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Mesozoic Metallogeny of the Russian Far East

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Russian Far East consists of heterogeneous tectonic blocks (Parfeno and Kuzmin, 2001; Khanchuk, 2006). Among them are the following structures (Goryachev, Pirajno, 2014): (1) Precambrian Siberian Craton and its deformed in Mesozoic time Verkhoyansk passive continent margin; (2) Omolon and Okhotsk Precambrian microcontinents; (3) Argun, Solonker and Bureya-Khanka superterranes of Paleozoic Central Asia Orogenic Belt; (4) the Mongolo-Okhotsk, Okhotsk-Koryak, Yana-Kolyma, Arctic, Sikhote-Alin – North Sakhalin, Koryak Late Mesozoic orogens and (5) the Sakhalin - Kamchatka and the Eastern Coast of Kamchatka Cenozoic orogens.

Growth of metallogenic areas from ancient continental cores (the Siberian continent and its fragments) with the change of the rare-earth elements – iron specific for Precambrian to rare-metal – noble-metal specifics for Mesozoic - Cenozoic time traced throughout the geological history of the Russian Far East. Late Mesozoic and Cenozoic epochs had a major importance in the region. Changing of structural and metallogenic trend of ore formation from Circum Siberian to the Circum Pacific occurred at this time.

World-class ore deposits form the basis of a metallogenic potential of orogenic structures. Among them are the Late Mesozoic deposits of Au (Natalka orogenic), Sn (Deputatskoye, Pravo-Urmiiskoye - orogenic), Ag (Dukat, Prognoz – subdection related), Sb (Sarylakh, Sentachan - orogenic) and W (Vostok-2, Lermontov – skarn orogenic). These deposits with other large, medium and small ore deposits formed during the Late Mesozoic (Middle Jurassic – Cretaceous) metallogenic epoch.

Major orogenic belts were formed in the territory of the Late Jurassic - Early Cretaceous (Mongolo-Okhotsk and Yana-Kolyma), Early Cretaceous (Okhotsk-Koryak and Arctic), Midle-Late Cretaceous (Sikhote-Alin – North Sakhalin) and Late Cretaceous (Koryak) time. Giant continental margin post-accretionary Late Cretaceous Okhotsk-Chukotka volcanic belt originated at the end of this era. These orogenic and volcanogenic belts identified of the modern tectonic plan and the main metallogenic potential of this territory.

Gold deposits of orogenic and intrusion-related types are widespread in all orogenic belts. About 6,000 t Au were recovered from these deposits and many placers (Goryachev and Pirajno, 2014), which determined the overall shape of these metallogenic areas. Gold ore deposits are associated with different types of Sn, W, Sb and base metall deposits in Yana-Kolyma and Sikhote-Alin – North Sakhalih orogenic belts, and W, Cu, Mo, epithermal Au and Sb-Hg deposits in Arctic, Mongolo-Okhotsk and Okhotsk-Koryak orogenic belts.

The eastern flank of the Mongol-Okhotsk orogenic belt includes Early Cretaceous orogenic and granitoid related gold deposits (Tokur, Kirovskoye, Berezitovoye with Ar-Ar age of 134–125 Ma) closely spatially and chronologically associated with molybdenum and antimony-mercury mineralization. Synchronized rift-related epithermal gold and gold-telluride mineralization extended to the northern and southern flanks of Mohgolo-Okhotsk orogenic belt within the Siberian craton (Kuranah - 134–130 Ma) and Argun superterrane (Pokrovsky mine - 125 Ma) (Goryachev and Pirajno, 2014). Longitudinal and transverse gold deposits distribution zonation is known for all area of this orogenic belt. The age of gold deposits changed in eastward direction along belt from 190–175 Ma to 125–122 Ma (Goryachev, Pirajno, 2014).

Yana-Kolyma orogenic belt formed in two stages: (1) the Late Jurassic – Early Cretaceous (U-Pb, Ar-Ar 154–134 Ma and (2) Early Cretaceous (Ar-Ar 125–115 Ma) (Goryachev, Pirajno, 2014; Goldfarb et al., 2014). Orogenic (Degdekan, Natalka, Transportnoye, Nagornoye – Ar-Ar 140–135 Ma) and granitoid-related (Dubach-Malysh, Chepak, Chistoye, Myakit – K-Ar, Ar-Ar 149–141 Ma) gold deposits are characteristic of early stages. They are associated with Sn-W skarn deposits (Canyon

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Ar-Ar 146 Ma) and greisen – quartz-vein type (Burgaliyskoe) and small deposits of base metal and molybdenum. Late stage orogenic Au deposits (Nadezhda, Vetrenskoye - K-Ar, Ar-Ar 126–124 Ma) are closely associated with Au-Sb deposits (Sarylakh, Sentachan, Kyuchyus - K-Ar 124–115 Ma). Preorogenic deposits are represented by small island-arc related kuroko type deposits, mercury and gold-silver epithermal and Carlin-type deposits of the Uyandina-Yasachny volcanogenic belt.

Koryak-Okhotsk orogenic belt is a proposed continuation of Mongolo-Okhotsk orogenic belt to northeast. It is characterized by age change of orogenic event eastward from 140–135 to 115–103 Ma. Orogenic (Nezhdaninskoe – Ar-Ar 120–119 Ma) and granitoid related (Levo-Dybinskoe – Ar-Ar 124 Ma) Au deposits are associated with Cu-Mo, Sn-Nb-Li and Co-As (Priiskatel, Khakandya, Verkhne-Seymchanskoye – K-Ar 134–103 Ma). Pre-orogenic epithermal Au-Ag (Julietta – Ar-Ar 136 Ma) and base metal ores are associated with the formation of Uda-Murgal continental-margin magmatic belt (Khanchuk, 2006).

Arctic (or Oloy-Chukotka) orogenic belt has sub-latitudinal orientation different from the other Mesozoic belts and located along the Arctic Ocean coast from the lower reaches of Yana River in the west to Alaska in the east. Orogenic granitoids within this belt dated of 125–103 Ma (Ar-Ar, U-Pb) (Parfenov and Kuzmin, 2001; Khanchuk 2006; Goldfarb et al., 2014; Goryachev and Pirajno, 2014). Orogenic and granitoid-related Au deposits dated by Ar-Ar 125 Ma and K-Ar 121–115 Ma and associated with small deposits of Mo and Sn. Pre-accretionary Cu-porphyry deposit (Innakh, Peschanka – U-Pb 141 Ma) and epithermal Au-Ag mineralization was formed in island arc setting within Oloy and South Anyui tectonic zones.

It is possible that a number of ore deposits of the second phase of Yana-Kolyma orogenic belt (Vetrenskoye, Hadezhda, Shkolnoye) localized in the southern part of the belt are associated with the formation of the Okhotsk-Koryak orogenic belt. Therefore, it may be preferable to propose of common late Mesozoic orogenic collage of this part of the region was formed in three stages (Goldfarb et al., 2014).

Koryak orogenic belt is characterized by the association of minor orogenic Au deposits with pre-accretionary chromite-PGE deposits in ultramafic rocks and volcanogenic sulfide ores into Talovsky and Maynitsky terranes, as well as the presence of small pre-accretionary Mn ore deposits in chert strata of Yanranay terrane (Khanchuk, 2006).

Sikhote-Alin – North Sakhalin orogenic belt was formed in the Middle Cretaceous in the active transform continent margin geodynamic setting (Khanchuk, 2006). Orogenic and granitoid-related Au deposits are associated with W (Vostok-2, Lermontov with K-Ar age of 120–110 Ma), Sn (Pravo-Urmiiskoye), Mo and base metal deposits. The age of orogenic gold deposits changed along the belt in a southerly direction from 120–105 Ma (K-Ar) in the Lower Amur area to 88–79 Ma (Ar-Ar) in South Primorye area. Pre-accretionary Late Jurassic Ti-Fe-V ore deposits (Ariadnoye) are known within Samarka terrane of this orogenic belt (Nokleberg et al., 2005; Khanchuk, 2006).

Metallogeny of Okhotsk-Chukotka volcanogenic belt characterized mainly by the association of epithermal Au-Ag mineralization (Karamken, Dukat) with Mo-Cu-porphyry, silver – base metal, W and Sn-Ag ore deposits. Chromite-PGE ore deposits (Conder) known in the southern flank of Okhotsk-Chukotka volcanogenic belt, but their geodynamic setting is unclear.

For this epoch was typical of the combination of three localization trends for tectonic structures and metallogenic belts: (1) the Arctic, (2) the Mongol-Okhotsk and (3) Pacific. The first two were dominated in the Jurassic – Early Cretaceous time. The Pacific trend dominated in the Late Cretaceous time.

Ore deposits of Late Mesozoic – Early Cenozoic epoch (Maastrichtian - Paleogene) have not so large distribution as Late Mesozoic. Sakhalin-Kamchatka orogenic belt and Eastern Coast of Kamchatka orogenic belt and related orogenic Au mineralization (Sakhalin and Koryak) were formed during this period. Hg-W and Cu-Ni (Kamchatka area), rarely Sn (North Kamchatka – South Koryak area) mineralization is also associated with them. Continental-margin Maastrichtian- Paleocene Anyui-Beringovsky volcanic belts (Hg and epithermal Au-Ag mineralization and East Sikhote-Alin epithermal Au-Ag, porphyry Cu-Mo mineralization and boron) are associated with these orogenic structures. Pacific trend in localization of orogenic belts and post-orogenic already prevails in this era.

Thus, different combinations of ore deposits are characterized for the Mesozoic metallogeny of Russian Far East. In some cases, they mainly reflect of crustal character of the metallogeny (Yana-Kolyma and Okhotsk-Koryak orogenic belts), in other cases (Koryak orogenic belt) mantle, in the third, mixed (Mongolo-Okhotsk and Sikhote-Alin – North Sakhalin orogenic belts). It is reflected in the isotopic characteristics of the ore (S, Pb) and vein (O, C, Sr) minerals and suggests that mineralization in the Late Mesozoic orogenic structures was formed with a noticeable influence of mantle-crust

interaction (Goryachev, 2014).

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