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The Metallogenic Province of the Russian Far East

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러시아 극동지역의 광상생성구에 대하여

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1. INTRODUCTION

The Russian Far East is a group of ten territories(Khabarovsk Krai, Primorsky Krai, the Jewish Autonomous Oblast, Amur Oblast, Sakhalin Oblast, Magadan Oblast, Kamchatka Oblast, Chukota Autonomous Okrug, Koryak Autonomous Okrug, and Republic of Sakha (Yakutia)) and has an area of 5 million Km^2 (30% of the area of the Russian Federation).

The territories are the largest treasure house of mineral resources in Russia. The prospected ore reserve come under 86%-tin, 80%-fluorite, 34%-tungsten, 41%-antimony, 49%-gold, 50%-platinum, and 21%-silver of total Russian. Also, the potential of iron, titanium, apatite, boron, rare metals, lead and zinc, alunite and other endogenous minerals is rather great.

Mining is a fairly stable industry in the Russian Far East despite the turblence and crisis of the first half of the 1990s. In other words, contractions in this sector have been the smallest. Minerals like gold, diamond, lead and zinc, etc. are oriented towards stable foreign markets, and this industry has managed to attract foreign investment from large multi-national companies such as Homestake Mining, Cyprus/Amax, Glencore International and etc..

The purpose of this note is to introduce the common characteristics of an ore occurrence of the metallogenic provinces and regional ore-bearing systems forming them, metallogenic zones and ore districts in the Russian Far East.

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2. GENERAL FEATURES OF METALLOGENIC PROVINCE

During formation and development of the Earth's crust of the Far East territory which a number of basic geostructures were formed, the scale and occurrence of ore of each metallogenic province, a rather large ore-bearing area coinciding with a geosynclinal area, folded system or a large structure of platforms, are characterized by a definite type of mineralization and formed during several orogenic systems-metallogenic epochs. The metallogenic provinces of the Far East territory are classified as follows: Aldan-Stanovoy, Amursky, (Khokkaido-)Sakhalin, Verkhoyan-Chukotsky, Okhotsk-Chukotsky and Kuril-Kamchatsk-Chukotsky.

Arrangement and borders of the outlined provinces are illustrated by the scheme of Fig. 1. As the elements of the province, the borders of regional ore-bearing systems (OBS), ore-magmatic systems (OMS), metallogenic zones (MZ) and ore districts (OD) are shown at the scheme (Sukhov *et al.*, 2000).

2.1. Aldan-Stanovoy province

The Aldan-Stanovoy province has near-latitudinal elongated shape with parameters 1000×600 km. The borders of the province are formed by the

North-Tukuringsky plutonic fault in the south, Dzheltulaksky structural suture in the southwest, and Udykhyno-Nelkansky plutonic fault system in the east. Less clearly defined northern border generally corresponds to a boundary area of outcrops of the Early Precambrian crystalline basement from under the platform cover.

The characteristic feature of the province is a full display of Early-Precambrian megacycles (Early and Late Archean, Early Proterozoic), ensuring the formation of the continental crust. The zoning of the province is shown in Fig. 1. For Early Archean megacycle and an appropriate metallogenic epoch, the major metallogenic character of linear structure of Olekmo-Stanovoy area was established by the granulite-amphibolite complexes of magmatic nature. Almost all Early Archean ore bodies are concentrated in this area, which have been formed in the process of magmatic-metasomatic fractionation and differentiation of primary material of the Earth (deposits of apatite-ilmenite-titanomagnetite, Cu-Ni with platinoids, and rare earths and muscovite pegmatites). Another group of Early Archean ore bodies-ferruginous quartzites, high alumina and graphite-bearing gneisses and shales-develops along the areal distribution, which ties in with their formation as a result of interaction of primary material.

Late Archean megacycle is subsequently significant by origins and developments of rift-geosynclinal and orogenic regimes. Structural-formational complexes of a geosynclinal regime have the same borders of the foregoing Olekmo-Stanovoy area, and those of orogenic regime are extended to east and overlapped on Early Archean structures of Okhotsko-Timptonsky area. Rather high productivity of the metallogenic epoch of Late Archean are associated with rift-geosynclinal complex and include the large sedimentary-volcanogenic iron deposits, graphite and high-aluminous raw material deposits of metamorphic origin and metamorphic-hydrothermal mineralizations of talc, asbestos and gold. Another group of Late Archean ore bodies is connected with the granitic plutonism and formation of granite-gneiss domes(orogenic stage) and is accompanied with the formation of skarn-type deposits of phlogopite, Fe and Mo as well as ore occurrences of muscovite, rare metal and rare earth elements of the alkaline-metasomatic and pegmatitic origin.

Early Proterozoic metallogenic epoch is associated with the first exposed regime of orogeny which is synchronous developed to the south of the geosynclinal regime in the Amur geosystem. The orogeny originated along the southern part of Archean Aldan-Stanovoy area by 100-300 km in width and 1500 km in length. This epoch is characterized by the copper (Cu-bearing sandstone and shale formations), copper-nickel, rare-earths and rare-metal mineralization, and the development of metamorphic-hydrothermal mineralization (Si, Au and Mo) in connection with differentiated tectonic movements at the ending of megacycle (Early Riphean) (Fig. 1).

Late Proterozoic-Early Paleozoic megacycle related to the endogenetic mineralization is just Late Riphean stage. Its occurrence of ore is associated with basaltic sill-dike (Cu-sulfide mineralization) and alkaline-ultramafic plutonism (chromite with platinoids, apatite-rare earths, rare-earths and rare-metal of carbonatite-type mineralization).

Essentially all area of Aldan-Stanovoy province is affected by mineralization, which is related with intensive Mesozoic orogeny. At the regional level the metallogenic zoning of Mesozoic ore-content corresponds to the zoning of areal magmatism. The Aldan and Stanovoy OMS include the metallogenic zones and ore districts. In the southwest Stanovoy OMS is conjugated to the East-Transbaikal province. The latter is represented by Upper-Priamur OMS (Au and Mo, Sergachinsky MZ).

2.2. Amur province

In geological-structural relationships, the Amur province comprises Amur-Okhotsk, Sikhote-Alinsky folded systems, and Bureinsky and Khankaisky median masses (Fig. 1). In the west and south, the province is extended into Transbaikal and China, and corresponds with the borders of the continent in the north-east and east. The northern boundary is clearly defined by Mongolo - Okhotsk - North-Tukuringrsky deep fault system. The province includes Bureinsky, Khankaisky, Amur-Okhotsky and Sikhote-Alinsky ore-bearing systems. In Late Mesozoic, the vast ore-magmatic systems overlapped on folded structures were formed as a result of intensive orogeny, and the OMS consist of Middle- and North-Bureinsky,

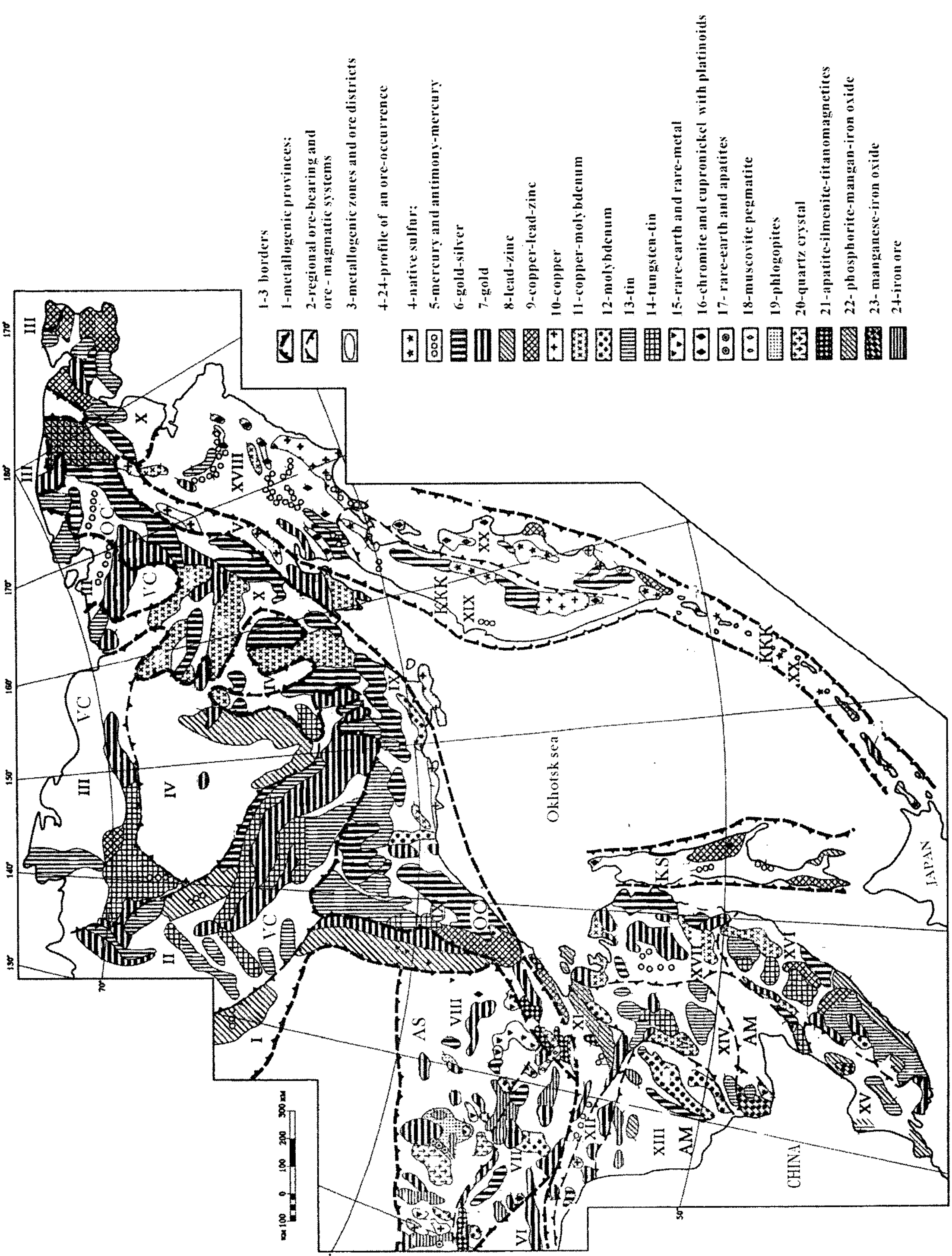

Fig. 1. The map of metallogenic provinces of the Russian Far East (Sukhov *et al.*, 2000).

Khingano-Okhotsky, Lower-Amur, Sikhote-Alinsky as well as Cenozoic basaltic belts. Each system is characterized by their own age of formation, features of formational composition of igneous complexes, and one or another features of deep-seated structure and endogenetic occurrence of ore. The metallogenic zoning of Bureinsky and Khankaisky ore-bearing systems reflects a series of megacycles of continental crust formation: Early Archean megacycle with formation of granulite and amphibolite complexes of chemogenic-sedimentary origin, Early Proterozoic geosynclinal one with formation of iron ore, sulfide and graphitic deposits, and Late Proterozoic-Early Paleozoic one with formation of the deposits of iron ore, manganese, magnesites, polymetals, fluorite, tin, molybdenum, and rare metals. The geosynclinal and displacement processes in Late Proterozoic-Early Paleozoic, Middle-Late Paleozoic and Early Mesozoic megacycles played an important role in formation of Amur-Okhotsk OBS. The metallogenic zones and ore districts are distinguished into the development of sedimentary-volcanogenic pyrite and chalcopyrite, iron-ore, silicious-manganese and phosphorite, and metamorphic- hydrothermal gold-sulfide-quartz and mercury ore formations. The Sikhote-Alinsky OBS was formed during Middle-Late Paleozoic and Early Mesozoic geosynclinal and orogenic regimes. The occurrence of ore in geosynclinal stage is characterized by rare pyrite and more widely distributed silicious-manganese deposits and in orogenic stage by deposits of scheelite-skarn, wolframite-cassiterite-quartz and ilmenite-titanomagnetite, which is clearly zonated according to geological conditions.

The OMS was associated with the Late Mesozoic-Cenozoic orogeny and are characterized by the Au, Au-Ag, polymetals, porphyritic Cu-Mo, Sb-Hg, rare-metal, and alunite-zeolite mineralization.

2.3. Sakhalin (Khokkaido-Sakhalin) province

The main geostructure of the province are rift-geosynclinal and island-arc complexes of Late Paleozoic-Cenozoic megacycle. The province is composed of Eastern, Middle and Western metallogenic zones. The Cr, Ni, Co, Cu, platinoid, talc, and asbestos occurred in the Eastern, associated with Late Paleozoic-Early Mesozoic basic-ultrabasic complexes. The quartz-manganese and metamorphic-hydrothermal gold occur in the same epoch. Also, the Eastern is characterized by occurrences of polymetallic, Cu-sulfide and mercury in Late Cretaceous-Neogene. The occurrences of Cu-sulfide and polymetallic mineralization are shown in Western, and mercury mineralization in the Median.

2.4. Verkoyan-Chukotsky province

Verkoyan-Chukotsky province correspond to a folded system, including Kolymsky, Omolonsky, Okhotsky, and East-Chukotsky massifs. The province is composed of Kolym-Omolonsky, Sette-Dabansky, Yan-Kolymsky, Chukotsky, and Penzhino-Taigonossky ore-bearing and ore-magmatic systems (Fig. 1). The formation of metallogenic pattern of the province is mainly associated to the development of craton (Middle Proterozoic-Paleozoic) and geosynclinal trough (Upper Paleozoic-Lower Mesozoic), island-arc complexes (Middle Jurassic-Lower Cretaceous) and displacement, and magma activity (Lower Cretaceous-Upper Cretaceous).

The Kolym-Omolonsky and Sette-Dabansky OBS are characterized by the copper-polymetallic stratiform and epithermal gold-silver mineralization, and by the carbonatite deposit (rare-earths) and stratiform deposit (Pb-Zn, Cu, Au, Sb and Hg) of telethermal origin, respectively. It is supposed that the nature of telethermal deposits caused by the geochemical differentiation of Vendian-Early Paleozoic and Late Paleozoic sediments is polygenetic. Thus the occurrence of ore is connected with the chronic (Vendian-Late Paleozoic) process of diagenesis and epigenesis of deposit enriched with ore components. It should be noted that the features of lateral metallogenic zoning correspond to those of deep-seated structure intrinsic to Sette-Dabansky OBS. The Yudom-Maisky and Sedyan-Kuelsky zones with Cu and Pb-Zn mineralization are confined to a linear band of the crust of moderate thickness, and the Allah-Yunsky zone with the stratiform gold mineralization parallels to the polymetallic zone and encloses the crust margin of increased thickness.

The geological structure of Yan-Kolymsky OBS is represented by Triassic-Jurassic miogeosynclinal and island-arc-orogenic complexes, complicated with the development of granitic plutonism during Late Mesozoic orogeny. The metallogeny is characterized by the polymetallic mineralization with Au, Sn, Sn-W, Sb, and minor amount of Mo, Cu, Pb-Zn, Au-Ag, Hg and etc.. The Chukotsky OBS is overlapped by Cenozoic sedimentary and volcanic rocks of Okhotsk-Chukotsky magmatic belt at the broad area. The metallogeny is proximal to that of Yan-Kolymsky system, and the Cu, Pb-Zn, Au and Sn mineralizations are shown. The Penzhin-Taigonossky ore-magmatic system is located in the boundary position between Okhotsk-Chukotsky and Kurilo-Kamchatsko-Koryaksky geosystem. The metallogeny is mainly represented by the porphyry Cu, Mo and Cu-Mo deposits, associated with subvolcanic phases of island-arc and final of tonalite-granodiorite intrusions.

2.5. Okhotsk-Chukotsky province

The Okhotsk-Chukotsky province is particularized within the Okhotsk-Chukotsky magmatic belt, and is clearly represented by the metallogenic specialization and the features of deep-seated structure. The province, including its metallogenic zoning (Fig. 1), is characterized by epithermal gold-silver and widely developed Cu-Mo- pophyritic deposits. And the Sn, W, Au and Cu mineralizations are observed in the province.

Ore-controlling role of deep faults is clearly expressed: the lateral faults control the distribution of metallogenic zones and ore districts, linked to Au-Ag mineralization; the transverse faults take charge of the Sn and porphyritic Cu, Mo and Sn mineralizations.

2.6. Kuril-Kamchatsk-Koryaksky province

The province encompasses a geosystem formed mainly during Paleozoic-Mesozoic geosynclinal and subsequent island arc-orogenic geotectonic cycles. The province is composed of Koryaksky, West-Kamchatsky and Kuril-Kamchatsky OBS (Fig. 1). The metallogeny of Koryaksky OMS is represented by the repeated occurrence of the basic-ultrabasic plutonism linked to chromite and Cu-Ni mineralization with platinoids (Upper Paleozoic, Upper and Lower Cretaceous), as well as by the formation of Au, Au-Ag, Sn, Hg, and Cu deposits related to Cenozoic plutonism. The West-Kamchatsky OMS is characterized by the occurrence of gold-silver and native-sulfur linked to Cenozoic island-arc volcanism and the development of porphyritic Cu and polymetallic mineralization in association with Mesozoic rift-geosynclinal complexes.

The Kamchatsky part of Kuril-Kamchatsky OMS is characterized by the development of chromite, Cu-Ni, and platinoid as well as asbestos and talc mineralizations linked to Late Cretaceous basic-ultrabasic intrusions. The Au-Ag and native sulfur mineralization are associated with Cenozoic volcanic rocks, and also the porphyritic Cu mineralization are observed. The Kuril part of the system is defined as Au, Au-Ag and polymetallic mineralization.

3. CONCLUSION

The above-mentioned metallogenic zoning of the Far East is a general scheme, and requires the addition by the specific content. The zoning was categorized by the authorized distribution of an ore assemblage within the specific areas (Smirnov, 1976). This method makes it possible to access the most common principles of spatial distribution of several types and kinds of endogenetic mineralization and simplify the characteristic of the metallogenic specificity of the distinguished provinces.

This note will hereafter be a background information for the selection of target mineral and area during the survey and exploration on mineral resources of the Russian Far East.

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