Metallogenic Belt and Mineral Deposit Maps of Northeast Asia

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Contents

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Introduction

This report contains explanatory material and summary tables for lode mineral deposits and placer districts (Map A, sheet 1) and metallogenic belts of Northeast Asia (Maps B, C, and D on sheets 2, 3, and 4, respectively). The map region includes eastern Siberia, southeastern Russian, Mongolia, northeast China, and Japan.

A large group of geologists—members of the joint international project, Major Mineral Deposits, Metallogenesis, and Tectonics of Northeast Asia—prepared the maps, tables, and introductory text. This is a cooperative project with the Russian Academy of Sciences, Mongolian Academy of Sciences, Mongolian National University, Ulaanbaatar, Mongolian Technical University, Mineral Resources Authority of Mongolia, Geological Research Institute, Jilin University, China Geological Survey, Korea Institute of Geoscience and Mineral Resources, Geological Survey of Japan, and U.S. Geological Survey.

This report is one of a series of reports on the mineral resources, geodynamics, and metallogenesis of Northeast Asia. Companion studies include (1) a detailed geodynamics map of Northeast Asia (Parfenov and others, 2003, 2014); (2) a compilation of major mineral deposit models (Rodionov and Nokleberg, 2000; Rodionov and others, 2000); (3) a series of metallogenic belt maps (Obolenskiy and others, 2004); (4) location map of lode mineral deposits and placer districts of Northeast Asia (Ariunbileg and others, 2003b); (5) descriptions of metallogenic belts (Rodionov and others, 2004); (6) a database on significant metalliferous and selected nonmetalliferous lode deposits and selected placer districts (Ariunbileg and others, 2003a); and (7) a series of summary project publications (Ariunbileg and 74 others, 2003b).

This report provides digital files for maps of mineral deposits and metallogenic belts of Northeast Asia. The maps are a companion to U.S. Geological Survey Professional Paper 1765 on the Metallogenesis and Tectonics of Northeast Asia (Nokleberg, 2010). The purpose of the digital maps and brief descriptions in this report is to provide large-format color maps, mainly in Acrobat PDF format, as compared to the page-size figures in Professional Paper 1765. A detailed GIS compilation of Northeast Asia geodynamics, mineral deposits, and metallogenic belt maps, and associated data tables is provided in Naumova and others (2006).

Detailed descriptions of geologic units, mineral deposits, and metallogenic belts depicted in this report are provided in tables 1–3 of this report and in Ariunbileg and others (2003b), Nokleberg (2010), Nokleberg and others (2004), and Parfenov and others (2014).

Definitions

Terms defined below are used for the compilation, synthesis, description, and interpretation of lode mineral deposits. The definitions are adapted from Coney and others (1980), Jones and others (1983), Howell and others (1985), Monger and Berg (1987), Nokleberg and others (1994, 2001), Wheeler and others (1988), and Scotese and others (2001).

Accretion Tectonic juxtaposition of two or more terranes, or tectonic juxtaposition of terranes to a craton margin. Accretion of terranes to one another or to a craton margin also defines a major change in the tectonic evolution of terranes and craton margins.

Accretionary wedge and subduction-zone terrane Fragment of a mildly to intensely deformed complex consisting of varying amounts of turbidite deposits, continental-margin rocks, oceanic crust and overlying units, and oceanic mantle. Divided in this report into units composed predominantly of turbidite deposits (type A) or predominantly of oceanic rocks (type B). Units are interpreted to have formed during tectonic juxtaposition in a zone of major thrusting of one lithosphere plate beneath another, generally in zones of thrusting along the margin of a continent or an island arc. May include large fault-bounded units with a coherent stratigraphy. Many subduction-zone terranes contain fragments of oceanic crust and associated rocks that exhibit a complex structural history, occur in a major thrust zone, and possess blueschist-facies metamorphism.

Collage of terranes Groups of tectonostratigraphic terranes, generally in oceanic areas, for which insufficient data exist to separate units.

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

Craton margin Chiefly Late Proterozoic through Jurassic sedimentary rocks deposited on a continental shelf or slope. Consists mainly of platform successions. Locally has, or may have had, an Archean and Early Proterozoic cratonal basement.

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

Cratonal terrane Fragment of a craton.

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

Island-arc terrane Fragment of an igneous belt of plutonic rocks, coeval volcanic rocks, and associated sedimentary rocks that formed above an oceanic subduction zone. Inferred to possess a simatic basement.

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

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

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

Mine A site where valuable minerals have been extracted.

Mineral deposit A site that contains potentially valuable concentrations of minerals for which grade and tonnage estimates have been determined.

Mineral prospect A site of potentially valuable concentrations of minerals determined on the basis of surface sampling and other exploration work. However, estimates of grade and tonnage have not been determined.

Mineral occurrence A site of potentially valuable minerals on which no visible exploration has occurred and grade and tonnage estimates have not been made.

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

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

Passive continental margin terrane Fragment of a craton margin.

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

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

Prospect A site of potentially valuable minerals that was excavated.

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

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

Tectonic linkage The interpreted association of a suite of coeval tectonic units that formed in the same region as the result of the same tectonic processes. For example, a coeval continental-margin arc, forearc deposits, a back-arc rift assemblage, and a subduction-zone complex, are associated with the underthrusting of a continental margin by oceanic crust.

Tectonostratigraphic terrane A fault-bounded geologic entity or fragment that is characterized by a distinctive geologic history that differs markedly from that of adjacent terranes (Jones and others, 1983; Howell and others, 1985). A terrane constitutes a physical entity, for example, a stratigraphic succession bounded by faults, inferred faults, or an intensely deformed structural complex bounded by faults. Some terranes may be displaced (faulted) facies of other terranes.

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

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

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Lode Mineral Deposit and Placer Districts

This part of the report contains explanatory material and summary tables (tables 1 and 2) for sheet 1, which shows the location of 1,672 significant lode deposits and 91 significant placer districts of the region on a 1:7,500,000-scale generalized geodynamics map. Lode mineral deposits and placer districts are listed in tables 1 and 2, respectively.

Lode and Placer Mineral Deposit Models

Lode mineral and placer deposits are classified into various deposit models or types. Detailed descriptions of deposit models are provided in the companion paper by Obolenskiy and others (2003). Three main principles are employed for synthesis of mineral deposit models for this study.

Deposit-forming processes are closely related to rock-forming processes (Obruchev, 1928), and mineral deposits originate as the result of mineral mass differentiation under their constant circulation in sedimentary, magmatic, and metamorphic cycles of formation of rocks and geological structures (Smirnov, 1969).

The classification must be as understandable as possible.

The classification must be open so that new types of deposits can be added in the future (Cox and Singer, 1986).

In this report, lode mineral deposits are classified into levels of metallogenic taxons according to features such as (1) environment of formation of host and genetically related rocks, (2) genetic features of the deposit, and (3) mineral and (or) elemental composition of the ore. The hierarchal levels are as follows:

- Group of deposits
  - Class of deposits
    - Clan of deposits
      - Genus of deposits
        - Deposit types (models)

The deposit models are grouped according to deposits related to major geological rock-forming processes: magmatic, hydrothermal-sedimentary, metamorphic, surficial, and exotic (impact diamonds) deposits. Each group is further subdivided. For example, the group of deposits related to magmatic processes is subdivided into two classes: (1) deposits related to intrusive rocks and (2) deposits related to extrusive rocks. Each class is further subdivided, and so on. The most detailed subdivisions are for deposits related to magmatic processes because they are the most abundant in the map area. In this classification (see appendix), lode deposit types that share a similar origin, such as magnesian and (or) calcic skarns or porphyry deposits, are grouped together under a single genus with several types within the genus. Included in appendix is a list of the hierarchial ranking of mineral deposit models for this report, which follows the organization of models of Cox and Singer (1986).

Descriptions of Significant Lode Deposits and Placer Districts

Map Number, Name, Major Metals

On sheet 1, a black number indicates the lode mineral deposit site (metalliferous, non-metalliferous/industrial); a red number indicates the placer deposit site in a given region. Lode deposits, both metalliferous and non-metalliferous, and placer districts are numbered separately within individual quadrants delineated by a grid of 4° of latitude and 6° of longitude (sheet 1, tables 1, 2). The quadrants are labeled 44 through 54 from west to east and A through U from south to north. A latitude and longitude location is stated for each deposit in tables 1 and 2. Names of lode deposits (table 1) are derived from either published sources or common usage. In some cases, two deposits are grouped and both names are given. In other cases, an alternate name is given in parentheses. The known potentially valuable major metals in each deposit are listed in order of decreasing abundance and (or) value and are shown by standard chemical symbols (tables 1 and 2).

Lode Deposit Type

The type of lode deposit or lode deposit model is interpreted by examining the summary of the deposit (Ariunbileg and others, 2003) and then classifying the deposit using the deposit models listed above. The type is queried where insufficient description precludes precise determination. For a few deposits, either the closest two deposit models are listed or a short description is given in parentheses.

Metallogenic Belt Maps

Sheets 2, 3, and 4 show the locations of the 314 major metallogenic belts on a generalized geodynamics map of the region (Parfenov and others, 2004) that is derived from a more detailed map by Parfenov and others (2003). The generalized geodynamics map depicts the major geologic units and structures that host the major metallogenic belts. Three map sheets (sheets 2, 3, and 4) contain twelve 1:15,000,000-scale metallogenic belt maps, each map representing a time slice ranging from the Archean through the Quaternary. A summary of lode mineral deposits and the major features of metallogenic belts outlined on each map sheet are listed in table 3. For each time slice, the metallogenic belts are listed from north to south and east to west.

The metallogenic belts of Northeast Asia are synthesized, compiled, described, and interpreted with the use of modern concepts of plate tectonics, analysis of terranes and overlap assemblages, and synthesis of mineral deposit models. The supporting data include (1) comprehensive descriptions of mineral deposits; (2) compilation and synthesis of a regional geodynamics map at 1:5,000,000 scale with detailed explanations and cited references; and (3) compilation and synthesis of metallogenic belt maps at 1:15,000,000 scale with detailed explanations and cited references.

Metallogenic belts are characterized by a narrow age of formation and include districts, deposits, and occurrences. The metallogenic belts are synthesized and described for the main structural units of the North Asian Craton and Sino-Korean Craton, framing orogenic belts that consist of a collage of accreted tectonostratigraphic terranes, younger overlap volcanic and sedimentary rock sequences, and younger stitching plutonic sequences. The major units in the region are the North Asian Craton, exterior passive continental margin units (Baikal-Patom, Enisey Ridge, Southern Taymir, and Verkhoyansk passive continental margin units), the early Paleozoic Central Asian orogenic belt, and various Mesozoic and Cenozoic continental margin arcs (see Cratons and Craton Margins, on sheet 1). Metallogenic belts are interpreted according to specific geodynamic environments including cratonal, active, and passive continental margin, continental-margin arc, island arc, oceanic or continental rift, collisional, transform-continental margin, and impact.

Previous classifications of metallogenic zonation are published by the following: Bilibin, 1955; Itsikson and others, 1965; Shatalov, 1965; Itsikson, 1973, 1979; Guild, 1978; Shcheglov, 1980; Mitchell and Garson, 1981; Radkevich, 1982; Tomson, 1988; Zonenshain and others, 1992; Koroteev, 1996; Parfenov and others, 1999; Sukhov and others, 2000; and Plyushchev, 2001. The metallogenic units include (1) planetary deposit-hosting province or planetary metallogenic belt (≥1,000 x 103 km^2); (2) deposit-hosting belt or metallogenic belt (150–1,000 x 103 km^2); (3) deposit-hosting system or metallogenic system (40–150 x 103 km^2); (4) deposit-hosting zone or metallogenic zone (20–40 x 103 km^2); (5) deposit-hosting subzone or metallogenic subzone (2–20 x 103 km^2); and (6) ore district (0.4–2.0 x 103 km^2).

In some cases, it is difficult to differentiate between some of these metallogenic units. For example, metallogenic system versus metallogenic zone or ore district versus deposit-hosting subzone. For this study, only two simple terms are employed: metallogenic belt and contained district. A metallogenic belt is essentially synonymous with the term "mineral resource tract" originally defined by Pratt (1981) and used for assessment of mineral resource potential in the United States, as exemplified in Luddington and Cox (1996). Generally, the size of a metallogenic belt is partly a function of the scale of the analysis.

The metallogenic belt maps, which are combined with the underlying regional geologic and terrane and overlap assemblage maps, constitute a basic part of the three-part methodology of quantitative mineral resource assessment as described by Cox (1993) and Singer (1993, 1994).

Concepts and Problems for Synthesis of Metallogenic Belts

In this study, we employed the following concepts for the synthesis of metallogenic belts.

Mineral deposit association with metallogenic belt Each mineral resource tract or metallogenic belt includes a single mineral deposit type or a group of coeval, closely located and genetically related mineral deposits types.

Geodynamic event for deposit formation Each metallogenic belt contains a group of coeval and genetically related deposits that formed during a specific geodynamic event such as collision, continental-margin arc, accretion, or rifting.

Favorable geological environment Each metallogenic belt is underlain by a host rock and (or) geological structure that is favorable for a particular suite of mineral deposit types.

Tectonic or geological boundaries Each mineral resource tract (or metallogenic belt) is usually bounded by favorable units (either stratigraphic or magmatic) or by major faults (sutures) along which substantial translations have occurred.

Relation of metallogenic belt features to host unit The name, boundaries, and composition of each metallogenic belt correspond to previously defined characteristics of rocks or structures hosting the deposits, and to a suite of characteristics for the group of deposits and host rocks.

Based on these concepts, the area defined for a metallogenic belt is predictive or prognostic for undiscovered deposits. Consequently, the synthesis and compilation of metallogenic belts is a powerful tool for mineral exploration, land-use planning, and environmental studies.

For modern metallogenic analysis, three interrelated problems exist:

- What is the relation of geodynamics to regional or global metallogeny? As discussed by Zonenshain and others (1992) and Dobretsov and Kirdyashkin (1994), this problem includes the role of convective processes in mantle and mantle plumes, the global processes of formation of the continents and oceans, the dynamics of development of major tectonic units of the earth's crust, metallogenic evolution of the earth, and the role of mantle processes in the origin of major belts of deposits.
- What is the relation of regional metallogeny to individual lithosphere blocks? As discussed by Guild (1978), Mitchell and Garson (1981), and Koroteev (1996), this problem involves the genesis of specific metallogenic belts as a function of specific geodynamic environments using the modem concepts of plate tectonics.
- What is the relation of metallogeny to individual tectonostratigraphic terranes and overlap assemblages? As discussed by Nokleberg and others (1993, 1998) and Parfenov and others (1999), this problem includes the genesis of specific metallogenic belts in individual fault-bounded units of distinctive stratigraphy, defined as tectonostratigraphic terranes, and in younger overlapping assemblages often containing igneous rocks formed in continental margins or island arcs, along rift systems in continents, or along transform continental margins.

Methodology of Metallogenic and Tectonic Analysis

The compilation, synthesis, description, and interpretation of metallogenic belts involves an intricate process of analyzing the complex metallogenic and tectonic history of the region. The methodology for this type of analysis consists of the following steps: (1) The major lode deposits are described and classified according to defined mineral deposit models. (2) Metallogenic belts are delineated. (3) The tectonic environments are assigned on the basis of stratigraphic, structural, metamorphic, isotopic, faunal, and provenance data. Tectonic environments include cratonal, passive continental margin, metamorphosed continental margin, continental-margin arc, island arc, transform continental-margin arc, oceanic crust, seamount, ophiolite, accretionary wedge, subduction zone, turbidite basin, and metamorphic. (4) Correlations are made between terranes, fragments of overlap assemblages, and fragments of contained metallogenic belts. (5) Coeval terranes and their contained metallogenic belts are grouped according to a single metallogenic and tectonic origin, for instance, a single island arc or subduction zone. (6) Igneous-arc and subduction-zone terranes, which are interpreted as being tectonically linked, and their metallogenic belts are grouped into coeval, curvilinear arc, and subduction-zone complexes. (7) The original positions of terranes and the associated metallogenic belts are interpreted on the basis of geologic, paleontological, and paleomagnetic data. (8) The migration paths of terranes and contained metallogenic belts are constructed. (9) The timings and nature of accretions of terranes and contained metallogenic belts are determined on the basis of geologic, age, and structural data. (10) The nature of collision-related geologic units and their related metallogenic belts are interpreted on the basis of geologic data. Finally (11), the nature and timing of post-accretionary overlap assemblages and related metallogenic belts are determined on the basis of geologic and age data.

Geologic Time Scale and Time Spans

Geologic time scale units are according to the International Union of Geological Sciences (IUGS) Global Stratigraphic Chart (Remane, 1998). In this study, the term "Riphean" is used for the Mesoproterozoic through Middle Neoproterozoic (1,600 to 650 Ma), and the term "Vendian" is used for Neoproterozoic III (650 to 540 Ma) for some descriptions of metallogenic and geologic units.

The following twelve time spans are identified for analysis of the metallogenic belts and host geologic units of Northeast Asia.

- Archean (>2,500 Ma)
- Paleoproterozoic (2,500 to 1,600 Ma)
- Mesoproterozoic (1,600 to 1,000 Ma)
- Neoproterozoic (1,000 to 540 Ma)
- Cambrian through Silurian (540 to 410 Ma)
- Devonian through Early Carboniferous (Mississippian) (410 to 320 Ma)
- Late Carboniferous (Pennsylvanian) through Middle Triassic (320 to 230 Ma)
- Late Triassic through Early Jurassic (230 to 175 Ma)
- Middle Jurassic through Early Cretaceous (175 to 96 Ma)
- Cenomanian through Campanian (96 to 72 Ma)
- Late Cretaceous through Paleogene (72 to 24 Ma)
- Miocene through Quaternary (24 to 0 Ma)

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Appendix. List of hierarchial ranking of mineral deposit models.

1. Deposits related to magmatic processes
    - Deposits related to intrusive rocks
        - I. Deposits related to mafic and ultramafic intrusions
            - A. Deposits associated with differentiated mafic-ultramafic complexes
                - Mafic-ultramafic related Cu-Ni-PGE
                - Mafic-ultramafic related Ti-Fe (+V)
                - Zoned mafic-ultramafic Cr-PGE
            - B. Deposits associated with ophiolitic complexes
                - Podiform chromite
                - Serpentinite-hosted asbestos
            - C. Deposits associated with anorthosite complexes
                - Anorthosite apatite-Ti-Fe-P
            - D. Deposits associated with kimberlite
                - Diamond-bearing kimberlite
        - II. Deposits related to intermediate and felsic intrusions
            - A. Pegmatite
                - Muscovite pegmatite
                - REE-Li pegmatite
            - B. Greisen and quartz vein
                - Fluorite greisen
                - Sn-W greisen, stockwork, and quartz vein
                - W-Mo-Be greisen, stockwork, and quartz vein
            - C. Alkaline metasomatite
                - Ta-Nb-REE alkaline metasomatite
            - D. Skarn (contact metasomatic)
                - Au skarn
                - Boron (datolite) skarn
                - Carbonate-hosted asbestos
                - Co skarn
                - Cu (±Fe, Au, Ag, Mo) skarn
                - Fe skarn
                - Fe-Zn skarn
                - Sn skarn
                - Sn-B (Fe) (ludwigite)skarn
                - W±Mo±Be skarn
                - Zn-Pb (±Ag, Cu) skarn
            - E. Porphyry and granitoid pluton-hosted deposit
                - Cassiterite-sulfide-silicate vein and stockwork
                - Felsic plutonic U-REE
                - Granitoid-related Au vein
                - Polymetallic Pb-Zn ± Cu (±Ag, Au) vein and stockwork
                - Porphyry Au
                - Porphyry Cu (±Au)
                - Porphyry Cu-Mo (±Au, Ag)
                - Porphyry Mo (±W, Bi)
                - Porphyry Sn
        - III. Deposits related to alkaline intrusions
            - A. Carbonatite-related deposits
                - Apatite carbonatite
                - Fe-REE carbonatite
                - Fe-Ti (±Ta, Nb, Fe,Cu, apatite) carbonatite
                - Phlogopite carbonatite
                - REE (±Ta, Nb, Fe) carbonatite
            - B. Alkaline-silicic intrusions related deposits

Alkaline complex-hosted Au
Peralkaline granitoid-related Nb-Zr-REE
Albite syenite-related REE
Ta-Li ongonite

C. Alkaline-gabbroic intrusion-related deposits

Charoite metasomatite
Magmatic and metasomatic apatite
Magmatic graphite
Magmatic nepheline

Deposits related to extrusive rocks

IV. Deposits related to marine extrusive rocks

A. Massive sulfide deposits

Besshi Cu-Zn-Ag massive sulfide
Cyprus Cu-Zn massive sulfide
Korean Pb-Zn massive sulfide
Volcanogenic Cu-Zn massive sulfide (Urals type)
Volcanogenic Zn-Pb-Cu massive sulfide (Kuroko, Altai types)

B. Volcanogenic-sedimentary deposits

Volcanogenic-hydrothermal-sedimentary massive sulfide Pb-Zn (±Cu)
Volcanogenic-sedimentary Fe
Volcanogenic-sedimentary Mn

V. Deposits related to subaerial extrusive rocks

A. Deposits associated with mafic extrusive rocks and dike complexes

Ag-Sb vein
Basaltic native Cu (Lake Superior type)
Hg-Sb-W vein and stockwork
Hydrothermal Iceland spar
Ni-Co arsenide vein
Silica-carbonate (listvenite) Hg
Trap related Fe skarn (Angara-Ilim type)

B. Deposits associated with felsic to intermediate extrusive rocks

Au-Ag epithermal vein
Ag-Pb epithermal vein
Au potassium metasomatite (Kuranakh type)
Barite vein
Be tuff
Carbonate-hosted As-Au metasomatite
Carbonate-hosted fluorspar
Carbonate-hosted Hg-Sb
Clastic sediment-hosted Hg±Sb
Epithermal quartz-alunite
Fluorspar vein
Hydrothermal-sedimentary fluorite
Limonite
Mn vein
Polymetallic (Pb, Zn±Cu, Ba, Ag, Au) volcanic-hosted metasomatite
Polymetallic (Pb, Zn, Ag) carbonate-hosted metasomatite
Rhyolite-hosted Sn
Sulfur-sulfide (S, FeS2)
Volcanic-hosted Au-base-metal metasomatite
Volcanic-hosted Hg
Volcanic-hosted U
Volcanic-hosted zeolite

2. Deposits related to hydrothermal-sedimentary sedimentary processes

VI. Stratiform and stratabound deposits

Bedded barite
Carbonate-hosted Pb-Zn (Mississippi valley type)

- Sediment-hosted Cu
- Sedimentary exhalative Pb-Zn (SEDEX)

VII. Sedimentary rock-hosted deposits
- Chemical-sedimentary Fe-Mn
- Evaporate halite
- Evaporate sedimentary gypsum
- Sedimentary bauxite
- Sedimentary celestite
- Sedimentary phosphate
- Sedimentary Fe-V
- Sedimentary siderite Fe
- Stratiform Zr (Algama Type)

VIII. Polygenic carbonate-hosted deposits
- Polygenic REE-Fe-Nb deposits (Bayan-Obo type)

3. Deposits related to metamorphic processes

IX. Sedimentary-metamorphic deposits
- Banded iron formation (BIF, Algoma Fe)
- Banded iron formation (BIF, Superior Fe)
- Homestake Au
- Sedimentary-metamorphic borate
- Sedimentary-metamorphic magnesite

X. Deposits related to regionally metamorphosed rocks
- Au in black shale
- Au in shear zone and quartz vein
- Clastic-sediment-hosted Sb-Au
- Cu-Ag vein
- Piezoquartz
- Rhodusite asbestos
- Talc (magnesite) replacement
- Metamorphic graphite
- Metamorphic sillimanite
- Phlogopite skarn

4. Deposits related to surficial proceses

XI. Residual deposits
- Bauxite (karst type)
- Laterite Ni
- Weathering crust Mn (±Fe)
- Weathering crust and karst phosphate
- Weathering crust carbonatite REE-Zr-Nb-Li

XII. Depositional deposits
- Placer Au and paleoplacer Au
- Placer diamond
- Placer PGE
- Placer Sn
- Placer Ti-Zr
- Placer Fe
- Placer Th
- REE and Fe oolite

5. Exotic deposits
- Impact diamond