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MINERALOGICAL PETROCHEMICAL AND GEOCHEMICAL FEATURES OF NEAR ORE METASOMATISM IN THE GOLD ORE DEPOSIT «VERKHNE-SAKUKANSKOYE» (NORTHERN TRANSBAIKAL REGION)
P. 1. A geological structure of the deposit and identification of the ore enclosing igneous rocks

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Discussion in comparative aspect of the nature of geochemical fields in the mesothermal gold deposits formed in blacks and a crystal substratum is continued. The relation of near vein metasomatic and geochemical auras for a case of intervein spaces of low gold-bearing quartz veins is shown on the example of the deposit «Verkhne-Sakukanskoye» of Northern Transbaikal Region located in southwest early Proterozoic frame of the Chara ledge of the Archean base – the western fragment of the Aldan board.

In the first part of the article the geological structure of the deposit, mineral structure of ores are considered. On the basis of studying of mineral composition and structure of rocks with attraction of original chemical silicate analyses and petrochemical calculations the enclosing ore containing bodies of plutonic rocks of the early Proterozoic Kodarsky complex are diagnosed as hornblende – biotite quartz diorite and quartz monzonite.

In the second part of the article for the first time a mineralogical – petrochemical zonation of near vein metasomatic auras is described, their belonging to a beresite metasomatic formation, and belonging of the deposit to the gold subformation of a gold – uranium – polymetallic beresite ore formation is proved. The geochemical materials revealing distribution on near Clarke levels of contents of ore genous elements (Au, Ag, Hg, etc.) in an intervein space is given, genetic connection of near vein geochemical auras with near vein metasomatic ones in frames of mesotermal ore-forming process of late Paleozoic epoch is substantiated. The obtained results are consistent with conclusions about structure and conditions of formation of the geochemical fields, made earlier in others mesothermal gold deposits of blacks and not slate types.

Introduction

There are problems in the theory of mesothermal ore formation which by virtue of insufficient development, but the high theoretical and applied importance demand the further analysis, discussion and the decision. In application to gold ore deposits at the significant knowledge of physical and chemical and thermodynamic modes of formation of mineral ores complexes and near ore metasomatite achieved up tow, the debatable problem of conditionality of ore formation by more scale geological processes is highlighted. An abundance of corresponding multiple decisions and as consequence, hypotheses reflects as it seems, not so much variety of possible geological modes and situations of formation of deposits, sources of metallic bearing solutions and metals in them, as deficiency and, as it regrettably to recognize, ignoring of the known reliable facts if they are «inconvenient» for a discussed hypothesis – are not entered in it or contradict it.

The many years discussion on a theme about origin of the largest Sukhoy Log and other similar deposits located in series of carbonaceous slates serves the example of it. Set of the facts showing material – geological – genetic uniformity of these deposits with gold mesothermal deposits, formed in any other, including a crystal substratum [1, 2], still is in works of many researchers beyond of discussion frames of the problem. These facts include space – time relations of ores, near ore metasomatites and magmatic rocks of the basic composition. The Kadali – Sukhoy Log deep fault, controlling the ore bodies of the Sukhoy Log, is saturated with basite dikes (diabases) [3], which age is equal to the ore age [4], among which one distinguished early prevein and aftervein ones. [5]. The prevein dikes include applied mineral associations representing near vein metasomatic changes of the beresite profile, the aftervein include specific sets of epigenetic minerals (biotites, amphiboles, etc.) which are qualified as products of inner dike metasomatism, which does not go beyond dike limits and is caused by accumulation in still hot dikes jets rising from the centers of generation of metallic bearing solutions.

Similar metasomatically changed, including intraore and lateore dikes – fluids conductors of dolerites which are known in the «Sovetskoye» and other gold ore deposits of the Yenisei range, have been found and investigated in different age deposits of the Mariinskaya taiga, Southern Nearbaikal Region, Northern Transbaikal Region, formed in volcanic series, ultrametamorphical substratum of Archean base and Paleozoic nucleation site dome constructions, granitoids, series of prepaleozoic carbonaceous slates [1]. These and other facts testify to realization of ore-forming processes in conditions of high fluid-magmatic activity of the mantle and, taking into account ability of water-gas fluids to extract metal compositions from melts [6, and others], are passed with magmatogenous – hydrothermal concept of ore formation [7]. From positions of metamorphogenous – hydrothermal concept such relation of basites and ores are to be explained by any way, however up to now it is not made.

Efforts of specialists taking part in development of the ore formation problem in the blacks substratum by tradition of times of popularity of the littoral-secretory hypothesis of the beginning of XX century are focused on studying of gold content of enclosing blacks. The sight on the blacks series as donors of gold at ore formation, being popular among supporters of the metamorphogenous – hydrothermal concepts, leans on those results of geochemical researches according to which blacks possess increased and even high, up to grams on ton, preore gold content [8–12, and others]. It is considered as the necessary and sufficient prerequisite (condition) of ore formation. Alternative estimations of preore gold content of the same ore enclosing slates at the level of the first mg/t [13, 14, and others], meaning a recognition of sinore enrichments of near ore spaces with gold and other metals, are not discussed. In that rare case when one of authors of the estimation of low gold content of slates has made attempt to explain it, discussion of the geological reasons of ore formation did not go beyond frames of the one side-narrow geochemical approach and its substantiation was reduced to the assumption about generally high preore gold content of the slates impoverished with metal owing to its resedimentation from them in ore bodies [15].

Now, after many decades of geochemical researches in the gold ore areas of slate type, the estimation of preore gold content, and, hence, donor potential of rocks remains still contradictory. As it was noted earlier [16], the reason is in use of methods of search geochemistry which provide obtaining of the information about final metal content of enclosing and surrounding substratum, but are not capable to open the geological history of metals in them and are not intended to solve the given genetic problem. Its correct solution is possible by means of detailed mineralogical-petrochemical and geochemical mapping of rocks forming ore fields, formations of multilevel system of geochemical sample which basis is formed by the mineral complexes according to a stage of initial formation of rocks and stages of their subsequent changes, including the ore formation stage.

The given approach in the multiplan analysis of ore forming factors is realized by the author in comparative aspect. Searches of a possible geochemical originality of ore enclosing blacks series compared with other, crystalline, volcanic substratum are carried out by means of comparison of structure and parameters of geochemical fields in that and other case with differentiation of near ore space in dependence on industrial parameters of ores. Results are partly published [16–21, and others].

The article is continuation of the publication of the materials revealing mineralogical-petrochemical features of nearvein metasomatism and distribution of the metals (Au, Ag, Hg, etc.) being geochemically bound in ores and in nearvein space for the case of low gold content at levels available for studying being localized in crystalline rocks of quartz veins on the example of the gold ore deposit Verkhne-Sakukanskoye of Northern Transbaikal region the object which earlier has been not described in the literature.

The complete chemical silicate analyses of rocks are carried out in the CL PGO «Zapsibgeologiya» (Novokuznetsk) under I.A. Dubrovskaya`s leadership. Contents of gold and silver were defined by base (all sample array) atomic – absorption method with sensitivity of 0,1 mg/t in the laboratory of nuclear-physical methods of analysis of United Institute of Geology, Geophysics and Mineralogy of the Siberian Branch of the Russian Academy of Science (Novosibirsk, analyst V.G. Tsimbalist), for the control (15 % of samples) – by neutron-activation one (sensitivity of 0,1 mg/t) in laboratory of nuclear-physical methods of analysis of the nuclear reactor of the Tomsk polytechnic university (analyst V.L. Chesnokov), by chemical-spectral one (sensitivity – 0,3 mg/t) in the CL PGO «Chitageologia». The estimation of convergence of results is given in [18]. We shall note, that the average relative error (?) on differences of double measurements of Au contents by the first and second methods makes 23 %, the first and third methods – 50 %. According to the internal control of definition by the method of nuclear absorption of Au contents ? does not exceed 23 %, Ag contents – 14 %. Contents of mercury in rocks was defined by the atomic – absorption method (sensitivity of 1,0 mg/t), nonferrous metals – by the spectral method in the CL of the PGO «Beresovgeologia» (Novosibirsk) under N.A. Charikova's leadership.

Brief essay of geological setting and mineral composition of ores of the deposit Verkhne-Sakukanskoye

The deposit Verkhne-Sakukanskoye of quartz – vein type has been discovered in 1950. by P.E. Lunenok and is located in the right board of the bottom current of the left inflow of the Chara-river in its top current – the Verkhny Sakukan river, originating on the near watershed slopes of the Kodar riedge (fig. 1). Detailed search works in difficult geomorphological conditions of the steep slope (up to 60°) relief with numerous steep cliffs, kurums, cedar stlannick found and followed 20 quartz veins which majority has been estimated in 1951–1953 with working of ditches, clearings, deep (up to 10 m) inclined prospecting shafts and gallery (on the main vein) with length 83 m.

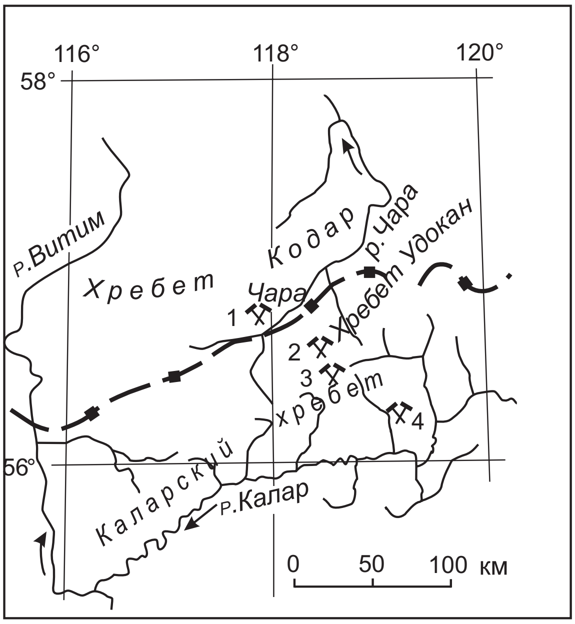

Fig. 1. The chart of arrangement of ore deposits of the Northern Transbaikal Region. Deposits: 1) Verkhne-Sakukanskoye, gold ore, 2) Udokanskoye, silver – copper, 3) Chineyskoye, titanium – magnetite, 4) Katuginskoye, rare metal. The dotted line shows the BAM line

The deposit is located in southwest early Proterozoic frame of the Chara ledge of the Archaic base – western fragment of the Aldan board. Ore enclosing faults with extent up to many hundreds meters and thickness up to 2,5 m are oriented in submeridional direction with falling under flat (up to 45°) angles on the West, set in the large massif of middle acid plutonic rocks of the Kodarsky complex which age is 1780±30 and 1900±40 mln years [22], 1,70...1,76 bln years [23]. There are rare dikes of aplite, pegmatite, dolerite which is after by hydrothermal way (biotites, chlorites, sericite, etc.) in magmatic rocks. Preore dikes of the last serve as localizers of some ore enclosing infringements (fig. 2), carrying attributes of chip origins, – smooth change of orientation, numerous mirrors of sliding on the walls of cracks, blowings and clutchings as result of sliding of their trailing and lying sides, friction clay. The ore enclosing faults are crossed by rare cross-section infringements with amplitudes of displacement up to several meters.

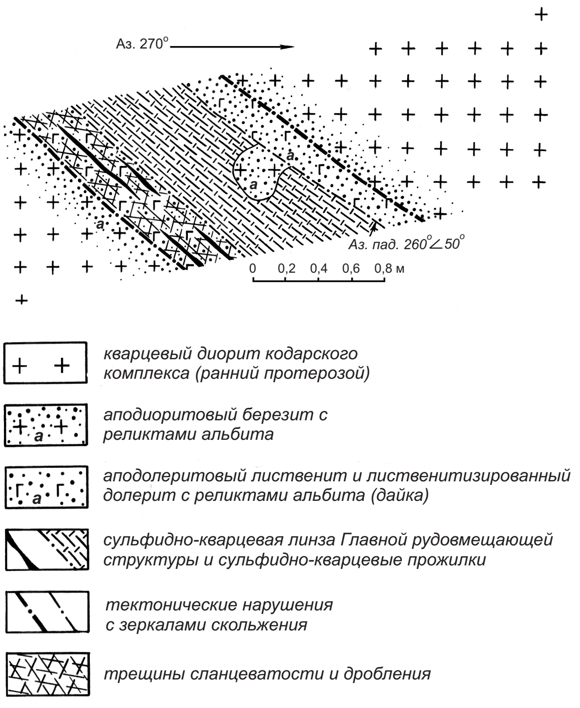

Fig. 2. *Bedding of the main ore enclosing structures and a quartz lens in dolerite dike. The vertical cut, the mouth of gallery № 1*

Sulphide carbonate – quartz carrying out of faults is lense-shaped broken and reaches thickness 2 m at extent of lenses up to many tens meters. There are some lenses, divided by «conductors» or intervals of fine slaty and crushed rocks in the majority of faults. In intervals, being transitive from blowings to clutchings, forming the basis of the vein carrying out early milky-white, whitish-grey granular quartz is broken by system of splitting fissures being subparallel to faults which basically control localization of a late gold-sulphidic mineralization and carbonates. The volume of sulfides and carbonates does not exceed 1 and 10 % of the total volume of vein carrying out, accordingly

The mineral composition of ores, thermodynamic – physical and chemical modes of ore formation are not investigated yet. Among sulfides it is possible to diagnose pyrite, arsenopyrite (it is rare), pyrrhotine, sphalerite, galenite, chalcopyrite, fahl ore, listed, by structural relations, in sequence of their sedimentation. Gold was localized in a solid phase in part together with early pyrite and arsenopyrite, forming in them the most thin emulsion sprinkling, basically – simultaneously with galenite, chalcopyrite and fahl ore in the form of inclusions of various scales, including rather large (up to 1...2 mm). Carbonates are presented by early and late calcite, late ankerite and siderite.

The gold content in quartz lenses is non-uniform at variation factor not more than 150. Over the length of many meters it does not exceed shares g/t – the first g/t, in local sites – ore jacks it increases up to first tens g/t. The gold – silver relation in ores by the results of atomic-absorption and assaying analyses of 23 samples is 0,38.

According to radiological definitions the deposit is formed 285±5 mln years ago [24, samples with index BC – ...].

Identification of ore host rocks

On the site of localization of quartz veins plutonic rocks of the Kodarsky complex are presented by two kinds – quartz diorite and quartz monzonite which space-time relations remain up to now unclear. On the background of the general motley-grey color the rocks are distinguished by slightly locally expressed pinkish shade of quartz monzonite, caused by participation of alkaline feldspar (up to 15 %) in its structure. The textura of rocks is massive, structure is hipiodiomorphous grained with sizes of the main mass of crystals of a magmatic stage of formation up to 7 mm.

The main minerals include lime-alkaline and alkaline field spars (up to 55 %), hornblende and biotite (in the sum up to 30 %), bluish quartz (up to 15 %). Minor ones are presented by augite, accessory ones – by magnetite, zircon, apatite. Rocks in intervein space are after by hydrothermal way, including slightly; composition of the secondary mineralization is given in the Part 2 of the articles.

Plagioclases are present at the form of large idiomorphic lengthened – table cut crystals with a complex configuration of face borders or splices of shortly – prismatic grains of basic oligoclase-andesine (from № 30 up to № 42). Zonation in them is expressed slightly. Quartz monzonite usually contains relicts of plagioclases with size of the tenth – hundredth parts of millimeters included in large xenomorphic excrections of orthoclase-pertite at sporadic participation of microcline-pertite.

Among dark-coloured minerals augite is the earliest and kept in the form of fine (up to the tenth parts of millimeters) grains in the frame of ordinary hornblende or biotite. The last one prevails appreciably in comparison with hornblende which is presented by three versions – generations. The early generation forms large crystals, slice of crystals of brown color ($-2V$=68°, $C{:}Ng$=24°, Ng=1,668, Np=1,646), in part edged by deep-green,

Table. *Chemical compositions of magmatic rocks of the Kodarsky complex outside and inside of the subzone of slight change of the external zone of nearvein metasomatic auras of the gold ore deposit Verkhne-Sakhukanskoye*

Distance from gold ore veins, m	Content, mas. %														Σ
	SiO_2	Al_2O_3	K_2O	Na_2O	S sulphides.	CO_2	CaO	MgO	FeO	Fe_2O_3	TiO_2	MnO	P_2O_5	H_2O^+	
3,5	59,52	14,16	1,87	3,22	0,18	0,04	4,61	1,30	8,81	2,43	1,61	0,09	0,50	1,85	100,19
2,2	59,92	14,70	2,00	3,50	0,16	0,09	4,47	1,20	7,20	2,86	0,97	0,14	0,37	1,84	99,42
1,4	61,88	13,63	3,00	3,04	0,09	0,09	4,19	1,20	6,31	2,49	1,22	0,09	0,40	1,72	99,35
1,2	62,82	14,06	3,56	3,20	0,15	0,36	3,35	1,20	5,88	2,37	1,12	0,12	0,31	1,05	99,55
0,8	62,95	14,70	4,30	3,14	0,25	0,27	3,21	1,40	5,36	2,11	1,00	0,05	0,31	0,39	99,44
0,8	62,23	14,30	3,80	3,14	0,13	0,13	3,49	1,00	5,80	2,14	1,08	0,05	0,35	1,57	99,21

blue-green hornblende of the second generation ($-2V$=74°, C:Ng=23°, Ng=1,690, Np=1,675). Green hornblende is met and in the form of the independent large crystals having «fragmentary» shape and poikilite structure. Fine, up to the tenth parts of millimeters, lengthened crystals of pale-green hornblende of the third generation with various orientation form aggregates in accretion with fine-grained quartz and fine scale red-brown biotite. Large scales, probably, of early red-brown biotite of the first generation with coveshaped face borders alongside cleavage and also frequent with poikilite structure replace hornblende of both generations.

Besides fine-grained aggregates it is characteristic for quartz to have accumulation of rather large, up to 2...3 mm, xenomorphic grains filling intervals between excrection of listed minerals and having with them reactionary relations.

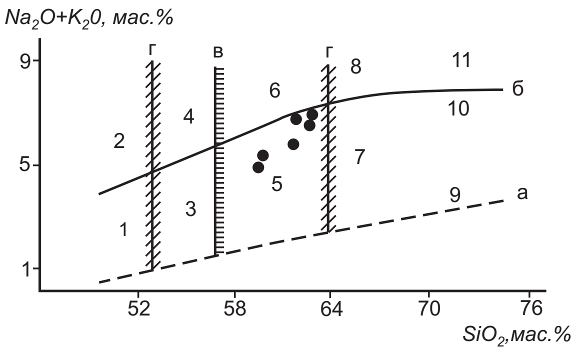

Fig. 3. *Location of magmatic rocks of the Kodarsky complex in coordinates SiO_2 – (Na_2O+K_2O): а) low border of spreading of chemical compositions of magmatic rocks, б) low border of spreading of chemical compositions of moderately alkaline magmatic rocks, в) border of quartz spreading >5 %, г) border of separation of magmatic rocks on groups with «uncertainty fields». The spreading fields of: 1) gabbrides, 2) moderately alkaline gabbrides, 3) diorites, 4) moderately alkaline diorite monzonites, 5) quartz diorites, 6) moderately alkaline quartz diorites quartz monzonites, 7) granodiorites, 8) quartz sienites, 9) low alkaline granites, 10) granites, 11) moderately alkaline granites. Borders of rocks fields spreading are borrowed from [25]*

Chemical compositions of rocks are given in the table. As one can see on the TAS-diagram (fig. 3), figurative points of rocks are dispersed in the top half of quartz diorite field that the part of points is approached to the separation line between middle rocks of normal row and moderately alkaline ones. Obviously, this line has «a uncertainty zone», which frames it as belonging of rocks to quartz monzonite (the top group of points) at other parameters of the chemical composition adequate to it is proved by participation of alkaline field spares, which are absent in quartz diorite (the bottom group of points) in rocks.

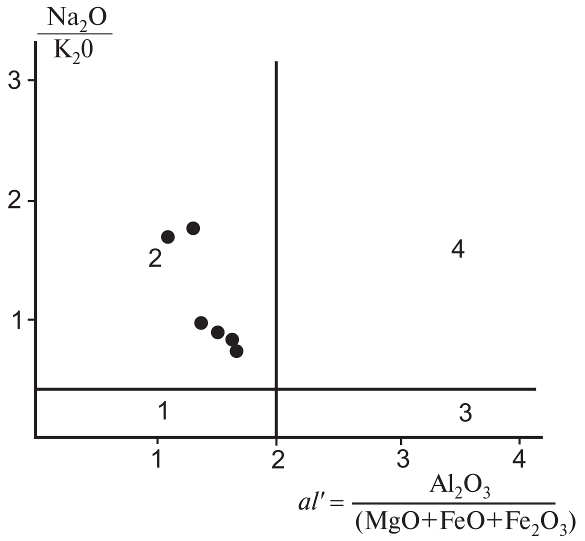

Fig. 4. *Location of magmatic rocks of the Kodarsky complex in coordinates Na_2O/K_2O – $Al_2O_3/(MgO+FeO+Fe_2O_3)$. Series, alumonousity: 1) potassium, high aluminous, 2) potassium – sodium high aluminous, 3) potassium, very high aluminous, 4) potassium – sodium, very high aluminous. Borders of series fields and coefficient of aluminosity are borrowed from [25]*

Both kinds belong to potassium – sodium petrochemical series with high value of sodium – potassium ratio in quartz diorites (Fig. 4). Indices of leucocrativity of both rocks are similar and correspond to high aluminous varieties. Index of femicity of quartz monzonite is in range 9,87...10,57, one of quartz diorites – 11,22...14,15. At low magnesiality of rocks of both kinds (Table) increase of this index in quartze diorites is caused by higher contents of oxide ferrum and titanium in comparison with quartz monzonites.

As a result the rocks are identified as hornblende-biotite quartz diorite and quartz monzonite.

The second part which ends the article contains consideration of the structure of near vein metasomatic halos, distribution of oregenous elements in intervein space of the deposit and discussion of obtained results.

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