stockwork, and quartz vein; Sn-W greisen, stockwork, and quartz vein; Fe skarn; and polymetallic Ni-vein deposits) have isotopic ages of Cenomanian through Campanian, and are hosted in the Cretaceous Bulgugsa granite that intrudes the Sino-Korean craton. The belts and deposits are interpreted as having formed in a continental-margin arc during subduction of the ancestral Pacific Ocean Plate.

(2) The Hidaka belt (HD, figs. 4, 44) with Cyprus Cu-Zn massive sulfide deposits is hosted in Middle Cretaceous through Eocene stratiform units that occur in tectonic fragments in the Shimanto subduction-zone terrane, part of the East Sakhalin collage. The belt is interpreted as having formed in basalt generated along the Kula-Pacific oceanic ridge, with subsequent structural incorporation of host rocks and deposits into a subduction zone.

(3) The Inner Zone Southwest Japan belt (ISJ figs. 4, 44) with a wide variety of vein and replacement and granitoid-related deposits (Zn-Pb skarn; W-Mo-Be greisen; stockwork, and quartz vein; W skarn; Cu skarn; porphyry Mo; polymetallic Pb-Zn vein and stockwork; fluorspar vein; and metamorphic graphite deposits), is hosted in the Nohi rhyolite volcanic belt and coeval Hiroshima granitic belt that overlie and intrude previously-accreted terranes. The host rocks and deposits have isotopic ages of Cretaceous through Paleogene and are interpreted as having formed during generation of granitoids along an East Asia continental-margin arc that was tectonically-linked to subduction of the Kula and Pacific Ocean Plates. The East Asia continental-margin arc is interpreted as being the southern extension of the East Sikhote-Alin arc.

Maastrichtian through Eocene Tectonic and Metallogenic Model

Major Tectonic and Metallogenic Events

For the Maastrichtian through Eocene (72 to 34 Ma), the major metallogenic and tectonic events were (figs. 5, 45, tables 1, 2): (1) migration of the Olyutorka-Kamchatka island arc toward the northeast margin of Northeast Asia and formation of associated metallogenic belts; (2) slightly later, accretion of the Olyutorka-Kamchatka island arc and formation of collision-related metallogenic belts; (3) migration of the Terprniya-Nemuro island arc towards the eastern margin of Northeast Asia and formation of associated metallogenic belts; (4) continuation of transpressional-fault zones along the axis of the closed Mongol-Okhotsk Ocean and formation of associated metallogenic belts; (5) postcollisional, transform faulting along within-plate transpression zones in northeast China and formation of associated metallogenic belts; (6) continued formation of a major continental-margin transform-fault system and generation of the East Sikhote-Alin volcanic-plutonic belt (and East Sikhote-Alin transform continental-margin arc) in the Russian Southeast and northeast China and formation of associated metallogenic belts; and (7) continued rifting and formation of the Eurasia Basin and the Arctic Ocean.

The major Maastrichtian through Eocene metallogenic belts in Northeast Asia are portrayed on figure 5. The tectonic setting of each metallogenic belt is portrayed on figure 45.

Major Maastrichtian through Eocene Metallogenic Belts

Metallogenic Belts Related to East Sikhote-Alin Continental-Margin Arcs

The Kema and Lower Amur metallogenic belts (KM, LA, figs. 5, 45; table 2) (with Ag-Au epithermal vein; porphyry Cu-Mo; porphyry Cu; porphyry Au; porphyry Mo; Au-Ag epithermal vein; epithermal quartz-alunite; and Sn-W greisen, stockwork, and quartz-vein deposits) are hosted in the granitoids and associated veins in the Late Cretaceous through Paleocene East Sikhote-Alin volcanic-plutonic belt that is a major overlap assemblage in the Russian Far East. The isotopic ages for the granitoids hosting or associated with the deposits range from Late Cretaceous through Paleocene. The belt is part of a very extensive continental-margin arc that formed along the eastern margin (present-day coordinates) of the North Asian craton and cratonal margin and previously-accreted terranes to the east. The arc is interpreted as having formed during oblique subduction of the ancestral Pacific Ocean Plate.

Metallogenic Belt Related to Meteorite Impact

The unique Popigay metallogenic belt (PP, figs. 5, 45) contains impact diamond deposits and is hosted in the Popigay ring structure. The isotopic age from tagamite (impact melt rock) and impact glasses is 35.7 Ma. The belt is interpreted as having resulted from meteoritic impact with formation of pseudotachylite, diamond, high-grade shock metamorphic minerals, and allogenic breccia.

Oligocene through Quaternary Tectonic and Metallogenic Model

Major Tectonic and Metallogenic Events

For the Oligocene through Miocene (34 to 5.3 Ma), the major tectonic and metallogenic events were (figs. 5, 46, tables 1, 2) (1) formation of the short-lived Central Kamchatka continental-margin arc along the outboard margin of northern Northeast Asia; (2) migration of the Kronotskaya island arc towards the northeast margin of Northeast Asia; (3) slightly later, accretion of the Kronotskaya island arc outboard of the Central Kamchatka arc; (4) formation of the Japan continental-margin arc and back-arc spreading between the arc and the southern part of Northeast Asia; (5) formation of the Izu Bonin intraoceanic arc to the south; and (6) continued rifting and formation of the Eurasian Basin and formation of the Arctic Ocean.

For the Pliocene through Present (5.3 to 0 Ma), the major tectonic and metallogenic events were (figs. 5, 47, tables 1, 2) (1) formation of the Kuril-Kamchatka continental-margin arc along the eastern margin of Northeast Asia; (2) continued formation of the Japan continental-margin arc and back-arc spreading between the arc and the southern part of Northeast Asia; (3) continued formation of the Izu Bonin continental-margin arc to the south; (4) continued rifting and formation of the Eurasian Basin and formation of the Arctic Ocean; and on the basis of modern-day earthquake foci, formation of several new tectonic plates across the region.

The major Oligocene through Quaternary metallogenic belts in Northeast Asia are portrayed on figure 5. The tectonic setting of each metallogenic belts is portrayed on figures 46 and 47.

Major Oligocene through Quaternary Metallogenic Belts Hosted in the Japan Arc

Five major metallogenic belts are hosted in the Japan arc. The arc is interpreted as having formed from subduction of the Pacific Ocean and Philippine Sea Plates beneath the East Asia continental margin. The belts are the Hokuriku-Sanin, Kyushu, Northeast Hokkaido, Northeast Japan, and Outer Zone Southwest Japan. The isotopic ages of host rocks or deposits range from Miocene to Quaternary (15 to 2 Ma). Some deposits are probably still forming in these belts along the axial or back-arc parts of the arc.

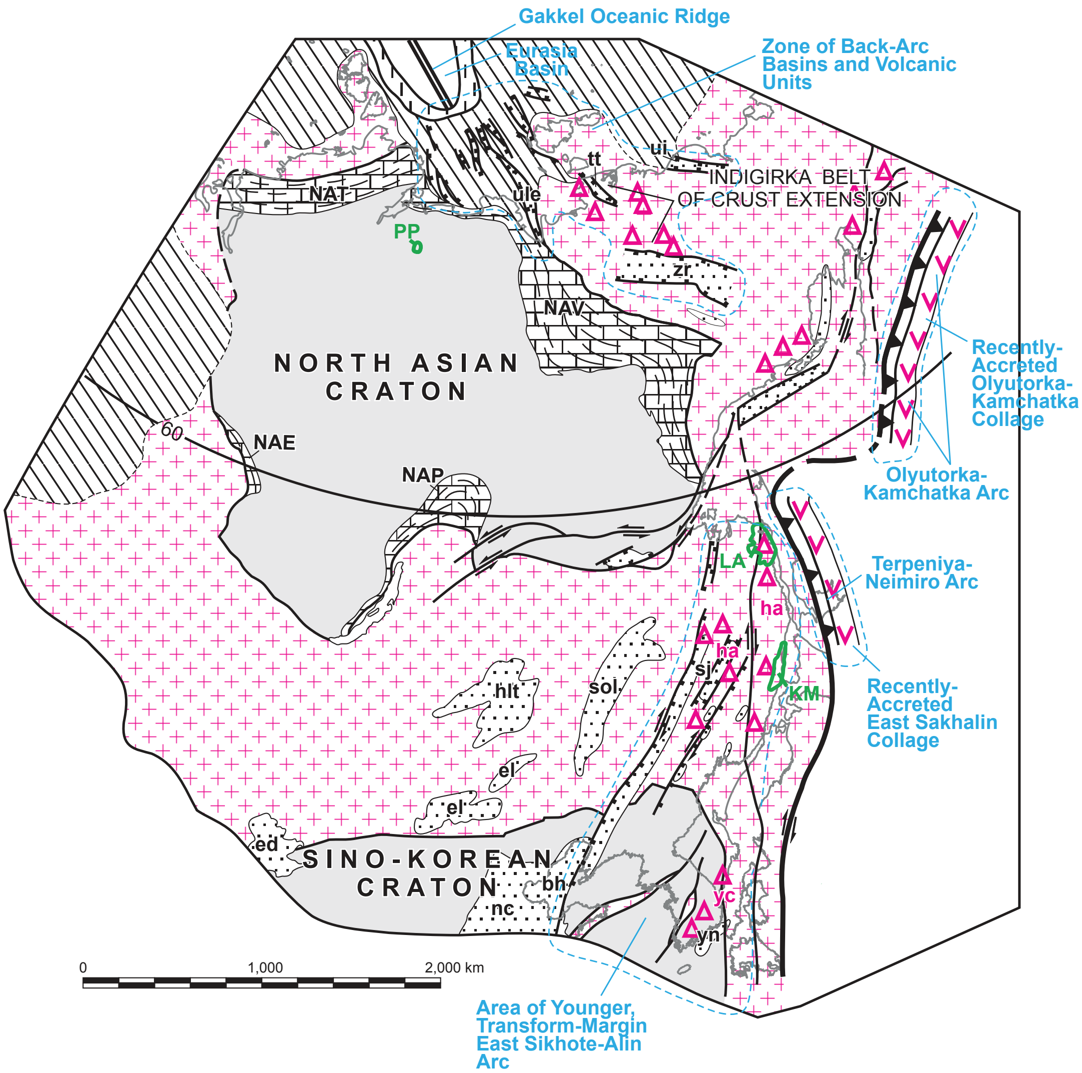
The Hokuriku-Sanin belt (HS, figs. 5, 46, 47) contains Miocene to Pleistocene Au-Ag epithermal vein, polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork, Ag-Sb vein, and clastic-sediment-hosted U deposits that are hosted in veins and replacements related to the Neogene Japan sedimentary basin that overlies the Hiroshima granitic plutonic belt and the Akiyoshi-Maizuru and Mino-Tamba-Chichibu terranes, both part of Honshu-Sikhote-Alin collage. The belt is interpreted as having formed along an island arc during back-arc rifting or along the axial part of the Japan arc.

The Kyushu belt (KY, figs. 5, 47) contains Pliocene to Quaternary Au-Ag epithermal-vein deposits that are hosted in veins and replacements related to the Quaternary Japan volcanic belt and Neogene Japan sedimentary basin that overlie and intrude Akiyoshi-Maizuru, Shimanto, and Mino-Tamba-Chichibu terranes and are both part of Honshu-Sikhote-Alin collage. The belt is interpreted as having formed during hydrothermal activitiy along the Japan arc in either back-arc rifting or the axial part of the arc

The Northeast Hokkaido belt (NH, figs. 5, 46, 47) contains Miocene to Quaternary Au-Ag epithermal vein, volcanic-hosted Hg, Hg-Sb-W vein and stockwork, and clastic sediment-hosted Hg±Sb deposits that are hosted in veins and replacements in the Quaternary Japan volcanic belt and the Neogene Japan sedimentary basin that overlies and intrudes the Hidaka zone of the the Shimanto accretionary-wedge terrane that is part of the Honshu-Sikhote-Alin collage.

The Northeast Japan belt (NJ, figs. 5, 46, 47) contains volcanogenic Miocene to Quaternary Zn-Pb-Cu massive sulfide (Kuroko, Altai types), Au-Ag epithermal vein, polymetallic (Pb, Zn±Cu, Ba, Ag, Au) volcanic-hosted metasomatite, sulfur-sulfide (S, FeS2), polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork, Mn vein, volcanogenic-sedimentary Mn , chemical-sedimentary Fe-Mn, and limonite from spring-water deposits that are hosted in layers and veins in the Quaternary Japan volcanic belt and the Neogene Japan sedimentary basin that overlies the Hiroshima granitic plutonic belt and the Mino-Tamba-Chichibu and South Kitakami terranes, both part of the Honshu-Sikhote-Alin collage. The volcanogenic massive sulfide deposits are interpreted as having formed in back-arc and axial regions of the Japan arc.

The Outer Zone Southwest Japan belt (OS, figs. 5, 46) contains middle Miocene Sn skarn; Sn-W greisen, stockwork, and quartz vein; polymetallic Pb-Zn ± Cu (±Ag, Au) vein and



GEOLOGIC UNITS

North Asian Craton Margin

NAE - East Angara
NAP - Patom-Baikal
NAT - South-Taimyr
NAV - Verkhoyansk

Intracontinental Sedimentary Basin

bh - Bohai sedimentary basin (Cenozoic)
ed - Erduosi sedimentary basin (Triassic through Cretaceous)
el - Erlian sedimentary basin (Jurassic through Quaternary)
hlt - Hailar-Tamsag sedimentary basin (Late Jurassic and Cretaceous)
nc - North China sedimentary basin (Cenozoic)
sj - Sanjiang sedimentary basin and Yishu graben (Mesozoic and Cenozoic)
sol - Songliao sedimentary basin (Jurassic through early Tertiary)
tt - Tastakh Basin
ui -Ust-Indigirka Basin
ule - Ust-Lena Basin
yn - Yonil Group (Cenozoic)
zr - Zyryanka sedimentary basin (Late Jurassic through Cenozoic)

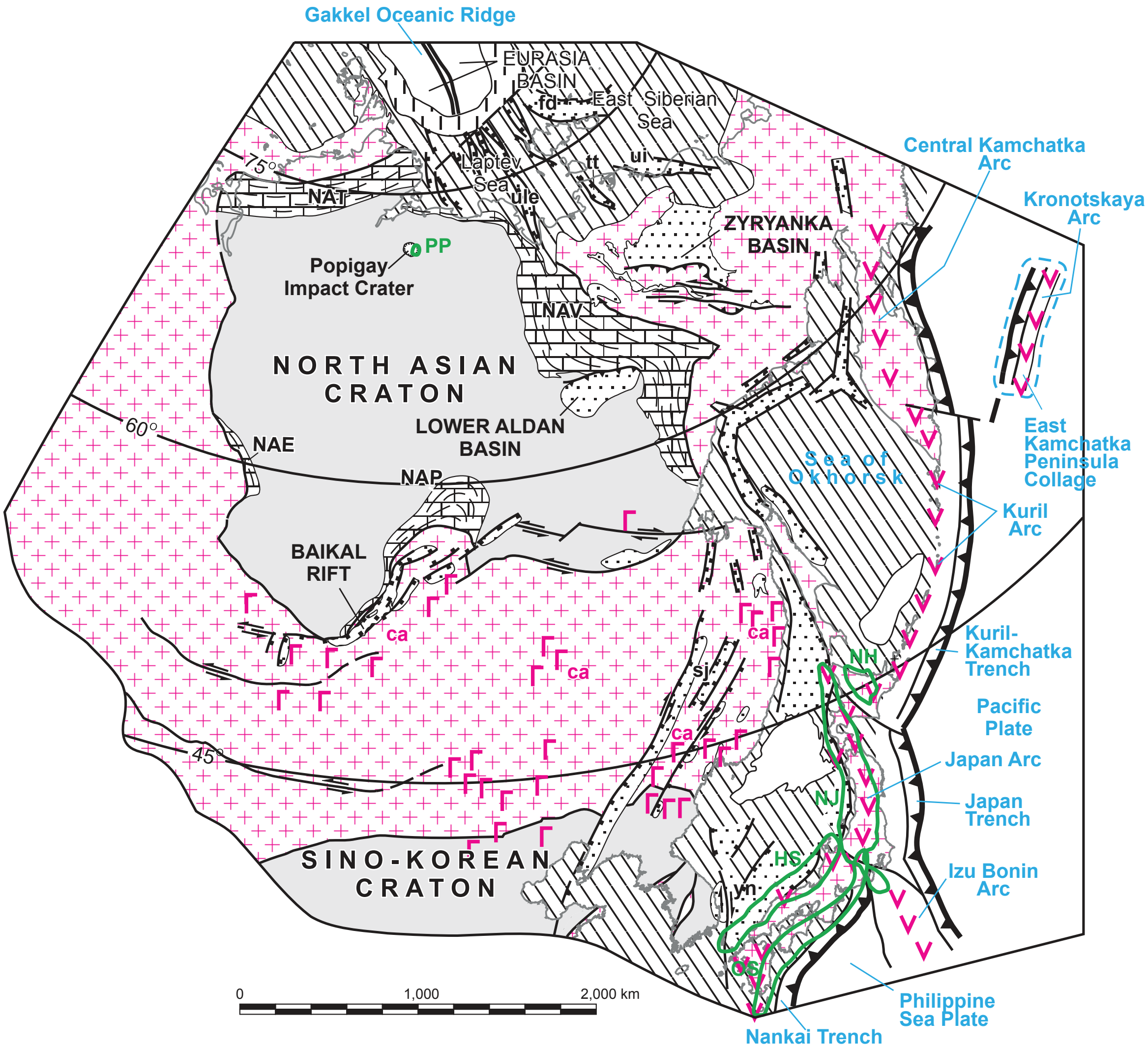
Overlap Continental-Margin Arcs and Granite Belts

yc -Yucheon volcanic belt
ha - Hasan-Amurian volcanic-plutonic belt (Paleocene to early Miocene)

METALLOGENIC BELTS

KM - Kema
LA - Lower Amur
PP - Popigay

Figure 45. Maastrichtian through Eocene (50 Ma) metallogenic and tectonic model for Northeast Asia. Adapted from Parfenov and others (this volume).



GEOLOGIC UNITS

North Asian Craton Margin

NAE - East Angara
NAP - Patom-Baikal
NAT - South-Taimyr
NAV - Verkhoyansk

Intracontinental Sedimentary Basins

fd - Faddeevskiy Basin
sj - Sanjiang sedimentary basin and Yishu graben (Mesozoic and Cenozoic)
tt - Tastakh Basin
ui -Ust'-Indigirka Basin
ule - Ust'-Lena Basin
yn - Yonil Group (Cenozoic)

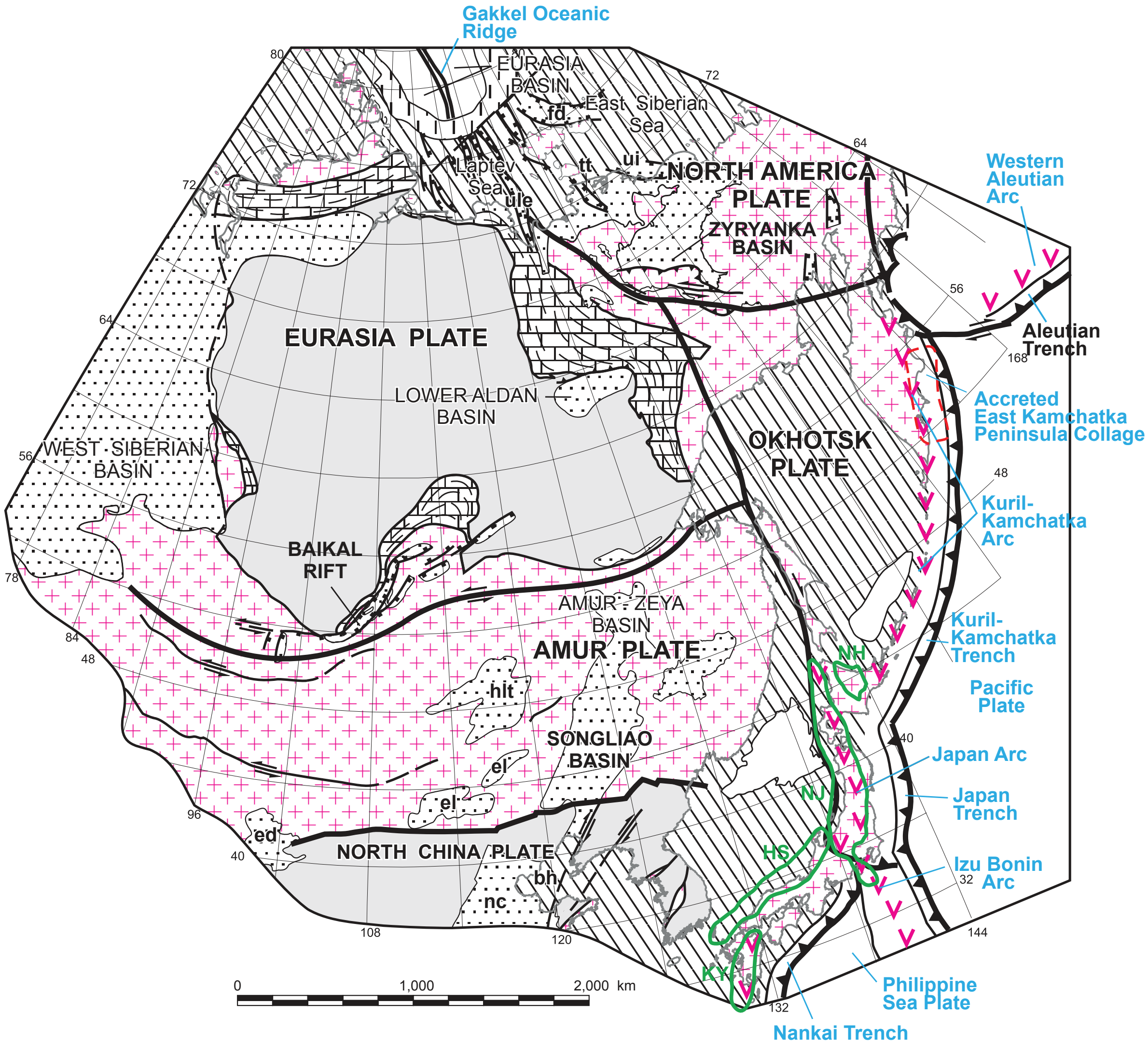
Plateau Basalt Belt

ca - Central Asian plateau basalt belt (Neogene and Quaternary)

METALLOGENIC BELTS

HS - Hokuriku-Sanin
NH - Northeast Hokkaido
NJ - Northeast Japan
OS - Outer Zone Southwest Japan
PP - Popigay

Figure 46. Oligocene through Miocene (10 Ma) metallogenic and tectonic model for Northeast Asia. Adapted from Parfenov and others (this volume).



GEOLOGIC UNITS

Intracontinental Sedimentary Basins

bh - Bohai sedimentary basin (Cenozoic)
ed - Erduosi sedimentary basin (Triassic through Cretaceous)
el - Erlian sedimentary basin (Jurassic through Quaternary)
fd - Faddeevskiy Basin
hlt - Hailar-Tamsag sedimentary basin (Late Jurassic and Cretaceous)
nc - North China sedimentary basin (Cenozoic)
tt - Tastakh basin
ui -Ust'-Indigirka Basin
ule - Ust'-Lena Basin

METALLOGENIC BELTS

HS - Hokuriku-Sanin
KY - Kyushu
NH - Northeast Hokkaido
NJ - Northeast Japan

Figure 47. Present (0 Ma) metallogenic and tectonic model for Northeast Asia. Adapted from Parfenov and others (this volume).

stockwork, clastic-sediment-hosted Sb-Au; Au-Ag epithermal vein, volcanic-hosted Hg; Ag-Sb vein; Zn-Pb (±Ag, Cu, W) skarn; W-Mo-Be greisen, stockwork, and quartz vein; Hg-Sb-W vein and stockwork; cassiterite-sulfide-silicate vein and stockwork; and clastic-sediment-hosted Sb-Au deposits that are hosted in veins and replacements related to the Neogene Japan sedimentary basin that overlies the Hiroshima granitic plutonic belt, and the Sambagawa, Shimanto, and Mino-Tamba-Chichibu terranes, all of which are part of the Honshu-Sikhote-Alin collage. The belt is interpreted as having formed in back-arc rifting or axial part of Japan arc.

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Table 1

Table 1. Summary of major Late Jurassic through Cenozoic (154 to 0 Ma) geologic units and characteristics for Northeast Asia (Russian Far East, Yakutia, Siberia, Transbaikalia, Northeastern China, Mongolia, South Korea, and Japan).

[Major units are listed from west to east, progressing from north to south. Units arranged in alphabetical order of map symbol in each major section on figure 2]

Name of unit. Map Symbol	Type of Unit (Craton, Terrane, Overlap Assemblage)	Age range	Tectonic Environment	Tectonic Linkage
NORTHEAST ASIA CRATONS				
North Asian. NAC Sino Korean. SKC	Craton	Archean through Mesozoic	Cratonal and passive continental margin	Primary units.
NORTH ASIAN CRATONAL MARGIN UNITS				
Baikal-Patom. BP East Angara. EA South Taimyr. ST Verkhoyansk. VR	Overlap assemblages	Neoproterozoic through Mesozoic	Passive continental margin.	Original overlap assemblages on North Asian craton that were subsequently transformed into fold and thrust belts and terranes.
SUPERTERRANE				
Bureya-Jiamusi. BJ7	Superterrane	Proterozoic through Permian	Composite.	Consists of early Paleozoic metamorphic, continental-margin arc, subduction zone, passive continental-margin and island-arc terranes. Interpreted as being a fragment of Gondwana. Accreted to the Sino-Korean craton in the Late Permian and accreted to the North Asian craton in the Late Jurassic.
TECTONIC COLLAGES EAST OF NORTH ASIAN AND SINO-KOREAN CRATONS				
Badzhal. BD	Collage	Triassic through Early Cretaceous	Composite.	Consists of Umlekan-Ogodzhin continental-margin arc and tectonically-linked subduction-zone terranes to the east with Tethyan fauna. Accreted in Late Cretaceous.
Chukotka. CH	Collage	Paleozoic through Triassic	Composite.	Consists of passive continental-margin terranes that formed along the long-lived Neoproterozoic through early Mesozoic North American continental margin. Accreted to the northern Verkhoyansk-Kolyma collage in the Late Cretaceous.
East Kamchatka Peninsula. EP	Collage	Paleocene	Composite.	Consists of the Kronotskiy island Pliocene.
East Sakhalin. ES	Collage	Late Cretaceous through early Tertiary	Composite.	Consists of the Late Cretaceous through middle Eocene Terpeniy-Tokoro-Nemuro-Shmidt island arc and tectonically-linked subduction-zone terranes. Accreted in early Tertiary.
Honshu-Sikhote-Alin. HS	Collage	Jurassic and Early Cretaceous	Composite.	Consists of fragments of island arc, continental-margin turbidite (flysch) and subduction-zone terranes that formed along a transform continental margin. Accreted in Cretaceous.
Koryak. KOR	Collage	Late Triassic through Cretaceous	Composite.	Consists of the Late Jurassic and Early Cretaceous Manitskiy island-arc and tectonically-linked subduction-zone terranes to the east. Accreted in Late Cretaceous.

Table 1. Summary of major Late Jurassic through Cenozoic (154 to 0 Ma) geologic units and characteristics for Northeast Asia (Russian Far East, Yakutia, Siberia, Transbaikalia, Northeastern China, Mongolia, South Korea, and Japan).—Continued

Olyutorka-Kamchatka. OK	Collage	Late Cretaceous and Paleocene	Composite.	Consists of the Olyutorka island arc and tectonically-linked subduction-zone terranes to the east. Accreted in early Cenozoic.
Penzhina-Anadyr. PA	Collage	Late Jurassic through Early Cretaceou	Composite.	Consists of the Murgal island-arc terrane and tectonically-linked subduction-zone terranes to the east. Collage rims the eastern Kolyma-Omolon superterrane and Verkhoyansk-Kolyma collage. The collage is also linked to the Uda continental-margin arc. Accreted in Late Cretaceous.
Sakhalin-Hokkaido. SK	Collage	Cretaceous	Composite.	Consists of the Late Cretaceous flysch terranes of Sakhalin and Hokkaido Islands, and tectonically-linked subduction-zone terranes to the east. Interpreted as a continental-margin forearc basin and tectonically-linked subduction-zone terranes that are associated with the East Sikhote-Alin continental-margin arc. Accreted in Eocene.
South Anyui. SA	Collage	Permian through Early Jurassic	Composite.	Consists of the Oloy island arc and tectonically-linked subduction-zone terranes. Accreted in Late Cretaceous.
West Kamchatka. WK	Collage	Mid-Cretaceous through early Tertiary	Composite.	Consists of late Paleozoic through Cretaceous subduction-zone terranes. Tectonically linked to Okhotsk-Chukotka continental-margin arc. Accreted in early Cenozoic.
Verkhoyansk-Kolyma. VK	Collage	Late Paleozoic through Early Jurassic	Composite.	Consists of a deformed passive continental margin, accreted ophiolite and subduction-zone terranes. Interpreted as having formed during accretion of the outboard Kolyma-Omolon superterrane. Accreted in Late Jurassic through early Early Cretaceous.
TECTONIC COLLAGE BETWEEN NORTH ASIAN AND SINO-KOREAN CRATONS				
Mongol-Okhotsk. MO	Collage	Devonian through Late Jurassic	Composite.	Consists mainly of the Permian through Jurassic Selenga, Late Carboniferous and Early Permian Hangay, and Uda-Murgal and Stanovoy continental-margin arcs. Composed of continental-margin igneous overlap assemblages, continental-margin turbidite terranes, and tectonically-linked, outboard subduction-zone terranes. Interpreted as having formed during long-lived closure of the Mongol-Okhotsk Ocean with oblique subduction of terranes beneath the southern North Asian cratonal margin and previously-accreted terranes.
JURASSIC TO EARLY CRETACEOUS CONTINENTAL-MARGIN ARCS				
Selenga. se	Overlap assemblage	Permian through Jurassic	Transform continental-margin arc.	Interpreted as having formed along the margin of the North Asian craton as a continental-margin transform system.
Uda-Murgal. us	Overlap assemblage	Jurassic through Early Cretaceous	Subduction-related arc.	Interpreted as having formed along the margin of the North Asian craton and cratonal margin during subduction of ancestral Pacific Ocean Plate.

Table 1. Summary of major Late Jurassic through Cenozoic (154 to 0 Ma) geologic units and characteristics for Northeast Asia (Russian Far East, Yakutia, Siberia, Transbaikalia, Northeastern China, Mongolia, South Korea, and Japan).—Continued

JURASSIC AND EARLY CRETACEOUS ISLAND ARCS OCCURRING ON OR ADJACENT TO KOLYMA-OMOLON SUPERTERRANE				
Oloy. ol	Island arc	Late Jurassic	Subduction-related arc.	Interpreted as having formed on the Kolyma-Omolon superterrane during subduction of the South Anyui Ocean Plate beneath the superterrane.
Uyandina-Yasachnaya. uy	Island arc	Late Jurassic through Early Cretaceous	Subduction-related arc.	Interpreted as having formed during subduction of the Oimyakon Ocean Plate between the North Asian cratonal margin and the Kolyma-Omolon superterrane.
JURASSIC THROUGH EARLY TERTIARY CONTINENTAL-MARGIN ARCS AND GRANITE BELTS OCCURRING ALONG EASTERN MARGIN OF NORTHERN ASIA				
East Sikhote-Alin. ea	Continental-margin arc	Late Cretaceous through early Tertiary	Subduction-related arc.	Interpreted as having formed during subduction of the ancestral Pacific Ocean Plate.
Umlekan-Ogodzhin. uo	Continental-margin arc	Jurassic and Cretaceous	Subduction-related arc.	Interpreted as having formed during subduction of the ancestral Pacific Ocean Plate.
Khingan-Okhotsk. ko	Continental-margin arc	Early and mid-Cretaceous	Subduction-related arc.	Interpreted as having formed during subduction of the ancestral Pacific Ocean Plate.
Main granite belt. ma	Continental-margin arc	Late Jurassic	Subduction-related arc.	Interpreted as having formed during and immediately after collision of the Kolyma-Omolon superterrane onto the North-Asian cratonal margin.
Northern granite belt. nb	Continental-margin arc	Early Cretaceous	Subduction-related arc.	Interpreted as having formed during the subduction of oceanic crust during a closure of a small oceanic basin during late stage of accretion of the Kolyma-Omolon superterrane.
Okhotsk-Chukotka. oc	Continental-margin arc	Late Cretaceous through early Tertiary	Subduction-related arc.	Interpreted as having formed during subduction of the ancestral Pacific Ocean Plate.
South Verkhoyansk granite belt. sv	Continental-margin arc	Late Jurassic through mid-Cretaceous	Subduction-related arc.	Interpreted as having formed during the accretion of the outboard Okhotsk terrane.
Transverse granite belt. tr	Continental-margin arc	Early Cretaceous	Subduction-related arc.	Interpreted as having formed during the late stage of accretion of the Kolyma-Omolon superterrane.
ACTIVE CONTINENTAL-MARGIN ARCS OCCURRING ALONG EASTERN MARGIN OF NORTHERN ASIA				
Izu-Bonin arc (ib)	Intraocean arc	Miocene through Present	Subduction-related arc.	Interpreted as having formed from subduction of the ancestral Pacific Ocean Plate.
Japan arc (ja)	Continental-margin arc	Miocene through Present	Subduction-related arc.	Interpreted as having formed during subduction of the Pacific Ocean and Philippine Sea Plates.
Kuril-Kamchatka arc (kk)	Continental-margin arc	Miocene through Present	Subduction-related arc.	Interpreted as having formed during subduction of the Pacific Ocean Plate.
TRANSPRESSIONAL ARCS				
Mongol-Transbaikal. mt	Transpressional arc	Late Triassic through Early Cretaceous.	Transpressional faulting after closure of Mongol-Okhotsk Ocean.	Interpreted as having formed during strike-slip faulting and rifting along the Mongol-Okhotsk fault during and after the final closure of the Mongol-Okhotsk Ocean.
Trans-Baikal-Daxinganling. tb	Transpressional arc		Middle Jurassic through Early Cretaceous.	Interpreted as having formed during strike-slip faulting and rifting along the Mongol-Okhotsk fault during, and after the final closure of the Mongol-Okhotsk Ocean.