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PETROLOGIC-GEOCHEMICAL EVIDENCE OF GEOLOGIC-GENETIC UNIFORMITY OF GOLD HYDROTHERMAL DEPOSITS FORMED IN BLACK-SHALE AND NON-SHALE SUBSTRATUM

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The problem of gold deposits origin lying in crystal and black-shale substratum is discussed. The expediency of comparative research of all geologic-real-genetic factors of their formation, among which a significant value is retained by the geochemical, is emphasized.
The technique of geochemical researches, based on use of substratum petrologic studying results of golden-ore fields and their frame, providing formation of multilevel system of geochemical selection representing stage-by-stage history of rock formation and their geochemical shape at each stage, is offered.
The results of the offered approach realization in golden-ore deposits of the North Transbaikalia lying in the crystal substratum and Proterozoic black-shale strata in the frame of the Muiskiy ledge of the Archean base of the Siberian craton are presented. The resulted materials prove in geochemical aspect the geologic-genetic uniformity of formed in non-shale and black-shale substratum of gold hydrothermal deposits, proved by the totality of empirical data. The offered technique provides formation of regional, and in the long term global banks, of correct geochemical data.

Introduction

The opposition between magmatogene-hydrothermal and metamorphogene-hydrothermal concepts of gold deposit formation in their different variants with an accent on geological situations of shale type areas continues more than forty years and there is no end to it. The uncertainty of problems, naturally, does not promote the theory of ore-formation and the decision of the major applied problem – the development of scientifically proved «working» criteries of forecasting of new ore-bearing areas.

It is known, and it is an axiom, that the discussion solitarily influences the development of any science, but its semicentenial, in this case, duration without achievement of positive results demands analysis of the situation and search for possible reasons of obviously tightened debates, no less than ways of elimination of key contradictions. Some reasons of the existing unsatisfactory state of affairs were analyzed and offered to discussion earlier [1]. The attention was paid to the two main ones.

The first one presumes that the metamorphogene-hydrothermal concept of ore-formation in shale type areas, assuming the local pedigree source of gold with rare exception [2], is based on position according to which the obligatory precondition is a superclark, with increased or high pre-ore golden-bearing ability of ore-containing rocks formed at stages of sedimentation or regional metamorphism, or at any of these stages. However, the continuing till now accumulation of numerous new excluding one another variants of the solution with an estimation in the same rocks and strata of pre-ore contents of gold (as a rule, with no attraction of other metal-satellites) from mg/t up to g/t [3–5, et al.] serves as an objective prove that often applied methods of such estimation are not correct.

The second reason explains the first. It is obvious, to prove pre-ore and sin-ore accumulation of the raised against clark or abnormal concentrations of metals in ore-containing rocks, meaning in the interore space of ore fields and/or behind their limits, it is necessary to use such methodical methods that would provide finding-out of geological history of chemical elements and, simultaneously, a goal achievement and solution of geochemistry problems as a science. In practice the methods of exploration geochemistry which have its purpose and are focused on the solution of, first of all, forecast-exploration problems, not always and not in full comparable with the problems of opening of geological history of the metals contained in ores and rocks [6–8, et al.].

At solution of geologic-genetic problems of ore-formation, in particular, in the areas of shale (black-shale) type, the situation is aggravated with usual realization of the unilateral geochemical approach in its designated variant which, as has shown its long-term application, does not provide the solution of the raised problems. Disturbing symptoms were designated. Authors of some published works, similarly to the situation in the ore-formational method [9], do not trouble themselves to find proofs in specific cases, for example the pre-ore origin of superclark contents of gold in rocks, submitting the disputable information as facts in evidence [10–16, et al.]. It is possible to find among the published works the ones which lack either awareness or willingness to see something that does not enter the author's representations. For example, the absence in gold deposits of magmatic rocks with formation of which the ore-formation would be possible to tie by time and other criteries [17]. This mismatching the validity statement gives the ground for another concept of ore-formation.

Since the 60th of the last century, an opposition of gold deposits formed in carbonaceous shale strata of sedimentary pools with extraction, as it is believed, of gold from the rocks, to the deposits created in a crystal substratum with extraction of gold from silicate melts has initiated the occurrence of popular notion about deep geologic-genetic distinctions between deposits of these two sets. For a long time there was a belief that in carbonaceous shales the near-ore changes of rocks are not expressed or they essentially different, at a level subfacies of regional regressive metamorphism, than in the deposits lying among granites, ultrametamorphites and other crystal rocks where ore bodies are accompanied by auras of pre-ore metasomatism of the propylite-beresite and other formations. However the commenced with convocation of the All-Union meeting [18] researches in the direction of search of these distinctions did not receive the further development. Meanwhile, in the appendix to East-Siberian region the results were obtained, according to which there are no fundamental distinctions in mineral structure, physical and chemical and thermodynamic modes of ore-formation, structure, mineralogical-petrochemical features and formation accessory of the pre-ore metasomatic aureoles, conditionality of ore-formation by geological processes [19]. It is possible to speak about distinctions when there is a question of grandiose scales of gold reserves at low content of metal in ores of the shale type deposits unlike more modest deposits formed in a crystal substratum which possess lesser reserves of gold, but its rather high contents. All this finds the resulted further simple explanation, is caused by features organization of the ore-formation environment, but is not connected with geologic-genetic distinctions of ore-formation processes.

In the set of proofs, which are called to solve the problem of the geologic-genetic essence of ore-formation in non-shale and black-shale substratum on the wide geologic-real-genetic basis and in the comparative aspect, the positions take place following from the correct research of a geochemical situation in golden-ore fields. In the article the methodical ways of such research are discussed, earlier published [1, 20–23] and additional materials are generalized, conclusions opening some general laws of formation of modern geochemical shape of the interore space combined of a crystal and a black-shale substratum are proved.

1. Substantiation of the experiment method

Theoretical substantiation of methodical techniques of the carried out from 1986 [20] and still proceeding [1, et al.] experiment leans on a number of initial factors which are represented by the axioms.

Firstly, chemical elements, including metals, come to movement (migrate) in rocks of any structure and origin only at influence on them of the geological factors, initiated by epigenetic geological processes, for example, regional or contact metamorphism and-or metasomatism. Without hot waters (solutions) the mechanism of intracrystal diffusion even in scales of geological time can provide substance migration only at disappearing small distances. It is proved by rather stable composition of the dissolved substance (molecules, ions, atoms) in gas-liquid inclusions of minerals hydrothermal similar in origin and to composition of ore deposits of minerals formed in remote from one another geological epoch.

Secondly, each geological process of epigenetic transformations of rocks leaves material traces in composition of neogenic minerals, mineral associations and complexes accessory of which to each stage is possible to diagnose. Petro- and oregenic elements synchronously participate in reactions of mineral replacements according to their chemical properties and the existing physical-chemical and thermodynamic modes.

Thirdly, in order to understand, following purposes of geochemistry, the geological history of metals, in particular gold, it is necessary to track their «behavior» at a stage of formation of each rock and at the stage (stages) of its subsequent transformations.

Since intermediate and final balances of metals (as well as of any substance) in rocks are calculated on the basis of comparison of distribution parameters, first of all, average content of metals in the test samples, the correct solution of a problem of their origin (and distributions) in the interore, near-ore, and, hence, and in ores should lean on rational system of geochemical excerpts. The latter should meet the following requirements. Each sample represents a specific kind (version) of the initial rock. It is the bottom level of the formed system of excerpts. Each sample represents a specific kind (version) of the initial rock and a specific mineral zone of an aureole of zonal regional, contact or near-dome metamorphism which in areas of the shale type usually precedes the ore-formation. It is the intermediate level of the formed system of excerpts. Each sample represents a specific kind (version) of the initial rock, a specific mineral zone of an aureole of zonal regional, contact or near-dome metamorphism and a specific mineral zone of the near-ore metasomatic aureole. It is the top level of the formed system of excerpts. Intermediate samples can represent two geological processes, for example, the early regional and the late metamorphism of the focal-dome type, that is two intermediate levels either to be absent, as it happens in the ore fields formed in, let's say, granites including the ancient ones.

Thus, in the given system the excerpts are responsible for, at least, two, three and more geological processes, beginning from the stage of rock formation and up to the last stage of their transformations, in ore areoles usually connected with ore-formation. Excerpts in the offered variant provide the solution of a problem of to what geological process the change of metal content of in the rock of each kind (version) and, depending on intensity of the process, – in what degree is obliged, and what geological process has not affected the content of metal (metals) and its (their) distribution in the rock. In other words, the genetic explanation can be given to a specific distribution of metal (metals) for each stage of transformations. In particular, a key question on an accessory of geochemical anomalies to a stage (stages) of pre-ore accumulation of metals or their sin-ore concentration in carbonaceous shales can be correctly solved.

Fourthly, the detailed petrologic researches with the purpose of reconstruction of the initial substratum of repeatedly transformed rocks and diagnostics of an accessory of epigenetic mineral associations (complexes) to the specific stages of their transformations should precede the procedure of formation of geochemical excerpts for statistical calculations. In this case each geochemical excerpts will represent a specific kind (version) of initial rocks, a specific stage of their transformations and in comparison with the excerpts of one and adjacent levels it is suitable for genetic generalizations.

In a long-term practice of performance of the experiment in hydrothermal golden-ore fields of the Pre-Paleozoic folded frame of the Siberian craton some typical situations were found. If sour igneous rocks serve as a substratum containing the ore field, including the ancient (from Early-Proterozoic), the geochemical excerpts can be generated and formed at two levels: initial, as a rule, fresh, meaning well preserved from the moment of becoming massifs of granitoids, and apogranitoid metasomatites formed at the stage of ore-formation. On the contrary, in the ore fields lying in the Proterozoic strata of carbonaceous terrigenous shales, the initial sedimentary rocks are changed at the pre-ore stage of regional metamorphism of the green-shale or epidote-amphibolite facies. Fresh initial sedimentary rocks did not preserve. In this case the geochemical excerpts represent levels of regional relatively to low-temperature metamorphism of sedimentary rocks and pre-ore metasomatism of the ore-formation stage. At that, using some of the attributes it is not a problem to diagnose the initial rocks even intensively transformed in the ore-forming process. The Archean ultrametamorphic rocks of the foundation represent a special case. The composition of the primary substratum is unknown, and the existing methods of its reconstruction do not always provide authentic results. At the same time, ultrametamorphic rocks, as well as granitoids, are capable to be preserved infinitely long (billions of years) down to the stage of ore-formation when they are exposed to hydrothermal transformations. The analysis of geochemical fields was carried out on the basis of the two-level system of excerpts: initial ultrabasic rocks and formed on them metasomatites.

The researches with use of the three-level system of excerpts are not yet realized due to deficiency of suitable for these purposes geological situations in the known ore fields.

Fifthly, the described procedure of realization of the offered approach in geochemical researches of the pre-ore, near-ore space of golden-ore fields will be deprived of sense if to not pay attention to cleanliness of the experiment regarding selection, processing and analysis of tests. As it has been shown earlier [1, 20, et al.], significant distinctions of gold content, for example, in the adjacent excerpts set in at a level of shares mg/t ... first mg/t. Therefore, the slightest failures in preparation and analysis of tests will lead to distortion of results, not giving in to updating as it is usually not known at what stage there was a failure.

2. Geological position of golden-ore fields

Participating in the experiment golden-ore fields are located in Uzhno-Muyskiy (Irokindinskoye, Zapadnoye, Kedrovskoye) and Severo-Muiskiy (Karalonskoye) ridges of North Transbaikalia among the Archean-Proterozoic structurally-real complexes composing a fragment of the Pre-Paleozoic folded frame of Siberian craton in the given territory (Fig). In Proterozoic folded constructions the Archean ultrametamorphic rocks are preserved in the Muyskiy ledge of the foundation limited by the zones of abyssal fractures, – Kilyano-Irokindinskiy in the west and Tuldunskiy in the east. These zones supervise accommodation of the discussed and other golden-ore fields and ore occurrence in the Muyskiy ledge area. The Karalonskoye ore field represents northern part in the chain of golden-ore deposits and the displays placed in the Syulbanskiy zone of abyssal fractures, limiting the Baikal-Muyskiy ophiolite belt in the east.

Ore bodies are presented by quartz veins, and in black-shale strata, besides the veins, by mineralized zones of the vein-stringer-porphyry ores. In rocks the ores are combined by five mineral complexes deposited within the limits of five stages of the pulse hydrothermal process in the temperature range 500...35 °C [25].

Ore fields are formed in the Late-Paleozoic metallogenic epoch [26].

The substratum, containing golden-ore fields provides the solution of the set problem. Here the powerful strata of carbonaceous terrigenous shales are presented in the volume of Proterozoic of the Kedrovskaya and the Wodorazdelnaya series containing industrial golden-ore quartz veins and mineralized zones. Kerogen in rocks it is diagnosed as graphite and graphitoid [27]. The crystal substratum, containing industrial quartz-vein the metalizing process varies in structure and origin and includes several kinds of Archean ultrametamorphic rocks of the Muyskiy ledge, quartz diorites of the Late-Paleozoic mature Kedrovskoye focal-dome structure, dyke rocks of the sour and the basic composition.

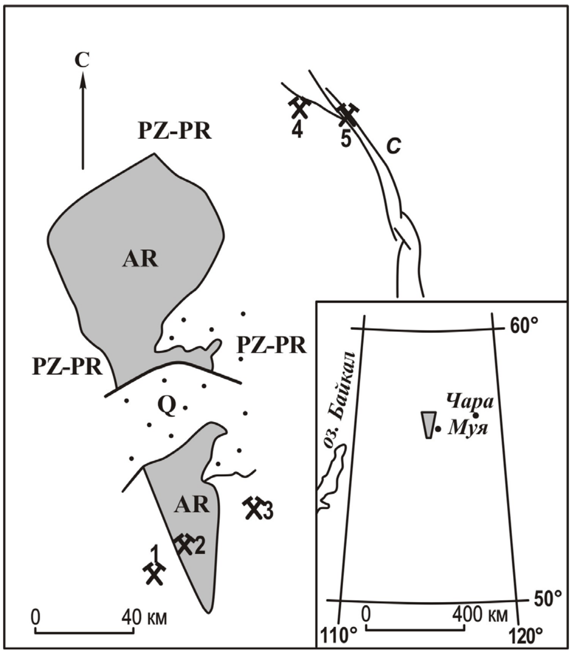

Fig. *The scheme of the golden-ore deposits arrangement in North Transbaikalia (geological situation under V.A. Laschenov [24]). AR – Muyskiy ledge of the Archean foundation of Siberian craton among Paleozoic-Proterozoic folded frame (PZ-PR);* ***c*** *– Syulbanskiy zone of abyssal fractures; Q – friable quarternary deposits of the Muyskiy hollow. Golden-ore deposits: 1) Zapadnoye, 2) Irokindinskoye, 3) Kedrovskoye, 4) Karalonskoye with Nizhne-Orlovskiy site (5). On the inset – geographical position of the Muyskiy ledge*

3. Mineralogical-petrochemical zoning of near-ore metasomatic aureoles

As a result of the lithologic and the petrologic studying of rocks the initial positions for the subsequent geochemical researches of interore and near-ore spaces are established.

All ore-enclosed crystal Archean ultrametamorphic and Paleozoic sour and basic igneous rocks do not contain material traces of epigenic, prior to the beginning of ore-formation, changes. For example, in gneisses, quartz diorites and other rocks the feldspars, pyroxenes, amphiboles, extremely sensitive to changes biotite are absolutely pure in episodically preserved blocks – remains of the interore space. Terrigenous sedimentary rocks at the pre-ore stage have undergone regional metamorphism of greenshale facies, material expression of which is served by muscovite-biotite with tourmaline paragenesis uniformly distributed in the strata of rocks. At that, the rocks have kept the basic premetamorphic features of composition and structure owing to what their specific accessory corresponding to the stage of sedimentation is diagnosed. At the same time, the non-metamorphized sedimentary rocks are not found in the areas of the discussed sedimentary strata distribution.

In crystal and black-shale substratum the mineral associations imposed on rocks and complexes are a part of the large-scale zonal near-ore metasomatic aureoles. The latter is proved by the accessory of minerals to the uniform metasomatic ensemble repeating in different combinations and in all rocks, natural change of mineral composition of metasomatic rocks from one mineral zone to another and, what is especially indicative, increase of content of epigenetic minerals from the periphery in a direction of rear zones of metasomatic aureoles and ore bodies.

According to scales, structure, i.e. the order of mineral zoning, petrochemical features of near-ore metasomatic aureoles are authentic in all the discussed rocks and described in details earlier in [1, 20–23, 27, et al.]. Therefore, we shall note the main thing in compliance with the purpose of the given clause.

Aureoles include various in volume mineralogic-petrochemical external, including actinolite-tremolite, chlorite (epidote-chlorite), albite and rear zones with an axial quartz vein or a mineralized zone of streaky-interspersed ores. Usually the capacity of the external zone reaches many hundreds meters, the chlorite – many tens meters, the albite – first few meters, the rear – many tens centimeters. At the sites of the close arrangement of ore bodies the aureoles merge one with another by their peripheral parts forming a uniform metasomatic aureole. At presence of local echelon subparallel to the ore bodies the ore-bearing structures of cracks-fractures due to strengthening mineral replacements in the frame of the latter the mineral zones repeatedly alternate in a cross-section of a single near-vein aureole.

The fullest set of neogenic minerals at their minimal mass is peculiar to the external zone of aureoles, consistently, from one mineralogic-petrochemical zone to another, decreases in the direction to the rear zone with simultaneous escalating of their weight and includes sericite + quartz + albite + leucoxene + rutile + magnetite ± pyrite ± actinolite – tremolite + chlorite ± zoisite ± clinozoisite ± epidote + calcite ± dolomite ± dolomite-ankerite ± ankerite ± siderite ± apatite ± graphite (graphitoid).

In the external and the chlorite zones only calcite is present from carbonates, and ferro-magnesial carbonates in addition to calcite appear in the internal albite and the rear zones with integration of metacrystals – rhombohedrons up to 2...3 mm which complicates the usual lepidogranoblastic finely-grained structure of metasomatites by the arising porphyroblastic. Actinolite-tremolite, together with chlorite replacing pyroxenes, amphiboles, biotite of the initial rocks, participates in the structure of mineral neogenesis on the abyssal horizon aureoles. Full replacement of these minerals, except for chlorite, marks transition from the external zone to the chlorite zone where it obtains the status of typomorphic. Full dissolution of chlorite with formation at its expense of muskovite – sericite «polluted» by leucoxene, rutile, magnetite where the liberated from the initial color minerals titanium and iron are fixed, occurs at the external border of the more rear albite zone. Minerals of the epidote group are not always present in the external and the epidote-chlorite zones and are most plentiful in rocks rich with basic – average plagioclases. Average-sour plagioclases are replaced by sericite usually in association with calcite and metasomatic quartz, supplementing quartz of the initial rocks. Deanortization is also peculiar to plagioclases. It expressed in occurrence in the external zone of albite borders on periphery of crystals; in athe albite zone the typomorphic albite completely replaces plagioclases of the initial rocks but is dissolved at the external border of the rear zone. The latter is combined of quartz, sericite (muskovite), ferro-magnesian carbonates with an impurity of calcite, sulfides (mainly pyrite), leucoxene, rutile, apatite, and graphite in apocalcified metasomatites [27]. From apoblack-shale metasomatites of the internal rear and the albite zones the carbonaceous substance, on the contrary, withdraws; at absence of kerogen and color minerals in them they obtain light grey color.

Distribution of mineral associations is characterized, as it was marked, that the weight of new growths accrues not only in the aureole as a whole in the direction of internal zones, but also in the volume of each mineralogic-petrochemical zone in the direction of its internal border. It is best expressed in the external and the epidote-chlorite zones. The external zone is differentiated onto three subzones: weak, moderate, and intensive change with the weight (volume) of mineral neogenesises accordingly up to 10, 20, 30 %. In conditions of rigid deficiency in the ore fields untouched by changes of rock it provides an opportunity to use for calculations the balance of petrogenicand oregenic elements, the analysis of parameters of metal distribution in the interore (near-ore) space of the least changed rocks hardly touched by changes from the far periphery of aureoles in which it is necessary to expect the absence of movement (migration) of metals. Zoisite is present at the external periphery of the epidote-chlorite zone in structure of neogenesises, usually in the form of «variolitic» inclusions in crystals plagioclase. Towards the internal border of the zone its crystals expand, and the zoisite itself is replaced by epidote quantity of which avalanchely accrues and it sharply disappears at the border of the zone. Simultaneously the ferriferousness of chlorite increases down to formation of ripidolite. All this is coordinated with the representation about the diffusion mechanism of mass-transfer common in processes of near-fracture metasomatism. [28].

Mineral transformations occur in conditions of change of the rock chemical initiated by influence metal-bearing fluids.

Quantitative indicator of scales of such redistribution – specific weight of the moved (added and subtracted) substance in percentage to the weight of the substance of the initial rock in standard geometrical volume in the external zone does not exceed 3...4 % and is usually formed due to natural non-uniformity of distribution in rocks of petrogenic components. Carbonic acid and sulfur forth come in a small amount to the non-carbon and non-sulfide environment to form an insignificant impurity peculiar to the zone of calcite and phyrite. In the more internal chlorite, albite, rear zones it increases reaching in the latter 40...50 % and showing an essential subtraction from the internal zones of silicon and sodium (up to 50 and 90 % accordingly) and forthcoming into the aureoles, mainly into their internal zones, the carbonic acids, the restored sulfur and potassium.

The cited mineralogic-petrochemical data represent a process of formation of the beresite metasomatic formation in the closest frame of the ore-bearing structures in a combination with the mineralogic-petrochemical chlorite and the external zones representing a propylitic metasomatic formation. The opportunity of similar combinations of the large-scale peripheral and local mineral zones within the limits of the uniform metasomatic columns created within the limits of uniform hydrothermal ore-forming processes has been emphasized earlier [29], including by means of allocation of the regional propylite-beresite metasomatic formation [30].

Contrast anomalies of femophilic elements – titanium, phosphorus, magnesium, iron, manganese in beresite as of apogneiss, apodiorite, and apoblack-shale near-ore metasomatic aureoles [28, 31, et al.] attract the attention emphasizing, besides other, the genetic uniformity of products of hydrothermal ore-forming processes in all the discussed rocks.

4. Metals in the near-ore space

The distribution of three metals finding close geochemical connections in ores – gold, silver, mercury into the rocks containing ore fields is analyzed. The first one of them defines an industrial value of the objects.

Massifs of tests, necessary for the calculation of statistical parameters of distribution and the comparative analysis, according to the declared principles are incorporated in exerpts by an accessory of rocks to the specific petrographic, lithologic kind at the bottom level and to the mineral zone (subzone) of the near-ore metasomatic aureoles – at the top. Owing to comparable contents of fractural fractions of the sandstone and the aleurite dimensions the terrigenous rocks of the Kedrovskaya and the Wodorazdelnaya series are qualified as sandy-aleuroshales.

Evaluation of quality of analytical works for gold and silver, executed in the accredited laboratory (table), was carried out by means of control analyses within the framework of the base high-sensitivity method of nuclear absorption (the internal control of 15 % from the massif of tests) and performance of neutron-activation and chemical-spectral analyses (10 % from the massif of tests) [22]. The average relative error on differences of

Table. *Estimation of the distribution parameters of oregenous elements and the correlation connections of gold with oregenous elements in mineral zones of the near-ore metasomatic aureoles of golden-ore fields of North Transbaikalia*

Elements	Distribution parameters	Mineral zones [number of tests]					
		External			Chlorite	Albite	Rear
		Subzones of change					
		Weak	Moderate	Intensive			
1. Irokindinskoye ore field Calciphyres							
Au	$x\bar{e}(\bar{x})$	0,9(1,2)[25]	0,9(1,4)[23]	0,9(1,0)[6]	1,0(1,2)[7]	1,7(5,7)[18]	7,2(188,0)[53]
	$t(s)$	2,1(1,7)	2,3(1,9)	1,8(0,6)	1,7(0,6)	4,0(12,1)	8,4(982,7)
Ag	$x\bar{e}(\bar{x})$	42,5(53,4)	30,9(36,1)	44,4(47,6)	52,0(70,8)	175,6(399,7)	112,0(242,0)
	$t(s)$	2,2(32,1)	1,9(20,2)	1,5(20,8)	2,8(46,8)	3,7(603,3)	3,5(408,0)
	$r(sr)$	**0,75**(0,17)	0,09(0,37)	**0,80**(0,16)	0,03(0,50)	**0,91**(0,05)	**0,47**(0,16)
	Au/Ag	0,02	0,03	0,02	0,02	0,01	0,06
Hg	$x\bar{e}(\bar{x})$	23,8(29,6)	21,6(32,4)	32,5(39,6)	23,4(30,3)	27,0(48,8)	41,7(64,7)
	$t(s)$	2,0(19,9)	2,3(35,3)	2,1(25,5)	2,2(24,2)	3,1(56,4)	2,7(63,6)
	$r(sr)$	−0,36(0,33)	−0,54(0,27)	-0,06(0,45)	0,47(0,39)	0,0002(0,29)	0,24(0,19)
Almandin-diopside-twofeldspar gneisses							
Au	$x\bar{e}(\bar{x})$	0,7(1,1)[29]	0,6(0,7)[48]	0,7(0,7)[29]	0,7(0,8)[23]	16,5(47,0)[65]	49,9(228,8)[169]
	$t(s)$	2,1(1,8)	1,5(0,3)	1,5(0,3)	1,4(0,3)	4,0(94,0)	5,7(646,0)
Ag	$x\bar{e}(\bar{x})$	35,7(43,9)	50,0(55,9)	60,3(85,3)	56,8(92,7)	153,1(222,0)	134,3(268,1)
	$t(s)$	1,8(36,8)	1,7(25,3)	2,2(95,1)	3,2(109,8)	2,3(239,8)	2,9(590,8)
	$r(sr)$	**0,73**(0,12)	0,02(0,20)	0,38(0,22)	**0,68**(0,14)	**0,82**(0,06)	**0,50**(0,12)
	Au/Ag	0,02	0,01	0,01	0,01	0,1	0,37
Hg	$x\bar{e}(\bar{x})$	17,1(22,0)	15,6(18,2)	19,3(34,4)	21,7(34,8)	19,7(33,4)	28,7(55,2)
	$t(s)$	2,0(17,0)	1,7(11,5)	2,4(56,5)	2,3(53,8)	2,6(47,0)	2,9(99,4)
	$r(sr)$	−0,07(0,19)	**−0,36**(0,13)	−0,10(0,18)	0,04(0,27)	0,05(0,11)	0,07(0,08)
Almandine-twomica gneisses							
Au	$x\bar{e}(\bar{x})$	0,5(0,6)[30]	1,2(1,4)[17]	1,9(2,5)[15]	1,7(2,4)[96]	2,3(4,1)[24]	11,5(1439,5)[34]
	$t(s)$	1,3(0,2)	1,7(0,7)	2,4(1,7)	2,3(2,4)	2,3(8,5)	21,0(1220,0)
Ag	$x\bar{e}(\bar{x})$	36,2(43,1)	33,3(42,4)	42,5(52,4)	38,9(56,0)	76,5(91,1)	160,2(777,8)
	$t(s)$	2,2(19,3)	2,3(25,9)	2,0(32,5)	2,5(50,3)	1,9(50,2)	4,0(н/д)
	$r(sr)$	0,12(0,33)	**0,61**(0,19)	−0,32(0,26)	**0,42**(0,20)	0,09(0,23)	**0,72**(0,12)
	Au/Ag	0,01	0,04	0,04	0,05	0,03	0,08
Hg	$x\bar{e}(\bar{x})$	19,4(21,4)	21,2(23,4)	17,0(19,7)	18,3(20,8)	15,0(19,9)	18,3(26,4)
	$t(s)$	1,6(9,5)	1,6(10,0)	1,7(11,8)	1,6(12,5)	2,2(16,3)	2,1(33,2)
	$r(sr)$	−0,46(0,26)	−0,23(0,29)	0,19(0,28)	0,33(0,22)	−0,33(0,20)	0,14(0,25)
Granites of migmatite fusion							
Au	$x\bar{e}(\bar{x})$	0,6(0,7)[28]	0,6(0,7)[10]	0,6(0,7)[17]	1,5(1,7)[49]	6,4(23,2)[99]	50,7(335,2)[24]
	$t(s)$	1,6(0,4)	1,4(0,2)	1,4(0,2)	1,8(0,9)	4,9(45,7)	10,6(688,3)
Ag	$x\bar{e}(\bar{x})$	47,9(70,3)	58,9(77,2)	47,3(54,8)	19,0(26,1)	96,8(122,9)	158,5(318,5)
	$t(s)$	2,4(71,6)	2,4(50,2)	1,8(27,3)	2,3(19,8)	2,2(78,2)	3,1(513,4)
	$r(sr)$	0,18(0,27)	−0,08(0,35)	0,28(0,28)	−0,37(0,22)	**0,40**(0,15)	**0,81**(0,10)
	Au/Ag	0,01	0,01	0,01	0,07	0,06	0,32
Hg	$x\bar{e}(\bar{x})$	20,6(24,1)	21,8(28,3)	16,2(30,1)	17,1(19,6)	27,8(41,0)	34,5(41,1)
	$t(s)$	1,7(16,6)	2,2(20,9)	2,5(55,1)	1,7(11,8)	2,4(45,9)	2,0(22,0)
	$r(sr)$	−0,15(0,27)	**−0,58**(0,24)	−0,20(0,29)	**0,49**(0,20)	0,14(0,18)	0,02(0,23)
Microgranite-porphyres felsitic dyke							
Au	$x\bar{e}(\bar{x})$			1,2(1,4)[6]	1,4(1,9)[37]	3,6(17,4)[120]	43,1(269,5)[64]
	$t(s)$			1,8(1,0)	2,0(1,8)	4,9(53,8)	9,0(736,4)
Ag	$x\bar{e}(\bar{x})$			24,4(24,6)	н/д	132,7(168,4)	143,8(164,3)
	$t(s)$			1,1(3,0)	н/д	1,8(160,0)	1,7(92,9)
	$r(sr)$	н/д	н/д	0,48(0,34)	н/д	н/д	н/д
	Au/Ag			0,05	н/д	0,03	0,3
Hg	$x\bar{e}(\bar{x})$			н/д	22,3(29,0)	38,2(54,0)	43,8(62,4)
	$t(s)$			н/д	2,0(26,2)	2,4(44,7)	2,2(68,7)
	$r(sr)$			н/д	0,07(0,21)	0,43(0,23)	0,15(0,15)

2. Zapadnoye ore field Dolerites pre-ore dyke							
Au	$\overline{xг}(\overline{x})$	н/д	н/д	0,8(0,9)[17]	1,3(1,4)[12]	1,0(1,0)[8]	2,7(9,8)[8]
	$t(s)$			1,7(0,7)	1,5(0,5)	1,5(0,4)	4,8(17,7)
Ag	$\overline{xг}(\overline{x})$			21,3(26,4)	23,5(28,7)	57,1(117,0)	22,8(27,0)
	$t(s)$			2,0(18,5)	2,1(17,3)	4,3(158,6)	1,9(17,0)
	$r(sr)$			0,11(0,24)	**0,54**(0,20)	**0,48**(0,22)	0,26(0,38)
	Au/Ag			0,04	0,05	0,02	0,1
Hg	$\overline{xг}(\overline{x})$			26,5(32,0)	35,3(41,3)	43,4(44,1)	33,2(37,8)
	$t(s)$			1,9(22,7)	2,0(19,0)	1,2(8,7)	1,7(20,8)
	$r(sr)$			0,37(0,21)	**0,70**(0,15)	**0,55**(0,25)	−0,47(0,32)
3. Kedrovskoye ore field Quartz diorites of the focal-dome construction							
Au	$\overline{xг}(\overline{x})$	0,7(0,8)[25]	0,7(0,8)[25]	0,8(1,0)[6]	1,4(1,7)[17]	1,5(2,3)[20]	3,6(3,8)[6]
	$t(s)$	1,4(0,4)	1,4(0,4)	2,1(1,1)	1,8(1,1)	2,6(2,4)	1,5(1,4)
Ag	$\overline{xг}(\overline{x})$	19,8(26,0)	19,8(26,0)	27,1(28,7)	34,0(33,6)	24,7(36,8)	46,4(47,2)
	$t(s)$	1,9(27,0)	1,9(27,0)	1,4(11,9)	2,4(75,6)	2,5(36,3)	1,2(9,2)
	$r(sr)$	**0,55**(0,16)	**0,55**(0,16)	**0,93**(0,05)	0,16(0,24)	0,35(0,21)	**0,69**(0,21)
	Au/Ag	0,03	0,03	0,03	0,04	0,06	0,08
Hg	$\overline{xг}(\overline{x})$	18,0(19,3)	18,0(19,3)	24,2(29,3)	17,3(17,8)	19,6(32,2)	25,7(39,3)
	$t(s)$	1,5(7,9)	1,5(7,9)	2,0(19,5)	1,3(4,6)	2,3(53,2)	2,7(38,4)
	$r(sr)$	−0,15(0,23)	−0,15(0,23)	-0,41(0,34)	−0,04(0,24)	0,13(0,23)	**0,94**(0,05)
Carbonaceous feldspar-quartz sandy-aleuroshales of the Kedrovskoe series							
Au	$\overline{xг}(\overline{x})$	1,2(1,6)[37]	0,7(1,5)[15]	1,1(1,7)[23]	1,8(2,6)[123]	3,9(6,9)[209]	5,8(15,3)[27]
	$t(s)$	2,1(1,5)	2,9(2,7)	2,7(1,6)	2,0(4,0)	2,8(9,5)	4,5(19,9)
Ag	$\overline{xг}(\overline{x})$	26,7(32,1)	23,3(26,0)	56,6(91,7)	61,7(165,1)	135,8(223,4)	165,0(278,5)
	$t(s)$	1,9(20,9)	1,6(13,9)	2,6(116,6)	4,6(340,4)	2,6(359,5)	3,1(257,0)
	$r(sr)$	0,001(0,2)	**0,79**(0,11)	0,22(0,21)	0,21(0,12)	0,11(0,09)	**0,44**(0,16)
	Au/Ag	0,04	0,03	0,02	0,03	0,03	0,04
Hg	$\overline{xг}(\overline{x})$	18,0(26,3)	28,3(34,7)	22,0(30,4)	24,5(34,1)	17,5(23,5)	30,5(36,0)
	$t(s)$	2,8(20,7)	2,1(18,7)	2,2(27,0)	2,4(30,1)	2,1(20,6)	1,8(21,4)
	$r(sr)$	**0,35**(0,16)	**0,50**(0,22)	0,20(0,21)	−0,15(0,12)	−0,11(0,08)	**0,58**(0,13)
4. Karalonskoye ore field Carbonaceous feldspar-quartz sandy-aleuroshales of the Wodorazdelnaya series							
Au	$\overline{xг}(\overline{x})$	1,0(1,1)[15]	н/д	1,6(2,0)[11]	2,0(2,8)[34]	2,0(3,5)[7]	24,7(73,5)[6]
	$t(s)$	1,6(0,4)		1,9(1,8)	2,4(2,6)	2,8(5,1)	5,6(100,9)
Ag	$\overline{xг}(\overline{x})$	25,1(35,1)		34,9(64,7)	45,6(65,1)	29,4(44,5)	53,3(60,2)
	$t(s)$	2,2(34,8)		2,9(99,3)	2,4(75,0)	2,9(39,9)	1,8(29,6)
	$r(sr)$	**0,56**(0,18)		**0,73**(0,14)	**0,52**(0,12)	**0,80**(0,13)	**0,70**(0,21)
	Au/Ag	0,04		0,04	0,04	0,07	0,4
Hg	$\overline{xг}(\overline{x})$	32,4(37,3)		47,0(49,0)	58,0(68,6)	42,2(61,6)	44,6(46,5)
	$t(s)$	1,8(19,2)		1,4(14,8)	1,7(61,4)	2,5(63,5)	1,4(16,3)
	$r(sr)$	0,12(0,25)		−0,007(0,30)	−0,22(0,16)	**0,55**(0,26)	−0,30(0,37)

Note. 1) $\overline{xг}(\overline{x})$ is the average geometrical and arithmetic content accordingly, mg/t; t is the standard multiplier; s is the standard deviation of contents, mg/t; r is the factor of pair linear correlation of elements with gold higher than the signification value is designated by the bold type; sr is the standard deviation of correlation coefficient; н/д -no data. 2) Content of Au and Ag was defined by the nuclear-absorption method (sensitivity is 0,1 mg/t) in the laboratory of nuclear-physical methods of substance analysis of Institute of Geology-and Gas and Mineralogy of the Siberian Branch of the Russian Academy of Science (Novosibirsk), analyst V.G. Tsimbalist. Content of Hg was defined by the nuclear-absorption method (sensitivity is 5 mg/t) in CL PGO «Berezovgeologiya» (Novosibirsk) under supervision of N.A. Charikov. The evaluation of quality of analytical works is executed in [22]. 3) Calculations are executed by N.P. Orekhov

double measurements of gold and silver content according to the internal control in the interval of contents 0,5...10 mg/t has made in different exerpts 18 and 23 % for gold, 11 and 14 % for silver, in the interval of contents 10,1...100,0 mg/t in one sample 26 and 13 % accordingly. The same error based on the data of nuclear-absorption and chemical-spectral analyses in the specified intervals of gold content has made 51 and 61 %, nuclear-absorption and neutron-activation in the interval of gold content from 0,5 up to 10,0 mg/t – 23 %. The content of mercury was defined from weighs of the same tests in the accredited laboratory with application of common standards; the quality of analytical works is satisfactory.

The results of calculations describing the distribution of metals in the near-ore (interore) space are shown in the table.

In all bearing environments, including black-shale, the geochemical fields possess similar features of a structure.

The lowest contents of metals are peculiar to the different in structure and origin of one and different ore fields rocks of the external zone of metasomatic aureoles. In all the subzones of this zone they are close to 1,0...1,5 mg/t sometimes falling up to 0,5 mg/t or rising up to 1,9 mg/t. Rather low values of the standard multiplier (standard deviation) of contents emphasize a weak dispersion of metal distribution on periphery of metasomatic aureoles. Towards the rear zone the contents and parameters of the dispersion of metal distribution increase reaching the maximal values in metasomatites of the rear zone.

Contents of gold in the internal albite and the rear zones of aureoles in absolute expression depend on a degree of gold-bearing ability of ore bodies which is not observed in the external zone. The dependence is expressed in that rocks of these zones are mostly enriched by gold in the frame of ore columns and veins with large reserves of metal and its average contents in ores at a level of not less than tens – many tens g/t. Aureoles of the Irokindinskoye deposit represent such situation, internal zones of which are tested in the frame of the largest with high industrial parameters Tuluinskoye, Yurasovskoye, 30 veins. Even the average geometrical content of gold reaches here tens of mg/t, exceeds 100 mg/t of silver; the content of mercury noticeably increases. Parameters of the dispersion of contents synchronously and sharply increase. The picture of stable increase in metasomatites of the internal zones of metal contents and the dispersion of their distribution (the latter is not always present) is maintained in the aureoles framing the poor ores with average contents of gold of no more than several g/t. However in the frame of poorly gold-bearing veins the beresite of the rear zone of apodolerite aureoles of the Zapadnoe and apodiorite aureoles of the Kedrovskoye ore deposits, for example, are enriched with gold up to the level of only several mg/t. In the frame of mineralized zones in carbonaceous shales (Karalonskoye ore field) the situation is intermediate, corresponding to their low gold-bearing ability with the average content of gold seldom exceeding 10 g/t.

Strong correlation connections in the volume of near-ore metasomatic aureoles as a whole and in their internal zones between gold and silver are usual and only episodic between gold and mercury. Thus, appreciable growth of mercury contents in the internal zones of aureoles only in apodiorite and aposhale aureoles of the Kedrovskoye ore field is accompanied by strengthening here of its positive connections with gold.

Weak or strong growth of gold-silver correlation towards the rear zone is also usual, but it is not always fixed.

5. Discussion of results and conclusions

The fact of low poorly differing or identical values of average contents of gold, silver, and mercury in rocks of subzones of the weak, moderate, and intensive change of the external zone of the near-ore (interore) metasomatic aureoles formed in all the discussed environments proves the inertness of metals at the stage of ore-formation and emphasizes their affinity to clarks in the corresponding magmatic, sedimentary, metamorphic rocks estimated under the standards of geological service of the USA [32] and in [33]. Therefore, two positions are represented: the specified values respond to local (regional) clarks of the corresponding initial for the metasomatism rocks; at the remote periphery of aureoles a weak influence of solutions which have caused a weak change of rocks, is not capable to initiate movement of metals, – their forthcoming into rocks or extraction from them. The situation changes in the more rear zones of the aureoles.

Monotonous, repeating in all the environments, including the black-shale strata, the picture of metal distribution in the near-ore, interore space of golden-ore fields reflects the fact that the same laws operate in formation of geochemical shape of this space.

The increase always and in all rocks irrespective of their previous geological history, contents of gold and silver towards the rear zone of the near-ore metasomatic aureoles and ore bodies is higher when the degree of the gold-bearing ability of the latter, points to: 1) metals migrate at metasomatism and always from solution-conducting and ore-bearing fractures, in the frame of which the intensity of rock transformations is the highest; 2) the mass of moving metals is defined by concentration of their compounds in metal-bearing solutions inherited by ores and rocks in their frame; 3) concentration of metals in rocks directly correspond to the degree of their metasomatic transformations.

Identified conclusions do not coordinate with the statements according to which in golden-ore deposits there are no attributes of near-ore changes of the bearing rocks [17], and gold (metals) is capable to migrate in rocks without their expressed material (mineral) attributes of epigenetic changes [34]. In the appendix to the discussed deposits the resulted conclusions deny the mentioned statements. At the same time, they do not contradict representation about the diffusion mechanism of mass-transfer at near-fracture metasomatism following from the analysis of the empirical data [28], –

in the process of extraction from solution-conducting channels and ore-bearing fractures, i.e. the sources, the masses of metals diffusing on the filled by hot solutions of the fracture-porous space of rocks gradually decrease.

In the consent with the resulted facts and the following from them conclusions, in the near-ore metasomatic and geochemical aureoles the quantitative correlations of gold and silver change. At the periphery of the aureoles in the non-changed or hardly touched by changes rocks with the subclark contents of these metals low values of Au/Ag-ration reflect sharply different clarks, – the content of gold here is a lot lower than the content of silver. In ores of mesothermal deposits the situation is different; – the content of gold differs from the content of silver by a little or even exceeds it, though there can be exceptions. Therefore, the increase of in the Au/Ag-ration towards the approach of its values to peculiar ores (0,5...1,5) as well as the previous facts emphasizes the genetic connection of the near-ore geochemical aureoles with near-ore metasomatic ones and ores, i.e. formation of all of them within the limits of uniform ore-forming processes.

At the same time, the near-ore geochemical aureoles always and in all rocks, including the strata of carbonaceous shales, are smaller in volume compared with the near-ore metasomatic, – the first ones enter the second. Obviously, the metals are capable to diffuse at limited distances, and it defines the fact that their basic mass, based on concentrations, is fixed in the near frame of ore bodies, – in the internal albite and the rear zones of the maximal transformations of the near-ore metasomatic aureoles. Further, towards the periphery of aureoles, metasomatic changes of rocks occur in conditions of heating up of the containing environment due to the internal resources of petrogenic components which is proved by the calculations of balance and low values of specific mass of the subjected to movement (migration) substance. Only rather mobile carbonic acid and hydrogen sulphide fixed there among the non-carbonaceous and the non-sulphideceous, for example rocks in the neogenic calcite and phyrite, are capable to diffuse at a distant periphery from the solution-conducting fractures.

Thus, geochemical researches and the following from them conclusions supplement the obtained earlier [19, 35, etc.] system of proofs of a deep geologic-genetic unity of golden-ore deposits of the both discussed sets, their accessory to mesothermal and formations in the black-shale strata and a crystal substratum within the limits of functioning of the antidrome fluid-magmatic granite-dolerite complexes of mantle levels of generation of melts and metal-bearing fluids.

It is pertinent to discuss the distinction noted above between the deposits of shale type and the ones formed in the crystal substratum, consisting in different, usually non-comparable scales of reserves and contents of gold in those and other objects.

In the shale strata the distribution of the whole mass forthcoming from the centers of generation of metal-bearing solutions along the set of seams and the fracture-porous space of large volumes of fractured well permeable rocks provides their participation in the ore-formation. All the forthcoming gold is fixed in ores and the near-ore space of deposits, however at the obvious low contents of its connections in solutions (by calculations, for formation of ore columns with average contents of metal 50 g/t its concentration in solutions of up to 100...200 mg/dm^3 is sufficient) the opportunities for concentration of metal in the forming ores in conditions of large volumes of ore-bearing environments are limited.

In the weak fracture crystal substratum, on the contrary, there are limited opportunities of accumulation of the whole mass of metal-bearing solutions forthcoming along the abyssal fractures, – they disperse only on low-volume teathering structures, mineralized zones not capable by virtue of limited volumes to contain the whole mass of solutions. Part of them, possibly a significant one, moving further upwards along the solution-conducting abyssal fractures dissipates near the surface or on the surface not being delayed on the physical-and-chemical and thermodynamic barriers created by meteoric waters. Together with solutions the gold also dissipates. However the repeated tectonic renewal (crushing) of the early mineral complexes in low-volume veins and mineralized zones and the repeating forthcoming into them of new portions of solutions with gold provides concentration of metal, especially in the most permeable parts of veins – ore columns.

The offered method of formation of geochemical excerpts is capable to provide creation, supplementation of regional, and in the long term global, banks of correct geochemical data. The correctness is reached by accumulation in banks of tests with the reconstructed geological history of rocks and chemical elements in them. Tests of rocks with diagnostics at a level «carbonaceous shales», «changed carbonaceous (coaly) shales», «sulphidized shales» and so forth, usual in a number of publications, in this case are inappropriate. On the contrary, the analytical data for tests with the reconstructed geological history of formation of their modern final mineralogic-chemical and geochemical content are suitable for the genetic analysis and the genetic generalizations necessary for development of the theory and achievement of the applied purposes.

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