INDUSTRIAL TYPES OF GOLD DEPOSITS OF THE EAST KAZAKHSTAN

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ABSTRACT

The East Kazakhstan territory is the unique geologic province where a number of large-scale non-ferrous and gold deposits are concentrated [1]. Gold base metals (gold-containing) type is represented by gold-containing sulphide complex deposits. It is characterized by many large-scale commercial deposits of copper, lead and zinc where gold as well as silver, cadmium, platinum, selenium and other elements are the associate component of copper-sulphide and sulphide complex deposits [2]. There are following ore types are distinguished: gold-listvenite type occurs in the Irtysh zone (Maraliha deposit); the gold-sulphide vein-disseminated type associated with island-arc, volcanogenic-carbonate-terrigenous formation C_1v_{2-3} (Suzdalskoye, Baibura, Mirazh, Zhaima); gold-quartzite type is characterized by gold-quartzite-vein deposits in West Kalba zone (Kuludzhun, Sentash, Kazan-Chunkur and others); gold-arsenic-carbon-bearing type is presented by large, middle and small deposits of Bakyrchik's group (Bakyrchik, Bolshevik, Gluboky Log and others). Last one is formed on middle-Hercynian collision ore-bearing level (C_2-C_3) [3]. Multiple-stage concentration of gold contributed to formation of very large deposits. Gold content ranges from is 0.2 to 60 g/t, average is 8-9 g/t. Considerable part of gold is found in micro- and nanoparticles, nanotubes containing Au, Ag, Pt, Pd, W, Mo, Sn, Y, Yb, Ta and other elements [4].

Keywords: *Gold, metals, sulphide-polymetallic ores, deposits*

INTRODUCTION

In recent ten years significant progress was achieved in classification, definition and notion of different types of gold-ore deposits. Each of them has a range of specific characteristics for this type and tectonic conditions for forming. The research data on gold metallogeny of collision gold-ore deposits in Kazakhstan provide establishing of connection between structure, tectonic evolution and magmatism of the region, as well as formation of large gold deposits. [5].

A lot of authors clearly determine some metallogenic epochs on the territory of Kazakhstan. Their leading element is gold(R_3-V, Є $_{1-2}$, O $_{1-2}$, 0_3-S_1 D $_{1-2}$, D $_{2-3}$, C_1,

C_{2-3}, C_3-P_1, K_2 и Pg-Q). The most active from the aspect of gold ore specialization there are following three - 0_3-S_1; D; C_3-P, characterized by active, magmatism and different metamorphism [6].

The leading geological and industrial types of primary gold ore deposits in Kazakhstan are: 1) gold-sulfide-quartz (plutonogenic stockwork and veined), 2) gold-sulphide (vein-impregnated), 3) gold-bearing crusts of weathering, 4) gold-adular- quartz, gold-quartz, gold-sulphide-quartz (volcanogenic), 5) gold-skarn[7].

The average gold content in Kazakhstan own gold ore deposits is 5-7 g / t. The most large-scale unique deposits are Vasilkovskoye (Akmola region) and Bakyrchik, Ridder-Sokolnoye (East Kazakhstan). Gold-bearing deposits include the following types: 1) gold-silver-pyrite-polymetallic, 2) gold-copper- porphyritic, 3) copper-pyrite and others [8].

MATERIALS AND METHODS

There were field expedition work, different type of sampling such as float sampling, lithogeochemical sampling. Samples and chips were used for making thin rock sections, polished sections. Geochemical researches were carried out in certified laboratory IRGETAS of D. Serikbaev East-Kazakhstan state technical university. There was studying of the composition of ore minerals with using optical and electronic microscopy. The study of ore minerals and gold (JSM) was carried out in separate grains and in artificial polished sections. There was also used ICP-MS for the chemical composition of ores and minerals studying.

MAIN RESULT

Gold deposits of East Kazakhstan region were formed in different geological conditions, they differ in age, material composition of ores, and immensity of mineralization. Among them there can be distinguished gold-bearing objects of various ore-formation types and gold ore deposits [9]. One of the most attractive commercial gold mining sites is the well-known base metal deposits.

Gold-copper-polymetallic (Rudny Altaic) type. This is the main geological-industrial type for East Kazakhstan, represented by gold-bearing pyrite-polymetallic deposits of Rudny Altai. It is characterized by many large industrial deposits of copper, lead and zinc, in which gold, along with silver, cadmium, platinum, selenium and other elements, is an associated component of copper-pyrite and pyrite-polymetallic deposits (Ridder-Sokolnoye, Tishinskoye, Maleevskoye, etc.) (figure 1).

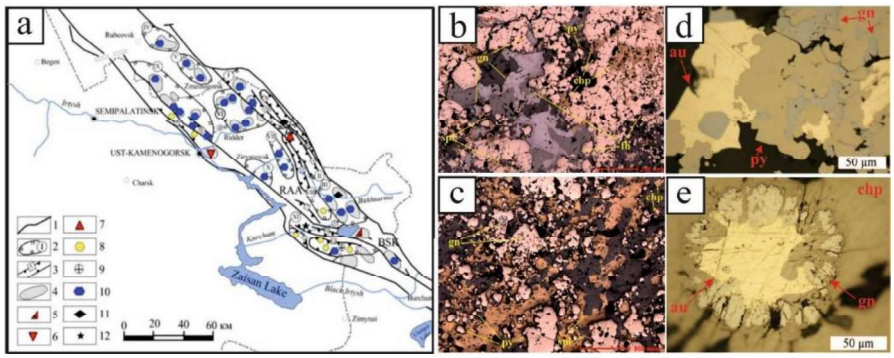

Figure 1. *Rudny Altai cupper-polymetallic belt 1 - boundary of metallogenic zones; 2 - ore district; 3 - ore zone; 4 - ore node; 5 - 12 - ore formations: 5 - epimagmatic; 6 - skarn; 7 - greisen-quartz-vein; 8 - quartz vein golden; 9 - gold-quartz berezitic; 10 - pyrite-polymetallic; 11 - volcanogenic-sedimentary iron-manganese; 12 - metamorphogenic (golden); a,b – mineral associations, Maleevskoye deposit; c,d- native gold in the copper-pyrite ores of Ridder-Sokolnoye deposit (G.D. Ganzhenko [10])*

The deposits formed in rifting and island-arc geodynamic conditions of the Hercynian tectogenesis. They genetically relate to the group of differentiated basalt-andesite-rhyolitic formations (D1-3). Multistage of formation and multiple-deck distribution of mineralization on several stratigraphic levels are determined for a number of large deposits (Ridder-Sokolnoye, Tishinskoye, Maleyevskoye, Orlovskoye, Artemyevskoye and others). Gold is related to the main ore-forming process corresponding to formation of commercial copper-polymetallic ores. The average gold content in pyrite-polymetallic ores is 0.8-1 g / t, while developing deposits, it is extracted in passing and composes a significant part in the balance reserves of the region and in Kazakhstan as a whole [10]. Ridder-Sokolnoye deposit specially stands out. According to the total volume of gold mining it is compared with large world objects (Muruntau, Sukhoi Log, and others).

MAIN TYPES OF GOLD DEPOSITS

Gold-listvenite type. Gold deposits were formed in collision geodynamic setting and are located within the West Kalba gold ore belt and the Irtysh shear zone.

The following ore types are distinguished: gold-listvenite type occurs in the Irtysh zone (Maraliha deposit). Crystalline schist and amphibolites including serpentinite lenslike mass, dikes of diabase porphyrites and plagiogranite-porphyrites are ore-hosting. Gold-bearing ores were formed in the process of fold-thrust deformations of collision stage and is fixed in ore fold silica-listvenite zones. Ore is vein-disseminated, main ore minerals are pyrites, arsenopyrites and gold. There are also chalcopyrite, sphalerite, galena and fahlore. Free and fine-grained gold is in pyrite, arsenopyrite and magnetic iron ore.

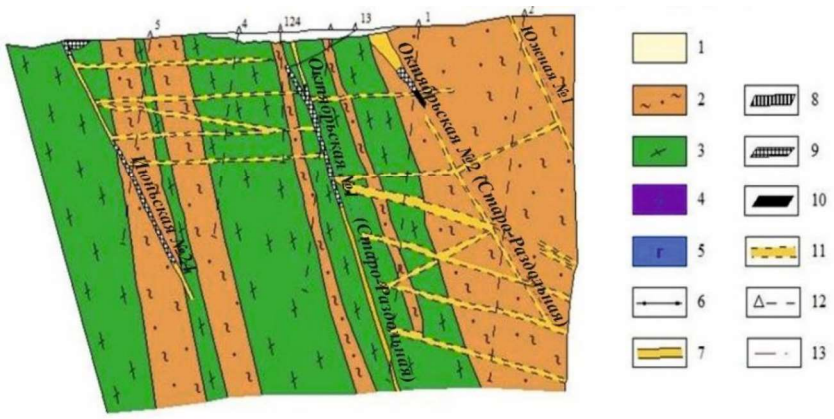

Figure 2. *Geological section of the Maralikha gold deposit. 1 - loose quaternary layers, 2 - biotite - quartz-feldspar crystalline schists, undivided, 3 - amphibolites, 4 - serpentinized hyperbasites, 5 - gabbro-diabases, 6 - granodiorite-porphyry dikes; 7-11 - ore bodies with gold content (7-0-2 g/t, 8-2-4 g/t, 9-4-10 g/t, 10-10-30 g/t) and 11-expected; 12 - design boreholes; 13 - breaking disruptions.*

The distribution of gold in the quartz of host rocks and quartz veins is given in the table 1. The most high-contrast contents of elements with concentration clusters (KK greater than 100) in berezites and listvenites are Au, As, and W. In quartz veins Ag, As, Au, Mo are the moderately contrasting (KK = 10-100). Low-class contents (KK less than 1) are defined for V, Ti, Zr, Mn, Cr, etc.

Table 1 - Content of gold and associated components in quartz veins of the Maralikha deposit

Sample number	Characteristic of quartz	Average content of Au, g / t	Elements of the impurity (maximum values in mass%)	Note
4327	Quartz in birch	3,9	Ag 4 g/t, As 5, Ti 0.6, Mn 0.2, Zr 0.03, Cu 0.02, V 0.01, Ni 0.008,Mo 0.0008	gold quartz
5553	Quartz in crushed birch	1,06	W 1, As 0.8, Ti 0.6, Mn 0.1, Zn 0.05, Cu 0.04, Zr 0.03, V 0.01, Mo 0.065, Ni 0.005, Sc 0.002	gold quartz
6589	Quartz in listenites	1,18	Ag 10 g/t, As 0.8, Ti 0.2, Mn 0.1, Zn 0.04, Cr 0.01, V 0.008, Mo 0.005, Ni 0.003, Pb 0.003, Cu 0.002, Sc 0.002, Co 0.0008	gold quartz
4328	Vein quartz	0,14	W 0.5, Mn 0.1, As 0.08, Ti 0.03, Ni 0.0025, Sc 0.0006	slightly gold-bearing quartz
4320	Vein quartz	0,10	Ti 0.1, Mn 0.06, Cu 0.004, Ni 0.003, Mo 0.0005	slightly gold-bearing quartz
3721	Quartz in quartz-feldspar-biotite schists	<0,01	Ti 0.1, Mn 0.025, Zr 0.005, Ni 0.003, Pb 0.003, Cu 0,0025, V 0.002, Cr 0.002, Co 0.0008, Mo 0.0006, Sc 0.0005	non-gold-bearing metamorphogenic quartz

The gold-sulphide vein-disseminated type. The gold-sulphide vein-disseminated type belongs to unconventional type of gold ore spatially associated with island-arc (Radtke 1995), volcanogenic-carbonate-terrigenous formation C_1v_{2-3} (Suzdalskoye, Mirazh, Zhaima and others) [11]. Geological-genetic model of ore formation is defined as hydrothermal-metasomatic and determined by formation of gold-bearing crushed vein and jasperoids in tectonically fractured carbonate-terrigenous rocks. Ore bodies were formed as a result of minor intrusions, plagiogranite dikes and granodiorites (Kunushsky complex C_3). Main ore minerals are pyrite, arsenopyrite, and antimonite. Free gold is fine and submicroscopic (average content is 8-10 g/t). Gold-quartzite type is characterized by gold-quartzite-vein deposits widely represented in West Kalba zone (Kuludzhun, Sentash, Kazan-Chunkur and others). They are located in low carbon sediments (Aganaktinskaya suite C_1S). Ore is controlled by faulting and is genetically associated with minor intrusions and Kunushsky complex dikes (C_3). Ores are characterized by great variety: pyrite, arsenopyrite, gold, chalcopyrite, sphalerite, fahlores, antimonite, scheelite and others. Gold is free in polysulfide and stibial assemblages. Suzdal deposit is allocated on the flanks of the of the same name reference gold-sulfide deposit of industrial importance (Figure 3).

It type of gold mineralization occurred in volcanic-carbonate-terrigenous formations of island-arc type D_3fm-C_1v_{2-3} (Arkalyk suite and others). The latter

during the activation of tectonic movements in the stage of the Hercynian collision underwent hydrothermal-metasomatic transformations in infolded-melange, mantled-thrust and ruptural structures, as well as in contacts with gold-bearing small intrusions and dikes of Kunushsky complex (C_3). These processes were accompanied by the addition of ore-bearing fluid flows and the formation of gold deposits and ore occurrences (Suzdal, Mirage, Baibura and others) [12]. Ore bodies are represented by discontinuous mineralized zones, bunches, veins and stockworks with impregnation of gold-bearing sulfides (mainly pyrite, arsenopyrite, less antimonite).

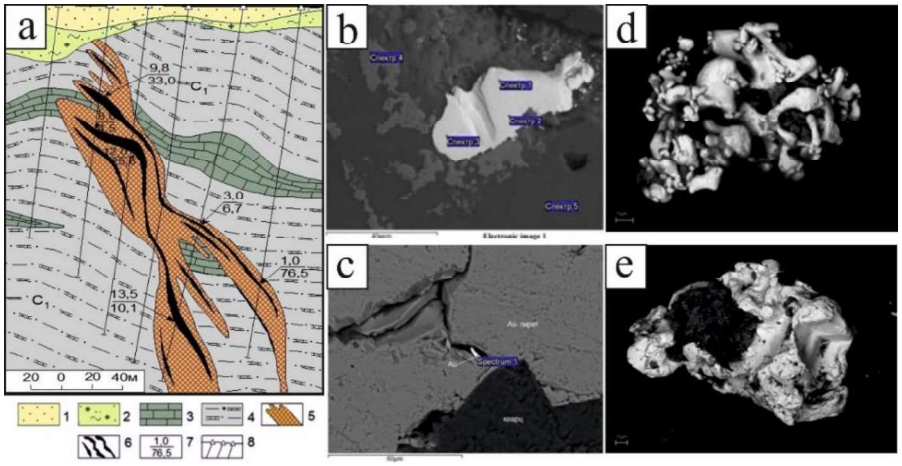

Figure 4- *a - Suzdal ore field. 1 - Cenozoic loose sediments; 2 - weathering crust; 3-4 - deposits of the arkalyk formation: 3 - limestones, 4 - calcareous siltstones; 5 - gold bearing zones; 6 - ore bodies; 7 - characteristics of gold-bearing intervals: in the numerator - power in meters, in the denominator - average content of gold, g / t; 8 – wells; b,c,d,e -native gold (with admixture of Ag, Pt) in the jasperoids of Baybura deposit (Dyachkov B.,Kuzmina O.)*

Gold is free, fine and submicroscopic. Its content in ores is variable, amounting to 8-10 g / t in the bedrock and weathering crusts. The main ore - hosting structure of the deposit is represented by a system of subparallel tectonic deformations in the north-eastern direction. Zones of primary gold-sulphide mineralization are crushed and strongly crumbling carbon-bearing and calcareous - carbon-bearing siltstones, limestones and sandstones containing the main ore bodies (figure 4). In the primary ores there are impregnated, veined- impregnated textures, the gold content of which is extremely random (at average value 9 g / t), gold is in a free state or in the form of finely dispersed impregnation in arsenopyrite, pyrite and quartz.

Gold-arsenic-carbon-bearing type is presented by larger deposits in terms of gold reserves (Bakyrchik, Bolshevik, Gluboky Log and others) and is formed on middle-Hercynian collision ore-bearing level (C_2-C_3). Sub-aerial grey molasses, alluvial-limnic and bog carbon-bearing black-shale lithofacies (Bukon suite ($C_{2\text{-}3}$)), subjected to intensive dynamic-metamorphic and hydrothermal-metasomatic

changes (zone of the Kyzylovsky deep-seated fault), and to the influence of deep seated (3-5 km) rock bodies. Multiple-stage concentration of gold contributed to formation of very large deposits (Figure 5). Gold content ranges from is 0.2 to 60 g/t, average is 8-9 g/t. Considerable part of gold is found in micro- and nanoparticles, nanotubes containing Au, Ag, Pt, Pd, W, Mo, Sn, Y, Yb, Ta and other elements[13].

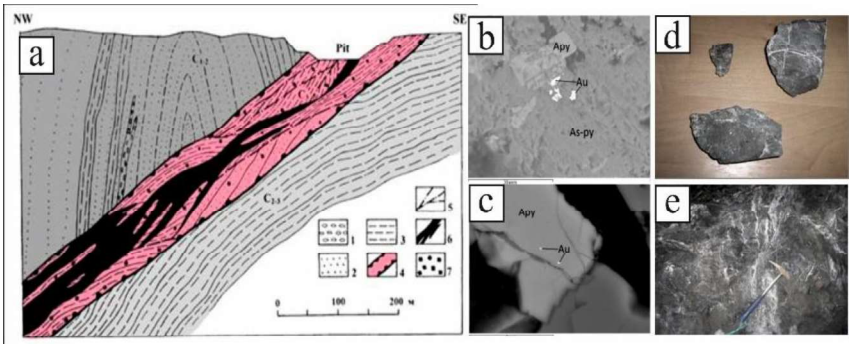

Figure 5 – *a - Geological section of gold-sulfide deposit Bakyrchik through the central ore body (based on the materials of V. M. Yanovsky, Y.V. Chudikova). 1-3 carboniferous sediments: 1 - conglomerates, gravelites, 2 - sandstones, 3 - carbonaceous siltstones and shales; 4 - Kyzylovskaya zone of deep fault: 5 - faults, tectonic cracks: 6 - ore body; 7 - diffuse sulphide mineralization; b, c – gold in arsenopyrite; d, e – gold ore samples*

CONCLUSION

From the modern theoretical concepts of the world geological science development, an urgent problem is the development of new scientific approaches to the analysis of the regularities in the formation of geological and ore-bearing structures in the most important mining regions of Kazakhstan with the aim to replenish the mineral and raw materials resources [14]. As a result of the analysis and generalization of geological materials of previous years and carrying out of scientific and research works on the general problem of geology and metallogeny of Great Altai, the regularities of the formation of the leading geological-industrial types of gold deposits in East Kazakhstan region have been specified. The main novelty of the results is the justification of the linear-nodal placement of gold-bearing structures and deposits. The formation of leading geological-industrial types of mineralization is connected with the collision process of Kazakhstan and Siberian lithospheric plates (C_1-C_3) [15].

On the basis of geotectonic, geophysical, geological-structural, ore-petrological and mineralogical-geochemical factors, the scientific base for the development of new forecasting technologies and searching of non-traditional apocarbonate (jasperoid) gold-sulfide mineralization and other gold ore objects has been prepared. There were defined ore-controlling role of the system of diagonal deep faults of the north-western direction (West Kalbinsky, Charsk-Gornostaevsky, and others) and the regmatic systems of latitudinal faults (Leninogorsk-Semipalatinsky and others) in the location of gold-bearing structures and objects

spatially timed to certain geochronological levels. There was studied the spatial-genetic connection of gold mineralization with small intrusions and dikes of gabbro-diorite-granodiorite-plagiogranite series of collision type (C_{2-3}-C_3) and ore-controlling role of deep mantle faults of ancient regmatic system and Hercynian activation, favourable role of the ore-hosting environment for the deposition and concentration of precious metals, the development of regional and local criteria of the new ore deposits forecast.

As a result of the carried out researches, the estimation of perspectives and gold forecast resources of the studied territory were made. The main scientific novelty and practical significance are in the justification of the definition of a new non-traditional type of gold-sulfide mineralization, which has an industrial importance, by the analogy with Suzdal deposit and the objects of Carlin trend. It is expected that the implementation of scientific and practical recommendations will contribute to the discovery of new deposits and the strengthening of the gold potential of East Kazakhstan.

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