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THE GOLD ORE DEPOSIT BAKYRCHIK AND VIEWS ON THE FORMATION OF THE MINERAL DEPOSITS IN BLACK SHALE STRATA

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ABSTRACT

Gold deposits in black shale type have huge reserves of hard-gold. The prevailing part of reserves of native gold is in carbonaceous terrigenous deposits in Russia. These deposits are represented by objects of various scales - from small to unique (In Russia – Olimpiada, Nezhdanin, Natalkin, May; in Uzbekistan – Muruntau, Kokpatas, Zarmitan, Daugyztau, Amantaitau; in Kazakhstan – Bakyrchik; in Tajikistan – Chore; in Kyrgyzstan – Kumtor; in the United States – Mather Lod; in Australia – Bendigo, Olympic Dam).

The Bakyrchik deposit is located in the Kyzyl zone, cutting the basic structure of Kalba region. Ore-bearing carbonaceous shales, mudstones, siltstones and sandstones are interbedded in the Bukon suite Middle Carboniferous age. The rocks were shale intensively, contain of carbonaceous matter and sulfides (till 5-10%). Siltstones are saturated most with gold-bearing sulfides (pyrite and arsenic pyrite) containing carbonaceous matter of 0.2-0.4% in the presence of carbonate material. The ore bodies are presented system en echelon mineralized zones of considerable power (till 20 m). The composition of the ore: pyrite, arsenic pyrite, antimony, gold, marcasite, chalcopyrite, pyrrhotite, gray ores (tennantite and tetrahedrite), galena, sphalerite, cinnabar, native silver, quartz, carbonates. Auriferous are pyrite II of pyritohedron habit and acicular arsenic pyrite. The gold in both sulfides is presented in the microscopic and submicroscopic forms. Direct contact with the carbon is installed in the interval of 0.2-1.5% content only. There is a positive relationship of gold with boron, strontium and phosphorus. Ore deposits have a wide range of elements: gold, silver, lead, zinc, copper, cobalt, nickel, molybdenum, arsenic, phosphorus, boron, strontium. The arsenic content in the ores of is 0.3-1.5%. Mineralization complex polygenic nature with multiple conversion of syngenetic sedimentogene auriferous material in the fault zone of dislocation-thermal metamorphism refers to the type mineralized zones of gold-sulphide type. In terms of reserves refers to the unique.

Keywords: gold, carbonaceous shale, pyrite, arsenic pyrite, deposits

INTRODUCTION

In solving the questions of the genesis of gold-sulfide deposits localized in carbonaceous terrigenous measures, one of the key problems is the determination of the role of sedimentary-diagenetic sulphides in ore formation.

According to point of view, justified by the example of Sukhoi Log Deposit, ore bodies represent the ores of gold-bearing sedimentary-diagenetic and sedimentary-hydrothermal sulphides, which experienced dislocation, regional and contact metamorphism *[1]*. Discussion of the proposed model is primarily connects with absence of relict formations in the ores of the named deposit, which can be reliably identified as sedimentary-diagenetic. It is assumed that they were almost completely regenerated and redeposited in epigenetic processes.

According to the data of many authors dealing with the genesis of gold-sulfide deposits in the black shale strata, models for their formation have been developed, based on real observations in many gold-bearing provinces associated with zones of influence of deep faults penetrating into the mantle.

In the formation of ores of gold-sulphide deposits with carbonaceous matter, mantle and crust-mantle sources of gold are assumed. Among the main models are the following: ***1) sedimentary-metamorphogenic model*** consists in the formation of industrial gold mineralization, as a result of segregation and redeposition of chemogenic and clastogenous gold scattered in the precambrian flyschoid strata, which got there during the erosion of the ancient weathering crusts. The formation of gold deposits occurred in three stages. During the first, hydrothermal-sedimentary stage, sediments with increased background gold content were formed at the bottom of marine basins under sharply reducing conditions. In the second, water expelling-catagenetic stage, due to the submergence of metalliferous sediments to considerable depths, the elution water was formed, capable of dissolving and transporting heavy metals to the upper horizons of sedimentary basins. At this stage might occur industrial ore concentration already *[2]*. The main part of industrial deposits was formed at the latest stage connected with the processes of dynamometamorphism, as well as contact and regional metamorphism. It is assumed that at this stage, also could take part fluids of magmatic original which regenerate and redeposit earlier gold concentrations; ***2) the metamorphogenic***-hydrothermal model considers the formation of ores with the manifestation of high-gradient zonal metamorphism, widespread in orogenic-folded regions. As a source of ore matter, sedimentary and sedimentary-volcanic complexes are considered, much deeper levels of metamorphism relate to ore-bearing strata. From the beds located above the foci of granitization, ore matter is extracted by metamorphic solutions and transferred to the upper low-temperature zones. From located above cauldron of the granitization strata, the ore substance is extracted metamorphic fluids and transferred to the upper low-temperature zones. Direct ore deposition occurs from hydrothermal solutions of the regressive stage of metamorphism, which appear after diaphthorite redeposition of ore-bearing rocks. This genetic concept is most fully developed by V.A. Buryak *[3]* for gold-quartz-sulphide mineralization of the "sukholozhsk" type; ***3) a model of intratelluric carbon metasomatism*** was proposed by P.F. Ivankin and co-authors to explain the conditions for the formation of gold deposits in black shale there are two stages of their formation, sharply differing in physico-chemical conditions of ore deposition. At the first stage, metasomatic transformations of dislocated rocks occur in the form of carbon metasomatic under the influence of highly regenerative fluids of mantle origin with the addition of gold and other metals in quantities exceeding their Clark. At the second, actually ore-forming stage, consequently of two three-fold processing of sulphidized carbonaceous rocks arise an industrial gold concentration; *[4]* ***4) magmatogenic-hydrothermal model*** is the earliest and well-developed model. It supposed a connection between gold mineralization and solutions of magmatic origin, the sources of which could serve as intrusions of granitoids. A similar connection is assumed for the fields of the Bakyrchik region *[5]*.

Unique in terms of gold reserves, the Bakyrchik deposit is a close analog of the world famous giant Muruntau in Uzbekistan and has many similarities with it in the formation of industrial gold ores. The main feature of the formation of the deposit is - the remobilization of syngenetic gold from black shale carbonaceous-argillite-siltstone deposits in the main process of tectonometamorphic transformation of rocks *[6]*. Mineralization at the Bakyrchik deposit is explored to a depth of 1000-1500 m, and the ore-localizing structures are traced by geophysical methods to a depth of 3 km, the average gold content is 9.4 g/t.

The Bakyrchik ore field, including the carbon-gold sulfide deposits of Bakyrchik, Bolshevik, Gluboki Log, Promezhutochnoe, Chalobay, Kholodnyi Kluch and Sarbas, is located in the area of complication of zones of late Herches collisions of the simatic blocks and blocks of tectonized ophiolites of the Zaisan fold system (Fig. 1). It is composed of carboniferous marine (C_S-C_2b), coastal-marine (bukon suite C_2m) and continental (bakyrchik black shale stratum C_3) terrigenous deposits with several stratum levels of gold-bearing carbonaceous-siltstone-pelitic horizons with syngenetic gold-pyrite mineralization. The content of gold in them is an order of magnitude higher than the background content, and in the Bakyrchik black shale 100-150 mg/t, organic matter 0.2 to 1.5-2.0%, in the anthraxolite lenses of the bakyrchik stratum reaches 26.5-54.1%. In siltstone-sandstone deposits, the horizons of tuffs and the covering of trachyandesite porphyrites are singular. Carboniferous terrigenous sequences are intruded with single stocks and numerous dikes of plagiogranite-porphyries and diorite porphyrites forming belts of the northwestern and sublatitudinal strike.

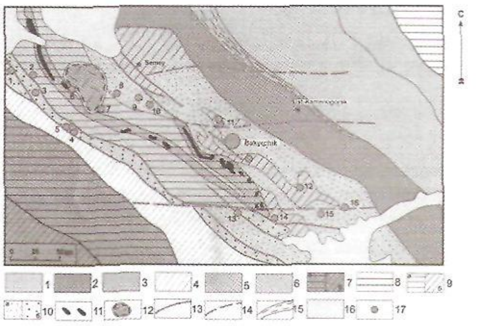

Figure 1 - the association Bakyrchik deposit to the site complications late gercynian collision of blocks Zaisan fold system

1-6 - Zaisan Hercynian fold system: 1-2 - Zones of - rift collisions of blocks: 1 - simatic (West Kalbinsky gold-bearing carbon-terrigenous belt), 2 - sialic (Kalba-Narym tantalum-tungsten-tin belt), 3 - Zone tectonized ophiolites of Charsk late Devonian rift, 4 - zone of the ensialic arcs (Zharma-Saur gold-copper-nickel-rare metal belt), 5-6 - zones of the ensymatic arcs: 5 - Early, D_1-D_2 and 6 - Late, D_2-D_3 (Rudnyi-Altai polymetallic belt) stages; 7-8 - caledonian fold systems: 7 - Chingiz-Tarbagatai (the zones of the island's ensimatic arcs early, C_1-O_2 (a) and late, O_{1-2} (б) stages), 8 - Gornyi-Altai (passive continental margin); 9-12 - Structure of the West Kalbinsk gold belt: 9 - The areas of block (a) and consedimental early-orogenic (b) uplifts, 10 - troughs: a - orogenic molasses (with reduced volcanism), b - volcanic-molasses; 11 - ultrabasics; 12 - Imposed continental volcanic-tectonic structures of cimmerian rifting; 13 - deep faults; 14 - hidden sublatitudinal fractures of the hercinide basement; 15 - Irtysh crush zone; 16 - mesozoic-cenozoic deposits; 17 - gold ore deposits in carbon-terrigenous sequences: 1 - Baltemir, 2 - Baldykol, 3 - Kempir, 4 - Alimbet, 5 - Zhanan, 6 - Mirazh, 7 - Suzdalskoye, 8 - Mukur, 9 - East Mukur, 10 - Kedei, 11 - Miyaly, 12 - Sentash, 13 - Eastasilevskoye, 14 - Balazhal, 15 - Zhumba, 16 - Kuludzhun.

Sedimentary deposits are contorted by the basic folding of the mesozonal-suture type into compressed (north-western orientation) linearly elongated folds with a wide development of viscous faults and zones of cleavage flow of rocks. They are crossed by a powerful (50-350 m) sub-latitudinal Kyzylovskaya thrust fault zone, manifested along the single deep fault fault in the upper mesozonal-suture zone of superimposed folding. In the footwall and its central part, a system of viscous faults that are close together, hollow, falling to the north is developed, accompanied by obliquely lying cramped folds, bedding cleavage and plication.

In the footwall and in its center is a system of viscous faults that are close together, hollow, falling to the north, is developed, accompanied by obliquely lying compressed folds, by layerwise cleavage and plait. The buding of dykes of lamprophyres and interbeds of sandstones, development of discharge folds is noted. A plagiogranite-granodiorite intrusion of the Kunushsky complex (C_3-P_1), revealed by geophysical studies at a depth of 2-5 km and having gold-arsenic-rare metal specialization (Au, As, Sb, W, Mo, and. etc.) was interposed into the tectonically weakened Kyzylovskaya zone. Exactly tungsten is as an indicator of large gold deposits in black shale strata *[7]*. It is accompanied by gold-quartz-occurrencing (Kilometrovaya, Zolotaya, Fabrichnaya, etc.), which are later in relation to the predominant carbon-gold sulfide mineralization.

For the deposits a clear structural control of gold mineralization characterized. All ore objects of the carbon-gold-sulfide type are located within the Kyzylovskaya crushing zone and are confining to the intersection nodes of viscous faults of the main folding in Fig. 2. Ore bodies are represented by a sub-consistent lenticular form. They pitches to the north at an angle of 35-40°, extending along the incidence of the Kyzylovsky thrust fault along the lines of intersection with viscous disturbances and zones of the cleavage current of the rocks of early folding. In particular, all gold deposits of the Bolshevik deposit are controlled by the linkage area of the Kyzylovskaya shear zone with a series of viscous faults developed in the axial planes of tight congruent folds. The length of ore bodies along the strike does not exceed 120 m, the reach length in the direction of immersion exceeds 1200 m.

Structural control of mineralization is confirmed by the tracing of the ore-localizing zones of dislocations by secondary complex and metallogenic scattering haloes of As, Sb, Mo, W, and Au. There is a change in the composition of the typomorphic geochemical association in the vertical direction from Hg - Sb - Ag in the near - surface horizons to Mo - Bi - W - Be at depth is noted, which allows us to distinguish between the, sub-ore - wallrock and over-ore zones by the ratio of the elements *(As/P, As Pb Mo) [8]. The most contrast coefficient v=Au/P Cu Pb Mo.*

The dominant ore minerals are pyrite and arsenopyrite, antimonite is noted in the near-surface horizons, marcasite, chalcopyrite, pyrrhotite, and galena are rarer. There are four different age-related paragenetic associations-pyrite-I-melnikovite-marcasite, gold-I-pyrite-II-arsenopyrite, gold-II-sphalerite-galena-chalcopyrite and gold-III-antimonite-marcasite-enargite *[9]*. Gold in ores is mostly finely-dispersed, in arsenopyrite and pyrite in the thin drop-shaped form (0.1-5 micron) inclusions, dendrites and grains. Visible gold (tenths of a millimeter) occurs along cracks in sulphides and in association with antimonite. Among the prevailing finely dispersed gold identified three morphological varieties of gold like: sputum-fibrous, massive and crystalline-granular *[10]*. High-grade gold (95-98%). A nickel is a typomorphic trace element. Pyrite (20-300 g/t) and arsenopyrite (32-145 g/t) are distinguished by high nickeliferous. Thin-fiber gold is often associated with bunzenite, $AuNi_2$ intermetallide is noted. New forms of ultramicroscopic native gold (nano-gold) - colloid and ionic phases - are identified on the deposit *[11]*.

Researches of M.G. Marchenko gold is identified not only in sulphides, but also in the carbonaceous matter of the deposits of the "black shale" type of Kazakhstan, which increases the ore potential of these objects *[12]*. Nano- and microformal minerals of gold and platinoids were discovered in sulphides and carbonaceous matter, which in a chemically bound state are contained in certain (fullerene- and graphene-like) nanostructured particles that play a leading role in the ore accumulation and transfer of ore components.

Mineralization is formed in three main stages: 1) sedimentary sedimentary-diagenetic, 2) tectonometamorphogenic and 3) intrusive-thermal-metamorphogenic.

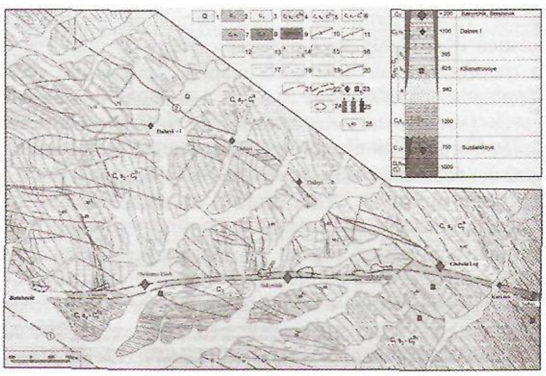

Figure 2 - The confinedness of gold ore deposits of the Bakyrchik ore field to the areas of the Kyzylovsky shear zone with the viscous faults of the main folding.

1 - neogene-quaternary precipitation; 2 - Baryschyk black-shale measures C_3; 3 – bukon conglomerate-sandstone formation C_2m; 4-6 - bedsets of aleurolite-sandstone layer C_1-S_2-C_2b: 4 - upper pelite-siltstone, 5 - medium siltstone-sandstone,6 - lower sandstone, 7 - aganacty siltstone-sandstone formation C_1S_1; 8 - opanov mudstone-limestone formation C_1v; 9 - karabay basaltic-siliceous suite D_3fm_2-C_1t; 10-11 - dikes: 10 - subalkalic granite porphyry and monzonite-porphyry, 11 - diabase and diorite porphyrites; 12-19 - varieties of rocks: 12 - sandstones, 13 - interbedding of sandstones and siltstones, 14 - clayey siltstones (a) and clayey-argillaceous (b), 15 - conglomerates, 16 - limestones, 17 - phthanites, 18 - tuffs, 19 – basalts and andesites; 20 – breaks (1 - West Kalbinsky, 2 - North-West); 21 - viscous breaks; 22 - Kyzylovskaya thrust zone; 23 - carbon-gold sulfide (a) and manifestations of gold-quartz-veined deposits (b) type, 24 - gold mining pit; 25 - intrusive complexes: a - gabbro-monzonite-granosyenite-granite porphyry (semeytau T_1), c - granodiorite-plagiogranite (C_3-P_1); d - protrusion of ultrabasites; 26 - elements of occurrence of rocks.

The sedimentary-diagenetic stage - gold, as well as the associated nickel and cobalt, was extracted by juvenile fluids during the tectonic activation from the ultramafic rocks of the oceanic base and zones of serpentinite protrusions. Mobilized gold deposited in the mud-like environment of shallow basins and underwater deltas rich organic matter and hydrogen sulfide, globular-framboidal inclusions and veins of pyrite developed with the formation, in the process of diagenesis, of rhythmically-layered gold-bearing carbonaceous-argillaceous and carbonaceous-siltolite-pelitic sediments. The isotope composition of rhythmic carbon δ13C = -14 ÷ -31% indicates its biogenic nature (N.M. Zairi, 1978). Removal and migration of gold in diagenesis (a slightly alkaline environment, T = 100-150 °C) was carried out in the form of hydrosulfide complexes $Au(HS)^-_2$.

The tectonic-metamorphogenic stage - the formation of mesosonal-suture folding under conditions of elevated temperatures of the zeolite and chlorite-sericite facies of metamorphism and cleavage of the rocks, dehydration of epizonal carbon-terrigenous sediments took place, extraction of gold from them in the form of chloride complexes $AuCl_2$, formation of hydrothermal-metamorphogenic solutions and their circulation over highly fluid-permeable viscous faults. The carbonaceous substance was transformed into schungite, graphite, and a rare carbine, and the recrystallized famboidal-globular pyrite acquired a pentagon-dodecahedral and cubic habit. At this stage (stress-metamorphic, according to V.B. Chekvadze, 1999), the migration of metamorphic solutions was accompanied by scattered near-faulty sericitization and the occurence of hugger-veined silicification and the formation of schungite-sericite metasomatites. The content of carbonaceous matter in the shungite-sericite metasomatites and tectonites framing the mineralization is 13.4-15.2%. Remobilized gold was deposited on reducing geochemical barriers, most intensively at the fusion sites of multidirectional flows of hydrothermal-metamorphic solutions circulating along the viscous faults of the main folding and the Kyzylovskaya shear zone. The metamorphogenic nature of the neogenesis is confirmed by isotopes of shungite carbon ($\delta^{13}C$ = -22 ÷ 26,8%), oxygen and carbonate of carbonates ($\delta^{18}O$ = +12 ÷ +18%, $\delta^{13}C$ = -2,5 ÷ -10%). The temperature interval of the metamorphogenic transformation (according to the difference of 613°C graphite carbonate) is 200-250°C (N.M. Zairi, 1978). The predominance of nitrogen, hydrogen, methane, carbon dioxide in the gas phase *[13]* is due to their formation during the decomposition of organic, including nitrogen-containing compounds in the tectonometamorphic transformation of rocks.

The intrusive-thermal-metamorphogenic stage is the remobilization of syngenetic and hydrothermal-metamorphogenic gold in the areas of intrusion and dikes of the granodiorite-plagiogranite complex (C_3-P_1) and pyroxene diabases of the family-intrusive complex (T_1); Transportation of gold by hydrothermal solutions for viscous breaks, formation of gold-antimonite-enargitic paragenetic association with enrichment of previously formed ore deposits and accompanying metasomatites. In contrast from early lead ores, the absolute age of lead fluids in the intrusive-thermal-metamorphogenic phase is 300 ±15 (C_3-P_1) and 230 ± 10 (T_{1-2}) million years *[14]*.

CONCLUSION

The main indicators of the deposits of the Bakyrchik type:

1. Gold-bearing rhythmically layered carbonaceous-clayey and carbonaceous-aleurolite-pelitic microfacies of the black shale stratum with increased contents of syngenetic gold (10-150 mg/t), organic matter (1-10%) and in the form of globular-framboid pyrite.
2. Intensive occurence of mesozonal-suture folding accompanied by viscous faults and zones of cleavage flow of rocks, multi-stage deformation processes and the formation of hybrid structures of intersection of plicative dislocations.
3. The widespread development of chlorite-albite, schungite-sericite and sericite-phlogopite-carbonate metasomatites in cleavage zones and viscous faults.

When compiling the model, materials of Yu.V.Gostev, V.I. Zenkov, L.G. Marchenko, E.Nusipov, V.B. Chekvadze, A. A. Shiganova are taken into account.

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