Introduction to Metallogenic Belt and Mineral Deposit Maps for Northeast Asia

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Introduction and Companion Studies

The metallogenic belts and locations of major mineral deposits of Northeast Asia are portrayed on this CD-ROM on Sheets 1-4. Sheet 1 portrays the location of significant lode deposits and placer districts at a scale of 1:7,500,000. Sheets 2-4 portray the metallogenic belts of the region in a series of 12 time-slices from the Archean through the Quaternary at a scale of 1:15,000,000. For all four map sheets, a generalized geodynamics base map, derived from a more detailed map by Parfenov and others (this CD-ROM), is used as an underlay for the metallogenic belt maps. This geodynamics map underlay permits depicts the major host geologic units and structures that host metallogenic belts. Summary features of metallogenic belts are described in the companion table.

The metallogenic belts for 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 data supporting the compilation are: (1) comprehensive descriptions of mineral deposits; (2) compilation and synthesis of a regional geodynamics map the region at 5 million scale with detailed explanations and cited references; and (3) compilation and synthesis of metallogenic belt maps at 15 million scale with detailed explanations and cited references. These studies are part of a major international collaborative study of the *Mineral Resources, Metallogenesis, and Tectonics of Northeast Asia* that is being conducted from 1997 through 2002 by geologists from earth science agencies and universities in Russia, Mongolia, Northeastern China, South Korea, Japan, and the USA. Companion studies on this CD-ROM and previous publications are: (1) a detailed geodynamics map of Northeast Asia (Parfenov and others, this CD-ROM); (2) a compilation of major mineral deposit models (Rodionov and Nokleberg, 2000; Rodionov and others, 2000; Obolenskiy and others, this CD-ROM); and (3) a database on significant metalliferous and selected nonmetalliferous lode deposits, and selected placer districts (Ariunbileg and others, this CD-ROM).

Concepts and Problems for Synthesis of Metallogenic Belts

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 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. 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 metallogenic units published by various authors for studies of metallogenic zonation include (Bilibin, 1955; Itsikson and others, 1965; Shatalov, 1965; Itsikson, 1973, 1979; Guild, 1978; Scheglov, 1980; Mitchell and Garson, 1981; Radkevich, 1982; Tomson, 1988; Zonenshain and others, 1992; Koroteev, 1996; Parfenov and others, 1999; Sukhov and others, 2000; Plyuschev, 2001): (1) planetary deposit-hosting province or planetary metallogenic belt (≥1000 by 10^3 km^2); (2) deposit-hosting belt or metallogenic belt (150 to 1000 by 10^3 km^2); (3) deposit-hosting system or metallogenic system (40 to 150 by 10^3 km^2); (4) deposit-hosting zone or metallogenic zone (20 to 40 by 10^3 km^2); (5) deposit-hosting subzone or metallogenic subzone (2 to 20 by 10^3 km^2); and (6) ore district (0.4 to 2.0 by 10^3 km^2).

However, often determination of differences between some of these metallogenic units is difficult. Examples are metallogenic system versus metallogenic zone, or ore district versus deposit-hosting subzone. For this study, only a two simple terms are employed: metallogenic belt and contained district. Generally, the size of metallogenic belts is partly a function of the scale of the analysis. For this study, metallogenic belts are synthesized and compiled at 5 M scale.

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

The following concepts are employed for the synthesis of metallogenic belts.

Mineral Deposit Association. 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 were formed in a specific geodynamic event. Examples are collision, continental-margin arc, accretion, rifting, and others.

Favorable Geological Environment. Each metallogenic belt is underlain by a geological host rock and (or) 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 either stratigraphic or magmatic units, or by major faults (sutures) along which substantial translations have occurred.

Relation of Features of Metallogenic Belt to Host Unit. The name, boundaries, and inner composition of each metallogenic belt corresponds to previously define characteristics of rocks or structures hosting the deposits, and to a suite of characteristics for the group of deposits and host rocks.

With these definitions and principles, 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.

(1) 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 mantle processes in the origin of major-belts of deposits.

(2) What is relation of regional metallogeny to individual lithosphere blocks? As discussed by Guild (1978), Mitchell and Garson (1981), and Koroteev (1996), this problem includes the genesis of specific metallogenic belts as a function of specific geodynamic environments using the modem concepts of plate tectonics.

And (3) 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 margin or island arcs, along rift systems in continents, or along transform continental margins.

Methodology of Metallogenic Analysis, Key Definitions, Geologic Time Scale, and Time Spans

Methodology of Metallogenic and Tectonic Analysis

The compilation, synthesis, description, and interpretation of metallogenic belts of Northeast Asia is part of a intricate process to analyze the complex metallogenic and tectonic history of the region. The methodology for this type of analysis of 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) Tectonic environments for the cratons, craton margins, orogenic collages of terranes, overlap assemblages, and contained metallogenic belts are assigned from regional compilation and synthesis of stratigraphic, structural, metamorphic, isotopic, faunal, and provenance data. The tectonic environments include cratonal, passive continental margin, metamorphosed continental margin, continental-margin arc, island arc, transform continental-margin arc, oceanic crust, seamount, ophiolite, accretionary wedge, subduction zone, turbidite basin, and metamorphic. (4) Correlations are made between terranes, fragments of overlap assemblages, and fragments of contained metallogenic belts. (5) Coeval terranes and their contained metallogenic belts are grouped into a single metallogenic and tectonic origin, for instance, a single island arc or subduction zone. (6) Igneous-arc and subduction-zone terranes, which are interpreted as being tectonically linked, and their contained metallogenic belts, are grouped into coeval, curvilinear arc-subduction-zone-complexes. (7) By use of geologic, faunal, and paleomagnetic data, the original positions of terranes and their metallogenic belts are interpreted. (8) The paths of tectonic migration of terranes and contained metallogenic belts are constructed. (9) The timings and nature of accretions of terranes and contained metallogenic belts are determined from geologic, age, and structural data; (10) The nature of collision-related geologic units and their contained metallogenic belts are determined from geologic data. And (11) the nature and timing of post-accretionary overlap assemblages and contained metallogenic belts are determined from geologic and age data.

Key Metallogenic and Tectonic Definitions

For the compilation, synthesis, description, and interpretation of metallogenic belts, the following and mineral deposit, metallogenic, and tectonic definitions are employed. The definitions are adapted from Coney and others (1980), Jones and others (1983), Howell and others (1985), Monger and Berg (1987), Nokleberg and others (1994a, b, 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 into units composed predominantly of turbidite deposits or predominantly of oceanic rocks. Units are interpreted to have formed during tectonic juxtaposition in a zone of major thrusting of one 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.

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.

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.

Cratonal terrane. Fragment of a craton.

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

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

Island-arc terrane. Fragment of 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 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 either from a nearby craton margin or from a distant site.

Mine. A site where valuable minerals have been extracted.

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

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

Oceanic crust, seamount, and ophiolite terrane. Fragment of part or all of a suite of *eugeoclinal* deep-marine sedimentary rocks, pillow basalt, gabbro, and ultramafic rocks 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 postaccretion unit of sedimentary or igneous rocks deposited on, or intruded into, two or more adjacent terranes. The sedimentary and volcanic parts either depositionally overlie, or are interpreted to have originally depositionally overlain, two or more adjacent terranes, or terranes and the craton margin. Overlapping plutonic rocks, which may be coeval and genetically related to overlap volcanic rocks, link or stitch together adjacent terranes, or a terrane and a craton margin.

Passive continental margin terrane. Fragment of a craton margin.

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

Pre-accretion rock unit. Suite of sedimentary, volcanic, or plutonic rocks 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 in which excavation has occurred.

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 exhibit similar, but not identical geologic history relative to another fault bounded unit in the same terrane.

Superterrane. An aggregate of terranes that is interpreted to share either a similar stratigraphic kindred or affinity, or a common geologic history after accretion (Moore, 1992). An approximate synonym is *composite terrane*.

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

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

Transform continental-margin arc. An igneous belt of coeval plutonic and volcanic rocks, and associated sedimentary rocks 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 deposited on oceanic crust. May include minor epiclastic and volcaniclastic deposits.

Geologic Time Scale and Time Spans

Geologic time scale units are according to the IUGS Global Stratigraphic Chart (Remane, 1998). For this study, for some descriptions of metallogenic belt and geologic units, the term *Riphean* is used for the Mesoproterozoic through Middle Neoproterozoic (1600 to 650 Ma), and the term *Vendian* is used for Neoproterozoic III (650 to 540 Ma).

According to the main geodynamic events and the major deposit-forming and metallogenic belt-forming events for Northeast Asia, the following twelve time spans are used for groupings of metallogenic belts.

Archean (> 2500 Ma)
Paleoproterozoic (2500 to 1600 Ma)
Mesoproterozoic (1600 to 1000 Ma)
Neoproterozoic (1000 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)
Maastrichnian through Oligocene (72 to 24 Ma)
Miocene through Quaternary (24 to 0 Ma)

Mineral Deposit Models

For descriptions of metallogenic belts, lode mineral deposits are classified into various models or types. Detailed descriptions are provided in the companion paper by Obolenskiy and others (this CD-ROM). The following three main principles are employed for synthesis of mineral deposit models for this study. (1) Deposit forming processes are close 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 circles of formation of rocks and geological structures (Smirnov, 1969). (2) The classification must be as more comfortable and understandable for appropriate user as possible. And (3) the classification must be open so that new types of the deposits can be added in the future (Cox and Singer, 1986).

In this classification for this study, lode deposits are grouped into the hierarchic levels of metallogenic taxons according to such their stable features as: (a) environment of formation of host and genetically-related rocks, (b) genetic features of the deposit, and (c) mineral and (or) elemental composition of the ore. The six hierarchial levels are as follows.

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

The deposit models are subdivided into the following four large groups according to major geological rock-forming processes (Table 1): (1) deposits related to magmatic processes; (2) deposits related to hydrothermal-sedimentary processes; (3) deposits related to metamorphic processes; (4) deposits related to surficial processes and (6) exotic deposits. Each group includes several classes. For example, the group of deposits related to magmatic processes includes two classes: (1) those related to intrusive rocks; and (2) those related to extrusive rocks. Each class includes several clans, and so on. The most detailed subdivisions are for magmatic-related deposits because they are the most abundant in the project area. In the below classification, lode deposit types models 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 (or species) within the genus.

Some of the below deposit models differ from cited descriptions. For example, the Bayan Obo type was described previously as a carbonatite-related deposit. However, modern isotopic, mineralogical, and geological data recently obtained by Chinese geologists have resulted in a new interpretation of the deposit origin. These new data indicate that the deposit consists of ores that formed during Mesoproterozoic sedimentary-exhalative process, and along with coeval metasomatic activity, sedimentary diagenesis of dolomite, and alteration. The sedimentary-exhalative process consisted of both sedimentation and metasomatism. Later deformation, especially during the Caledonian orogeny, further enriched the ore. Consequently, the Bayan Obo deposit type is herein described as related to sedimentary-exhalative processes, not to magmatic processes. However, magmatic processes also played an important role in deposit formation. Consequently, this deposit model is part of the family of polygenetic carbonate-hosted deposits. Similar revisions are made for carbonate-hosted Hg-Sb and other deposit models.

Table 1. Hierarchial ranking of mineral deposit models.

Deposits related to magmatic processes
- Deposits related to intrusive magmatic 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 ($\pm$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) skarn (ludwigite)
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-silisic 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 from spring water
- 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, FeS_2)
- Volcanic-hosted Au-base-metal metasomatite
- Volcanic-hosted Hg
- Volcanic-hosted U
- Volcanic-hosted zeolite

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)

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
Deposits related to surficial proceses
XI. Residual deposts
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 and paleoplacer Au
Placer diamond
Placer PGE
Placer Sn
Placer Ti-Zr
REE and Fe oolite
Exotic deposits
Impact diamond

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