UDC 553.311

GEOCHEMICAL ZONING OF SKARN-GOLDEN-ORE DEPOSITS OF WESTERN SIBERIA. P. 2.

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Geochemical zoning of Western Siberia gold-skarn deposits is investigated. The concentric zoning construction of geochemical field abnormal structures accompanying studied deposits is revealed. Groups of concentrating and deconcentrating (in relation to golden-ore bodies) elements are determined. Close spatial connection of gold with the complex of chalcophile elements-satellites, set of which can change during evolution of hydrothermal system, is established. The set of deconcentrating elements, accumulated on periphery of ore bodies, in general is standard and includes Ni, Co, Cr, V, Ba, Mn. Discussion of genetic aspects of the revealed geochemical zoning is realized.

Besides golden-ore skarn deposits itself, significant resources of gold are possessed by numerous skarn-magnetite deposits of the Altai-Sayanskaya folded area. Their gold-bearing ability has been known for a long time, but due to a number of reasons the majority of them was fulfilled and continues to be fulfilled as purely metal-ore. Meanwhile, numerous special investigations show that the given group of deposits possesses solid precious-metal potential, development of which is an actual problem. In particular, the auditing works lead by «Tetis-T» corporation in skarn-magnetite deposits of the Telbesskiy ore belt of the Mountainous Shoria was established that within the limits of each of the ore fields, which are part of the belt, dozens of tons of gold and silver [1, 2] are contained in industrial concentration. The Kazskiy ore field, being a component of the Telbesskiy group of metal-ore deposits, is the most studied one concerning precious-metals mineralization., therefore, can serve as a standard for model development of Western Siberia skarn gold-magnetite deposits geochemical ash value.

Tectonically speaking, The Kazskiy ore field is dated to the Telbesskiy deflection of latitudinal strike, generated along the abyssal fracture which defined a block-like area structure and created favorable conditions for magmatism and metasomatose display. The ore field territory is presented by sublatitudinal horst combined by vend-cambrian volcanogenic-sedimentary deposits – marble, andesite-basalts, andesites, less often sandstones, dacites belonging to the Sucharinskiy complex of the Telbesskiy sector of the Altai-Kuznetsk vend-early-ordovician volcano-plutonic belt [3]. The monzo-gabbro-melanosienite hypabyssal complex cropping out in the limits of the same name deposit belongs to magmatic formations of this stage [3].

Vend-ordovician rocks with angular disagreement are blocked by volcanites of the limestone-alkaline structure belonging to the Altai-Minusinskiy early-mid-ledevonian volcano-plutonic belt formations. Magmatic formations of the lower Devonian belong to the Bolsherechenskiy gabbro-norite and the Telbesskiy monzodiorite-granodiorite-melanogranite complexes [3].

The gabbro-norite complex is characterized by low alkalinity, weak differentiation and basic rock leucocratic gradient which testify to their accessory to weakly-differentiated gabro-norite-diorite formational type [4].

The Telbesskiy complex is presented subalkaline diorites (1st phase), granodiorites and granites (2nd phase).

Skarnization, magnetite and gold-sulphidic mineralization are connected both with timber industry and the Telbesskiy complexes. On magnesial and limy skarns magnetite and gold-sulfide-quartz paragenesises are consistently imposed. The overwhelming part of gold-bearing skarn-magnetite deposits of the Kazskiy ore field is spatially dated to contact zone of the Telbesskiy complex diorites which allows considering the given complex as the main ore-generating for these deposits. Within the limits of the ore field in present time more than 30 gold-bearing quartz-sulphidic zones usually dated to magnetite deposit periphery are allocated [1, 2]. Gold is closely associated with galenite, sphalerite, pyrite, pyrrhotite. In structural plan gold-bearing zones of sulphidization are dated to tectonic infringements and hinges of anticlinal folds (Fig. 1). Vertical scope of gold mineralization within the limits of the Kazskiy ore field is estimated not less than in 1000 m [1].

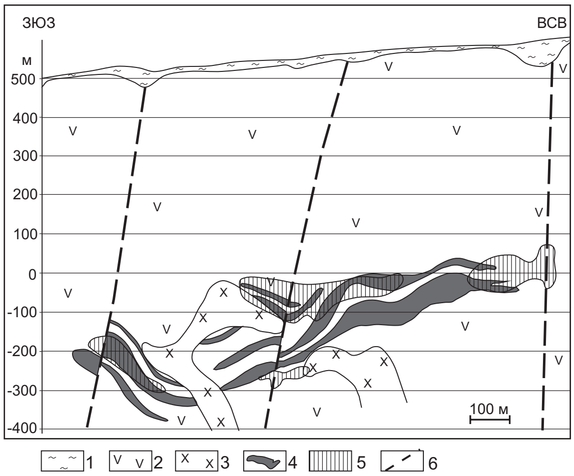

Fig. 1. *Longitudinal geological section through Southern Zone of the Kazskiy ore field deposit (based on materials of «Tetis-T»): 1) Friable deposits; 2) the Sucharinskiy complex: andebasalts, calcitic and dolomitic marble; 3) diorites of the Telbesskiy complex; 4) skarn-magnetite ore deposits; 5) quartz-sulphidic mineralization zones; 6) explosive infringements*

To study deposits geochemical zoning we use results of 4500 spectral, spektrogoldmetrical and assay analyses (on Au and Ag) on wells core and mountain developments of the easten part of the ore field (Tsentralnie Shtoki, Dalnie Shtoki, Uzhnaya Zona). Following geochemical parameters were used: 1) associations of correlated elements revealed by the factorial analysis, 2) ore-formation energy [5], 3) coefficients of elements relative concentration (OK) Co:Ni, Pb:Zn [6].

The structure of abnormal geochemical field is most evidently shows in longitudinal sections of sulfidized skarn-magnetite deposits (Fig. 2).

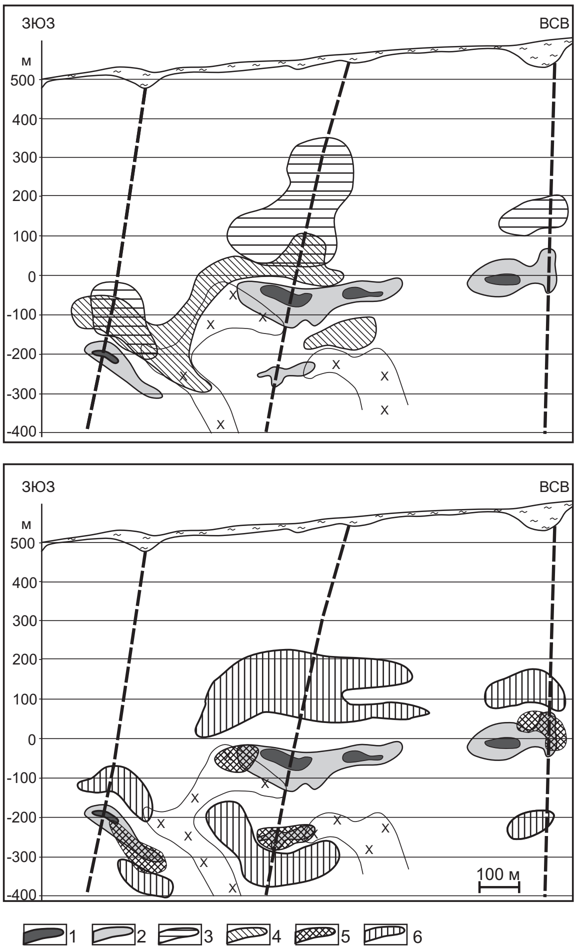

Fig. 2. *Distribution of geochemical parameters anomalies in a cut through Southern Zone deposit of the Kazskiy ore field: 1) F1=0,36Ag+0,35Pb+0,28Cu+0,25Zn+0,23Au+0,19As (>4,8); 2) F2=0,48Ni+0,46Cr+0,20Co (>3,0); 3) F3=0,47Ba+0,42Mn (>2,4); 4) Ti (more than 0,55 %); 5) OK Co:Ni (more than 12,0); 6) OK Pb:Zn (more than 50,0)*

Areas of gold-sulphidic mineralization concentration are characterized by accumulation in their central part of Au, Ag, Pb, Zn, As, Cu. According to the factorial analysis this association of correlated elements can be presented in the form of the regress equation: F1=0,36Ag+0,35Pb+0,28Cu+0,25Zn+0,23Au+0,19As.

Element content is expressed in geophones (correlation of element content in a sample to its background content in corresponding rocks). Levels of background and minimally abnormal concentrations for all revealed associations were calculated by a standard technique based on the lognormal law of distribution. In unchanged rocks values F1 fluctuate within the limits of 0,55...4,8, in sulfidized skarns they reach 1580. Areas of superbackground values of this association in general correspond to golden-ore bodies. Here, the raised concentration of elements of platinum group elements was revealed by special research [7].

For periphery of sulfidization zones the accumulation of Co, Ni, Cr connected with pyrite-pyrrhotite mineralization is typical. The regress equation for the factor uniting these elements looks like: F2=0,48Ni+0,46Cr+0,20Co. Parameter values in unchanged rocks do not fall outside the limits of 0,6...3,0, on periphery of sulfidization zones they reach 42,0.

The factorial analysis also reveals the association F3=0,47Ba+0,42Mn, abnormal values of which (up to 35,0) are dated to supra-ore parts and gravitate to ore-controlling fractures. In unchanged rocks the fluctuation parameters make 0,7...2,4.

On periphery of sulfidization zones located near contact with diorites titan anomalies are usually marked (0,7...1,0% at content minimum-abnormal level in unchanged rocks 0,55 %).

Abnormal values of OK Co:Ni (up to 50,0 in the background 5,8...12,0 in containing rocks) are typical for flanks of sulfidization zones and usually gravitate to ore-controlling fractures. The most intensive anomalies of the parameter OK Pb:Zn (up to 10000 in the background 5...50) are marked in the supra-ore area (40...60 m above sulfidization zones); less intensive (up to 500) – in the sub-ore.

Parameters of ore-formation energy are calculated separately for concentrating (Au, Cu, Ag, Bi, As, Pb, Zn) and deconcentrating (Ni, Co, V, Ba) in elements golden-ore bodies. For concentrating elements the maximal values (up to 11000) of the ore-formation energy parameter (E_{conc}) are established in central parts of sulfidization zones, in containing rocks its fluctuations is within the limits –1,0...70,0. Deconcentrating elements are collected in periphery of sulfidization zones where values of the parameter E_{deconc} reach up to 50,0 at background values from –1,4 up to 8,0.

Discussion of results

Characteristic feature of gold geochemistry is high degree of its protoconnections stability (inherited from protoplanet-mantle level) with Fe, Ag, Cu, Ni, Co, Hg, Mn, Ti, Mg, P [8,9]. In hydrothermal process itself the closest connections of gold are established with the elements forming intermettalites (Ag, Te, Se) and sulfides (Cu, As, Sb, Bi, Pb, Zn) [10]. As a result, in primary aureoles of hydrothermal deposits gold associates with Ag, Cu, As, Bi, Sb, Pb, Zn, and anomalies Ti, Mg, P, Mn are usually dated to orecontrolling structures outside of ore bodies. Peripheral position in abnormal structures of geochemical fields (ASGF) also barium, one of the most centrifugal elements. There are some exceptions from this rule: gold-barite-polymetallic ores in pyrite-polymetallic deposits, anomalies Ti, P, Mg in beresites of other golden-ore deposits controlled by deep fractures [11].

In considered skarn-golden-ore deposits certain evolution of gold connection with the complex of its elements-satellites is traced. In skarn-magnetite deposits industrial concentration of gold are dated to chalcopyrite-galenite-sphalerite mineralization (Cu, Pb, Zn, Ag), in smaller quantity – to pyrite-phyrrhotite-arsenopyrite (As). In golden-ore deposits of the Sinuhinskiy type gold is closely associated with Te and Bi and concentrates in bornite and chalcosine, much less often – in chalcopyrite. Galenite, sphalerite, asenopyrite, pyrrhotite, pyrite here practically are not gold-bearing. In Mayskiy magnetite-golden-ore deposit (Mountainous Shoria) which in ore structure takes an intermediate position between two considered types of deposits gold is connected with two mineral associations: 1) chalcopyrite-galenite-sphalerite (Cu, Pb, Zn, Ag) and rather later tetrahedrite-telluride-sulfosalt (Cu, Ag, Bi, Te) [12]. Pyrite, arsenopyrite, pyrrhotite have poor gold-bearing ability.

The reason of the revealed distinctions is covered, probably, in a different degree of considered hydrothermal systems evolution. At formation stage of early sulfides gold in the form of impurity and in a natural kind concentrated in pyrite, pyrrhotite, arsenopyrite (up to tens of g/t). The subsequent chalcopyrite-galenite-sphalerite mineralization is characterized by further addition of gold (up to hundreds g/t). Late sulfide-telluride-sulfosalt mineralization is accompanied by the greatest degree of gold concentration (up to several kg/t in ores of the Sinuhinskiy type) correlated with low gold-bearing ability of other mineral paragenesis. The latter testifies not only about addition, but also essential redistribution of gold at each subsequent impulse of ore deposition. As a result the central parts of ore bodies (and ASGF) are presented depending on type of the deposit, by association of gold or with the complex Ag, Cu, Pb, Zn, As, Bi, Te, or with a part of these elements (the others in this case are collected behind a contour of industrial mineralization). Pyrite from the external frame of ore bodies has poor gold-bearing ability but contains Co, Ni, V in high concentration (up to 0,1 %), therefore, it is possible to consider the given association as the indicator of ASGF frontal zones.

Ti, Ba, Mn on the studied skarn-magnetite deposits quite often form mutual anomalies in near-ore space but this overlapping is only spatial and, probably, does not bear genetic obligation. It is characteristic that titan anomalies are dated to granitoids contact zone, which allows connecting the addition of this element with intrusive development. At the same time, super-background addition of Ti is fixed only in a frame of sulfidization and silicification zones. Possibly, sedimentation of the titan migrating in alkaline solutions is connected with inversion of acid-alkaline mode of fluids and occurs in external border of acid metasomatosis zones. For Ba and Mn, on the contrary, it is possible to assume their subtraction from skarn minerals at silicification and sulfidization (as their content decreases in 1,5...2,0 times) and redeposition outside of skarn bodies, mainly in supra-ore areas.

On the whole, the character of spatial distribution of concentrating and deconcentrating elements finds an explanation within the limits of hydrothermal ore-formation convection models. In the initial period of hydrothermal system functioning fluids are quiet uniformly oozing in weakened zones forming abnormal structures of simple construction with direct temperature zoning. Hydrothermal system self-organization on the background of focusing influence of explosive infringements [13, 14] and involving in it convective streams of colder vadose waters leads to division of the general thermal anomaly into system of competing convective cells. As a result, in the most permeable part of structure the central (nuclear) zone of system is formed, and on flanks – a zone of the peripheral thermal anomalies separated from the center by area of lowered temperatures [15]. Along ascending branches of the convective system there is a contact of juvenile and local fluids and their gradual mixing with formation of ore mineralization. As in external zones of convective cells only local solutions circulate, the element structure of anomalies arising here practically does not depend on structure of the juvenile fluid. Subtracted from the central zone at acid metasomatosis elements also precipitate at its periphery. From ore-forming silicates a standard set of elements-impurity is usually leaching, hence, the content of ASGF external zones in deposits of various gelogo-industrial types should be close. Indeed, the set deconcentrating elements is close for the majority of hydrothermal sulphidic deposits and includes Ni, Co, V, Cr, Mn, Ba, less often Ti. Many researchers note the decrease in concentration of these elements in the field of ore deposition and their accumulation outside of acid metasomatosis zones, which is often interpreted as subtraction and redeposition [16–22].

The additional information on ASGF structure and its genesis give relative concentration (RC) coefficients of related elements. According to U.G. Scherbakov [6], values of RC parameters in ores increase from root sections of hydrothermal deposits to apical, which reflect a various degree of elements, included in coefficients, configurality. The similar tendency is established by V.I. Silaev in distribution of elements-impurity in ore minerals: in the central parts of various rank ore objects minerals are enriched by centripetal elements, and on their periphery – centrifugal [23]. The results obtained by us also testify to the differential distribution of elements caused by their different configurality: RC anomalies Co:Ni are dated to flanks and root parts of sulfidization zones, and Pb:Zn – to supra-ore space. Presence of sub-ore anomalies OK Pb:Zn stated by us on studied deposits is connected, probably, with lead leached from containing rocks and deposited on descending branches of convective systems.

Conclusion

1. During hydrothermal systems evolution of skarn-golden-ore deposits gold consistently concentrates in mineral parangenesises: pyrite+pyrrhotite+arsenopyrite chalcopyrite+galenite+sphalerite borni-

te+chalcosin+tellurides and sulfosalts. Depending on completeness degree of gold redistribution process it can be connected either with one of these complexes, or with two neighboring ones. Accordingly, the typomorphic elements golden-ore bodies are either a complex of elements Ag, Cu, Pb, Zn, As, Bi, Te, or its part (the others in this case are fixed behind a contour of industrial mineralization). The external zone of interspersed pyritization is characterized by abnormal concentration of Co, Ni, Cr. In supra-ore parts of ore-controlling fractures the anomalies Ba and Mn, connected with subtraction of these elements from quartz-sulphidic zones, are marked. At periphery of sulfidization zones titan anomalies are also stated.

2. The revealed abnormal structures of geochemical fields have a concentric zonal structure. The content of the internal zones of these structures reflects metallogenic specialization of hydrothermal solutions; in external zones the standard set of elements leached from containing rocks is collected: Ni, V, Co, Cr, Ba, Mn. Features of spatial distribution of concentrating and deconcentrating (in relation to ore bodies) elements find an explanation within the limits of the hydrothermal ore-formation convective model.
3. The confinement of coefficients RC Co:Ni anomalies to flanks and the sub-ore space imposed on skarns of gold-bearing quartz-sulphidic zones, and RC Pb:Zn – to supra-ore, less often sub-ore areas is stated.

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Received on 04.09.2006