Preliminary Description of Mineral Deposit Models (Types) for Mongolia

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INTRODUCTION

This report provides a preliminary description of the major mineral deposit models (types) for Mongolia. This preliminary description is being compiled as part of a project on the Mineral Resources, Metallogenesis, and Tectonics of Eastern and Southern Siberia, Mongolia, Northeast China, South Korea, and Japan. For additional information on the project, please refer to the companion project summary by Nokleberg (this volume). In future publications of the project, the descriptions of mineral deposit models will be expanded.

CLASSIFICATION OF MINERAL DEPOSITS

Metalliferous and selected non-metalliferous lode and placer deposits in this report are classified into various models, or types, described below. This classification was derived mainly from the mineral deposit types of Eckstrand (1984), Cox and Singer (1986), Nokleberg and others (1987, 1993, 1994a, b, 1997), cited references for specific models, and unpublished data of the Mongolian authors. The mineral deposit types used in this report consist of both descriptive and genetic information that is systematically arranged to describe the essential properties of a class of mineral deposits. Some types are descriptive (empirical), in which instance the various attributes are recognized as essential, even though their relationships are unknown. An example of a descriptive mineral deposit type is the basaltic Cu type in which the empirical datum of a geologic association of Cu sulfides with relatively Cu-rich metabasalt, or greenstone, is the essential attribute. Other types are genetic (theoretical), in which case the attributes are related through some fundamental concept. An example is the W skarn deposit type in which case the genetic process of contact metasomatism is the essential attribute. For additional information on the methodology of mineral deposit types, the reader is referred to the discussions by Eckstrand (1984) and Cox and Singer (1986).

COMMODITY GROUPINGS OF DEPOSITS

Gold Deposits
By Gunchin Dejidmaa

The lode gold mineralization of Mongolia has been described by Marinov (1963), Dornfeld and Kraft (1964), Borzakovskii and others (1971), Kraft, Taubert and others (1974), Tsypukov and Lombo (1975), Blagonravov and Shabalovskii (1977), Blagonravov and Tsypukov (1977), Poznyak and Dejidmaa (1977), Gottesman (1978), Tsherbakov, Roslyakov and others (1979), Blagonravov, Byambaa., and Podkolzin (1980), Tsherbakov and Dejidmaa (1984), Blagonravov, Blagonravova and others (1984), Tsherbakov, Dejidmaa, and Kalinin (1986), Dejidmaa

(1980, 1985), Alkin, Kunytsyn and others (1989), Blumen and others (1989), Bolotova, Dejidmaa and others (1990), Bokulev (1991), Blumen (1991), Dejidmaa, Eideliman and others (1993), Mironov and Trofhimov (1993), Mironov and Soloviev (1993), and Dejidmaa (1996). Gold deposit types discussed below are derived from above references, from Eckstrand (1984), and Cox and Singer (1986), with revisions by Gunchin Dejidmaa. The principal gold deposit types are Au-Ag epithermal vein (low sulfide epithermal Au), conglomerate-hosted clastic Au, granitoid-related Au, Au skarn (Contact metasomatic replacement), and porphyry Au.

Hg Deposits
By Gunchin Dejidmaa

Hg deposits in Mongolia have been studied by Blagonravov (1977) and Obolenskii (1971, 1984, 1985), and Metallogeny of the Mongolian Peoples' Republic (1986). Hg occurrences of Mongolia are classified into the following subtypes: (1) magnesium-carbonate-cinnabar or listvenite subtype with examples of the the Khangi ovoo occurrence in the Sulinkheer terrane and the the Olgii occurrence in Mongol Altai terrane; (2) quartz-dickite-cinnabar subtype with examples of the Ulaanhus occurrence occurring along the deep-seated Tolbonuur fault in the Mongol Altai terrane, and the Kharzat occurrence in northeastern Mongolia; and (3) the fluorite-cinnabar-sulfide type with examples of the Idermeg Bayankhaan Uul occurrence occurring along the deep-seated Onon fault in northeastern Mongolia; (4) the quartz-sericite-cinnabar subtype with examples of the Tunkhel and Balj occurrences along the Eroogol regional fault in the North Khentii terrane; and (5) the quartz-barite-cinnabar subtype with examples of the Dalai Am gol and Khotol nuur occurrences occurring along the Ulzgol fault in northeastern Mongolia.

The first subtype occurrence is hosted in ultramafic rocks. The second and fourth subtypes are hosted in clastic sedimentary rocks. The third and the fifth subtypes are hosted in granitic rocks.. These subtypes can be readily classified by the following host-rock lithologies: (1) clastic sediment-hosted Hg deposits (quartz-dickite-cinnabar and the quartz-sericite-cinnabar subtypes); (2) silica-carbonate (listvenite) Hg (magnesium-carbonate-cinnabar subtype); and (3) volcanic-related Hg (fluorite-cinnabar-sulfide and quartz-barite-cinnabar mineral subtypes).

Fe and Mn Deposits
By Gunchin Dejidmaa

Fe and Mn deposits of Mongolia have been described by Philippova and Vydrin (1977), Bakhteev and Chijova (1984), Izokh, Polyakov, and Krivenko (1984), Samoylov, Ivanov, Kovalenko and others (1984), Podlessky, Aksuk, Vlasoova, Baikova, Shuleshko, and Kozakov (1987), Podlessky, Vlasova, and Kudrja (1988), Kovalenko, Koval and others (1988), Tsend-Ayuush and Chrbotarev (1989), Antonov, Blyumen and others (1989), Chebotarev, Chebotareva, and Tsend-Ayuush (1990), Sokolov and Zaitsv (1990), and Izokh, Polyakov, Krivenko, Bognibov, and Bayarbileg (1990). The Fe and Mn deposit types of Mongolia discussed below are derived from Eckstrand (1984) and Cox and Singer (1986) using data from the above references and unpublished data of Gunchin Dejidmaa. The Fe and Mn deposit types are grouped according to host rock lithology and origin. The Fe and Mn deposit types are volcanogenic-sedimentary Fe-Mn, ironstone (clastic magnetite in sedimentary rocks), and chemical-sedimentary Fe or ironstone (Fe-Fe, Mn-Mn).

REE Deposits
By Ochir Gerel

REE model deposit types in Mongolia include economically important deposits that are relatively well studied. The deposit types include REE carbonatite, REE pegmatite, peralkaline granite-related REE (Nb-Zr-REE), ongonite-hosted Ta-Li, Cs Glass, Be Tuff, REE-albite, and Ta-granite (Kovalenko and others, 1986; Kovalenko and Yarmolyuk, 1995). Many REE deposits and occurrences have complex mineralization and are sometimes very difficult to classify. Most of the REE deposits and occurrences are spatially and genetically related to calc-alkaline and peralkaline granites and alkaline rocks. The REE ore minerals occur in the apical part, endocontact, or sometimes in the exocontact that are mainly hypabyssal or subvolcanic facies plutons composed of highly fractionated magma. These REE deposits and occurrences are interpreted as forming mainly in continental postaccretion or rift tectonic environments. The commercial REE mineral deposits and occurrences are mainly of Mesozoic age, and formed within collisional intracontinental belts. Some also along a middle and late Paleozoic active continental margin.

Fluorspar Deposits
By Dangindorjiin Dorjgotov

Fluorite mineralization occurs mainly in eastern Mongolia (Khrapov, 1977). Fluorspar deposits and occurrences of Mongolia were first classified into: (1) vein type (with quartz-fluorspar, barite-quartz-fluorspar mineral type; and (2) vein/replacement type (calcite-quartz-fluorite mineral deposit type). For exploration and prospecting, fluorite (fluorspar) deposits are classified into two types: fluorspar vein; and fluorspar-carbonate-hosted. These fluorspar deposit subtypes are hosted mainly in Late Mesozoic volcanic-tectonic grabens containing Early Cretaceous bimodal volcanic and sedimentary rocks in eastern Mongolian and southern Mongolian. These host rocks are part of various late Mesozoic intercontinental volcanic belts that occur along active deep faults that border large, uplifted blocks.

Pb-Zn Deposits
By Dangindorjiin Dorjgotov

Mesozoic Pb-Zn deposits of Mongolia are classified into following three deposits types: (1) Fe-Zn skarn (contact metasomatic) related to subalkaline granite; (2) Ag-bearing Pb-Zn hydrothermal vein related to subalkaline polyphase intrusion; and (3) Ag-Pb epithermal vein related to subalkaline subvolcanic rocks. This classification is mainly based on mineral association, rocks related to mineralization, host-rock lithology, alteration, and ore structure (Table 1).

Table 1. Classification of Pb-Zn Deposits related to Mesozoic subalkaline magmatic rocks in Mongolia.

Type of Deposit	Example
Contact-metasomatic (skarn)	Bayandun, Erdenetolgoi, Gurvansaikhan, Tumurtiin-Ovoo, Salkhit, Tumurtei, Kharaat and others.
Hydrothermal vein and stockwork	BaitsBuilst, Tsav, Delger-munkh, Khavtsgait and others, Ulaan, Mukhar, Bayan-Uul.
Epithermal vein	Bayankhaan, Modon, Salaa-Undur, Modon, Khartolgoi, Mungun 24-Biluut, Boorch.

COPPER DEPOSITS
BY GUNCHIN DEJIDMAA

Copper deposits and Cu deposit types of Mongolia have been described by Yakovlev, (1977), Sotnikov, Berzinaand, and others (1985) and Sotnikov, Jamsran, and others (1985). Cu deposits and occurrences of Mongolia are classified into: (1) Cu-Mo; (2) Cu skarn; (3) native copper; (4) Cu-Ni veins and masses in gabbroic rocks; (5) sandstone and shale- hosted Cu; and (6) Cu-kolchedan formation types. Cu deposits and occurrences of Mongolia, have been studied by Berzina and others (1983), Volchanskaya, (1980), Gumbina and others (1979), Demidovand others (1975), Jamsran (1971, 1975, 1977), Polyakov and others (1984), Sotnikov and others, (1980a), Sotnikov and others (1981), Sotnokov and others (1980b), Sotnikov and others (1985), Sotnikov, Sanduijav, and others (1978), Yudin and others (1975), Yakovlev and others (1979), Davaasambuu and others (1976a), Davaasambuu and others (1976b), Sotnikov and others (1976), Movsesyan and Isaenko (1974), Khasin and others (1977), Sotnikov and Berzina (1985), Sotnikovand others, (1979, 1981, 1984), Gerel (1989, 1990), Gerel and others (1984, 1985), Koval and Gerel (1986), Gavrilovaand others, (1984, 1988, 1989).

The Cu deposit types of Mongolia discussed below are derived from Eckstrand (1984) and Cox and Singer (1986) using data from the above references. The Cu deposit types are grouped according to host rock lithology and origin. The Cu deposit types are: (1) porphyry Cu-Mo with Cu, Cu-Mo and Mo-Cu subtypes; (2) mafic-ultramafic related Cu-Ni sulfide; (3) Cu skarn; (4) basaltic Cu; (5) sediment-hosted Cu; (6) Cu vein/stockwork related to granite rocks; (7) Cu-(Ag) vein in regionally metamorphosed rocks; and (8) volcanogenic-massive and disseminated Cu (±Zn, Au, Ag) sulfide.

STRATABOUND DEPOSITS IN CLASTIC SEDIMENTARY ROCKS AND SUBAERIAL BASALT

Sediment-Hosted Cu Deposit Type
By Gunchin Dejidmaa

This sediment-hosted Cu deposit type first was defined by Yakovlev (1977) as Cu-bearing sandstone formation and subsequently by Sotnikov, Berzina, and others (1985) who named the deposit type as Cu-bearing sandstone and shale formation. Significant sediment-hosted Cu occurrences are distributed in the Mongol Altai and in Kharkhiraa terranes and are hosted in upper Ordovician, in middle to upper Devonian and Lower Jurassic sedimentary rocks.

The Omnogovi and Bayanbulag occurrences are hosted in Late Ordovician Erdeneburen unit that contains sandstone and siltstone, in the Kharhiraa terrane. The occurrences consist of sandstone, rare siltstone lense, and tabular bodies with visible chalcocite, malachite, and azurite. Covellite and chalcopyrite also are identified by microscope. The thickness of ore bodies ranges from 5.0 m to 50.0 m, and the length ranges up to 1.5 km. The grade of Cu ranges from 0.01 to 1.47%, and Ag ranges up to 20.0 g/t.

A few Cu occurrences of sediment-hosted Cu deposit are present in the western part of the Deluun basin in the Middle to Late Devonian Bardamgol and Khatuugol units in western Mongolia (Obolenskiy and others, 1989). The basin contains thick Devonian deposits (up to 9 km) that unconformably overlie the early Paleozoic units of the Altai and Kharhiraa terranes. The lower part of the Devonian units consists of volcanic and sedimentary rocks of the Otogiin unit (rhyolite, andesite, andesite-dacite porphyry, tuffs, volcanic breccia, tuffaceous sandstone, tuff-graywacke and conglomerate), the middle part consists of the Bardamgol unit in the Sagsai River basin, and the middle part consists of the Khatuugol unit near Tolbo Lake. The Middle and Upper Devonian units consist of black-gray siltstone, black shale, and sandstone. A special feature of the sedimentary rocks in the Khatuugol unit is a high grade of carbonaceous material (up to 5.5% of organic C in carbonaceous siltstone) and sulfides (Borisenko and others, 1992). Sulfides consist of stringer-impregnations, concretions mostly of pyrite-marcasite. There also are Cu-bearing sandstone strata horizons (for example, the Khatuugiin Gol River occurrences). Exceptions are epigenetic pyrite-pyrrotite stringers that occur in hornfels and are the result of contact metamorphism. In this area, the sulfide-bearing zone occurs conformably with host rock for strike distances of several tens of km and ranges up to 1.5 to 2.0 km wide (Borisenko, 1992). There are several strongly mineralised sandstone lenses, from 1.0-7.0 m thick, tabular bodies that contain malachite, melaconite, chalcopyrite, and pyrrotite. In grab and rock chip samples, the grade of Cu ranges from 0.5 to 3.0%, and Ba from 0.1 to 0.5%.

Sediment-hosted Cu occurrences in Jurassic sedimentary rocks, occur along the deep-seated Tsagaanshiveet fault that separates the Kharhiraa terrane from the Nuuryn terrane. Examples of the latter are the Kupol and The Khargait occurrences that are hosted in Jurassic sedimentary rocks, mainly conglomerate, greywacke, and sandstone. Cu mineralization consists of chalcocite, malachite, and azurite and occurs in sandstone horizons and lenses with thicknesses of 0.1 to 3.0 m, and lengths up to 400.0 m. The grade of Cu ranges from 0.1 to 2.5%.

Clastic Sediment-Hosted Sb-Au Deposit Type
By Gunchin Dejidmaa

The clastic sediment-hosted Sb-Au deposit type consists of simple and complex ladder, and concordant carbonate-quartz veins and veinlets. The host rocks are terrigenous and volcanic-terrigenous units in accretionary wedge terranes, and are silicified, carbonatized, pyritized, and rarely argillized and sericitized. The ore minerals are pyrite, stibnite, arsenopyrite, chalcopyrite, gold, rare galena, sphalerite, tetrahedrite. The gangue minerals are quartz, ankerite, and lesser calcite, dolomite, sedirite, and sericite. The deposit type occurs mainly in linear fold zones that are associated with regional strike-slip faults, sometimes in thrust fault zones. Where localized in thrust fault zones, extensive alteration occurs, including silicification, carbonatization, and argillization. The thrust zones generally contain vertical, quartz-carbonate veins with high grade Sb and moderate grade Au. The deposits of this type in linear fold zones generally contain ladder and concordant carbonate-quartz veins and the Au grade is higher than the Sb grade. The Talyn Meltes and Khatansuudal occurrences in the Tomortein Nuruu belt in southwestern Mongolia. examples of this deposit type in thrust zones are the Sb-Au occurrences in the Baitag district of the Baruun Khuurai belt.

Clastic-Sediment-Hosted Sb Deposit Type
By Gunchin Dejidmaa

The clastic-sediment-hosted Sb deposit type consists of quartz veins or mineralized breccia hosted in Paleozoic terrigenous rocks. The ore minerals are stibnite and antimony oxides that occur as impregnations, nests and stringers. The host terrigenous rocks may also contain minor stibnite. A few Sb occurrences, possibly belonging to this deposit type are located near the Shar Us gol River in the Khangai mountain range (Arhoviin Am, Urt Am, Metegiin Ovoo occurrences) and in northeastern Mongolia (Khuts Ondor and Gorkhitbulag occurrences and others). These occurrences were first described by Khasin (1977).

Ironstone (Clastic Magnetite in Sedimentary Rocks) Deposit Type
By Gunchin Dejidmaa

The ironstone deposit type is herein defined and consists of massive and disseminated magnetite that occurs in bed-like and lens-like bodies in sandstone and conglomerate. Magnetite is mainly of clastic origin. The deposit type is interpreted as ancient lithified sea beach placers. A few small occurrences of this deposit type are known in the Lower Carboniferous molasse that is interpreted as forming in a marine beach environment.

Conglomerate-Hosted Clastic Au Deposit Type
By Gunchin Dejidmaa

The conglomerate-hosted clastic Au deposit type consists of clastic gold-bearing bed-like and lens-like bodies in layers of sandstone and conglomerate in Permian, Jurassic and Cretaceous molasse that form overlap assemblages (Sherbakov and others, 1986**)**. The deposit type is interpreted as ancient lithified sea and lake-beach placers. Known occurrences are in the Uyanga-Taragt, Delgerhaan, and Eroogol districts. They are a primary source of several economic placer Au deposits of Neogene and Quaternary age in Mongolia. Exploration is needed to clarify their economical importance.

STRATIFORM DEPOSITS IN FINE-GRAINED AND SILICEOUS SEDIMENTARY ROCKS

Volcanogenic-Sedimentary Fe-Mn Deposit Type
By Gunchin Dejidmaa

The volcanogenic-sedimentary Fe-Mn deposit type consists of stratiform massive and disseminated magnetite-hematite that occur in sheet-like or lens-like tabular bodies that are interbedded with marine volcanic-sedimentary and sedimentary rocks including quartzite, chert, sandstone, siltstone, shale, and siliceous rocks. Filippova and others (1977) called this deposit type jasper-quartzite Fe-Mn formation. The host rocks are mostly chert, quartzite, siliceous rocks, jasper, and jasperoid. Ore minerals of the deposit type, Fe and Mn minerals, are complex. According to mineralogy and Fe and Mn grade, this deposit type is divided into three subtypes: (1) volcanogenic-sedimentary Fe; (2) volcanogenic-sedimentary Fe-Mn; and (3) volcanogenic-sedimentary Mn. The ore minerals are magnetite, hematite, pyrolusite, hausmannite, and braunite. The depositional environment consists of marine epicratonal and intracratonic basins, back arc basins, and in volcanic-terrigenous units of ophiolite complexes. Deposits and occurrences of this deposit type are widespread in Mongolia. They are located in the Khangai metallogenic belt (in the Devonian to Carboniferous volcanogenic-terrigenous Khangai Seri Formation), the Govi-Altai metallogenic belt (in the early Paleozoic Togrog volcanogenic and Ukhinnuruu volcanic-terrigenous Formations), in the Urgamal metallogenic belt (in the Upper Proterozoic siliceous-carbonate Shuvuun Formation), and in other metallogenic belts.

DEPOSITS IN CARBONATE AND CHEMICAL-SEDIMENTARY ROCKS

Chemical-Sedimentary Fe or Ironstone (Fe-Fe, Mn-Mn) Deposit Type
By Gunchin Dejidmaa

The chemical-sedimentary Fe or ironstone (Fe-Fe, Mn-Mn) deposit type consists of sheet-like and lens-like horizons containing massive and disseminated Fe and Mn oxide and carbonate minerals that are hosted in sedimentary and clastic carbonate rocks, including limestone and dolomite. The ore-bearing horizons consist of sedimentary chert, quartzite, quartz-sericite-chlorite schist, and clastic carbonate. Filippova and others (1977) called this deposit type iron-quartzite formation. According to mineralogy, and Fe and Mn grade, the deposit type is divided into Fe, Fe-Mn, and Mn subtypes. The ore minerals are magnetite, hematite, siderite, pyrolusite, hausmannite, braunite, and rhodochrosite.

Occurrences of this deposit type exist in early Paleozoic chemical-sedimentary carbonate rocks formed in basins overlying Precambrian granitic and metamorphic complexes, and in Late Cretaceous and Neogene, intracratonic lake basins. An example of the first is in the Khovsgol carbonate basin located in northern Mongolia where Fe, Fe-Mn, and Mn occurrences are associated with sedimentary phosphate, allunite, and vanadium deposits. These occurrences are confined to a single stratigraphic level but exhibit no regular, spatial distribution. Zaitsev and others (1984) noted that where phosphate deposits are extensively developed, low-grade sedimentary Fe, Mn, and Al deposits also occur, and where Fe, Mn and Al deposits are extensively developed, low-grade phosphate deposits also occur. Occurrences of the Fe subtype are located in southern and southeastern Mongolia. Occurrences of the Fe-Mn subtype are associated with sedimentary gypsum, alunite, and rare barite and bauxite deposits and occurrences.

Chemical sedimentary V deposit type
By Gunchin Dejidmaa

The chemical sedimentary V deposit type consists of V-bearing chert-carbonaceous shale and cherty, sheet-like horizons. The chert-carbonaceous shale horizon consists of intercalated siliceous shale, carbonaceous-calcareous shale, clay-shale, siltstone, chert, and rare limestone. The chert horizons consist of chert and sedimentary quartzite. Main examples of the deposit type are V occurrences in the lower Paleozoic Khovsgol Shelf basin (Poznaikin and others, 1990). The grade of V ranges from 0.01 to 1.0%. These V-bearing horizons vary from 20.0 m to 70.0 m wide and from 0.5 km to 2.7 km long. The mineralogy of these occurrences is not studied.

Bedded Barite Deposit Type
By Sodov Ariunbileg

This deposit type consists of veinlet and nodular barite interbedded with marine cherty and calcareous sedimentary rocks, mainly dark chert, shale, sandstone, and dolomite (Marinov and Hasin, 1977). This deposit type is often associated with sedimentary deposits. Calcite-barite veinlet deposits mainly occur in the southern Gobi depression. The associated minerals are minor calcite, hematite, pyrite, sulfide ocher, galena, and sphalerite. The most important bedded barite occurrences are in Precambrian recrystallized limestone. The depositional environment is stable shallow marine basins commonly on passive continental margins.

DEPOSITS RELATED TO MAFIC CONTINENTAL VOLCANIC ROCKS

Fluorspar Vein Deposit Type
By Dangindorjiin Dorjgotov

The fluorspar vein deposit type consists of quartz-fluorite and quartz-sulfide-fluorite veins, and fluorite-altered zones that occur in various rocks intruded by mafic Cretaceous dikes (Khrapov, 1977). The ore bodies are steeply dipping, and the length along strike varies from several hundreds meters to 3,000 meters, up to 300-500 m down dip. The thickness of ore bodies varies from 1 to 30 meters. Large scale silicification is the most important alteration. Brecciated silicified rock is the main host rock and is developed in multiple, large layers. The mineral assemblage for this deposit subtype is a simple, quartz and fluorite. Minor minerals are barite, adularia, pyrite, galena, stibnite, and Ag minerals. The deposit subtype has three major stages: quartz-sulfide, quartz-fluorite and quartz-carbonate. Examples of this deposit type are at Berkh, Khar-Airag, Khavirga, Khongor, and Bor-Undur.

Fluorspar-Carbonate-Hosted Deposit Type
By Dangindorjiin Dorjgotov

This fluorspar-carbonate deposit type consists of metasomatic calcite-quartz-fluorite in lenses and wedges that are hosted in Proterozoic carbonate intruded by mafic Cretaceous dikes (Khrapov, 1977). The ore bodies are steeply dipping, and the length along strike varies from several hundreds meters to thousand meters, and up to 100 m down dip. The thickness of the ore bodies ranges from 1 to 30 meters. Large-scale silicification and fluoritization are the most important alterations. The major mineral are quartz, fluorite, and calcite. Minor mineral are barite, adularia, siderite, ankerite, dolomite, and clay minerals. Examples of this deposit tpe are at Zuuntsagaandel, Bujgar, Zam, Maihant, Bilh-Uul, and Shanaga.

Basaltic Cu Deposit Type
By Ayurzana Gotovsuren and Gunchin Dejidmaa

This basaltic Cu deposit type was originally named as Cu-zeolite formation (Yakovlev, 1977), and as native Cu formation (Sotnikov, Jamsran, and others, 1985 and Sotnikov, Berzina, and others, 1985). This deposit type occurs in two regions of Mongolia: (1) the Orkhon-Selenge volcanic belt; and (2) the Khan Khohii mountain range. Cu occurrences of this deposit type in the Orkhon-Selenge belt are hosted in andesite porphyry, amygdaloidal basalt, and basaltic tuff of Early and Late Permian, and Early Triassic age. Cu occurrences in the Khan Khohii region are hosted in amygdaloidal basalt and andesite porphyry in Lower to Middle Devonian volcanic and sedimentary rocks. In most cases, native Copper occurs in epidote-altered andesite and basalt, and more rarely in amygdules and in the matrix of less altered volcanic rocks (Sotnikov, Berzina, and others, 1985). Native Cu is associated with quartz, epidote, carbonate, and chlorite. Main examples of the deposit type are the Bots, Baruunburen, Mech Uul, Zuunturuu Gol, Orkhon, and other occurrences are in the Orkhon-Selenge volcanic belt. The Baga Nuur and Khordaga occurrences are in the Khon Khohii Montain Range.

DEPOSITS RELATED TO CALC-ALKALINE TO SUBALKALINE PLUTONIC ROCKS

Porphyry Cu-Mo Deposit Type
By Ayurzana Gotovsuren

This porphyry Cu-Mo deposit type was first defined by Movsesyan and Isaenko (1974) for Mongolia**.** The deposit type consists of quartz-sulfide, quartz-carbonate-sulfide and quartz-sericite-sulfide stockworks that occur in or near porphyritic intermediate to felsic intrusion, mainly in stocks and breccia pipes that intrude granitic, volcanic, or sedimentary rocks. The depositional environment is high-level granitic porphyries. The main ore mineral are pyrite, chalcopyrite, molybdenite, bornite, chalcocite, and covellite. Associated minerals are rare sphalerite, galena, and gold. Porphyritic intrusion and host rocks are intensive silicified, sericitized, K-feldsparized, biotitized, chloritized, propyllitized. Most deposits exhibit argillic overprints. The tectonic environment is mainly weakly to strongly alkalic granitic plutons emplaced in active continental margins and in interplate rifting environments. The deposit type consists of three subtypes, porphyry Cu, porphyry Mo-Cu, and porphyry Cu-Mo. Main examples of the deposit type are the Erdenetiin-Ovoo Cu-Mo, Tsagaansuvarga, and Avdartolgoi Mo-Cu and porphyry Cu deposits, the Bayan Uul and Khongoot porphyry Mo-Cu deposit, and the Zost Uul, Shand, Oyuut, and Khatavch porphyry Cu-Mo occurrences.

Cu Skarn Deposit Type
By Ayurzana Gotovsuren

The Cu skarn deposit type consists of chalcopyrite, magnetite, and pyrrhotite in calc-silicate skarn that replaces calcareous sedimentary rocks and mafic igneous rocks along intrusive contacts with plutons. The plutons range in composition from felsic to intermediate granite. The tectonic environment is mainly weakly alkalic granitic plutons emplaced along active continental margins or island arcs. Cu-rich skarns occur mainly in sedimentary rocks. Main ore minerals are chalcopyrite, bornite, chalcocite, and covellite. Associated minerals are pyrite, hematite, galena, molybdenite, sphalerite, and scheelite. The main examples of the deposit type are in the Nuuryn terrane.

Porphyry Mo, W, Sn Deposit Types
By Ochir Gerel

Porphyry Cu-Mo deposits are very important in Mongolia. The operating Erdenetiin Ovoo mine is well known. Cu grade ranges from 0.4 to 0.7% and Mo grade ranges from 0.002 to 0.007 g/t. Although other localities are not well studied, Cu-Au deposits have a large potential in the southern and central Mongolian (Sillitoe and others, 1996). Occurrences are known at Bayan Uul, Shuuten, Tsagaan Suvraga, and Oyuut Ovoo. These deposits occur in felsic to intermediate porphyritic intrusions that associated with volcanic depressions. A genetic association consists of subalkaline andesite volcanic rocks that are superimposed on gabbro-syenite-granite intrusives. Volcanic rocks are enriched in Rb, Sr, Ba, Ree, Nb, Zr, Ta, Cr, and Ni (Koval and Gerel, 1986; Koval and others, 1988). The ectonic settings of deposits (as at Erdenetiin Ovoo and Bayan Uul) is interpreted as continent-continent collision in contrast with the southern Mongolian belt where many deposits and occurrences are interpreted as subduction-related. The primary ore minerals are pyrite, molybdenite, chalcopyrite, tennantite, galena, sphalerite, and enargite. Secondary enrichment zone includes chalcosite, covellite, and bornite (Gavrilova and others 1984). Porphyritic, quartz-sericitic and argillic, and incipient K-feldspar alteration also occur (Sotnikov, Berzina and Bold, 1984).

Granitoid-Related Au Deposit Type
By Gunchin Dejidmaa

The granitoid-related Au deposit type consists of quartz veins and veinlet-stockwork zones that are often localized in altered wall rocks with sulfide stringer-zones. The deposit type was previously called vein/replacement type (Dejidmaa, 1996). Free gold occurs in veins and stockworks and also as disseminatations in altered wall rocks. The deposits and occurrences generally exhibit a close spatial and possible genetic relation to small, complex, granitic intrusions of variable composition. The granitic rocks include gabbro, diorite, granodiorite, and granite of both calc-alkaline and sub-alkaline compositions. The tectonic environment is interpreted as epizonal plutons that formed in island arcs, continental margin arcs, or continental rift zones. Most deposits and occurrences in Mongolia are related to granitoids formed in Mesozoic interplate epeirogenic uplifts and continental rift zone environments.

Wall rock alteration, mineralogy and geochemistry are divided into the following subtypes: (1) Au-beresite, (2) Au-listvenite, (3) Au-sheelite-quartz vein-stockwork, (4) Au-sulfide-quartz vein, (5) Au-As -Sb vein-stockwork, (6) Au-Te quartz vein-stockwork, (7) Au-Cu-Ag -quartz vein-stockwork, (8) Au-Pb-Zn-Ag -quartz vein-stockwork, and (9) Au-magnetite-hematite-quartz vein-stockwork. The host rocks are generally intensively altered. The Au-beresite and Au-listvenite subtypes contain most of the gold, as disseminations, in these subtypes. Alteration in the Au-beresite subtype often occurs in siliceous and intermediate composition host rocks. Alteration in the Au-listvenite subtype often occurs in mafic and ultramafic rocks. Disseminated sulfide minerals in wall rocks, especially pyrite and arsenopyrite in the Au-beresite subtype, and pyrite, arsenopyrite and chalcopyrite in the Au-listvenite subtypes, are commonly enriched in gold. The main examples of the Au-beresite subtype are the Boroo deposit in the Boroo-Zuunmod district, and the Tsagaanchuluut Khudag 1 occurrence in the Turgen district. The main example of the Au-Listvenite subtype is the Khyargas occurrence in the Khyargas district. Host rocks are variably altered in other subtypes, but gold occurs mostly along with sulfides in quartz veins and stockworks that contain disseminated gold-bearing sulfide minerals.

The Au-sulfide-quartz vein subtype is very closely related to the Au-beresite subtype. Ore composition of these two subtypes are very similar, but ore-body shapes are different. The differences result from characteristic ore-hosting tectonic structure. The main examples of the Au-sulfide-quartz vein subtype are the Tsagaanchuluut, Narantolgoi, Sujigt, and other deposits in the Boroo-Zuunmod district.

The Au-scheelite-sulfide-quartz vein/stockwork subtype is widely distributed in western Mongolia, but rarely occurs in central and eastern Mongolia. However, additional exploration is required. Known occurrences consist of fissure veins, en-echelon vein systems, and veinlet-stockworks that contain free gold and scheelite, and sulfide minerals that occur in apical and periphery part of granodiorite-granite calc-alkaline intrusions. The subtype is closely related to Mo-W vein and greisen types and sometimes as overprints.

The Au-As-Sb, Au-Te, Au-Pb-Zn-Ag subtypes are generally associated spatially with polymetallic vein deposits and are widespread in eastern Mongolia. They consist of en-echelon vein systems with disseminated gold-bearing sulfides, sulfosalts, and free gold. Gold-telluride minerals are common in Au-Te subtype. The fineness of gold is lower (680-800) for these subtypes than for other subtypes of the granitoid-related Au deposits.

The Au-Cu-Ag quartz vein/stockwork is sometimes closely related to porphyry Cu-Au, porphyry Cu and Au-Fe-Cu skarn subtypes. The Au-Cu-Ag quartz vein-stockwork subtype consists of fissure veins, en-echelon vein systems, and veinlet-stockwork zones, mostly with disseminated gold, sulfide minerals, and rare free gold. Cu-sulfides are more common, and except for Au, Cu, and Ag grades are high. This subtype contains complex ores of Au, Ag, and Cu. The main examples are the Tavt deposit and a few occurrences in the Teshig district.

The Au-magnetite-hematite-quartz vein/stockwork subtype occurs only rarely, and potential exists for additional discoveries. The main occurrences are in the Narsynhondlon district in eastern Mongolia. This subtype consists of en-echelon veins and veinlet-stockwork zones of magnetite-(hematite)-sulfide-quartz. The host rocks are silicified, sericitized and pyritized. Gold is generally disseminated. Most gold is related to sulfide minerals. Some deposits contain replacement magnetite-actinolite-chlorite-quartz vein-like bodies.

Porphyry Au Deposit Type
By Gunchin Dejidmaa

The porphyry Au deposit type deposit type consists of stockwork and veinlets of quartz, pyrite, and chalcopyrite in granite porphyry, granodiorite porphyry, and diorite porphyry stocks, dikes and breccia pipes that intrude granitic, volcanic or sedimentary rocks (Dejidmaa, 1996). The tectonic environment is mainly sub-alkaline diorite, granodiorite, or granite porphyry intrusions that are parts of subduction-related, late Paleozoic or Mesozoic active continental margin. This deposit type is divided into a porphyry Cu-Au subtype, and a porphyry Au subtype. The deposit type has a large potential in Mongolia.

The porphyry Cu-Au subtype consists of magnetite-sulfide-quartz stockwork veinlets, and breccia-pipes that contain sulfide stringers. The main ore mineral are chalcopyrite, pyrite, magnetite, and gold. Gold is mostly free and fine-grained. Alteration minerals are quartz, sericite, kaolinite, biotite, potassium feldspar, and chlorite. The grade of gold varies 0.1 to 15 g/t, and the average Cu grade is 0.3 to 0.4%. The host porphyry intrusions are mainly diorite- and granodiorite porphyry stocks. The main examples of the subtype are the Khadat deposit in the Ugtaaltsaidam district, and the Kharmagtai, Ovoot Khyar, Ukhaa Khudag deposits and occurrences in the Kharmagtai district.

The porphyry Au subtype is related mainly to granite-porphyry stocks and dikes that contain quartz - pyrite stockwork veinlets. The dikes are generally silicified, sericitized, and pyritized. Gold is mostly free. This subtype is related to porphyry Cu-Au subtype and occurs in the periphery of porphyry Cu-Au deposits. The main examples of the subtype are the Ulaangozgor, Ulaanhad, Erdenetsog Ovoo occurrences in the Ugtaaltsaidam district.

Au Skarn (Contact Metasomatic Replacement) Deposit Type
By Gunchin Dejidmaa

The Au skarn (contact metasomatic replacement) deposit type forms at the contacts between calc-alkaline and sub-alkaline granitic intrusions that intrude carbonate or calcareous rocks (Dejidmaa, 1980; Sherbakov, and Dejidmaa, 1984; Dejidmaa, 1996**)**. This subtype is divided into Au-, and Au-rich Fe-Cu; Cu skarn. The skarns are usually are composed of calc-silicate and sometimes magnesium-silicate minerals. Au skarn and Au-rich Fe-Cu skarns are related closely to granitoid-related Au deposit type.

For Au skarns, Au is main commodity and Cu is a byproduct. The major ore minerals are gold, pyrite, chalcopyrite, bornite, arsenopyrite, and bismuth minerals. Minor minerals are sphalerite, enargite, tetrademite, cubanite, bittehenite, magnetite, stannite, millerite, and linneaite. The major calc-silicate minerals are garnet, scapolite, epidote, clinopyroxene, amphibole, biotite, chlorite, albite, and calcite. Au skarns are related to sub-alkaline diorite-granite intrusions that intruded terrigenous-carbonate, and ophiolite formations in active continental margin arc and continental rift tectonic environments. The main example of this subtype is the Khohbulgiin Khondii deposit in the Bayanhongor belt.

Au-rich Fe-Cu skarn deposit type is related to sub-alkaline gabbro-diorite-granite intrusives that intrude terrigenous-carbonate, and carbonate formations in island arc, active continental margin arc, and continental rift tectonic environments. The main ore minerals are magnetite, chalcopyrite, pyrite, bornite, and gold. The minor ore minerals are arsenopyrite, sphalerite, enargite, sheelite, and ludwigite. The calc-silicate minerals are garnet, pyroxene, actinolite, chlorite, epidote, and calcite. The main examples of this subtype are the Bayanhairkhan and Erdenehairkhan occurrences in the Urgamal belt, the Teshig group occurrences in the Teshig district, the Oyuuttolgoi occurrence in the Bayangol belt, the Buutsagaan group occurrences of the same name belt, and the Erdenetolgoi occurrence in the Dochgol district.

Fe and Fe-Sulfide Skarn Deposit Type
By Gunchin Dejidmaa

The Fe and Fe-sulfide skarn deposit type consists of magnetite and rare magnetite-hematite that are associated with magnesium-silicate and calc-silicate contact metasomatic replacements (Podlessky and others, 1984, 1988). The deposit type is associated with calc-alkaline granitic rocks.

Magnetite-bearing magnesium-silicate skarn is genetically and spatially related to early Paleozoic granodiorite and granite intrusions. The skarns generally occur along the contacts between the intrusion and host dolomite marble, and rarely along contacts between dolomite and gneiss. The main skarn minerals are fassaite, spinel, forsterite, diopside, phlogopite, and serpentine. Magnesium-silicate skarn has following idealized zonation as described (Podlessky and others, 1984,1988): (1) granitoid rock; (2) pyroxene-plagioclase rock; (3) spinel-pyroxene skarn; (4) pyroxene-forsterite or spinel-forsterite skarn; (5) forsterite calciphyre; and (6) dolomitic marble. Magnetite occurs mostly in the periphery of the skarn in forsteritic calciphyre, spinel-pyroxene zones. Magnetite succeeds deposition of phlogopite, serpentinite and tourmaline. In magnesium-silicate skarn, the ore minerals form massive, coarse to fine disseminations, vein-like, lens-like, and irregularly-shaped bodies. Magnetite-bearing magnesium-silicate skarn, with insignificant amount of sulfide minerals, are also classified as Fe skarn. Most deposits and occurrences of the Fe skarn deposit type (Dorvoljin and Ovoot deposits, and occurrences in the Buutsagaan and Uliastai groups) occur in the central Mongolian skarn belt that is associated with Proterozoic metamorphic basement rocks that are intruded by early to late Paleozoic calc-alkaline to subalkaline granitic rocks.

Magnetite-bearing calc-silicate skarn is genetically and spatially related to post-magmatic (retrograde) granite rocks that intrude marble, limestone, dolomite, and calcareous-clastic sedimentary rocks. Podlessky and others (1984, 1988) describe the following idealized zonation: (1) granite; (2) potassium feldspar- or amphibole-epidote; (3) epidote monomineralic zone; (4) epidote-garnet endoskarn; (5) garnet exoskarn; and (6) carbonate rock. The ore mineral assemblages is generally, magnetite, magnetite-hematite, and quartz-hematite, and is generally localized mostly in garnet, and rarely in monomineralic epidote and epidote-garnet skarn. Ore mineral deposition occurs in a characteristic sequence consisting of garnet, amphibole, chlorite, calcite, and quartz with anomalous Zn, Cu, and rare Sn. Complex sulfide-magnetite minerals may occur in the deep levels of this deposit type. For-example, the Tomortolgoi deposit of the Bayangol belt contains sulfide-magnetite ore at depth. Sulfide minerals are mostly insignificant in magnesium-silicate skarn, but are significant in calc-silicate skarn. The Fe-sulfide skarn subtype contains significant sulfides (pyrrotite, pyrite, chalcopyrite, sphalerite, and others).

Fe-Zn Skarn Deposit Type
By Dangindorjiin Dorjgotov

The Fe-Zn skarn deposit type occurs mainly in uplifted blocks of Late Paleozoic and Early Mesozoic rocks located on the periphery of the Late Mesozoic Eastern Mongolian intercontinental volcanic belt (Bakhteev, 1984; Podlessky and others, 1984, 1988). The uplifted blocks are surrounded by Late Mesozoic volcanic grabens with Permian and Triassic granitoids that intrude Proterozoic and Paleozoic metamorphosed sedimentary rocks. The skarns generally occur along contacts and faults between Proterozoic, Devonian limestone and shale sequences, and Triassic K-subalkaline granite and leucogranite bodies. The skarns may occur in lenses (Bayandun, Tumurtei, Kharaat, Salkhit, and other occurrences), or in layers (Tumurtiin-Ovoo), and generally range from tens to hundreds of meters in thickness and several hundreds meters along strike. The intrusives are seldom altered. The dominant skarn minerals are andradite, hedenbergite, and grossularite associated with abundant sphalerite. Zonation is typically developed with zones of epidote-feldspar, epidote-andradite, andradite-magnetite, andradite-pyroxene-magnetite, and pyroxene-magnetite. Characteristic retrograde minerals are actinolite, quartz, calcite, and chlorite. Major ore minerals are sphalerite and magnetite. Chalcopyrite, hematite, bismuthinite, molybdenite, pyrite, and galena may also occur. The deposits contain minor Pb and Zn.. Fe-Zn mineralization is irregular distribution and occurs mostly in garnet and garnet-pyroxene skarn. Pb/Zn/Cu ratios are 0.2/4.5/0.1. Deposits have four stages of mineralization: garnet-pyroxene skarn, andradite-magnetite aposkarn, sulfide, and quartz-carbonate.

W Skarn Deposit Type
By Ochir Gerel

The W skarn deposit type consists mainly of various types of scheelite skarn that occurs along the margin of Mesozoic plutons that intrude metamorphosed Precambrian carbonate-aluminosilicate rocks, and rarely Paleozoic carbonate-terrigenous or volcanic-terrigenous rocks. W skarn deposits in Mongolia presently constitute non-commercial occurrences associated with Mesozoic granitoids in northeastern and southeastern Mongolia. Typical examples are at Beise, Bayan-Ovoo, and Tumen Tsogt (Koval and others, 1984).

W skarns generally form layered bodies that may extend for much as 1.2 to 2 km along intrusive contacts and range from 3.5 to 7.0 meters wide (Podlessky and others, 1988). The skarns exhibit a very complicated structure with rhythmically repeated zones of pyrite, arsenopyrite, and Sn- W-, and Cu-sulfides. The varieties of skarn include clinopyroxene-plagioclase, banded garnet-clinopyroxene, and garnet-vesuvianite types. Scheelite with small amounts of molybdenite, sphalerite and pyrite are the common ore minerals and may occur in both endoskarn and exoskarn. Gangue minerals are quartz, plagioclase (andesine), epidote, and actinolite. Scheelite may occur as disseminations in quartz-feldspar veins in exoskarns. W skarns may contain late-stage quartz and hematite alteration, and superimposed sulfides (chalcopyrite and sphalerite). Calcareous skarns form stratabound bodies up to 400 m long and up to 50 m wide.

The associated intrusive rocks are mainly calc-alkaline felsic plutons and stocks. Two- or three-phase leucogranites are most common, and generally consist of coarse-grained porphyritic biotite granite (first stage), medium-grained biotite-muscovite granite (second stage), and leucogranite (third stage). The associated granites are characterized by high contents of REE and Zn, and low contents of CaO and lithophile elements.

W and Sn skarn with scheelite and cassiterite are generally interpreted as forming during by bimetasomatic processes along the contacts between schist, volcanic rock, and granitoids with limestone or marble. The skarns are very complicated and are characterized by alternation of endoskarn with epidote or clinopyroxene-plagioclase and exoskarn (clinopyroxene-garnet-vesuvianite and garnet skarns) Scheelite and cassiterite occur as disseminations along with minor sulfide minerals (molybdenite, chalcopyrite, sphalerite). Overprinting the skarn may be quartz-feldspar alteration (sometimes with garnet and amphibole) and greisen (quartz, albite, fluorite, rarely muscovite).

Sn Polymetallic Vein Deposit Type
By Gunchin Dejidmaa

This Sn polymetallic vein deposit type was first defined for Mongolia by Ripp and Sudakov (1991) as for the Mongon-Ondor deposit. The deposit type consists various replacements. The important variants are: (1) quartz-amphibole-chlorite-feldspar replacement zones with polymetallic and Sn minerals with thicknesses of 1.0 m to 6.0 m; (2). quartz-chlorite-muscovite-carbonate replacement in stockwork with polymetallic minerals; and (3) silicified and argillized zones with Ag and Sb minerals that are often overprinted on the second type of replacement stockwork (Ripp and Sudakov, 1991). The first type replacement contains quartz-chlorite-muscovite-albite.

Main ore minerals are galena, cassiterite, sphalerite, pyrargerite and freibergite. Main metals are Ag, Sn, Pb, Zn, Potential by-products are Cu, Cd and In. Three types of ores occur: (1) cassiterite-sulfide (cassiterite-quartz-arsenopyrite); (2) Pb-Zn (galena-sphalerite-marcasite), and (3) Sb-Ag (quartz-pyrargerite-freibergite). The deposit type is close associated spatially with porphyry W-Mo deposit type.

Hydrothermal Cu-Pb-Zn Vein and Stockwork Deposit Type
By Dangindorjiin Dorjgotov

The hydrothermal Cu-Pb-Zn vein and stockwork deposit type occurs in Jurassic domes containing polyphase intrusives that intruded along faults (Mironovand others, 1989). These intrusives range from monzodiorite Mongon-Ondor, Baits and others) consist of quartz-sulfide and quartz-carbonate-sulfide veins in alteration zones. The veins are related to small Mesozoic bodies of diorite, granodiorite, granite that intrude metamorphosed sedimentary rocks. The mineral composition of these deposits is complex is similar between deposits. Major minerals are quartz, sericite, carbonate, galena, sphalerite, pyrite, and Ag minerals, sometimes with chalcopyrite, pyrrhotite, tetrahedrite, boulengerite, and native gold. Metasomatic wall rock alteration consists of wide-spread propyllitic zones and narrow beresite zones composed of quartz, sericite, carbonate, and pyrite. The metasomatic rocks exhibit a zonal and internal structure with quartz, sericite, and pyrite commonly occurring in the center, whereas quartz and pyrite commonly occur in the periphery, along with an increase of carbonate and chlorite. The ore minerals are irregularly distributed. The ore zones exhibit streaky, massive, and brecciated structures, whereas barren zones are characterized by disseminated to linear disseminations, occasional encrusted, and nested structures. The deposits have three stages: quartz-sulfide; quartz-carbonate-sulfide; and carbonate-fluorite.

The stockwork deposits at Ulaan, Mukhar and others occur mainly inside of explosion breccia pipes that are formed along steeply dipping faults (Mironovand others, 1989). The ore bearing pipes have trapezoid or wedge shapes and intrude metamorphosed, Late Mesozoic sedimentary and volcanic rocks. The breccias are intensively altered by hydrothermal-metasomatism with a well-defined definite mineralogical zoning. In the central part and deep horizons of the pipes, the cement varies from epidote-actinolite-sulfide to epidote-actinolite. Other parts of pipes are cemented by quartz-fluorite-sulfide. Polymetallic mineralization is developed mainly in the pipes and occasionally in fractures near the breccia pipes. The ore bodies vary from vein to stockwork, strike for several hundred meters, with thicknesses of several tens of meters, and extend down dip for up to 700 m. The major ore minerals are galena, sphalerite, chalcopyrite, and pyrite. Also occurring are arsenopyrite, pyrrhotite, magnetite, thenantite, bornite, native silver, and gold. Gangue minerals are quartz, feldspar, fluorite, epidote, actinolite, carbonate, and chlorite. The ores exhibit disseminated, pocket-disseminated, and breccia structures. Deposits exhibit five stages of mineralization: diopside-magnetite; epidote-actinolite; quartz-sulfide; quartz-fluorite-sulfide; and quartz-fluorite.

Epithermal Ag-Pb Vein Deposit Type
By Dangindorjiin Dorjgotov

The epithermal Ag-Pb vein deposit type consists of quartz-sulfide veins and mineralized zones in various rocks intruded by mafic Cretaceous dikes. Ore minerals are related to the dikes. The ore bodies extend along strike for several hundreds meters, and extend down-dip up to 300 m. The thickness of ore bodies ranges up to several tens of meters. The ore bodies consist of quartz-carbonate-sulfide and carbonate-sulfide types. The major ore minerals are galena, arsenopyrite, stibnite, and Ag minerals. Chalcopyrite, sphalerite, cinnabar, and pyrite are subordinate. Gangue minerals are quartz, siderite, chalcedony, kaolin, calcite, barite, and fluorite. The principal wall rock alterations are quartz, chalcedony kaolinite and chlorite. The deposit type has following three major stages: quartz-galena, quartz-fluorite and quartz-carbonate. Epithermal Ag-Pb vein deposits (Khartolgoi, Boorch, Modon, and others) are located in the active, deep-seated fault zones of Kerlen, Modon, Elgen-Uul, Tolbonuur, and elsewhere (Batjargaland others, 1997 and Dorjgotovand others, 1997).

Au-Ag Epithermal Vein (Low Sulfide) Deposit Type
By Gunchin Dejidmaa

Au-Ag epithermal vein deposits have a high potential in Mongolia. The deposit type is divided into a low- and high-sulfide epithermal Au subtypes (Dejidmaa, 1996).

The low-sulfide epithermal Au deposit subtype consists of quartz-adularia, quartz-adularia-carbonate, quartz-adularia-fluorspar veins and stockwork with a wide variety of sulfides, gold, silver, sulfosalts, pyrite, argentite, chalcopyrite, galena, and sphalerite. Host rocks are exhibit silicification, argillization, sericitization, carbonatization, adularization, and propylitization. Silica minerals are mostly chalcedony. A few low-sulfide epithermal Au occurrences exist in eastern Mongolia. These occurrences are located in a fault zones between grabens and horsts that contain volcanic and sedimentary rocks that formed during Mesozoic continental rifting.

A few high-sulfide epithermal Au occurrences exist in southern Mongolia. These occurrences are closely spatially related to porphyry Cu-Au and porphyry Cu deposits and occurrences that formed in a late Paleozoic continental margin arc. The known high-sulfide epithermal Au occurrences are located in volcanic-tectonic structures, especially in caldera structures. The host rocks are intensively silicified, kaolinitized, alunitized, sericitized, and pyritized.

Volcanic Hosted Zeolite Deposit Type
By Sodov Ariunbileg

This deposit type is hosted mainly in stratified volcanic rocks and locally in lacustrine sedimentary rocks with interlayered units (up to 60 m thick) of siliceous tuff, tuff-argillite, and tuffaceous sandstone and conglomerate. The maximum zeolite content (60 to 90%) occurs along contact with underlying siliceous vitreous tuff with minor amounts of volcaniclastic rocks. The main zeolite group mineral is clinoptilotite, and in some cases, ferrierite, chabazite, and heulandite (Petrova and others, 1996). This deposit type is widespread in Mongolia, particularly in the eastern Mongolian volcanic belt that contains a distinctive type of igneous-limonite-related zeolite that is interpreted as forming in the Late Jurassic and Early Cretaceous. Several natural zeolite deposits occur in the southeastern and southern parts of Mongolia, including the Tsagaantsav and Tushleg deposits that have industrial importance.

W-Mo Greisen Deposit Type
By Ochir Gerel

The W-Mo greisen deposit type consists of wolframite, molybdenite, and beryl with muscovite. Accessory minerals are scheelite, pyrite, arsenopyrite, galena, sphalerite, fluorite and topaz) that occur in greisen zones, quartz veins, and veinlets. The deposits are generally hosted in subalkaline, hypabyssal leucogranites (Koval and Yakimov, 1984). Greisen is associated with late-stage, fractionated granites. The greisen occurs mainly in endocontact, apical zones. Alteration includes greisen and albite. The main examples are at Yugzer, Tumen Tsogt, Tsagaan Tolgoi (Khasin and Suprunov, 1977, Koval and Yakimov, 1984). The deposit type is associated with W vein, W - Mo vein deposits.

W-Mo Vein Deposit Type
By Ochir Gerel

The W-Mo Vein deposit type consists of wolframite, molybdenite, and beryl that occur in various veins and breccia zones (Koval and others, 1986). The veins generally also contain various combinations of muscovite, fluorite, carbonate, scheelite, pyrite, arsenopyrite, chalcopyrite, sphalerite, and bismutite. The deposits occur mainly in exocontact zones and sometimes in endocontact zones. The main examples are at Ugzer, Buren Tsogt, Chuluun Khoroot, and Undur Tsagaan.

Sn and W Vein Deposit Type
By Ochir Gerel

The Sn and W vein deposit type consists of veins and brecciated zones that occur near or in shallow granitic intrusions that are highly fractionated and enriched in lithophile elements such as Rb, Li, Be, Sn, W, Ta, Nb, REE, and F (Kovalenko and others, 1971; Gerel, 1990). Associated hydrothermal greisen-type alteration is common (Khasin and Suprunov, 1977, Ivanova, 1976). Associated intrusions are highly fractionated leucocratic granites with two-mica, or muscovite leucogranites. The granitic rocks are mainly of late Paleozoic, and early and late Mesozoic age. The deposit type is divided into two subtypes, wolframite-cassiterite and cassiterite subtypes. The wolframite-cassiterite and cassiterite-wolframite types both contain cassiterite and wolframite with quartz, muscovite, topaz, fluorite, and pyrite. In addition, arsenopyrite occurs in the cassiterite type, and molybdenite and beryl in occur in the wolframite-cassiterite type. Mineralization occur in veins, veinlets, stockworks and greisen zones along endocontacts or exocontacts of plutons. The main examples of cassiterite-wolframite subtype are at Modot, Bayan Mod, Bayan Ovoo, Tsagaan Ovoo, Bayan Khan, Janchivlan, and Khujkhan. The main examples of wolframite-cassiterite sub type are at Kumyr, Tsagaan Davaa, and Zuun Tarc Gol. This deposit type is well studied in Mongolia.

Sn Silicate-Sulfide Vein Deposit Type
By Ochir Gerel

The Sn silicate-sulfide vein deposit type is represented by cassiterite-tourmaline mineralization in veins and veinlets of exocontact zones of multiple granite and granodiorite intrusions (Kovalenko and others, 1986). The composition ranges from granodiorite and granite of calc-alkaline series to subalkaline granite. The main minerals are cassiterite, quartz, tourmaline, chlorite, carbonates, chalcopyrite, arsenopyrite, sphalerite, and molybdenite. The main examples are at Khukh Uul and Zan Shiree.

Sn-Sulfide Vein Deposit Type
By Ochir Gerel

The Sn-sulfide vein deposit type consists of elongated, brecciated zones along exocontacts adjacent to subalkaline and Li-F hypabyssal granitic plutons (Khasin and Suprunov, 1977). The deposit type is interpreted as forming in a post-orogenic setting. The main minerals are cassiterite, galena, sphalerite, muscovite, fluorite, tourmaline, chlorite, carbonate, pyrite, arsenopyrite, and chalcopyrite. Alteration minerals are tourmaline, chlorite, muscovite, and quartz. The main example is at Khar Morit. The deposit type is associated with muscovite-microcline pegmatite and Sn-W greisen. According to some investigators, the Sn-sulfide deposit type may be part of the Sn-silicate-sulfide deposit type (Kovalneko and others, 1986). This deposit type needs more study.

Sn-W Vein and Stockwork Deposit Type
By Ochir Gerel

The Sn-W vein and stockwork deposit type consists of individual veins, multiple vein systems, and vein and fracture stockworks The deposit type is one of the best studied and economically important for Mongolia (Khasin and Suprunov, 1977; Khasin and others, 1983). The deposits occur in or near granitic intrusions that were emplaced at relatively shallow levels. The deposits are structurally controlled by deep faults and fissures. Individual veins range from less than 1 cm to several meters wide. Vein systems are hundreds of meters wide and more than a thousand meters long. The tectonic environment is interpreted as continental collision belt.

The principal ore minerals are cassiterite, wolframite, and scheelite. Associated minerals are molybdenite, chalcopyrite, sphalerite, pyrite, arsenopyrite, sphalerite, muscovite, fluorite, beryl, topaz, feldspar, quartz, and tourmaline. Associated hydrothermal alteration assemblages consist mainly of greisen with fluorite, topaz, tourmaline, Li-mica, muscovite, biotite, and quartz, and other minerals such as albite and microcline. Cassiterite, wolframite, chalcopyrite, sphalerite, pyrite, and other sulfide minerals are disseminated in greisen-altered rocks. The alteration is generally zonal.

The associated intrusions are calc-alkaline, or subalkaline Li-F granites. The granites are highly fractionated, range from peraluminous to peralkaline in composition, and are characterized by high SiO_2 and alkalies, Rb, Li, Be, REE, Sn, W, Ta, Nb, and F, and depleted in CaO, MgO, Sr, and Ba (Gerel, 1990, 1995). The granites may be either A- and S-type, are highly fractionated with two or three stages. Formation of the Sn-W vein and stockworks is related to the second or third stage.

W-Sb (Hg) Vein and Stockwork Deposit Type
By Ochir Gerel

The W-Sb (Hg) vein and stockwork deposit type consists of veins, stockworks, and breccias with quartz (sometimes with chalcedony and opal), carbonate (dolomite, siderite, ankerite, magnesite and calcite). The ore minerals are wolframite, scheelite and minor pyrite, marcasite, arsenopyrite, chalcopyrite, pyrrhotite, sphalerite, galena, cinnabar, and gold. The deposits occur in regions of low-grade metamorphism along the margins of continental terranes, and are controlled by shear zones, nappe systems, or large faults. No proven relation exists with magmatic processes. The wall rocks are usually argillized and sericitized. An example is the Khovd gol and Mushguu in Mongolian Altai (Kempe and others, 1994, Getmanskaya and others, 1995).

Barite Vein Deposit Type
By Sodov Ariunbileg

This deposit type consists of quartz-barite, barite veins and veinlet in stockworks that are hosted by quartz-porphyry, diabase-porphyry, tuff, and biotite granite (Marinov and Hasin, 1977). The deposits often occur along contacts of volcanic and sedimentary rocks. This deposit type is commonly associated with fluorite deposits.

REE Pegmatite Deposit Type
By Ochir Gerel

The REE pegmatite deposit type contains the majority of potentially commercial pegmatites in Mongolia. These deposits consist of late Paleozoic or Mesozoic REE pegmatites that are mainly associated with calc-alkaline, Li-F leucocratic granite. Three subtypes of REE pegmatites are defined (Kovalenko and others, 1984): Li-mica; muscovite (muscovite-albite); and muscovite-microcline. The first two subtypes are Ta-bearing, and the last is composed of cassiterite-tungsten (Rossovsky and others, 1971; REE granitoids, 1971; Vladykin and others, 1974, 1981; Gerel, 1995). The Li-mica subtype contains Ta-Nb minerals, cassiterite, Li-mica, quartz, albite, microcline, apatite, tourmaline, topaz, beryl, and other minerals. The main examples are at Khuh Del Uul and Unjuul. The muscovite-albite subtype consists of columbite, tantalite, quartz, albite, microcline, muscovite. The main example is at Berkh. The muscovite-microcline subtype includes cassiterite, wolframite, quartz, microcline, and muscovite. The main examples are at Tumen Tsogt, Bayan Delger, Bayan Ovoo, and Khalzan Uul. Many of the known REE pegmatite deposits occur in the north-east REE province of Mongolia.

The Khuh del Uul, Unjuul, and Berkh REE pegmatite deposits and others occur as dike-like or lenticular bodies that range in size from few meters to hundreds of meters long, and from 1 to 10 meters wide. In these examples, the muscovite-microcline subtype is widely developed in subalakline granite.

Associated Li-Sn-Be pegmatites (Kovalenko and others, 1986; Kovalenko, Yarmolyuk, 1995) consist of Li-mica, Ta and Sn-W minerals that are hosted in post-accretionary intrusions that postdate the peak of batholiths emplacement. The associated granites are mainly calc-alkaline and Li-F leucogranites and their volcanic and subvolcanic analogues.

Peralkaline Granite-Related REE (Nb-Zr-REE) Deposit Type
By Ochir Gerel

The peralkaline granite-related REE (Nb-Zr-REE) deposit type is associated with peralkaline rocks. An example is the REE-Zr-Nb Khalzan Buregtei deposit in western Mongolia (Kovalenko and others, 1990, 1995), the Khan Bogd deposit in southern Mongolia (Vladykin and others, 1981), and a number of occurrences in western and southern Mongolia. The deposit type generally occurs in the apical part of cupolas, and is generally associated with highly fractionated magmatic phases including peralkaline pegmatite. The host granites are composed of potassium feldspar, quartz, albite, arfvedsonite, aegirine, fluorite, and various REE minerals, such as elpidite, gittincite, zircon, pyrochlore, monazite, REE fluorcarbonate, polylitionite and others. Alteration includes replacement by epidote, orthoclase, and postmagmatic albite. The deposits are generally hosted in microcline-albite granite and albite metasomatic rocks composed of quartz, albite, pyroxene, and microcline. Quartz-epidote metasomatic rocks contain zircon, fergusonite, allanite, chevkinite and titanite in vein-like zones. Fergussonite and zircon contain HREE and Y (Kempe, Dandar, 1995). Acessory minerals include amphibole, magnetite, zircon, epidote, ilmenite, fluorite, beryl, chevkinite, pyrite, and galena. REE pegmatites and quartz-fluorite veins may also occur (Dandar and others, 1995).

According to Kovalenko and others (1985), Zr-REE mineralization is of magmatic origin and is concentrated within highly fractionated REE granites. In contrast, Kempe and others (1994) and Andreev and others (1994) suggest a metasomatic origin. Their studies of the Khalzan Buregtei deposit, and the Tsakhir, Shar Tolgoi and Ulaan Tolgoi occurrences in the Mongolian Altai region show that these deposits are formed in endocontacts of alkaline plutons that consist of metasomatically-altered alkaline syenite (nordmarkite). These intrusions are small, metasomatically altered, and range from fine-grained to pegmatite. Nordmarkite, dolerite, and syenite are also metasomatically altered. Associated with the alteration was emplacement of mafic and ultrabasic dikes and volcanic rocks. The ore minerals are numerous and include more than 70 minerals. The rock forming minerals are potassium feldspar, albite, quartz, calcite, zircon, and Sr-fluorite. Accessory minerals are pyrochlore, barite, rutile, titanite, epidote, REE carbonates, and fluorite. Metasomatic rocks contain quartz, epidote, zircon, titanite, fergussonite, pyroxene, chevkinite, and others (as at the Tsakhir occurrence). Other examples are the Gurvan Unet and Ulaan Unet occurrences.

DEPOSITS RELATED TO ALKALINE IGNEOUS ROCKS

Fe-REE Carbonatite or Magnetite-Apatite Deposit Type
By Gunchin Dejidmaa

The Fe-REE carbonatite or magnetite-apatite deposit type consists of magnetite-apatite veins and bodies with 1 to 14.5% REE (mostly cerium group) that occur in apatite, magnetite, phlogopite, and rare celestine in alkaline plutonic and coeval volcanic rocks (Samoylov, Ivanov and others; 1984; Kovalenko, Koval and others, 1988). Magnetite is mostly altered to hematite The amount of apatite and of magnetite varies strongly in stock-like bodies and in veins. Some bodies contain rich bonanza ore formed of massive, very coarse-grained magnetite, or of fine-and medium-grained apatite. The deposit type is related genetically and spatially associated with REE-fluorspar carbonatite, REE-apatite carbonatite and REE-strontium carbonatite deposits in alkaline plutonic and volcanic rocks, and in explosive carbonatite breccia. Examples of the deposit type occur in the Mushgai Khudag district in southern Mongolia, and in the Ubs Nuur district in northwestern Mongolia.

REE Carbonatite Deposit Type
By Ochir Gerel

The REE carbonatite deposit type includes REE,-P-Sr-Ba-fluorite-Pb occurrences that are associated with late Mesozoic alkaline volcanic-plutonic complexes (Samoilov and Kovalenko, 1983). These complexes occur in intraplate areas and are controlled by major faults and anorogenic rifts. The host rocks are potassic alkaline volcanic rocks and carbonatite including melanephelinite, melaleucitite, phonolite, trachyte, latite, trachybasalt, and syenite. Typical examples are the Mushgai Khudag and Lugiin Gol occurrences in southern Mongolia. The main deposit types are (1) carbonatite and eruptive trachyte breccia with a carbonatite matrix containing of 0.1 to 0.8% REE, or are enriched in light REE and contain up to 18% Sr; (2) magnetite-apatite rocks with REE content of 1.0 to 14.5%;and (3) bastnaesite carbonatite with a REE content of 1 to 18% (Kovalenko and Yarmolyuk, 1995). The carbonatite and eruptive trachyte breccia deposit type forms large mineralized bodies. The magnetite-apatite rock deposit type occur in dikes and stock-like bodies. The bastnaesite carbonatite deposit types occurs mainly as dikes. In all three subtypes, the ore minerals include bastnaesite, carbonate, fluorite, celestine and barite, cerrusite, magnetite, apatit, and monazite.

As an example, the Mushgai Khudag alkaline series include more than 200 dikes of carbonatites that range from 20 m to 2000 m long and from 0.2 to 1 m wide. Besides calcite carbonatites, quartz veins with celestine-fluorite-calcite and calcite-celestine-fluorite-also occur. Magnetite-apatite rocks are also associated with this carbonatite complex. Another example is the Lugiin Gol carbonatite occurrence that is composed of pseudoleucite and nepheline syenite with ring and radial dikes of nepheline syenite, pulaskite, syenite-porphyry, and tingauites (Vladykin, 1997). The main REE minerals at the Lugiin Gol occurrence are synchysite, synchysite-parisite and synchizate-bastnaesite intergrows (Batbold, 1977). Sr- and Nd-enriched synchysite also occur (Batbold, 1977). Other carbonatite occurrences are those at Bayan Khushuu, Khotgor, and Ulgii, Tsogt Ovoo. In these areas, the carbonatites occur as dikes up to 1-2 m wide within plutons or host rocks of late Paleozoic volcanic and sedimentary rocks. The carbonatites are composed of calcite with mica, apatite, fluorite, bastnaesite, synchizite, rutile, zircon, and sulfides. Alterations include replacement of pre-existing minerals and recrystallization of pyroclastic rocks, formation of silica-jarosite, silica-fluorite, and silica-barite-fluorite metasomatic rocks.

Nepheline Syenite Deposit Type
By Ochir Gerel

The nepheline syenite deposit type is associated with nepheline-bearing alkaline complexes (ijolite, urtite, juvite and foyaite, pulaskite) and nepheline syenites (Zaitzev and others, 1984). The main examples are the Ujigiin Gol and Beltsiin Gol areas with small plutons with nepheline-bearing rocks that are related to a large alkaline province in northern Mongolia. The nepheline-rich rocks occur mainly occur along exocontacts of plutons. Al_2O_3 content varies from 20.4 to 30.9%, and alkali content varies from 12.5 to 17.6% (Zaitzev and others, 1984). The nepheline-rich rocks are composed of nepheline and pyroxene. Nepheline content ranges from 30% (in ijolite) to 90 persent (in urtite). Other minerals in nepheline-bearing rocks are microcline, lepidomelane, muscovite, and cancrinite. Alteration consists of albite and potassium feldspar replacement.

Ongonite-Hosted Ta-Li Deposit Type
By Ochir Gerel

This ongonite-hosted Ta-Li deposit type is subdivided into volcanic and plutonic facies both of which are volcanic analogues of Ta-bearing granites and pegmatites (Kovalenko and others, 1971; Kovalenko and Kovalenko, 1976). The main ore minerals contain Ta with Rb, Nb, Be, Li, and Sn. Plutonic ongonites are rich in Ta (up to 130 ppm, with average content of 88 ppm) and Li (average content of 2,780 ppm) and Rb (average content of 2,380 ppm). Ongonite is porphyritic with phenocrysts of albite, quartz, potassium feldspar, topaz, and Li-fengite within a fine-grained matrix of REE minerals. Volcanic ongonites (as at the Teg Uul occurrence) are poorer in REE (Ta 37 ppm, Nb 170 ppm, Rb 1,040 ppm and Be 90 ppm) than plutonic ongonites, but form large bodies: volcanic cones, stratified bodies, and sheets. The volcanic ongonites are vitreous. The main occurrences are at Teg Uul, Dorit Uul, and Durvent Uul in southern Mongolia. The Ni content the deposit type ranges from 0.05 to 0.8%, Zr from 0.5 to 5.0%, and REE from 0.3 to 4.5%. High concentrations of Li, Be, Sn and Zn are also characteristic. As an example, the Teg Uul occurrence is large, extends over 1 km^2, and is composed of tuff with a thickness of up to 10-20 m. Associated rocks are late Mesozoic rhyolites and ongorhyolites that formed as volcanic necks.

Cs Glass Deposit Type
By Ochir Gerel

The Cs glass deposit type consists of glassy dikes with phenocrysts of feldspar, quartz, and chevkinite (Kovalenko and others, 1977). The Cs content of the glass ranges up to 0.08%, but decreases during devitification. An example is the Braibung khiid (Khentei aimag) occurrence. This deposit type is not well studied.

Be Tuff Deposit Type
By Ochir Gerel

The Be tuff deposit type consists of bedded and graded-bedded tuff that contains fragments of ongorhyolite, rhyolite, quartz, feldspar, fluorite, and Be-bearing bertrandite (Kovalenko and Koval, 1984). The average Be content is 0.05%. The main examples are at Durvent Dorit Uul, and Teg Uul.

REE-Albite Deposit Type
By Ochir Gerel

The REE-albite deposit type forms in the endocontact of alkaline plutons that are composed of metasomatically altered alkaline syenite (nordmarkite) as at the Kovalenko occurrence (Andreev and others, 1994; Kempe and others, 1995). The main occurrences are Teg Uul, Dorit Uul, Durvebt Uul in southern Mongolia. Other examples of this deposit type may the Khalzan Buregtei deposit, and the Tsakhir, Shar Tolgoi, and Ulaan Tolgoi occurrences in the Mongolian Altai.

REE-Albite Nepheline Syenite Deposit Type
By Ochir Gerel

The REE-albite nepheline syenite deposit type occurs in contrasting volcanic peralkaline rocks (comendite, pantellerite, peralkaline trachydacite, trachyrhyolite and trachybasalt) that contain REE-albite nepheline syenite (Kovalenko and Yarmolyuk, 1995). The main examples are the Bomin Khara and Gzart Khudag occurrences in South Gobi. The ore minerals are REE-Zr-Nb minerals.

Ta-Granite Deposit Type
By Ochir Gerel

The Ta-granite deposit type occurs in the apical and endocontact zones of Li-F or subalkaline plutons or in small stocks and dike-like bodies (Kovalenko and others, 1981). The main ore minerals are columbite and tantalite with microlite, Pb-pyrochlore, and cassiterite. The major gangue minerals are albite, microcline, quartz, and Li-mica, and sometimes topaz, pyrochlor, and beryl in muscovite type. The Ta-granite deposit type is divided into two subtypes, Li-mica and muscovite. The Li mica subtype occurs in Li-fluorine leucogranite plutons, and the muscovite subtype occurs in calc-alkaline granites (Kovalenko and others, 1981). Muscovite REE type contains columbite-tantalite and beryl with albite, microcline, quartz and muscovite. Examples of the Li-mica subtype are at Janchivlan, Borokhjir, Baga Gazar, Avdar, Baruuntsogt, Yugzer, and others. Examples of muscovite subtype are at Yugzer, Tumentsogt, Baruuntsogt, Yargait, Uzyg, and others. Ta-Be and W-Mo mineralization is also associated with the Ta-granite deposit type. Associated alteration is mainly albitization.

Ag-Sb Deposit Type
By Gunchin Dejidmaa

The Ag-Sb deposit type consists of mostly siderite-sulphosalts veins hosted in carbonaceous terrigenous, terrigenous-carbonate or black shale that are enriched in sulfide minerals adjacent to intruding igneous rocks. This deposit type is widely distributed in western, but mostly in northwestern Mongolia. The known deposits and occurrences are close related spatially associated with alkaline basaltic dikes. This deposit type is well studied by Borisenko and others (1984, 1987, 1988, 1991), Obolenskii (1984); Berezikov and others (1986), Badarev and others (1989), Demin and others (1989), and Khrustalev and others (1989).

The deposit type consists of extended (up to 5-6 km) veins and vein zones containing siderite-sulphosalts. The main gangue mineral is siderite that comprises from 50% to 95% of the veins. The major gangue minerals are quartz, calcite, ankerite, barite, and fluorite. The predominant ore minerals are silver sulphosalts of Cu, Pb, Ag: tetrahedrite, chalcostibite, zincenite, bournonite, jemsonite, boulangerite, andorite, pyrargyrite, geokronite, and meneghinite, along with bismuth sulphosalts, bismuthinite, native bismuth, galena, chalcopyrite, stibnite, arsenopyrite, lollingite and others The ore minerals comprise from 1 to 5 to 50% of the veins. The major metals are Ag, Sb, Bi, and the main byproducts are Cu and Pb. Related deposit types are Co-Ni arsenide veins that are form in association with magmatism related to intraplate tectonism.

The deposit type is divided into two subtypes, Cu-Bi-Ag and Pb-Ag-Sb subtypes. The Cu-Bi-Ag subtype contains mainly Cu sulphosalts and sulfides (tetrahedrite, chalcostibite, chalcopyrite), and bismuth minerals. The Ag grade varies from 200 to 300 g/t to 1000 g/t. The main example is the Asgat deposit in western Mongolia. The Pb-Ag-Sb subtype contains predominantly Pb sulphosalts (jemsonite or zinkenite), and also gudmundite and rare stibnite. Tetrahedrite is the main Ag-bearing mineral. Bismuth minerals are uncommon, but always occur. Ag grade varies from about 400 to 600 g/t. The main example is the Tolbonuur occurrence in western Mongolia.

Co-Ni-Arsenide Deposit Type
By Gunchin Dejidmaa

The Co-Ni-arsenide deposit type consists of epithermal hydrothermal veins composed of carbonates (calcite, dolomite, and rare ankerite, and siderite), and sometimes significant amounts of fluorite and barite (Borisenko and others, 1992). The ore minerals are Co-Ni-Fe arsenides (nickeline, shmaltine, chloatite, skutteride, rammalsbergite, safflorite, lollingite, and also sulfoarsenids: cobaltine, glaukodot, gersdorfite, arsenopyrite), Cu-Ag-Pb-Bi sulfosalts and sulfides, and native Ag and Bi. The deposit type includes a series of complex of Bi-Ag-Cu-Ni-Co-arsenic ore minerals that form in mesobyssal and hypabyssal depths in genetic and spatial association with small intrusions of alkaline-basalt (Borisenko A.S. and others, 1984). Most of deposits occur along deep fault zones. The deposit type is divided into three subtypes according to mineralogy and host rocks: (1) Co-Ni-arsenide; (2) Co-sulfoarsenide; and (3) Cu-Co sulfoarsenide-sulfosalt . The Co-Ni-arsenide subtype mostly occurs in deep fault zones and at the intersections of deep-seated faults. The Co-sulfoarsenide and Cu-Co sulfoarsenide-sulfosults subtypes occur far from the first subtype, and mostly consist of replacement stringers and veins (Borisenko and others, 1984).

The second and third subtypes occur in western Mongolia. Examples of the Co-sulfoarsenide subtype are the Tsagaangol and Teht occurrences and others in the Tolbonuur district that also contains Ag-Sb vein occurrences. The Co-sulfoarsenide subtype is closely spatially associated with diabase dikes in the deep-seated Tolbonuur fault zone. The main ore minerals are cobaltine, glaukodot, scheelite, bismuth minerals, arsenopyrite, and lollingite. Other major minerals are pyrite, pyrrhotite, chalcopyrite, magnetite, tetrahedrite, and gold.. The host rocks are the Middle Devonian siltstone and sandstone of the Khatuugol unit. The host rocks are intensively silicified, sulphidised, and chloritized.

The Cu-Co sulfoarsenide-sulfosalts subtype is more widely distributed than the Co-sulfoarsenide subtype and occurs mainly in northwestern Mongolia. This subtype is poorly studied. Cu occurrences consist mostly of a replacement zones with high concentrations of Cu, Ag, and Bi, and occur near or in deep, regional fault zones. The main ore minerals are tetrahedrite, tennantite, chalcopyrite, pyrite, majors-bornite, sulfides, and sulfosalts of Pb and Cu, and rare sulfosalts and arsenides of Ni and Co. The gangue minerals are quartz, siderite, calcite, chlorite, and barite. The host rocks are vary in terms of composition and age from early Paleozoic to Jurassic. The host rocks are carbonatized, silicified, sericitized, argillitized, and chloritized. The deposit subtype sometimes is succeeded by Co-sulfoarsenide subtype deposition (Borisenko and others, 1984).

DEPOSITS RELATED TO SUBAERIAL FELSIC TO MAFIC EXTRUSIVE ROCKS

Clastic-Sediment Hosted Hg Deposit Type
By Gunchin Dejidmaa

The clastic-sediment hosted Hg deposit type consists of cinnabar in lenses, stockwork and other structures in flysch sequences composed of siltstone and shale. The ore bodies form stockworks, lenses, bed-like bodies, and simple and complex veins along fault zones. The ore bodies are generally controlled by sets of fractures (Kharzat, Tunhel, and Balj occurrences), or by thrust faults (Ulaanhus occurrence). The main ore mineral is cinnabar. The gangue minerals are quartz, sericite, dickite, and carbonate minerals. The host rocks are silicified, sericitized, argillized and carbonatized. Ore deposition is interpreted as occurring during lower temperature, hydrothermal fluids related to mantle-derived, alkaline basaltic magma.

Silica-Carbonate (Listvenite) Hg Deposit Type
By Gunchin Dejidmaa

The silica-carbonate (listvenite) Hg deposit type consists of cinnabar formed mainly at the contact of serpentinite and graywacke, or in serpentinite in major thrust zones and deep-seated faults that bound serpentinite and ultramafic rocks. The host rocks are argillized, carbonatized and mainly silicified. The main ore mineral is cinnabar, and other minerals are tetrahedrite, gersdorfite, brovaite, metacinnabarite, hematite, cromate, and chalcocite. The gangue minerals are dolomite, breunnerite, and ankerite, other gangue minerals are quartz, opal, chalcedony, calcite, dickite, and talc. The ore minerals occur as masses, in veinlets, and as disseminations in irregular lens-like bodies. The deposit type is closely related to clastic-sediment-hosted Hg deposit type. For example the Olgii occurrence, a silica-carbonate Hg deposit, and the Ulaanhus occurrence, a clastic-sediment-hosted Hg occurrence, occur adjacent to each other along the deep-seated Tolbonuur fault in the Mongol Altai.

Volcanic-Related Hg Deposit Type
By Gunchin Dejidmaa

The volcanic-related Hg deposit type consist of sparse, long, argillized and silicified zones, up to 50 m thick, that are hosted either in variable-age granitoids (Dalai Am gol, Khotol nuur, and Idermeg Bayan Khaan uul occurrences), or in carbonate rocks (Bituugol occurrence). Altered zones contain quartz, quartz-carbonate with barite, and carbonate veins, veinlets or stringers, and masses of sulfides, mostly galena, Hg-bearing sphalerite, cinnabar, chalcopyrite, and mostly pyrite. In the latter, the sulfides are cemented by quartz-chalcedony and chalcedony and contain altered, sulfidized, brecciated zones with fluorite veins. Occurrences of the volcanic-related Hg deposit type are located in eastern Mongolia in the northwestern marginal part of the eastern Mongolian Mesozoic continental rift system and the deep-seated Ulzgol fault zone.

Closely, spatially-related deposits consist of polymetallic breccia, fluorspar vein, and epithermal Au, quartz-barite vein and Hg deposits that also occur in the eastern Mongolian Mesozoic continental rift system. Overprinting deposit types include epithermal Au vein, fluorite vein; polymetallic breccia, and fluorite, barite deposits that are genetically related to the Hg deposits. Some polymetallic vein and fluorite deposits (the Galshar group), and breccia type deposits (Ulaan and Mukhar occurrences) are hosted in siliceous volcanic breccia. This relation suggests that Hg deposits are genetically related to basalt-rhyolite volcanic rocks that are widely developed along the eastern Mongolian continental rift system.

DEPOSITS RELATED TO MAFIC AND ULTRAMAFIC ROCKS:

Zoned Mafic-Ultramafic Ti-Fe (and Apatite-Ti-Fe)
By Gunchin Dejidmaa

The few known occurrences of zoned mafic-ultramafic Ti-Fe (and apatite Ti-Fe) deposit type occur in differentiated, concentrically-zoned gabbro, gabbro-anorthosite, and gabbro-pyroxenite plutons, and in rare diabase sills (Izokh and others, 1984, 1990). Three subtypes may exist for the deposit type, according to mineralogy and host rock composition: (1) Ilmenite-titanomagnetite (apatite-ilmenite-titanomagnetite) subtype related to gabbro-anorthosite; (2) Ti-Fe (titanomagnetite) subtype related to clinopyroxenite-gabbro; and (3) Ti-Fe subtype related to diabase sills. In all three subtypes, ore minerals formed in two main stages. (1) Early magmatic stage ore occurs as layers and lenses concordant to layering in host mafic-ultramafic intrusions. The ores occur in pyroxenite and peridotite layers and lens and consist of massive and disseminated ore minerals. And (2) post magmatic stage ore that forms mostly veins. Only a few occurrences of this deposit type are known in Mongolia.

The Ilmenite-titanomagnetite (apatite-ilmenite-titanomagnetite) subtype is hosted in Proterozoic gabbro-anorthosite that is part of an Archean and Early Proterozoic metamorphic basement. The host gabbro-anorthosite plutons (as at Most Uul, Khojuulyngol, and Olon Khudag) consist of anorthosite, leucogabbro, gabbro, pyroxenite, and peridotite. Ore-bearing pyroxenite and ilmenite-titanomagnetite and apatite-ilmenite-titanomagnetite layers, lenses and veins are occur in the plutons (Izokh and others, 1984, 1990). The main ore mineral is titanomagnetite; other major minerals are ilmenite, apatite, rare-pyrrhotite, pyrite, hematite, and spinel.

The Ti-Fe subtype is hosted in Upper Proterozoic (Riphean) layered clinopyroxene-gabbro plutons in northern Mongolia in the Khovsgol and Urgamal terranes, and in the Khan Khohii subterrane of the Nuuryn terrane. The host rocks are mainly high alkaline, high ferrugenous and high titaniferous clinopyroxene-gabbro intrusions that consist of gabbro, amphibole gabbro, clinopyroxenite, and ore-bearing clinopyroxenite (Izokh others, 1990). The plutons contain massive and thick disseminated titanomagnetite zones and layers in pyroxenite. Small amounts of ilmenite and apatite also occur. Examples of this subtype are the Khoshimgol occurrence of the Khovsgol terrane, and the Uet-Ondor occurrence of the Urgamal terrane.

The Fe-Ti subtype occurs in diabase sills in Late Paleozoic to Early Mesozoic volcanic-plutonic belt in northern Mongolia. In this area, abundant diabase sills intrude Permian volcanic and terrigenous-volcanic Khanyi Seri Formation. The diabase sills contain disseminated titanomagnetite.

Mafic-Ultramafic Related Cu-Ni Sulfide Deposit Type
By Ayurzana Gotovsuren

The mafic-ultramafic related Cu-Ni sulfide deposit type consists of massive, and disseminated sulfides that occur in small to medium size mafic and ultramafic intrusions (Sotnikov, Jamsran, and others, 1985; Sotnikov, Berzina, and others, 1985). In most areas of Mongolia, the depositional environment consists of gabbro and metavolcanic rocks that range in composition from dacite to basalt. The tectonic environment is mainly mafic and ultramafic igneous rocks occurring in ophiolites and along deep-seated fault zones. The main ore minerals are pyrrhotite, pentlandite, chalcopyrite, magnetite, and bornite, rare pyrite. Associated minerals are millerite, ilmenite, Ti or Cr-magnetite, and sphalerite, cobaltine, arsenopyrite, and gold. The main examples are the Oyuut Tolgoi deposit in the Khan Khohii area in western Mongolia, and the Serten-Nomgon occurrence in the Bayangol terrane in central Mongolia. These deposits also contain a relatively high grade of PGE (Izokh and others, 1990, 1991).

Magmatic Cr or Podiform Cr Deposit Type
By Gunchin Dejidmaa

The magmatic Cr or podiform Cr deposit type occurs mainly in zoned or layered ultramafic-mafic rocks associated with ophiolites. Podiform Cr occurrences are located in many ultramafic massifs of Mongolia. The more significant occurrences are the Naran, Taishir, Sulinkheer, and Ikh Khazuum massifs (Pinus and others, 1979, 1984a, b). The main examples are the Nogoon Tolgoi, the Bideriin Gol occurrences in the Khantaishar ophiolite, and the Sulinkheer group occurrences in same ultramafic-mafic massif. The host rocks are mainly dunite and harzburgite that are commonly serpentinized. Chromite ore occurs mainly in dunite, or in the transition zone from dunite to harzburgite (Pinus and others, 1984a, b). Shape of ore bodies is mostly lens-like. The length of lenses ranges from 10.0 to 100.0 m and thickness from 0.5 to 5.2 m. Massive ore is generally surrounded by disseminated chromite. The grade of Cr_20_3 ranges from 20.0% to 45.9% in the disseminated ore, and from 40% to 60% in massive ore. (Pinus and others, 1984a, b).

Serpentine-Hosted Asbestos Deposit Type
By Sodov Ariunbileg

This deposit type consists of chrysotile asbestos that replaces massive ultramafic and serpentinized ultramafic bodies (Bezubtsev and Volchec, 1963; Pinus and others, 1979a; Agafanov and others, 1983,1985; Pinus and others, 1984a, b). The most common host rock types are dunite, harzburgite, werhlite, and pyroxenite. The most important chrysotile-asbestos deposits occur in the Alag-Uul, Taishir, Ikh- Hajuu, Hotol Han-Hohiy ulmramafic massives in western Mongolia and in the Eastern Prehobsgol area. Asbestos content ranges from 0.2 to 1%. Associated minerals are magnetite, talc and tremolite. The depositional environment is usually ultramafic rocks in ophiolite sequences that are deformed and intruded by younger igneous rocks.

Rhodusite Asbestos Deposit Type
By Sodov Ariunbileg

This deposit type consists of actinolite-asbestos and tremolite-asbestos that form is association with quartz-albite-epidote veins along contacts in skarns, greenstone, and calcareous schist (Marinov and others, 1977). The deposition environment is deep-seated fault zones along which migrate low-temperature hydrothermal fluids. Associated minerals are wollastonite, calcite, muscovite, and apatite.

Talc Replacement Deposit Type
By Sodov Ariunbileg

This deposit type consists of two types of talc replacements: carbonate talc, and ferrous-serpentinite, talc. The carbonate talc is related to hydrothermally-altered shear zones in limestone and marble. Most of talc deposits and occurrences belong to the ferrous-serpentinite type that occurs in ultramafic rocks that have undergone intensive serpentinization (Pinus and others, 1979, 1984a, b). Associated minerals are carbonate, serpentine, chlorite, chromite, gemotite, and magnetite. Talc veins form as the result of hydrothermal-metasomatic replacement of alpine-type ultramafic rocks. An example is Tsagaan-gol deposit that formed along the deep-seated Ikh-Bogd fault zone. Talc deposits in Mongolia have not yet been mined.

Magnesite Deposit Type
By Sodov Ariunbileg

This deposit type is related to alteration of ultramafic rocks and consists of Mn-rich weathering crust of ultramafic massives (Pinus and others, 1979, 1984a, b). The most important magnesite deposits occurs are in the Manlay and Ih-Bogd areas of southern Gobi. A high quality magnesite deposit is at Bideriin-Gol located 15 km southeast from the center of the Gobi-Altai province.

DEPOSITS RELATED TO REGIONALLY METAMORPHOSED ROCKS

Au Quartz Vein Deposit Type
By Gunchin Dejidmaa

The Au quartz vein deposit type was first defined for Mongolia by Sillitoe and others (1996). The Au quartz vein deposit type consists of the following subtypes : (1) low-sulfide Au quartz and carbonate-quartz veins that are hosted in chert-volcanic-terrigenous units; (2) concordant Au quartz veins that are hosted in turbidite units; and (3) Au quartz or carbonate-quartz veins that are hosted in Fe formation. The tectonic environments for this deposit type are accretionary wedge and active continental margin arc. The associated intrusive rocks are diabase and diorite sill-like dikes. The deposit type consists of parallel, concordant, and saddle-reef veins of quartz and carbonate-quartz. The host turbidite and chert-volcanic-terrigenous rocks are generally metamorphosed into greenschist facies. The amount of sulfides is low, and the sulfide minerals are rare galena, sphalerite, chalcopyrite, and arsenopyrite. The host rocks are generally pyritized, strongly carbonatized, and sericitized, and weakly silicified. Free gold occurs in veins and as disseminatations in altered host rocks. Most occurrences of this deposit type consist of low-sulfide Au-carbonate-quartz veins that intrude volcanogenic-sedimentary units, and sedimentary Fe-formation. The main examples of this deposit type are occurrences in the Mergen Uul and Nukhniinuruu districts of the Baruun Khuurai accretionary wedge belt, and occurrences in Shuvuun Uul district of the Urgamal accretionary wedge belt, and vein deposits and occurrences in Zaamar district of the North Khentii accretionary wedge belt. These deposits and occurrences form the Ulziit metallogenic belt and are hosted in chert-volcanic-terrigenous formations and that originally formed as turbidites on a Paleozoic continental slope.

Disseminated Au-Sulfide Deposit Type
By Gunchin Dejidmaa

The disseminated Au-sulfide deposit type is herein defined and consists of disseminated sulfide (pyrite) minerals with subordinate quartz and carbonate-quartz veinlets that are hosted in deformed, metamorphosed, low-grade sedimentary rocks, mainly black and green shale with sandstone. Gold is associated with pyrite and with pyrite-quartz stringers hosted in sandstone. Occurrences of this deposit type are located in the Bayanleg belt that is interpreted as forming in a Paleozoic active continental margin arc. The associated intrusive rocks are sill-like bodies of gabbro, tonalite, and plagiogranite. An important lithological ore-control is coarse-grained sandstone horizons in shale.

Cu-Ag Quartz Vein (Vein Cu) Deposit Type
By Gunchin Dejidmaa

The Cu-Ag quartz vein (vein Cu) deposit type is herein defined and consists mostly of Cu-sulfides in quartz vein and stringers, in one case, in weakly regionally metamorphosed basalt, andesite-basalt, and in another case, in terrigenous sedimentary rocks including structural slices of ultramafic rock that occur along regional faults that cut conformably the terrigenous sedimentary rocks**.** The occurrences in lower grade, metamorphosed mafic volcanics consist mainly of a zone of sulfide-bearing quartz veins that occur over a large area. Cu-Ag quartz vein occurrences are widely distributed in the western part of Mongolia in the Altai, Kharhiraa, and Nuuryn terranes (Obolenskiy and others, 1989). Well-developed Cu sulfide quartz stringers may occur and Cu sulfide quartz veins may occur in the footwall parts of the volcanogenic Cu-Zn massive sulfide deposit type.

Ore minerals include chalcopyrite, bornite, chalcocite, covellite, pyrite, pyrrotite, malachite, azurite, and rare native copper. Alteration minerals are epidote, chlorite, actinolite, albite, carbonates and quartz. Special features are: (1) quartz veins and stringers that occur in significant size, linear zones; (2) ore textures consisting of impregnation, stringer-impregnation, stringer, banding, rare breccia; and (3) a high grade of Ag, Au, and Zn in some occurrences.

Many occurrences of this deposit type are located in mafic volcanics of Middle Riphean to Vendian age (Dulaankhar unit), and Vendian to Lower Cambrian age (Tsol Uul unit) in the western and the southern margins of the Nuuryn terrane. Cu-sulfide-bearing quartz veins also widely occur in terrigeneous rocks of the Kharhiraa terrane and are part of the massive, Ordovician-Silurian Biji unit. The hosting Toshint Uul unit, that contains the malachite and other related occurrences, are part of the Altai terrane. Occurrences of this deposit type are also located in the mafic volcaniclastic units of the Zamtyn and Uzuurtolgoi units, of Vendian to the Lower Cambrian age, that are exposed in tectonic blocks interlayered with early Paleozoic terrigenous rocks of the Uulyn Altai unit.

Banded Iron Formation Deposit Type
By Gunchin Dejidmaa

The banded iron formation deposit type consists of banded, massive, and disseminated magnetite and quartz that occur in bed-like, sheet-like and lens-like bodies in Archean and the Early Proterozoic rocks, and the deposit type was called silica-iron formation (Filippova, and Vydrin, 1977; and Bakhteev, 1984). The host rocks are granitic gneiss, migmatite, amphibolite, marble, mafic schist, and quartzite. The major minerals are magnetite and quartz and associated amphibole, pyroxene, garnet, epidote, phlogopite, zoisite, and diopside. Magnetite and quartz replace the metamorphic rocks and the replacements are generally conformable to with metamorphic layering, but locally are cross-cutting. The deposit type is confined to Archean and Lower Proterozoic strata,. Deposits and occurrences of this deposit type occur in the Khan Khohii, Tarvagatai, Baidrag and Middle-Govi metamorphosed cratonal terranes. Some authors (Sokolov and Zaitsev, 1990) interpret this deposit type as Fe-bearing silica-replacement.

Graphite Deposit Type
By Gunchodov Ariunbileg

This deposit type consists of two types (Marinov and. Hasin, 1977): contact-metasomatic or skarn zones formed between intrusive and calcareous sedimentary rocks; and in metamorphic rocks of Early Cambrian age. Graphite skarns contain large, blocky graphite, but the quality is not high. Graphite in metamorphic rocks contains coarse, scaly graphite. The content of graphite usually ranges from 2 to 6%. The graphite deposits and occurrences of Mongolia are in the area to the west of Khovsgol (Khargana gol deposit) lake, and in the Gobi region (Naidvar deposit).

DEPOSITS RELATED TO SURFICIAL PROCESSES

Placer Au Deposit Type
By Gunchin Dejidmaa

The placer Au deposit type consists of gold grains in alluvial, alluvial-proluvial, proluvial, deluvial, deluvial-proluvial, and rare glacial non-lithified deposits rich gravel and sand beds (Blagonravov, and Shabalovskii, 1977). The main ore mineral is native gold. Most placer Au deposits in Mongolia formed in the Neogene and Quaternary and are widely distributed in two regions. Neogene and Quaternary placer Au deposits occur mainly in northern and northeastern Mongolia. Neogene and lesser Quaternary placer Au deposits occur in the central Mongolia. Neogene Placer Au deposits also occur in southern and southwestern Mongolia, but are mostly buried. The placer Au deposit type is very important for Mongolia because of extensive mining of this type of deposit. Several papers have been published about Mongolian placer Au deposits (Levintov and others, 1984; Todor Nenov and others, 1994; Jamsrandorj and others, 1996).

Placer Sn Deposit Type
By Ochir Gerel

The placer Sn deposit type consists mainly of cassiterite, rare wolframite, and tantalite-columbite that occur in sand and gravel in alluvial or alluvial-deluvial deposits. The depositional environment is high energy alluvial where gradients flatten and river velocity lessen at the inside of meanders, and below rapids and falls. The main examples are at Janchivlan, Modot, and Kumir. More than 30 Sn placer deposits are known for Mongolia.

Placer Ti Deposit Type
By Gunchin Dejidmaa

The placer Ti deposit type is herein defined and consists mainly of ilmenite in gravel and sand in alluvial or alluvial-proluvial deposits. Main economical ore mineral of the deposit type is ilmenite. Ilmenite placer occurrences occur in southwestern Khovsgol province. The primary source of the occurrences are Cenozoic basaltic plateaus. The main examples are the Jargalantyn Gol, Khujirt, and Amttaihany Khondii occurrences.

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