

# Areas of mineral resource deposit concentration within the boundaries of Sayans-Baikal mountainous region

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**Abstract.** The aim of this paper is to identify and briefly describe ore-bearing areas where industrially significant mineral deposits are concentrated. Methods. Generalization and analysis of materials covering specifics of location and localization of ore and rock deposits in the geological structure and rock complexes of Sayans-Baikal mountainous region. Results East-Sayans, Akitkan-North Baikal, Lower Vitim and Vitim-Charsk ore-bearing areas have been identified as being territorial groupings of mineral deposits. Geological characteristics of the most important mineral deposits are given for each of them, accenting the largest and unique deposits, such as Kholodninskoye polymetallic, Udokan copper, Sukhoy Log gold ore and others. Development conditions of these objects are highlighted.

## 1. Introduction

The territory under consideration is the Sayans-Baikal regional mineralogenic belt, wherein significant deposits of various mineral resources are localized. Among the most common and significant ones are polymetallic deposits, deposits of copper, gold, iron, rare and rare earth elements and others.

## 2. Results and Discussion

Various researchers previously performed zoning of the mineral-rich territory under consideration to identify localization of mineral deposits, which is reflected in a number of works [1-8]. Metallogenic belts and even provinces were identified, which is unlikely to be justified, as the mineralogenic province and metallogenic belt are units of a larger size as per current taxonomy (e.g., Sayans-Baikal metallogenic belt, Aldan metallogenic province). Thus, identification of ore regions, ore zones and nodes is more reasonable for this territory [4,6,8]. However, from the point of view of mineral wealth development, it is reasonable to turn our attention to identification of areas of mineral deposit concentration on the basis of geography and geology.

Within this framework, we identified ore-bearing areas that include deposits of certain groups of mineral resources and may overlap, partially or completely, with the previously identified territories of ore belts [4]. They are East-Sayan, Akitkan-North Baikal, Lower Vitim and Vitim-Charsk ore-bearing areas and they represent territorial groupings of mineral deposits; their brief characteristic is given below. The description is based upon the materials from territorial geological entities: summaries for mineral and resource base of the Irkutsk oblast, the Republic of Buryatia and Zabaykalsky krai [9-11].

East-Sayan ore-bearing area takes the northeastern part of East Sayan and adjoining territory of Cis-Sayans. A defining feature for the geological structure and regularity in location of mineral deposits is Cis-Sayans fault, accompanied with a wide zone of folds and disjunctive breaks on both



sides of the main tectonic suture and dividing the structures of Siberian platform and its folded margins.

There are significant deposits of tantalum, lithium, cesium, rubidium and niobium, among them there are 11 large deposits (Beloziminskoye, Sredneziminskoye, Goltsovoye, as well as Vishnyakovskoye in Taishet district, etc) linked to a complex of small-scale intrusions of alkali rocks localized in the folded structures of the East Sayan. Despite these deposits are capable of covering the national demand in rare metals, their development is impeded by a distance of 100 km or more from transport facilities and ore quality.

In the marginal part of the platform, there are deposits of nonmetallics. Coal is concentrated in rocks of Cheremkhovskaya depression in 22 deposits: Cheremkhovskoye, Azeisk, Mugun and others. Rock salts deposits of this old saliferous basin are of large importance, they include the most significant deposits: Usolsk, Tyretsky, and others, together accounting for 50% of rock salt reserves of the nation. Convenient geographic and economic conditions (location along the Transsib) determine industrial significance of these deposits. Of interest are also Savinskoye deposit of magnesites and Onotsk talcum deposit.

Akitkan-North-Baikal ore-bearing area (northwestern and northern shores of Lake Baikal) cover the influence zone of the Primorye fault, dividing the structures of the platforms and those of the folded area. The system of this fault includes a number of fan-shaped disjunctive dislocations around the main suture spreading to the north of Baikal. This is a range of volcanic and plutonic complexes of Akitkan volcanic belt in the south end of the area, terrigenous-carbonate, volcanogenic complexes of ancient metamorphic rocks, volcanogenic greenstone, granitoid, gabbro-peridotite formation of Proterozoic, Riphean and Upper Paleozoic age within the boundaries of Olokitsky and other troughs and domes of the northern part of the area. Tectonic features are characterized with fold-and-thrust deformations, which also determine the structural condition of ore node and deposit localization.

Of the highest significance in the considered ore-bearing area are the polymetallic deposits (sphalerite-galena and sphalerite-galena-fluorspar formations) localized in the northern part of the area under consideration. Non-industrial gold ore and radioactive mineralization has been established. The leading role pertains to a group of large deposits of polygenic polymetallic copper-lead-zinc mineralization. First of all, it is Kholodinskoye deposit with pyrite-lead-zinc and barite-polymetallic mineralization. Ore bodies appear as concordant bedded and lenticular deposits. In Kholodninskoye deposit, there are echelon fold zones with industrial mineralization in sedimentary-metamorphic black shale deposits appearing as a row of contiguous bedded and lenticular deposits with alternating layers of low-mineralization rock, pyritic-polymetallic and sulfur pyrite ores. The ores contain industrial concentrations of lead, zinc, sulfur and other valuable components, at that, this deposit is one of the largest zinc deposit in the world.

Deposits of sulfide platinum-copper-nickel formation in laminated basite-hyperbasite rock masses appearing as disseminated and massive ores in dunnite-troctolite-gabbro rocks are of importance. There are established gold-sulfide and gold-quartz mineralizations, as well as occurrences of nickel and iron.

In the southern part of the area (Akitkan volcanic belt) non-industrial uranium mineralization of pitchblende-fluorite and phosphorus-uranium formation are quite common. Ore nodes in ancient volcanic edifices are localized at crossing of longitudinal and traversal faults. Ore bodies are controlled by shear fracture, their form may be that of short veins (single or compound), lenses, nests, and in sandstone or sand tuff, they may appear as echeloned lenses.

While considering the development prospects for the deposits in the area, it is necessary to note that many deposits, in particular Kholodninskoye, located 40 km from Baikal-Amur Mainline, fall into the water protective zone of Lake Baikal.

Lower-Vitim ore-bearing area includes Bodaibo and Mamsky composite synclines, made of mainly carbonate-terrigenous series and containing black slate rocks. The rocks are metamorphosed and transected with granitoids and gabbroids. Tectonic features of the complex synclines are defined by

development of high-order overfolds accidented by high-angle faults and overthrusts that form subparallel systems.

Gold of black slate formation is a prevailing mineral wealth in the Bodaibo complex syncline: Sukhoy Log, Vysochayshy, Dogaldynskoye, etc.. These polychronic and polygenic deposits formed during long periods of time are concentrated in extended zones of faulting and foliation in fold hinges. The second industrial type is represented by placer deposits, which are operated for over three centuries. Primary ore deposits, according to A.A. Buryak (1982), are localized in shear zones that developed in the narrow axial parts of anticlines, where the ore zones of hydrothermal-metasomatic mineralization are formed. Mineralization is of vein-disseminated or quartz-vein type and localized in knees of folds or intersection nodes between the ore zones and faults.

Sukhoy Log is the largest deposit, it contains an ore zone extending for 2.5 km with a width of 200 m. There, quartz-sulfide veinlets and disseminated ore mineralization are concentrated in hydrothermally-changed carboniferous slates, appearing as layered linear stockwork. Besides, about twenty quartz veins of complex morphology have been established. Fluid-metamorphogenic saddle and intersecting veins have been discovered at Dogaldynskoye, Artyomovskoye, Pervenets and Kavkaz deposits.

Vein-disseminated mineralization of gold is considered as metamorphogenic-hydrothermal, while vein quartz gold ore mineralization is considered as the geothermal one at the last stage of the ore process. Gold ore alluvial and primary deposits of Bodaibo ore region are operating and their prospects (especially those of the primary deposits) are far from depletion.

Within the boundaries of Mamsky complex syncline there is a zone of muscovite deposits (Kolotovskoye, Vitimskoye, Lugovoye, etc.). There, among biotite and garnet-biotite gneisses, there are vein-shaped, lens-shaped and nest-shaped ore bodies of metamorphic genesis, concordant with or crossing the accommodating series. Operation ceased due to lack of profitability.

Vitim-Charsk ore-bearing area is located in the north-east of the territory and covers the Charsk massif of Aldan craton and Lower Proterozoic Kodar-Udokan downfold. In the foundation, there is an Archean series of crystalline schists, gneisses, quartzites and complexes represented by metamorphosed volcanogenic and sedimentary rocks, intrusions of ultrabasic rocks, plagiogranite-gneisses, plagiogranites, granites. The foundation is covered with a series of sedimentary and volcanogenic, carbonate and terrigenous rocks. Proterozoic and paleozoic magmatism is of granitoid and gabbroid composition.

Of large importance are big stratiform deposits of cupriferous sandstone, which are usually localized in downfolds and include copper-bearing beds of quartzitic sandstones with interbeds and lenses of calcareous sandstones, siltstones, argillites. The largest of them is an explored Udokan deposit, where ore-bearing beds extend for 21 km. Ore bodies with disseminated, veinlet, nest mineralization have forms of layers, interbeds, lenses and nests. Of significant interest are banded iron formations that form an extended iron ore zone, within which the Sulumatskoye deposit has been explored (2.5 km to the north of the Baikal-Amur Mainline).

It should be noted, that there are complex deposits containing titanium-iron-vanadium, copper-noble metals mineralization, platinum group metals in massifs of gabbro-anorthosite-norite formation (Chineyskoye deposit). Tantalum-niobium-rare-earth mineralization is established for rare-metal metasomatites (Katuginskoye deposit), deposited in the zone of deep fault at the boundary of Archean and Proterozoic complexes. Besides, Uranium mineralization may be of industrial importance: Torgoyskoye deposit within the boundaries of alkali rock mass and in the disconformity zone (Chepok).

In the south-western part of the area, there is the Muysky gold ore region with its North Muysky and South Muysky ore nodes. There, on ancient gneisses and shales there are deposits of non-metamorphosed Vendian-Cambrian terrigenous-carbonate masses.

Among the minerals, one shall, first of all, note the deposits of gold quartz formation (Irokindinskoye, Upper-Sakukanskoye, Kedrovskoye, Yubileynoye and others), which are localized in the deep fault zone. A prevailing form is vein-shaped bodies in garnet-pyroxene and amphibolic

gneisses. Irokindinskoye deposit includes low-angle bedding of various directions of quartz-carbonate composition with gold inclusions. Other deposits feature gold ore shear zones and gold-bearing quartz veins that are controlled by low-angle faulting. Besides, within the boundaries of the area there are a deposit of mercury in silicon-carbonate rocks (Kelyanskoye) and a tin deposit (Mokhovoye). The mercury mineralization is localized in the zones of veinlet-disseminated ores in Lower Cambrian dolomites. The Mokhovoye deposit consists of cassiterite-hematite-magnetite-chalcopyrite lenses with a width of 3-15 m, dipping down to the depth of 110 m.

Molodezhnoye deposit of chrysotil-asbestos, containing an ellipsis-shaped body within the boundaries of harzburgite-dunnite mass is also of notion. There, the central harzburgite core is surrounded with asbestos-bearing serpentinites.

Thus, the area under consideration is among the richest in mineral resources in the region. However, we should note a complex nature of mineral resource deposit development due to harsh natural conditions (modern relief-forming processes, dislocation of large volumes of weak materials, seismic activity and prolonged winter).

### 3. Conclusion

The considered ore-bearing areas are characterized with a wide variety of mineral deposits, their high concentration, and presence of a number of large-scale objects, which may serve as a justification for their future development. Of largest importance are polymetallic deposits of Akitkan-North-Baikal area, primary gold deposits in the Lower-Vitim ore-bearing area, stratiform deposits of copper and iron, deposits of gold ore, tantalum-niobium and rare earth mineralization in the Vitim-Charsk area. This area is the richest in deposits of valuable mineral resources.

East Sayan ore-bearing area is its most developed part, especially in its Cis-Sayan part. Development of the ore-bearing areas of the northern part of the Sayan-Baikal metallogenic belt would require solving a number of problems that are unlikely to be solved currently. They are: underdeveloped road infrastructure, limited capacity of the Baikal-Amur Mainline; energy delivery, requiring modernization of Hydroelectric plant and EPLs; harsh natural conditions; some deposits being located within the water protective zones; environmental problems. Due to these causes, importing some types of mineral resources is often more profitable currently. However, development of the northern areas will be required eventually, as the industrial development of the country will have required increased extraction of a number of mineral resources.

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