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GEOLOGY, MAGMATISM AND SPECIFIC FEATURES OF MINERALIZATION OF BAKYRCHIK ORE FIELD (EASTERN KAZAKHSTAN)

Purpose. Determination of the features of the formation of gold mineralization within the Bakyrchik ore field and the influence of deep intrusive rocks on the formation of ore bodies.

Methodology. Analysis of literature data, interpretation of geophysical studies, field work and laboratory studies on the mineralogical composition of ore bodies and dikes of the Kunush complex (ISP-MS – Agilent 7500cx), study on the main types of mineral associations and zone of alteration (JSM 6390LV)).

Findings. Peculiarities of geology, magmatism and ore formation of one of the gold ore deposits of the mesothermal class in the Bakyrchik black shales, located in the West Kalba metallogenic zone (WKMZ) in East Kazakhstan, are considered.

Originality. All geological and industrial types of gold mineralization known in the territory of Western Kalba are divided into several levels according to their priority. The most promising, but, despite many years of study, underexplored level is represented by the Bakyrchik ore district.

Practical value. The connection of the gold mineralization of the Bakyrchik deposit with zones of tectonically weakened lithosphere and with hidden granitoid intrusions identified by geophysical data is emphasized, which will allow using these data for further exploration within the Western Kalba.

Keywords: *geological structure, gold, magmatism, deposits, Western Kalba, metallogenic zone, Kazakhstan*

Introduction. The territory of East Kazakhstan stands out in the geological structures of Kazakhstan as the largest region in which large deposits of non-ferrous, rare metals and gold are concentrated. At the same time, in terms of gold reserves and production, this region occupies a leading place in Kazakhstan. Here are the largest deposits of VMS, in which the main associated components are gold, silver, rare and rare earth elements (Ridder-Sokolnoye, Maleevskoye, Artemyevskoye, etc.). The actual gold ore deposits are: gold-leaf type in the Southern Altai (Maralikha deposit); gold-sulfide vein-interspersed type (Suzdal, Baybura, Mirage, Zhaima); gold-quartzite type, which includes gold-quartzite vein deposits of the West Kalba zone (Kuludzhun, Sentash, Kazan-Chunkur, etc.); gold-arsenic-carbon-containing type represented by large, medium and small deposits (Bakyrchik, Bolshevik, Zherek, etc.).

Among gold ore deposits, there are such deposits as: gold-listvenite type, which 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 characterized by gold-quartzite-vein deposits in West Kalba zone (Kuludzhun, Sentash, Kazan-Chunkur and others); gold-arsenic-carbon-bearing type presented by large, middle and small deposits of Bakyrchik's group (Bakyrchik, Bolshevik, Gluboky Log, and others).

One of the leading gold-bearing structures is the West Kalba zone, characterized by multi-stage development and long-term ore-producing and ore-forming processes (Fig. 1).

At the first stage, in the conditions of the intercontinental sea basin (C_{1-2}, C_2), the donor carbon-terrigenous formation (Arkalyk, Bukon suits) is formed.

In the middle-late Carboniferous, under conditions of the beginning of the collision, the structures of the Kyzylovskaya fold zone are laid, magmatites are introduced (hypabissal plagiogranite-granodiorite formation of the Kunush complex, C3).

Tectonic shifts, the manifestation of metamorphism of various stages (mainly the green shale stage) contributed to the redeposition and concentration of gold due to the rejuvenation of primary volcanogenic-sedimentary gold and its introduction from deep magmatic sources. A large-scale deposit with mineralization of vein-interspersed, vein and stockwork types was formed [1].

Geological setting of the Bakyrchik deposit. Bakyrchik ore district unites 123 manifestations of gold of different formational affiliation. Structurally, the main deposits are controlled by the Kyzylov deep fault system of latitudinal extension (Fig. 2). The total length of the ore field reaches 17 km, with its width of up to 350 m. Ore-bearing deposits include the deposits of the Bukon Formation C2-3, represented by hydrothermal-metasomatically altered black shale carbonaceous rocks.

Bakyrchik ore region is located in East Kazakhstan region in the north-west of the central part of the Kalba structural-facial zone of Zaisan fold system. Together with minor deposits and ore occurrences, distributed in Kyzylovsky zone or in its plan-parallel splays, it forms a single the Bakyrchik-Bolshevik ore field (Fig. 2). Kyzylovsk zone is understood as a complex, long-lived structure that develops in the side part of the basin at the boundary of sediments of Arkalyk and Bukon formations and hosts dykes of Kunush complex and mineralization [2].

Bakyrchik deposit is located 40 km north of the Shar station. Discovered in 1953 by geologist F. S. Podsevatkin. Subsequently, the field was studied by N. I. Borodaevsky, A. Y. Kotov, Yu. A. Ovechkin, 3. E. Yensebayev, V. A. Narseev, G. B. Levin, M. M. Starova, V. I. Zenkova, V. S. Shibko, E. A. Elektorova, N. A. Fogelman, M. M. Bakenov, P. I. Poltoryin, T. M. Zhautikov, V. N. Sorokin, V. M. Yanovsky, and others.

The geological structure of the Bakyrchik ore field is presented in the works [1, 2]. The base of the incision is repre-

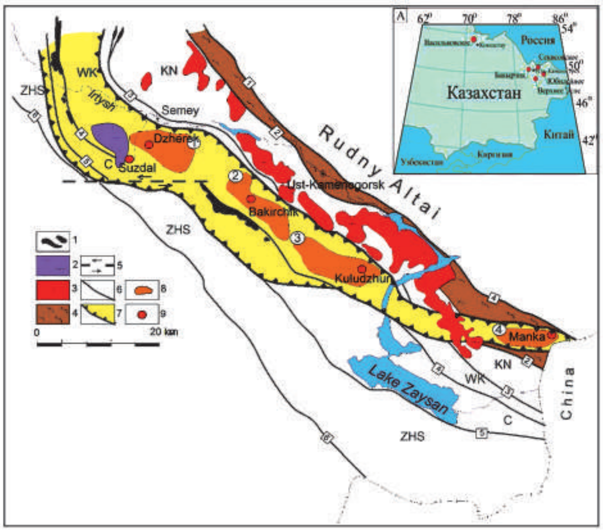

Fig. 1. West Kalba zone location:

1 — Charsko-Gornostaevsky belt; 2 — volcano-tectonic structure (Semeytau); 3 — Kalba-Narym pluton (granitoids, P_1); 4 — Irtyshskayy Crush Zone; 5 — shifts; 6 — metallogenic zones boundaries; 7 — West Kalba; 8 — ore regions; 9 — gold ore deposits. Ore regions (figures in the circles): 1 — Mukursky; 2 — Bakyrchik; 3 — Kuludzhun; 4 — South Altai); KN — Kalba-Narim zone; WK — West Kalba zone; ZHS — Zharma-Saur zone

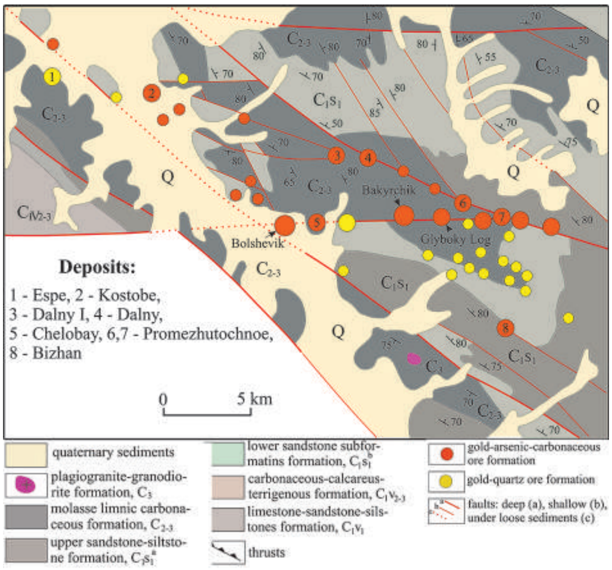

Fig. 2. Geological position of gold deposits along the Kyzylovskaya zone (based on the materials of V. I. Tikhonenko with changes of the authors):

1 — Quaternary deposits; 2–7 — geological formations: 2 — plagiogranite-granodiorite, C_3; 3 — molassic limnic carbonaceous carbonaceous, C2; 4–5 — siltstone-sandstone, C_{1s} (4 — upper sandstone-siltstone and 5 — lower sandstone subformations); 6 — flyshoid carbonaceous-calcareous-terrigenous rocks, C_{1v2-3}; 7 — limestone-sandstone-siltstone, C_{1v}; 8–11 — rupture disorders (8 — deep; 9 — small breaks; 10 — under loose sediments; 11 — ore-controlling); 12 — overdrafts; 13 — elements of occurrence; 14–15 are gold deposits, of which 13 are deposits of the Bakyrchik ore field

sented by a thickness of dark gray fillitized pelitolites (D3bm2). Above these sediments volcanogenic-siliceous formations of the late Devonian — Upper Carboniferous Karabai suite (D3-C1) and Limestone-pelitolite rocks of the Arkalyk suite (C1ar) lie. The section of the Bukon Formation (C2-3 bk) has a characteristic rhythmic structure [3], deposits with local erosions at the border lie on the rocks of the Karabay Formation (Fig. 1).

The sediments containing the gold ore bodies are the carbon-containing rocks of the Bukon suite.

Magmatism. In the previous years, the Western Kalba was considered as amagmatic structure and gold deposits were not associated with sedimentary rocks. However, all researchers noted that gold deposits formed in the black shale strata (Muruntau, Kumtor, etc.) have a spatial connection with the magmatism of the late Paleozoic age.

Further geophysical studies within the zones of mineralization of the western Kalba showed the presence of igneous formations in the supra- and near-intrusive zones that had not been opened by the erosion section [4], which influenced the formation of a number of quartz veined gold ore fields (Jumba, Kuludzhun, Laili, Sentash).

It was established that directly within the protrusions of small massifs of granitoids, gold-birch deposits (Balajal) were formed.

According to the data of Mysnik A. M., such deposits are distributed throughout the section of carbon-terrigenous formations, but they are most often encountered on four stratum levels: Late Visean period (Akzhal, Northern Ashaly), the Early Serpukhovsky period (Sentash, Jumba, Terekty), the Late Serpukhovsky period (Kulujun, Laily) and the Middle Carboniferous (Espe).

Igneous rocks are represented by small and medium intrusions of the Kunush gabbro-plagiogranite series (gabbro-diabases, biotite tonalites and plagiogranites) (Table).

By petrochemical features, they are considered as high-sodium rocks with increased alumina content and low total alkalinity. In addition to intrusives of Kunush complex, a gabbro-diorite dyke complex is formed in a number of gold ore fields, forming well-defined belts of the north-west and sublatitudinal extensions. Dykes of lamprophyre series (spessartites), subalkaline gabbroids and substantially sodium diorite porphyrites, and eruptive breccias are widely distributed in its composition. The rocks of the complex are characterized by high concentration of TiO_2 (up to 2.21 %) and P_2O_5 (up to 0.89 %) [6].

According to geophysical data, an intrusive massif (7 × 3 km) of gabbro-diorites, which is attributed by many authors to collisional granodiorite-plagiogranites of the Kunushsky complex (C_3), lies directly beneath Bakyrchik ore field in the zone of the Kyzylovsky fault. Differentiates of the intrusive complex at Bakyrchik are arranged in a tiered manner: the granitic focus lies at a depth of 3.0–3.5 km, and the dyke rocks are localized at the upper horizon — in the zone of the ore-bearing overlap [7–8].

The genetic relationship [8] of small intrusions and vein formations has been proven in terms of a similar mineral and petrographic composition.

Petrographic rocks are characterized by consistent quantitative and mineral composition (quartz 25–35 %, oligoclase 30–40 %, potassium feldspar 15–20 %, dark-colored minerals 5–7 %, ore minerals 1–2 %). The structures are porphyry, in inclusions there is constantly a round-shaped quartz and prismatic crystals of acid plagioclase, the groundmass is formed of a microgranitic aggregate.

Fig. 3, *a* shows the TAS diagram: ($Na_2O + K_2O$) — SiO_2 (Core, et al.,1979). According to the diagram, the rocks of the Kalba complex belong to the low-potassium calcareous-alkaline series.

This is also evidenced by the sum of alkalis $Na_2O + K_2O$ (up to 6.4 wt.% and high Na_2O/K_2O ratios (from 3.10 to 6.45), Table. According to the authors, the rocks belong to plagiogranites of the high-alumina type (Figs. 3, *b, d*). According to [9] and other processes, the formation of plagiogranite magmas of the Kunush complex can be associated with the melting of the substrate of the sinking ocean lithospheric plate in the subduction zone [9–10].

Mineralization of Bakyrchik gold deposit. Mineralization of Bakyrchik deposit was studied in different years by a number

Table

Chemical compositions of the Kunushsky complex magmatic rocks (data by D'yachkov BA with supplemented results of the authors) [8]

sampels (number of samples)	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO
Granodiorites (19)	67,55	0,57	16,36	4,22	0,07	1,16
Plagiogranites (9)	70,93	0,27	15,58	2,22	0,01	1,10
Bolshevik (23)	66,47	0,68	16,09	5,11	0,07	1,20
Bakyrchik plagiogranite-porphyry (9)	70,66	0,22	16,42	2,35	0,02	0,84
Granite-porphyry (13)	73,66	0,20	15,19	1,54	0,02	0,35
Quartz porphyry (12	73,44	0,13	14,70	1,85	0,02	0,45
Jumba-plagiogranite (1)	74,44	0,22	15,76	0,83	0,01	0,25
Suzdal-granodiorites (74)	71,91	0,10	12,50	1,73	0,04	0,23
sampels (number of samples)	CaO	Na_2O	K_2O	P_2O_5	nnn	Σ
Granodiorites (19)	2,85	3,66	2,81	0,17	0,76	***100,13***
Plagiogranites (9)	2,27	5,26	1,11	0,06	0,57	***99,38***
Bolshevik (23)	2,05	3,12	3,6	0,18	1,52	***100,13***
Bakyrchik plagiogranite-porphyry (9)	1,98	4,71	1,4	0,08	1,57	***100,25***
Granite-porphyry (13)	0,56	4,04	3,23	0,09	1,45	***100,33***
Quartz porphyry (12	0,94	4,00	3,51	0,04	0,96	***100,04***
Jumba-plagiogranite (1)	0,18	5,13	2,00	0,03	1,47	***100,32***
Suzdal-granodiorites (74)	4,30	3,59	1,17	0,02	4,65	***100,24***

of authors including Yu. A. Ovechkin, P. G. Kuznetsov, N. I. Boyarskaya, V. A. Narseev, M. M. Starova, G. B. Levin, M. S. Rafailovich, E. V. Bakhanova and S. I. Ignatiev, I. V. Begaev, A. V. Yurkov, and others. We researched typomorphic characteristics of basic mineral associations using highly precise research and SEM methods. There are three mineralogical ore associations that reflect the complex and long process of ore bodies formation. Below are the results of electron microscopic studies on ores of place of occurrence (Fig. 4).

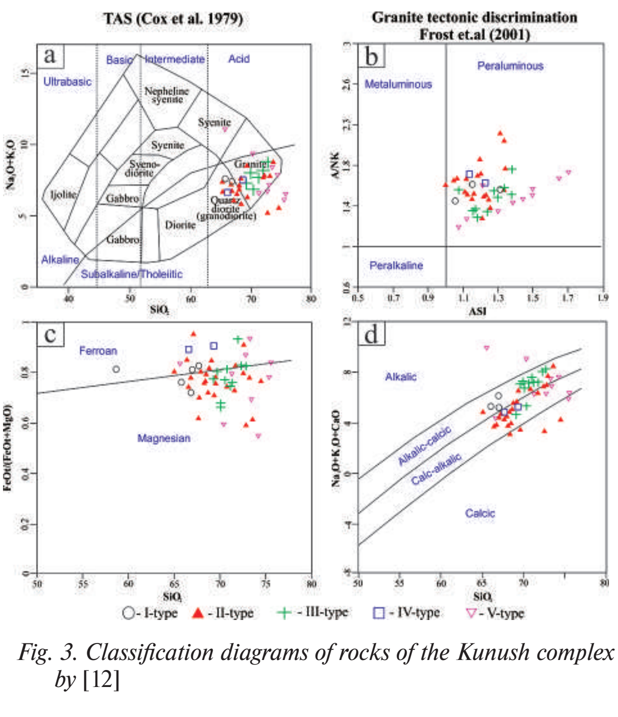

Fig. 3. Classification diagrams of rocks of the Kunush complex by [12]

Pyrites. Three types of pyrite were studied. Pyrite I associates with the sort of ferrous disulfide. It is found in all differences of carboniferous sedimentary rocks, has hexahedral faceting of crystals, their size is 0.1–1–2 mm (Fig. 4). Globular internal structure was defined in crystalline formations by structural etching, which is the ground to suppose that this pyrite type is formed due to ferrous disulfide of globular structure. Pyrite I is characterized by electron-hole conductivity, low value of thermoelectric coefficient, unit cell parameter changes from 5.406 to 5.409 A, sulphur to iron ratio is 1.93 + + 2.03. Characteristic impurity is manganese. According to our data, idiogenous sulphide mineralization is present in all rocks of Bakyrchik ore district although amount of early sulphides ranges from single crystals to pyritolite interbeds and depends on lithological composition enclosing rocks.

The minimal number and variety of pyrite I forms are characteristic for monotonous sandstone and gravelites where disulfide share does not exceed 1 %.

The biggest variety of pyrites I forms is characteristic in rocks of ore part – mixites and carbonaceous-shale aleurolites. The following formations can be found here: disseminated impregnation, massive lenticular and mashroom bundles with aureoles of disseminated (clouded) disulphides around them, pyritolites interbeds, clot and star formations. The ratio of syngenetic ferrous disulfide amount in sandstone interbedding and the rocks of ore pack is around 1 : 3 : 6.

Pyrite II is more spread. It is characterized by pyritohedron, rarely by hexahedral outlook. There are often combined crystal forms mainly with pyritohedron faces development. Pyrite II is characterized by zoned crystals. It closely associates with arsenopyrite, and its share is 75 % of total number of pyrites. It contains fine irregular grains of chalcopyrite, sphalerite, tennantite. The following nonmetallic minerals are connected with it – combed quartz, sericite, rarely albite.

Pyrite III has irregular hexahedral outlook of crystals, and forms veins in combination with copper sulfide, lead, zinc, in some places it replaces pyrrhotine. Its internal structure is

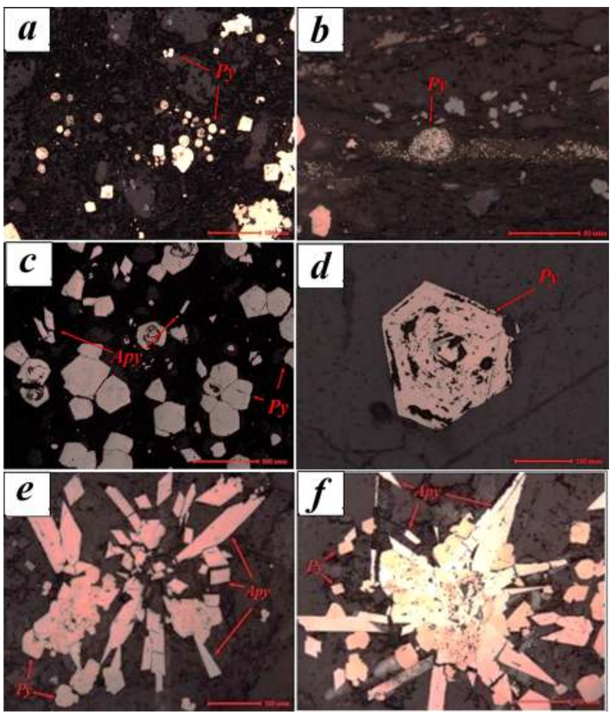

Fig. 4. Conversion pyrite I into dodecahedral pyrite II and pyrite III (optical microscope Olimpus)

simple. Characteristic impurity elements are copper, zinc, lead and arsenic (up to 0.3 %).

Marcasite is represented by three varieties. Marcasite I was formed during metamorphism of ferrous disulfide metacolloids recrystallization, having relics of colloform structure. Marcasite II appeared during recrystallization of earlier generation, whereas marcasite III is found in quartz-antimonite veins in the form of idiomorphic crystals replaced by antimonite.

Pyrrhotine associates with melnicovite-pyrite in metacolloid formations of ferrous disulfide in the form of globules, their relics are often found in arsenopyrite. Besides, it is in late associations with copper sulphides, lead, zinc, as well as in nickel-maucherite-chalcopyrite associations.

Arsenopyrite is represented by the three varieties: compact-grained (crystals in prism and pyramid combination), coarse-grained (acicular crystals with interpenetration twins and triplets), medium-grained (isometric bipyramidal crystals). All these varieties are found together. The mineral closely associates with gold-bearing pyrite II. Characteristic features of Kyzyl ore field arsenopyrite are increased parameters of crystal lattice, impurities of gold (up to 2000 g/t), stibium, low microhardness and reflective power.

The highest value of thermoelectric coefficient (120–250 μV/degree) is characteristic for the most gold-bearing acicular crystals, low value (50–120 μV/degree) is characteristic for short-prismatic crystals.

Gold is located in pyrite II and arsenopyrite. Both sulphides contain it in microscopic and submicroscopic forms (size < 10 μm). Gold grains – isometric particles of irregular shape, elongated, drop-shaped, vein-like. Three gold varieties were studied (Fig. 5).

Gold – I is finely dispersed and submicroscopic; it is found with pyrite II and arsenopyrite and disseminated in ore minerals (as in ores) rather uniformly. Average ratio of gold content in pyrite to gold in arsenopyrite is 1 : 2–3.

Gold – II development is restricted and distributed along micro-fissures in pyrite II and arsenopyrite in association with fahl ore, sphalerite , galenite, chalcopyrite, quartz and carbonate.

Gold – III is found in some cases in the form of inclusions in quartz- sericite-carbonate margins of sulphides in associations with antimonite.

Another type of ore mineralization is defined in deep horizons. This type is positioned in side and bottom walls of basic ores in relation to gold-arsenopyrite-pyrite. Ore formations are represented by lenticular concentration of brown spar with

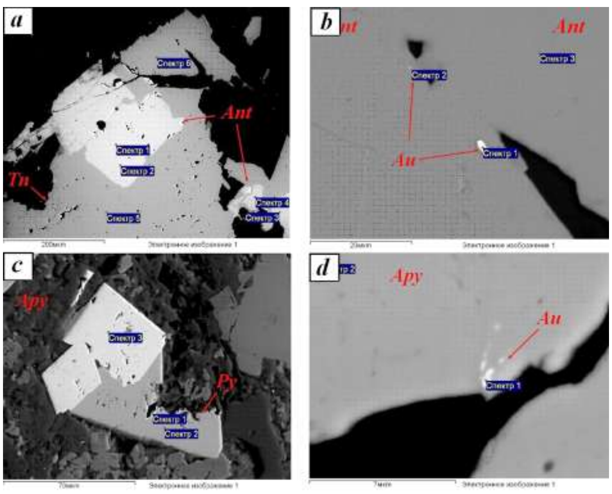

Fig. 5. Gold II in antimonite and in arsenopyrite (Scanning electronic microscopy):

a – antimonite and tennantite intergrowth; b – gold inclusion in antimonite; c – arsenopyrite and arsenical pyrite intergrowth; d – gold in arsenopyrite

quartz of nest and vein mineralization (up to 2 %). Its composition is as follows – free gold, pyrite: (100) and (100) + 111), chalcopyrite, sphalerite, scheelite, sometimes with pyrite II (210) and arsenopyrite. Gold is found in arsenopyrite at the contact of arsenopyrite with pyrite and quartz. Their shapes are oxygonal, octahedral, membrane-dendrite-shaped; particle size is 10–20 μm.

Free cloddy gold particles in quartz and carbonate are found in zones continuation and peripherally with impregnated pyrite-arsenopyrite mineralization. This gold share is up to 20 %. Arsenopyrite contains impurities of tungsten (up to 0.2 %), stannum, bismuth and molybdenum.

Chalcopyrite is present in ores constantly, but in small amounts in the form of inclusions and finest veins; it associates with sphalerite and fahlore in carbonates. It sometimes builds up central parts in globules of ferrous disulfides; forms decay structures with sphalerite.

Fahlores are represented by tennantite in pyrite-arsenopyrite ores and by tetrahedrite in quartz-antimonite ores. They develop everywhere but in very small amount; they associate with gold II, galenite, sphalerite, chalcopyrite.

Galenite and sphalerite are found in the same paragenesis and are disseminated in the same manner.

Antimonite is found in quartz-carbonate veins with marcasite III, native silver, stibium, and gold III, cinnabarite. Silver and cinnabarite are located in places of graphitized rocks with globular aggregates of ferrous disulfides.

Textural features of deposit ores are defined by two factors – ore-hosting rocks texture and abundance pattern of basic ore minerals (pyrite and arsenopyrite). The spread ores have impregnated spots and laminated structure.

Thus, the features of ore mineralization of Kyzyl ore field are confinedness of submicroscopic and microscopic gold to sulphide pyrite-arsenopyrite association, in some dikes – to gersdorffite-arsenopyrite. Besides, free gold was found in ores at deep horizons (V. N. Matvienko and V. L. Levin).

Zoning of gold mineralization of Bakyrchik ore field relative to deep intrusion. According to [3, 11], endogenous zoning of gold mineralization of the Western Kalba is manifested in the form of lateral zonation of formational and geochemical types, vertical sequence (dispersion) of deposits relative to deep intrusive bodies and vertical zonation of specific ore objects The reconstructed mesothermal ore-magmatic column of the region under examination, with a range of 3.0–3.5 km, consists of four indicator zones (rhythms), regularly replacing each other in the direction from the roof of the intrusive focus to the paleosurface (Fig. 7). From the bottom to the top of the column the following changes are noted: decrease in the temperatures of formation of productive mineral associations; change of mineralization profile from rare metal and gold-rare metal (rear and intermediate zones) to gold and gold-antimony-polymetallic (frontal and near-frontal zones); increase in sulphidity of mineralization against the background of the "through" development of the pyrite-arsenopyrite association; change of quartz-vein types of mineralization with free gold, impregnated ores with bound gold in sulphides; regular sequence of hydrothermal changes (tourmalinization – beresitization – argillization, albitization); a contrast increase in productivity of gold mineralization (the major Suzdal deposit and the very major Bakyrchik deposit are located in the near-frontal and frontal zones) (Fig. 6).

Tiered dispersion and vertical variability of deposits are considered as an indicator of multistage, polygenous ore formation, which includes concentrated redeposition of useful components with an active participation of carbon-bearing sediments with an increased gold clarke in this process.

The huge concentration of gold in the apical part of the column (Bakyrchik) is the result of a long (hundreds of million years) ore formation, metallogenic succession, the combination of several sources of noble metal (primary-sedimentary, metamorphogenic, fluid-hydrothermal). The spatial combin-

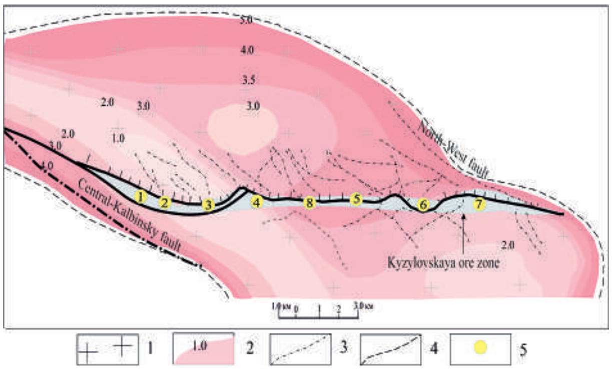

Fig. 6. The contours of the deep intrusive massif within the Kyzylovskaya crush zone:

1 – granitoids; 2 – contours of intrusions at depths of 1.0 km, 2.0 km, etc; 3 – faults; 4 – contours of the projection of intrusions on the surface; 5 – deposits: 1 Zap.Bolshevik; 2 Bolshevik; 3 Chalobay; 4 Cholodnyi Klyuch; 5 Bakyrchik Centralnyi; 6 Bakyrchik Promeshutochnyi; 7 Glubokii Log; 8 ore occurrence Zagadka

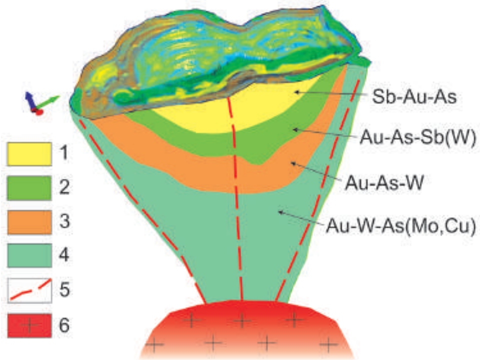

Fig. 7. Model of ore geochemical specialization of the Bakyrchik deposit:

1 – upper ore, quartz-carbonate, antimonite-tetrahedrite association (Sb-Au-As); 2 – ore, gold-pyrite-arsenopyrite (Au-As-Sb); 3 – medium-lower ore, gold-arsenopyrite with rare metal intrusion (Au-Ar (W)); 4 – lower ore, pyrite-arsenopyrite (Au-W-As (Mo, Cu)); 5 – deep intrusion

ation and "mutual transitions" of the rare metal (Sn, Mo) and gold types of mineralization observed in the rear zone, the location of such objects in a single system "intrusive-superintrusive zone" testify in favor of their formation under the prevailing influence of a magmatogene-hydrothermal source.

The analysis of the geological conditions of Bakyrchik deposit formation reveals a complex history of accumulation and concentration of gold in gold-arsenic-carbonaceous ores. Globally, this was the time of the closure of the Paleo-Asiatic Ocean, the merger of the Kazakhstani-Kyrgyz continent with the Tarim, East-European, and Altai-Mongolian continents during which the processes of final orogenesis and granitoid magmatism proved themselves in a contrasting and varied manner. There are known the presentations of Korobeynikov A. F., Fogelman N. A., Marchenko L. G., Mysnik A. M., Narseyev V. A., Zhautikov T. M., and other researchers on the staging of ore formation and the dual source of gold (sedimentary and juvenile) on the objects of the Bakyrchik type.

In this regard, the genesis of gold mineralization of Bakyrchik can be considered as a remobilizationally hydrothermal process with the primary accumulation of sedimentary-diagenetic gold in unlithified sediments of the Bukon formation and the receipt of hydrothermal solutions with juvenile gold of the magmatic source, redistribution and concentration of noble metal in thermo-abnormal zones. Such a process of ore formation with a staged concentration of gold probably contributed to the formation of major gold ore deposits in the black shale strata, which is in agreement with the ideas [12–13]. Subsequently, in the Permian and Mesozoic periods, Bakyrchik deposit ores, as well as ores on other objects of the Western Kalba, experienced transformation as a result of intraplate activation in the post-collision geodynamic environment [14–15].

The discussion of the results. Gold ore deposits in carboniferous volcanogenic-carbonate-terrigenous formation make up considerable share of the world gold reserves. Large objects are known in the USA, Australia, Russia, China, Kazakhstan and other regions of the world.

Analysis of geologic conditions for forming deposit Bakyrchik proves complicated history of gold accumulation and concentration in ores of gold-arsenic-carbon-bearing type. Ore bodies of the deposit are represented by mineralized zones of banded, phacoidal and tabular shapes of considerable thickness (up-to 10–20 m) and more than 1.0–1.2 km deep. Basic ore-control elements are failure frames of north-west and sublatitudinal direction (overthrusting, shift-upthrow fault), lithological composition of reservoirs and magmatic formations (granitoid mass hidden in depth 3.0–3.5 km and dikes of marmorate compound noted in the zone of ore-bearing reverse) [16–17].

Carbon-bearing, sericitic, kaolinite-hydromica, quartz-sericitic, sericite-phlogopite-carbonate, chlorite-albite and other metasomatic associations develop on the deposit. Metasomatic zoning of Bakyrchik deposit looks like follows below. Carboniferous-kaolinite-hydromicacous metasomatites develop on upper horizons, carboniferous-sericitolitic changes have "through" expansion (they are most developed in central part of ore reserves), sericite-phlogopite-carbonate with apatite and tourmaline association occupies lower levels. The ore bodies of the deposit can be traced according to geophysics data and drilling operations to a depth of 1.5 km. The shape of the ore bodies is ribbon-lenticular and residential. The capacity of ore bodies is up to the first tens of meters. Ore minerals of Bakyrchik deposit form five paragenetic assemblages [18–19]: early melnicovite-pyrites-pyrrhotine-marcasite (with nickeline and pentlandite); ore gold-pyrite-arsenic pyrite (with cubanite and gersdorffite), gold-quartz-polymetallic (fahlore, chalcopyrite, galenite, and sphalerite), and gold-quartz-carbonate-scheelite-chalcopyrite (with breunnerite, dolomite, aikinite, free gold); late quartz-carbonate-antimonite-tetrahedrite (with marcasite, remanie gold). Gold-pyrite-arsenic pyrite assemblage have "through" expansion, melnicovite-pyrites-pyrrhotine-marcasite melnicovite-pyrites-pyrrhotine-marcasite and gold-quartz-carbonate-scheelite-chalcopyrite are developed at deep levels, gold-quartz-polymetallic and quartz-carbonate-antimonite-tetrahedrite are inclined to upper and medium horizons. Impregnated and vein-impregnated gold-pyrite-arsenic pyrite assemblage association is the most significant (90 %) in total mass of sulphides and total gold balance [20].

Conclusion. The considered region was formed into collision stage of Hercynian structures development in eastern part of Kazakhstan. Geodynamical evolution of earth crust and active tectonic transport of lithospheric blocks at the border of Kazakhstan and Siberian continental margins provided duration of development mineralization process. These global shifts formed systems of diagonal faults of west-north-west extension at an angle of initial faulting of north-west direction. In paleo-depression, which occurred when earth crust was expanded, terrigenous molasses and volcanogenic molasses (C_2, $C_{2\text{-}3}$) were formed. Intrusive magmatism of gabbro-diorite-granodiorite-plagiogranite series of crust-mantle origin developed. Obviously, sources of ore substance were combined due to remobilization of disseminated gold from enclosing terrigenous rock mass according to exogenous-endogenous ore-energy model and formation of gold-bearing minor intrusions and dikes.

The data obtained on the influence of heat fluxes and hydrotherms of small intrusions and of the Kunush complex on the ore formation processes of the deposits of the Kyzylov crumple zone (Bakyrchik ore field) allow us to identify promising areas for the search for new gold ore objects of gold sulfide and quartz-vein types. First of all, these are zones confined to the areas for the fall of ore columns of already known deposits and manifestations of the Kyzylov zone.

Also, promising areas can be countered by lying at depths from 1.0 to 3.5 km, the West Kalba intrusive belt and the frame of discontinuous violations of various orders. Signs of ore mineralization can be different in their composition and degree of prevalence of metasomatic formations, as well as specific mineral paragenesis.

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Геологія, магматизм і особливості мінералізації Бакирчикського рудного поля (Східний Казахстан)

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Мета. Визначення особливостей формування золотого зруднення у межах Бакирчикського рудного поля та впливу глибинних інтрузивних порід на формування рудних тіл.

Методика. Аналіз літературних даних, інтерпретація результатів геофізичних досліджень, проведення польових робіт і лабораторні дослідження мінералогічного складу рудних тіл та дайок кунуського комплексу (ISP-MS – Agilent 7500cx), вивчення основних типів мінеральних асоціацій і навколорудних змін (JSM 6390LV).

Результати. Розглянуті особливості геології, магматизму й рудоутворення одного із золоторудних родовищ мезотермального класу в чорних сланцях Бакирчик, розташованого в Західно-Калбінській металогенічній зоні (ЗКМЗ) у Східному Казахстані.

Наукова новина. Усі відомі біля Західної Калби геолого-промислові типи золотого зруднення за пріоритетністю діляться на кілька рівнів. Найбільш перспективний, але, незважаючи на багаторічні дослідження, недостатньо вивчений рівень, представлений Бакирчикським рудним районом.

Практична значимість. Підкреслюється зв'язок золотого зруднення родовища Бакирчик із зонами тектонічно ослабленої літосфери та з виявленими за геофізичними даними прихованими гранітоїдними інтрузіями, що дозволить використовувати ці дані для проведення подальших геологорозвідувальних робіт у межах Західної Калби.

Ключові слова: *геологічна будова, золото, магматизм, родовища, Західна Калба, металогенічна зона, Казахстан*

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