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GOLD IN DISLOCATED CARBONACEOUS LAYERS OF THE SOUTH URALS.

Typomorphic peculiarities are shown of upper Precambrian gold-bearing carbonaceous layers of the South Urals. A gold-concentrating role is established of sulfide-carbonaceous depositions and hydrothermal-metamorphic nature of metallization. A qualitative model of gold-formation is represented, proposing a multi-time extraction of gold from host rocks in the process of lithe- and tectogenesis.

Carbonaceous depositions represent themselves as a rather favorable geo-chemical medium for a primary accumulation of many industrially important elements. At certain conditions, particularly in the fields of exposure of zonal metamorphism and tectonic activity, carbonaceous rocks may serve themselves as a source of metals and concentrate in themselves large deposits of gold, molybdenum, vanadium, manganese, platinum and other elements. During the last years, a new type of vein-dispersed gold sulfide mineralization with dispersion gold was founded among gold deposits, typical for carbon-bearing terrigenous layers, timed to mio- and mesogeosyncline systems, pericraton depression, avlakogenes, folded sedimentary rocks of deformed platforms and submerged average massifs. The general feature of gold – ore minerallization of this type, not depending on the mature of host rocks, is its constant timing to dislocated areas of earth crust – fissured and folded structures, zones of intensive crush of the rocks, fault-line zones of thermal metamorphism and diaphthogeris, capable to secure a migration and a deposition of ore substance. Such zones are usually controlled by large explosive faults and have considerable scales, defining a high economic importance of this type of metallization.

The carbonaceous depositions are known in the South Urals at several levels of riphean section, where they are included in the structure of rift-depression complexes and form layers and horizons in association of aleurolites, fine-grained sandstone's and carbonate rocks. Gold ore body or its upper-Clarke contents are discovered in these black-shale layers, usually accompanied with dispersed dissemination and by-layer pyrite secretions, localized in fault-line structures with distinctively displayed dynamothermal re-grouping of ore substance.

A gold-bearing quartz-sulfide minerallization, industrial analogues of which is well-known in many fold systems, is not of any industrial interest for a while being in the examined region due to its weak studies, but it may turn to be quite non-deficient for the development in the nearest future as per a whole number of indications. In this connection, an exposure of typomorphic signs of gold-bearing carbonaceous-sulfide formation with the aim of an elaboration of efficient forecasting criteria of this type of metallization seems to be actual.

Typomorphic features of gold-bearing carbonaceous layers

The upper precambrian carbonaceous depositions of the South Urals are mostly tabular, sometimes bedded, fine-grained dark-colored sedimentary rocks, characterized by a bed's form of deposits and consisting of poorly-rounded and badly sorted wrecking of feldspar-mica-quartz composition, cemented with a carbonaceous-clayey or carbonaceous-quartz-chlorite material. A rough (dozens of centimeters – first meters) and uneven inter-bedding is typical for them with aulevrolites, sandstone and carbonate rocks. The carbonaceous complexes are distinguished by facial change, various quantitative co-relation of terrigenous and carbonate rocks, instability of paleography environments of the sedimentation, and in main features, they show similarity and possess the following peculiarities:

- Heterogeneity of the structure, conditioned by inter-bedding of various lithologic types of rocks;
- Prevalence of massive and horizontal bedding structure at a fragmentary development in the rocks of wavy bedding and cross-bedding;
- Essentially clayey-alevrolite structure of terrigenous formations, almost a complete absence among depositions of the volcanic material;
- Sedimentary-diagenetic form of the emission of a carbonaceous substance and its maximum timing to the most clayey differences of rocks;
- Presence of dispersed dissemination of pyrite and pyrrhotite.

The composition of sedimentary complexes, their structure and facial peculiarities witness of intracratonic rift nature of the sedimentation and of a standard evolution of sedimentary basins, which includes an appearance of an areh at the initial stage with laying of graben structures, filling them in with a coarse-grained material and alkali volcanic rocks and a further stabilization of the tectonic situation, leading to the accumulation of a fine-grained clastics and a hemogenous carbonate-formation.

In rift distortions, favorable situations were created in the conditions of contrast bathymetry for a stable accumulation of fine-grained sediments, enriched with an organic substance. Shallow-sea conditions dominated at the flanks of these structures, and the accumulation of carbonaceous depositions was accompanied with an exposing influence of clastic and hemogenic carbonate material. Ore-bearing carbonaceous layers are located mostly in the average part of sections of the sedimentary complexes, gravitating to inundation phases of transgressive-regressive series.

At least five levels of strike of different-matured horizons of carbonaceous depositions, relating to terrigenous –carbonaceous and lime-carbonaceous formation types, may be distinguished in the sedimentation complexes' structures [11]: 1) biginzer with various typical carbon-bearing carbonate and terrigenous formations, cross-bedding with feldspar-quartz sandstone, hemogenous limestone and dolomites of sea origin; 2) suransky (berdagulovsky and serdauksky sub-levels) with a mixed complete set of shallow coastal-sea depositions – alevrolites,sandstones, dolomites, clayey-lime and carbonaceous shales with a bedding-to-bedding dissemination of pyrite; 3)yushinsky, represented by an inter-bedding, sometimes by rhythmic sericite-clayey shales with alevrolites, sandstone and dolomites, finalizing an early Riphean sedimentary cycle; 4) mashakski, opening a section of a middle Riphean sedimentary cycle with a complete set of typical graben lythotypes – main and sialic volcanic rocks, conglomerates, gravelstones, sandstones and alevrolites with layers and horizons of carbonaceous-clayey shales; 5) zigazino-komarovsky (sereginsky and tukansky sub-levels), represented by shallow-sea carbonaceous-clayey and carbonaceous-quartz-clayey phyllite shales in combination with alevrolites, sandstones and dolomites.

Two types of the carbonaceous substance (CS) are distinguished clearly in black shales:

1. sedimentary-diagenetic, inherent to non-deformed, poorly-metamorphic sediments layers and
2. methamorphogenic, peculiar to carbonaceous depositions, were subject to intensive dislocations and metamorphism in the zones of regional thrust faults.

A fine-dispersed form of CS's emission more often than not represents the sedimentary-diagenetic type. With the presence of a thin horizontal bedding, CS separates itself in a form of separate layers with the thickness from some millimeters to 10-15 cm. CS is available in the form of thin-dispersed dust-like inclusions in dolomites and limestone of a lime-carbonaceous type; a cleaning of grains takes place in re-crystallized carbonate depositions with a granoblastic texture-a carbonaceous substance is taken away out of the limits and forms thin edgings on the edges of singular crystals or their aggregates. According to the data of X-ray diffraction and thermoanalysis as well as electronic microscope examinations, in stratified layers the carbonaceous substance conforms to the amorphous carbon, which is close to shungite.

The metamorphogenous type of CS is represented by graphite. Its main mass stands apart in the form of foliation-, stringer- and lens-like and irregular form of accumulations, among which the following may be distinguished: 1) scaly secretions of hexagonal and prismatic shape, often distorted, deformed and oriented in parallel to foliation and schistosity. Graphite is usually timed to quartz grains, its inclusions are met more seldom in carbonate minerals or aggregate accumulations inside pyrrotine; 2) fine-grained flocks-like and clot secretions as well as lenz-like micro-interlayers in the association with mica plates; 3) dust-like and thin-scaly isolations in fine-grained quartz.

Well-known are traces of metamorphic re-grouping of CS – a formation of laid micro-cracking secretions among fine-grained carbonaceous mass, and sometimes, stringers of quartz-carbonate-scaly-graffito's structure are present among bearing rocks out of borderlines of carbon-bearing inter-bedding, which obviously points to a partial migration of CS during metamorphism.

Contents C_{org} depend on the conditions of sedimentation and on following epigenetic transformations. Even in the borderlines of one layer as per its strike and thickness, differences in meanings of values C_{org} fluctuate from 0,1 to 2,5%. A statistic analysis of the concentrations of C_{org}, made for several levels of the accumulation of carbonaceous depositions showed that most of black shales might be referred to low-carbonaceous type of sediments with average contents of free carbon 0,65%. This value depends on a granulometric and substantial structure of rocks and usually increases at the enlargement of sediment's dispersion.

Out of petrochemical indices a stable prevalence of potassium over sodium should be noted in rocks, moderate silica saturation, higher concentrations of aluminum oxide and titanium.

The contents of most minor elements in depositions of lime-carbonaceous type are almost two times lower than Clarke's for ordinary clays and clayey shales. Very low concentrations of the elements of terrigenous group are typical as well as lower contents Cr and near-Clarke value Cr/Ti. Values of the concentrations of all elements of the terrigenous group in the carbonaceous depositions change quite in conformity, which points to their common source and one form of the location. Low values of the relations K to Ca (<0,5) are connected with a visible increase in the specific weight of a carbonate component and a decrease of a clayey one; a contribution of the elements of carbonate group (Ca, Sr) for the given deposits becomes dominant.

Stable higher fluorine concentrations are typical for carbonaceous rocks, meanwhile they are obviously controlled by a lithologic factor: sandstones turn to be with less fluorine-contain, than aulevrolites (0,05-0,07% against o,1-0,15%) and carbonate rocks (0,2-0,3%), and abnormal fluorine concentrations (0,5%) are inherent to only carbonaceous lime-dolomite and carbonaceous terrigenous formations.

The terrigenous-carbonaceous type of depositions is most widely spread and it is met almost at all levels of the section of early-middle Riphean sediment complexes of the South Urals. A common geochemical feature of most earlier depositions, opining a terrigenous stage of the sedimentation is a lower content of Ni, Co, Cr, Mn, V, Sr in relation to Clarke and a small concentration of Cu, Zn, Pb, Ba and Zr. Typical are parameters of hydrolizate (0,29) and femic (0,059) modules as well as a high value of potassium module (0,56). Judging by a structure of petrogenic oxides, diorite-gneiss and hypersthene plagio-gneiss of Precambrian protuberances of platform crystal basement was subject to destruction. An average content of barium in carbonaceous rocks is considerably higher of the world Clarke for ordinary clays and amounts to 1176 g/t. With a comparable lithology, it is 2-4 times more than in other depositions of terrigenous- carbonaceous type. On the background of abnormally high contents of Ba in rocks an obvious deficit Sr (4 times lower than Clarke) is discovered. An abrupt prevalence of Ba over Sr is typical usually for carbonate-free (or poor-carbonated) clayey sediments in relation to deep-watered basins, for which Ba/Sr≥5 is an indicator value, and a carbonate phase of cement serves as the main bearer of Sr. A high relation of Ba to Sr in early Riphean carbonaceous sediments is explained well by a non-compensated condition of a carbonate-free basin of the sedimentation in the period of a destruction of the basement and an active stage of the development of a rift depression.

In the end of early Riphean period in the conditions of passive-flowing or passive rifting, a geo-chemical form of carbonaceous sediments becomes some other. An impoverishment is peculiar to them as per almost all specter of the analyzed elements Ni, Co, Cr, Mn, V, Cu, Pb, Ba, Sr, Zr, a higher value of the alkaline module is typical due to an abrupt reduction of potassium concentration in the structure of rocks as well as a higher value of protoxide module, indicating at the prevalence in a primary sediment of hydrolizated iron oxide. These and other peculiarities, in particular a high content of alumnae, higher values of hydrolizated and aluminum-silica module point to a relatively big mature of products of chemical weathering of feeder provinces of this time, and a frequent change of carbonate and terrigenous modes of the sedimentation as well as a considerable enrichment of carbonate rocks with a clustogenic material witness of an unstable tectonic mode and of a started gradual regression of the basin.

The carbonaceous depositions, beginning from middle-Riphean sedimentary cycle, are distinguished by a deep minimum as per Cu, Zn, Pb, Ni respectively in 9,2,4 and 1,5 times lower than a Clarke level for ordinary clayey rocks. Meanwhile, a higher content of Co and Cr in 1,2-1,4 times is noted there relatively to Clarke. The general petrochemical feature for black shales, confirming a substantial contribution of the basis material in the carbonaceous sediment, is their enrichment with the elements – hydrolizates, such as Ti and Fe. The same tendency is kept in the impoverishment by the most of ore-genic elements-mixtures in the carbonaceous deposits, finalizing middle Riphean riftogenesis.

Gold content in the most samples of lime-carbonaceous rocks amounts to 0.05-0.07 g/t, that somehow more of a value of regional Clarke for similar depositions. In some samples gold concentrations vary considerably and have a high dispersion, fluctuating in a range of 0,01-0,001 g/t. Taking into account a considerable deficit of elements-mixtures in the characterized depositions, as well as essential differences in gold contents, it is possible to admit, that we deal with residuals of their values, conditioned by post-sedimentation alteration of rocks.

In terrigenous-carbonaceous deposits of early riphey, gold concentrations amount to 0.003-0.005 g/t, which is comparable with Clarke values; its contents in basal layers of middle riphey somehow increase and usually amount to 0.005-0.01 g/t, and when they are elevated as per the section, they decrease anew and do not exceed 0.005 g/t.

Carbonaceous depositions' gold-bearing

A gold-ore mineralization in black shales is represented by two morphologic types: 1) sulfide-embedded, mostly of pyrite and quartz-pyrite-pyrhotite compositions, timed to linear intensive crush belts and shistosity of rocks and 2) veined (quartz-veined) and stringed (quartz-stringered), forming fields and stockwork zones with low contents of sulfides.

Both types are combined spacey and represent themselves a successive genetic row of gold-sulfide-quartz and gold-quartz mineralization, localized in various zones of metasomatic column [12].

Pyrite is the main concentrator of gold, represented by four varieties, observed in paragenetic associations of premineral and mineral stages of mineral-formation.

An early sedimentary-diagenetic pyrite (pyrite-1) is met in the form of relicts and, mainly, in layers of thin inter-bedding of carbonaceous-lime shales with quartz sandstone of different grains. A layered pyrite's distribution is observed in weakly infringed section areas and texture-structural signs of its sedimentary-diagenetic origin are maintained. A form of its secretion is close to spherulitic; the dimensions amount to from 0.01mm to 1-2 mm. Judging by textures of the carbonaceous depositions and their geochemical peculiarities, a formation of sulfide mineralization occurred synchronically with a sedimentation and was connected closely with a process of the accumulation of the carbonaceous substance. Data, available of the conditions of a formation of black shales, show that the carbonaceous sediment was accumulated in a stagnant shallow-sea basin with an abruptly reducing situation, favorable for sulfur reducing bacteria. Isotope characteristics of pyrite ($\delta\ S^{34}$ from +8.4 to $+27.4^{0}/_{00}$) show a crust sulfur's participation in its composition, which was formed due to a biogenic sulfate reducing of sea sulfates.

Contents of gold in pyrite are always higher, than in host rocks and vary from 0.05 to 0.5 g/t. Taking into account a weak metamorphism of sedimentary depositions and a frequent timing of a sulfide imbedding to clayey layers, enriched by organic, one may consider, that gold was entrapped with sulfides of iron in the process of diagenesis of sediments at their crystallization growth.

Metamorphogenic pyrite (pyrite-2) is represented with big crystals, frequently in association with pyrrhotite. It is usually localized in zones of layers of cleavage cracks or in fold core in a form of lens-like isolations and it has a distinctive epigenetic character. An almost ideal crystalline texture and a distinctive idiomorphism in respect to the surrounding minerals are inherent to pyrite. Many crystals are rich with the inclusions of rock-forming minerals, entrapped in the process of a pyrite's growth; the inclusions of such minerals in metacrystals keep their initial orientation, and conform to a general direction of schistosity of rocks. Inclusions of quartz and carbonate are present in shades of pressure in periphery of crystals.

Metacrystals of pyrite were formed, probably, due to a mobilization and recrystallization of early pyrite in the conditions of greenschist stage of metamorphism. This witnesses of a wide development in sulfide zones of a typically average-temperature chlorite-sericite-calcite mineral association as well as a spacious combination of syngenetic and epigenetic sulfide mineralization and regeneration connections between them.

Metamorphogenic sulfides are concentrators of the most of elements-mixtures. More than a half of the number of the studied elements – Cu, Ni, Co, Pb, Au, Ag, Mo, As – show a close connection with a sulfide phase. 80-100% of the total mass of Co, Ni, Ag, As, Au are concentrated in pyrite when its content in carbonaceous depositions is within the range of 5 – 15 %. As far as host black shales are concerned, metacrystals of pyrite are considerably enriched with Ni, Co and especially with As (Fig.1). A value Co/Ni varies from 1 to 5, not exceeding for most part of the samples 1. A level of the concentration of elements reduces in pyrrhotite essentially – for Co and Ni more than in 5 times, and a content of As for ten times lower than in pyrite.

Gold is distributed in pyrite extremely unevenly - from Clarke values to 1-3 g/t. The concentrations of silver are uneven in the same degree, amounting to from 1 to 40 g/t. A co-relational dependence for couple gold-silver is not available. Values of Au/Ag vary from 0.05 to 0.1. Considerable variations in contents of gold, probably, are connected with a process of its Metamorphogenic re-grouping in early sulfides and black shales and, with the beginning of native form of gold.

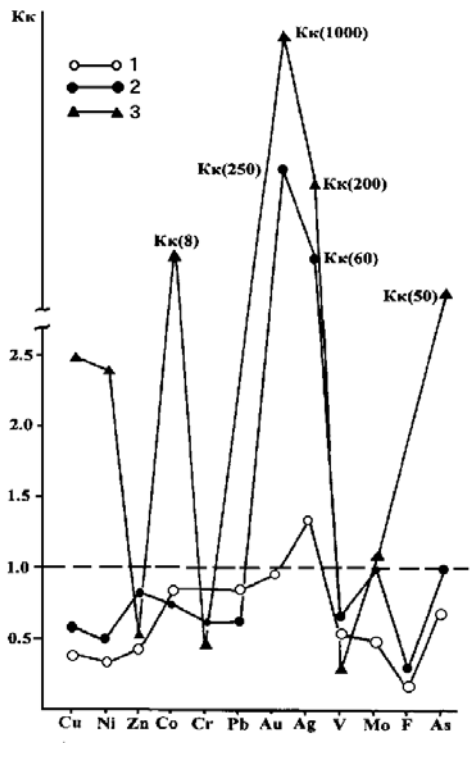

Fig. 1. Coefficients of the concentrations of the elements in

- ✓ carbonaceous (1),
- ✓ carbonaceous-sulfide (2) and
- ✓ Metamorphogenic pyrite (3)

in relation to average contents in clays and shales

(per Vinogradov, 1962).

The embedded metasomatic pyrite (pyrite-3) was formed in the very beginning of the mineral period. It is represented by fine (3-4mm) crystals of various shapes in the association with quartz, carbonate and sericite, forming narrow halos around areas of veined and metasomatic quartz. Stable gold contents from 1.0 to 1.5 g/t are founded out in pyrite.

A stringered hydrothermal pyrite (pyrite-4) is a main concentrator of gold. It forms metasomatic stringers of the execution in quartz veins and in host rocks, where it associates with quartz, sericite, shaleopyrite and arsenopyrite. Gold contents vary in it from 1.0 to 11 g/t.

It is quite obvious, that a gold accumulation in ore zones was of a staged character with a successive increase in its contents in a row: carbonaceous rock-pyrite-1 - pyrite-2 – ore pyrite-3,4. The intermediate over-Clarke gold concentrations in a pre-mineral pyrite served as a source for the following formation of industrial golden-sulfide-quartz ores.

Gold in sulfide-quartz type of metallization is met not only in pyrite, but in a free form directly in veined quartz, too, or on its contact with sulfide minerals. Is controlled by zones of crushing, gravitating to large regional faults, and defining a specificity of fields of tectonic and magmatic activity. Ore objects are timed to the sections of crossing of explosion infringes, to the areas of their attachment with plicate dislocations, to the belts of dike bodies and small intrusions, and they are represented by linear quartz-vein fields or stockwork zones (Fif.2).

Discordant, concordant and complex forms (or close per a position to bedding) may be pointed out in respect to bedding of rocks among stringers. A complex of ore minerals in quartz is represented mostly by sulfides: pyrite, arsenopyrite, pyrrhotite, shaleopyrite, galena, sphalerite. Chalcocite, marcasite, bornite are less spread over. Gold is usually of small and middle classes of size with a high assay (880-960) and an insignificant mixture of copper, selenium, and tellurium.

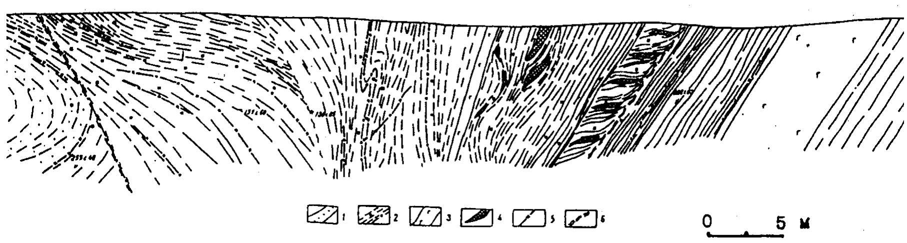

Fig.2. Section of a dislocated gold-bearing carbonaceous layers.

1- aulevrolites and sandstones; 2- pyrite carbonaceous shales;

2- magmatic rocks of the main texture; 4- budinite quartz veins;

5- quartz stringers; 6- zone of tectonic infringements.

Typical types of altered country rocks aresericitization, silication, carbonization, chlorization and pyritisation. At some objects across spreading mineralized ore zones, a general successiveness of transfer from weakly transformed rocks of outer zone to ore-bearing metasomatites of the inner zone is distinguished as a deformation becomes stronger and the following types of the alterations are established:

1- rocks with the initial cata-metagenetic alterations of structure-textural peculiarities and substantial composition;
2- metamorfites with typical transitive blastic structures and mineral new formations;
3- Metamorfites with well-expressed secondary structure-textural properties and rich accumulations of quartz, muscovite, sulfides, carbonate.

As per a set of mineral para-genesis, the listed epigenetic transformations of the rocks conform to the final products of lythogenesis and dynamothermal metamorphism of albite-muscovite-chlorite subfacies of greenschist facies. Timing of secondary alterations to folded structures and synfolded dislocation zones points to a conjugation of dislocation and hydrothermal processes – layered, interlayered, diagonal and interlayer-cleavage cracks, defining spacious and accompanying metasomatites. An assay of bearing rocks showed rather a high dispersion in gold distribution in an ore-around space: in 10% of all samples that were analyzed, gold was not discovered, and in 30% of analyses, its contents did not exceed 0,001 g/t, that is much lower of the regional Clarke for a similar type of sedimentary rocks.

Geologic-genetic model of gold-formation

Typical morphemic features of gold-ore mineralization, determined by us earlier – a simplicity of mineral composition, generality of thermodynamic situation of gold-formation and greenschist metamorphism, a participation of dislocation metamorphism in the formation of structures and metallization, absence o connection with magmatism- allow to ground well a Metamorphogenic-hydrothermal genesis of vein-embedded and stockwork developments and to point out a possible model of ore-formation. A developed at present time conception of Metamorphogenic-hydrothermal gold-formation in application to blackschist layers [4,5,7] proposes a complex participation in ore-genesis of mutually-connected processes of the sedimentation, tectonics, magmatism and metamorphism with a leading role of the last mentioned one. Crust gold was determined for many gold-ore quartz-veined fields and a possibility was shown of the mobilization of metal out of ore bearing and ore bodies laying rocks. Meanwhile the last ones are often considered as intermediate reservoir gold rocks when forming gold-bearing quartz veins.

Despite the fact itself that gold migration is known since a long time and it does not cause any doubts, a possibility of a complicated and most discussion question still remains, as before, together with ways of gold's mobilization out of rocks and its transition to a hydrothermal solution. It was shown [14], that sedimentation of metals from seawater is possible by means of absorption by their colloidal solutions or, as per hypothesis of biominerallization [10] by means of the accumulation of micro-organisms of colloidal gold, delivered to a sea basin by hydrothermal solutions. A further fortune of the pelitic sediments enriched by colloidal gold was defined by an influence of high-energetic sources on them – magmatism and metamorphism, causing to a re-crystallization of rocks, when gold, not possessing a capability to enter crystal lattices belonging to new forming minerals [2], transformed into a mobile state, and in a form of complex alkaline compounds together with silica was transferred by metamorphogenic solutions and settled in cracking structures.

According to data mentioned above, the following elements were included in a proposed model of gold-formation, which compose most of schemes of metamorphogenic-hydrothermal ore-genesis [6,8]:

- substance sources: ore-bearing/containing riftogenic-depression stratifying carbonaceous layers, examined as micro-ore formations;
- energy source: dislocated metamorphism near break-up, developed due to Riphean-vendian activity
- transportation agents: buried mineralized pore waters and high-mineralized metamorphogenic solutions:
- Ore-deposition fields; cracking and folded structures in zones of the development of strike-up faults and thrust faults.

Available data [13] witness of a long and poli-staging formation of golden metallization, the history of which covers all Late Proterozoic-Paleozoic megacycle, including periods of tensioning and destruction of the basement with a wide development of sedimentary rift depositions and their successive multi-time tectonic-magmatic activity. According to data by L.V. Anfimov [1], a considerable removal of micro-elements from the sediment by means of buried pore and hydration waters takes place in the course of the evolution of clayey rocks from sedimentogenesis till metamorphism. In the process of diagenesis and catagenesis of sediments, S,F, organic acids and Cl, may serve as active solvents for gold, which, by the opinion of V.A. Buryak [5] are always present in pore waters, particularly in carbon-containing facies. That is why precisely, such layers are characterized by very low, at Clarke's level, gold contents.

Its re-distribution and a local concentration in upper-Clarke quantities in pyrite's carbonaceous-clayey depositions accompanied gold's removal out of sediments. A selective timing of higher metal contents to these rocks is explained by proximity of geochemical properties of gold and iron, their siderophilness and barrier functions of sulfides, developing most actively at low-temperature conditions. The presence of higher concentrations of metal in carbonaceous-sulfide rocks directly at a level of the localization of main metallization or in underlie rocks may be considered as one of the gold sources at metamorphogenic-hydrothermal ore-formation.

At the following lithogenetic transformations, accompanied by biochemical and thermal decomposition of an organic material, as well as a desorption of clayey fraction of the sediment, a degree of mineral saturation in pore waters increases constantly, reaching approximately 10-20 mg/l and more [3]. Mainly the elements of chemical group-Pb, Zn, Cu, Au,- are concentrated, which accumulate actively in the conditions of an aerobic oxidation of the organic substance in clayey minerals with a high sorption capacity.

A dissociation of carbonates, sulfides, hydromica and other minerals, as well as a further thermal decomposition of the organic matter with the transition into a solution of metals occurs at an average temperature greenschist metamorphism. A concentration of metamorphogenic solutions still more increases and may reach 340 g/l and over [9].

At this stage, apart from metals and petrogenic oxides, extracted from containing rocks, a concentration of carbon dioxide increases abruptly in metamorphogenic solutions, being formed due to the oxidation of C_{org} and dissociation of carbonates. In the conditions of dislocation metamorphism, zones of a higher penetration served as locations of ore-deposition, formed by regional thrust faults and attended by strike-slip faults. Strike-slip faults and thrust fault paragenesis and combined with them local folded and explosive structures served as fluid-and warmth-mass conductors with thermo-gradient fields, vertically arranged, favorable for the accumulation of the ore matter. The Metamorphogenic solutions, entering drainage zones of break-ups, became of non-equal weight due to an abrupt pressure fall down, securing their active discharge and ore deposits forming.

Thus, a proposed model of ore-formation may be considered as sedimentary-hydrothermal-metamorphogenic, including a complex of mutually-related processes (fig.3): 1) sediment-accumulation with a chemical sorption of gold by carbonaceous-clayey depositions; 2) geostatic metamorphism, activity of elision pore solutions, extracting ore-genic elements and gold out of a clayey fraction, their re-distribution and a mobilization in reservoir rocks (carbonaceous sulfide sediments as geochemical barriers) and creation of intermediate upper-Clarke concentrations; 3) dynamo-metamorphism, thrust-formation and fold-up, accompanied by metamorphogenic re-grouping and re-deposition of the mineral matter and a final formation of gold-quartz deposits.

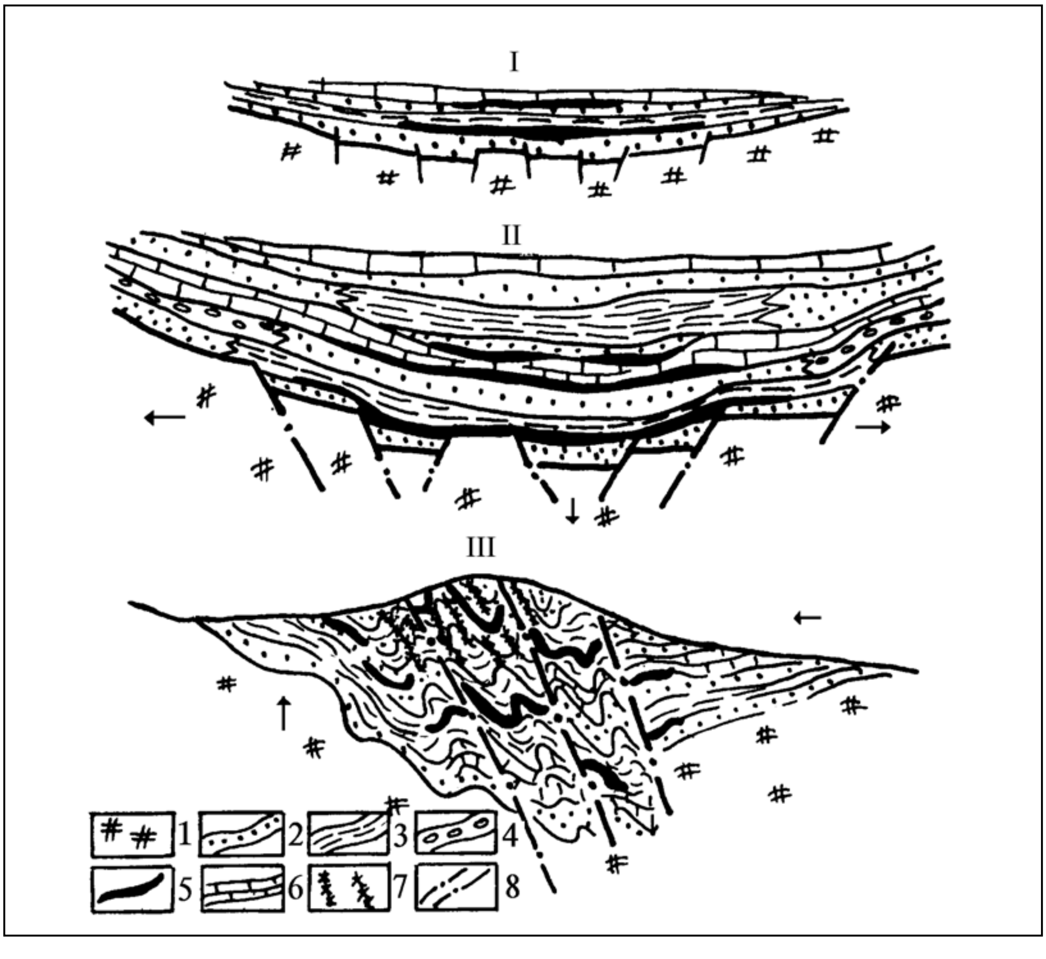

Fig.3 Stages of forming of gold-quartz-sulfide metallization of hydrothermal metamorphogenic type. I – stage of the accumulation of primary gold concentration in stratified terrigenic-carbonaceous sulfide-containing depositions; II – geostatic metamorphism, wringing of pore waters out, gold and other elements removal out of bearing rocks, and their concentration in sulfide minerals (elision stage); III – thrust-formation and napping of sedimentary depositions, dynamo-metamorphic

transformation of gold-containing sulfide-carbonaceous formations and forming of of gold-quartz-sulfide metallization (dynamo-metamorphic stage); 1-rocks of basement; 2 – sandstone; 3 – clayey shale; 4 – conglomerates; 5 – sulfide carbonaceous depositions; 6 – limestone; 7 – gold-bearing quartz-sulfide veins; 8 – explosion faults.

CONCLUSIONS

Received data on mineral-geochemical peculiarities of blackschist depositions allow formulating some conclusions, the application of which may increase an efficiency of forecast search works for gold in carbonaceous formations of the south Urals.

1. A favorable searching indication in regional plan is the presence of thrust structures and combined diagonal strike-slip faults with them, creating a total high splintering of rocks and forming synfolded systems of attended joints, filled with sulfide-quartz veins.

2. The presence of sandy and clayey differences of rocks in section, re-bedding with carbonaceous depositions, provided from one hand with an optimal mode for proceeding an elision process, and from the other hand,- it promoted to the development of inter-layer tectonic zones, de-schisting, splintering, conditioned a withstood character of position of ore bodies.

3. Sulfide mineralization, which performed a role of geochemically buffer medium, served a favorable factor for ore-localization. Cross-bedding zones of sulfide-imbedded mineralization served as micro-ore formations, capable to accumulate intermediate upper-Clarke concentrations of gold. In the course of a successive tectonic and metamorphic development, these gold-enriched sulfide-carbonaceous zones served as main sources of metal for ore deposits.

4.Gold transfer in the conditions of greenschist dynamothermal metamorphism could be implemented by pore carbonic acid fluids, a great number of which was formed during reactions of dehydration and de-carbonation. A direct co-relative connection between gold contents and metamorphogenic sulfide minerallization, as well as a wide development around ore zones of halo of carbonic-acid metasomatism show that a mobilization of ore matter and its isolation in deposits occurred precisely under an influence of dynamometamorphic processes. Iron-magnesian carbonates (dolomite, ankerite, siderite), indicating to the essentially reducing character of the development of metallization are constant sputniks of gold-ore minerallization.

The work has been implemented with a financial support of Ministry of general and professional education of Russian Federation (grant GB-01-98).

REFERENCES

1. Anfimov L.V. Ore metasomatism, catagenesis and initial metamorphism in lower-Riphean layers in the south Urals // Geology of metamorphic complexes. - Sverdlovsk, 1990.- P.20-29.
2. Betekhtin A.G. Hydrothermal solutions, their nature and processes of ore-formation / Main problems in the study of magmatogenic ore fields. - M.: AN USSR,1955.
3. Bogashova L.G. Metal-bearing pore solutions of salt-bearing depositions //DAN USSR.- 1983.- V. 269.- No 4. - P.932.
4. Buryak V.A. Metamorphogenic-hydrothermal type of gold metallization //Geology of ore fields.- V.17.-1975. - No.2. - P.37-46.
5. Buryak V.A. Metamorphism and ore-formation. - M.: Nedra, 1982. - 256 p.
6. Buryak V.A. Conditions of formation of metamorphogenic-hydrothermal fields //Criteria of distinguishing of metamorphogenic and magmatogenic of hydrothermal fields. - Novosibirsk, Science, 1985. - P.14-22.
7. Buryak V.A. Sources of gold and accompanying components of gold-ore fields in carbonaceous layers // Geology of ore fields.- V. 28. 1986. - No 6.- P.31-43.
8. Dobretsov N.L., Krivtsov A.I. Models of magmatogenic-hydrothermal ore-accumulation and criteria of their distinguishing //Criteria of distinguishing of metamorphogenic and magmatogenic of hydrothermal fields. - Novosibirsk, 1985. - P.5-14.
9. Lomtadze V.D. Conditions of water and oil pressing out of clays //Notes of Leningrad Mining inst. – 1951. - V. XXV, issue 2. - P.49-886.
10. Ovcharenko F.D., Ulberg Z.R., Garbar S.V. and others. Mechanism of biogenic forming of autigenic inclusions of gold in fine dispersed sediments //Report AN USSR. – 1985. - V.283. - No. 3.- P. 711-713.
11. Rykus M.V., Andreyev N.I., Murkin V.L. and others. Carbonaceous deposits of dokembri of the south Urals // Preprint, UNTs RAN. - Ufa, 1993. - P.40.
12. Rykus M.V. Metamorphism and gold-ore minerallization in dokembrian depositions of the South Urals //Gorny vestnik.– 1998. – N 4. - P.58-64.
13. Rykus M.V., Snachev V.I. Gold of western slope of tjhe south Urals //UNTs RAN , Ufa. – 1999. - 170p.
14. Strakhov N.M. Bases of theory of lithogenesis. - V. 1-3. Issue 2. - M.: AN USSR, 1960-1963.

RESUME

Typomorphous features of the texture and structure of riphean carbonaceous gold bearing of the south Urals are examined. Main levels of the localization of blackschist rocks of carbonate-lime and terrigenic-carbonaceous types are characterized. Data are given on the C_{org} contents in the rocks, a conclusion is made of their belongings to a low-carbonaceous type of the sediments. An essential deficit of elements-mixtures and gold in carbonaceous depositions is fixed, which is connected with a post-sedimentary transformation of the rocks.

Four morphogenetic varieties of pyrite are determined, belonging to prior-to-ore and ore stages of the mineral formation. It is shown that gold concentrations are regularly increased in row: carbonaceous rock – pyrite – 1 – pyrite 2 – ore pyrite. A prior to ore metamorphogenic pyrite is considered as an additional source of gold for ore deposits. A qualitative model of hydrothermal-metamorphogenic gold formation is

elaborated, securing a multi-time extraction of gold out of country rocks in the process of litho- and tectogenesis. Forecast – searching signs of gold bearing of blackschist formations of the region are scheduled.