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ORE-METASOMATIC ZONING OF THE PORPHYRY COPPER FIELD OF THE GOSH-GARCHAY ORE-MAGMATIC SYSTEM (LESSER CAUCASUS, AZERBAIJAN)

Mamoy I.Mansurov, Tarana A.Mammadova, Ulker I.Karimli, Ruslan A. Shamiyev, Aygun G. Mammadova

Baku State University, 33, Z. Khalilov str. AZ 1148 Baku, Azerbaijan

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Abstract

Analysis of the nature of mineralization and metasomatite zoning for known porphyry copper fields of the Goshgarchay ore-magmatic system (OMS) associated with the Murovdag group of intrusions. Complex structural-geological, metallogenic, geological-petrological, ore-metasomatic, petrochemical parameters of metasomatites and studies taking into account earlier scientific-thematic, geological exploration works were used. There is certain regularity between the petrochemical parameters of metasomatites and the copper and molybdenum contents. It has been established that the thickness of metasomatically altered rock zones ranges from several meters to tens and sometimes even hundreds of meters (at the intersections of differently oriented faults) within the Goshgarchay OMS. Their length is measured from 500-1000 to 2000-3000m. There are three elliptical metasomatic zones, gradually replacing each other in space, surrounding the intrusive massif of porphyry composition around the ore-generating intrusions of the Goshgarchay OMS. The inner zone, covering the endocontact and apical parts of the porphyry intrusion, is represented by intensely silicified rocks, almost completely transformed into secondary quartzites. The middle zone is distinguished as quartz-sericite-chlorite facies of secondary quartzites. The third, external zone of the metasomatic column is represented by the propylitic facies of secondary quartzites. Ore zoning was studied within the contours of the Goshgarchay field, and the following series of zoning of elements vertically (from bottom to top) was obtained: Mo→Cu→Co→Ni→Cr→Ag→Pb→Zn. Hydrothermal-metasomatic alteration of host rocks in zones of different types of metasomatites formed during the formation of the field were investigated and compared based on petrochemical data.

Keywords: Goshgarchay OMS, intrusive complexes, porphyry copper fields, metasomatic column, ore-metasomatic zoning, ore minerals, ore-bearing.

Corresponding author.

E-mail address: mmansurov@bsu.edu.az (Mamoy I. Mansurov) taranamammadova2@bsu.edu.az (Tarana A.Mammadova)

Introduction:

Murovdag is one of the most promising ore regions of the Lesser Caucasus orogene and is characterized by the presence of a number of fields and ore occurrences promising for copper, molybdenum, gold, lead, zinc and other minerals. There are also several fields and ore occurrences of the porphyry copper type, in which the copper ore resources can be classified as large fields. The most studied is the Goshgarchay field, where exploration work was carried out, which allowed to identify it as very promising.

The problem of forecasting, studying and assessing porphyry copper-molybdenum fields in the volcanogenic belts of the Azerbaijani part of the Lesser Caucasus is one of the most urgent for solving the issue of expanding the mineral resources base not only of copper and molybdenum, but also of gold and silver, elements of platinum groups, polymetals, rare and rare earth elements. Copper fields and ore occurrences are widespread in all metallogenic zones in the Lesser Caucasus. They belong to three genetic types of industrial importance: porphyry copper, copper-pyrite and copper-polymetallic. All of them are associated with volcano-intrusive and plutonic complexes of the Lesser Caucasus. Porphyry copper mineralization associated with plutonic granitoid massifs of the Murovdag ore region is the most promising. There are also several fields and ore occurrences of the porphyry copper type, where copper ore resources can be classified as large fields. The most studied is the Goshgarchay field, where geological exploration work was carried out, which made it possible to identify it as very promising.

Materials and methods of the research. The basis of the factual material was a collection of samples (about 150 pieces), collected inside and around the stockwork with veinlet-impregnated mineralization and to a depth of more than 500m from the day surface on its flank. The collection includes samples collected from gabbroids, quartz diorites, quartz veins with galena-sphalerite-chalcopyrite mineralization. Petrographic thin sections and double-sided polished plates were made from the sample to study fluid inclusions, and the rest of the sample was crushed and sieved. Atomic absorption analysis on a Perkin Elmer device allowed quantitative determination of elements such as Cu, Mo, Cr, Ni, Co, Pb, Zn, Sr, As, Bi. Rock samples were analyzed by Inductively Coupled Plasma Mass Spectroscopy (ICP-MS). Silicate chemical analysis was carried out in the Laboratory of the University of Izmir, Turkey. Thermobarogeochemical analysis of gas-liquid inclusions of quartz of different generations was carried out using modern high-precision methods in the analytical laboratory of the USGS of the US Geological Survey (Denver).

The Goshgarchay ore-magmatic system (OMS), being a component of the Lok-Karabakh paleoisland arc, occupies NW elevated part of the Murovdag anticlinorium, an asymmetric structure composed of rocks of the Lower Bajocian volcanogenic sequence in the core and Upper Bajocian and Bathonian sequences of basalt-andesite-rhyolite successively differentiated formation on the wings. The intrusive component of the OMS is the Goshgarchay complex of granitoid intrusions (Goshgardag, Ojagdag, Balaja Goshgardag) and their dyke formations, which break through a powerful complex of effusive-pyroclastic formations, exerting a contact effect on them. Intrusive complexes with porphyry copper mineralization according to geological and petrological features belong to the Late Jurassic-Early Cretaceous gabbro-diorite-granodiorite formation (Fig. 1).

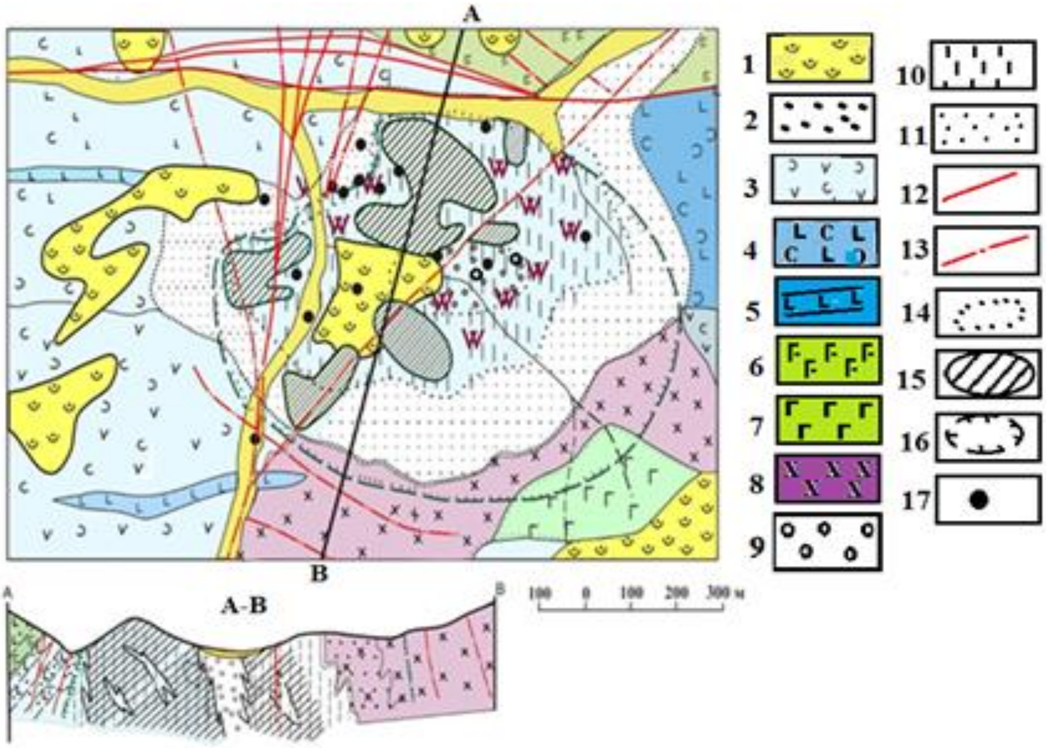

Fig. 1. Geological map of Goshgarchai deposit of porphyry copper ores (scale 1:10 000):

1 – recent eluvial-deluvial deposits; 2 – alluvial, proluvial deposits; 3– andesites and their tuffs; 4 – diabases and their tuffs; 5 – dykes of diabase porphyrites; 6 – bedded bodies of gabbro, gabbro-pyroxenites; 7 – gabbro, gabbro-diorites; 8 – diorites, quartz diorites. Facies of secondary quartzirtes; 9 – monoquartzite; 10– quartz-sericite; 11 – propylite (chloritized, silicified, calcitated, epidotized and pyritized rocks with vein-disseminated ore mineralization. Faults: 12 – regional ore control; 13 – other; 14 – borders of secondary quartzites facies; 15 – ore porphyry copper outlines with commercial content on surface; 16 – aureole of porphyry copper ores distribution; 17 – boreholes.

Porphyry copper mineralization covers the Gashgachay, Goshgardag, Gizilarkhach, Kechaldag, Erik-Manuk and other fields and ore occurrences, where it is in close spatial and genetic connection with the granitoid massifs of the same name in the Goshgarchay OMS. According to the geological position and spatial distribution, the intrusive formations of the Murovdag group are divided into the Goshgardag and Gyzylarkhach groups by R.N. Abdullayev [1].

It should be stated that the intrusions penetrate a thick complex of Middle Jurassic effusive-pyroclastic formations, on the basis of which their lower age limit is established with sufficient degree of accuracy. Due to the lack of direct data, R.N.Abdullayev [1] determined the upper age boundary of the intrusions indirectly on the basis of the analogy of their petrographic composition with the rocks of the Dashkesan-Zurnabad massif, where the latter break through the Upper Jurassic effusive-pyroclastic and carbonate rocks and are overlapped by Coniacian sediments with granitoid pebbles at the base in the area of the village of Zurnabad. So, the upper boundary of intrusions of the Murovdag group is accepted by R.N.Abdullayev [1] as post-Upper Jurassic-Coniacian.

Intrusive rocks are widely developed and are represented by gabbro, gabbro-diorites, diorites, quartz diorites and porphyritic granodiorites within the Goshgarchay deposit. Three main phases of the Upper Jurassic-Lower Cretaceous intrusive series are outlined: 1) diorites, quartz diorites, quartz diorite porphyrites; 2) granodiorites, granodiorite porphyries and granite porphyries; 3) dykes of gabbro-dolerites, diorite porphyrites, quartz-diorite porphyrites [1].

The Goshgardag group of intrusions is located on the eastern and western slopes of Mount Goshgardag, on the southern slope of Mount Ozagrag and also at the confluence of the Balaja and Boyuk Goshgarchay rivers. It was first identified by R.N. Abdullayev and described by him [1].

The structure of the OMS was formed as a result of a succession of several stages of deformations, accompanied by the formation of fracturing in the intrusive massif, the intrusion of dykes, the movement of blocks along tectonic faults and the filling of cracks with various mineral associations.

The sublatitudinal or Caucasian orientation of faults is directly ore conduit, and the NE strike-slip faults supporting the Goshgarchay fault from the side of its hanging wall are ore-localizing structures, which is explained by: 1) the arrangement of ore zones in the footwall; 2) the same direction of dip of ore zones and faults with steeper angles of the latter; 3) localization of ore zones mainly in small fracture systems and faults of local significance; 4) confinement to the main faults of subvolcanic bodies and dykes, zones of intense hydrothermal alterations of rocks and impregnated sulfide mineralization [10].

Results of the research and their discussion. Studies of many fields, especially those of hydrothermal origin show that the occurrence of zonality of minerals and chemical elements in ore bodies is inextricably associated with the zonality of wallrock metasomatites. Porphyry copper fields are typical in this regard, in which horizontal and vertical components of zonality are most clearly occurred in the locations of ore-forming elements and various metasomatite formations [2].

In general, the rocks of the Goshgarchay intrusion have many common peculiarities: hypabyssal conditions of formation; intense hydrothermal alterations; identical mineral composition of the rocks; similar sequence of crystallization of minerals in all groups of rocks [8].

The formation of the multiphase intrusions and associated mineralization of the Goshgarchay OMS occurred over a long period of time. The metasomatic zoning of the Goshgarchay OMS indicates that the model corresponds to a typical object of the porphyry copper ore formation. As in many fields of this type, the outer zone of altered rocks is represented by propylites, the intermediate zone by quartz-sericite metasomatites and argillizites, and the inner zone by essentially quartz metasomatites [7,9].

The separation of metal-bearing fluids was repeated during the formation of the Goshgarchay massif, which led to the formation of an extensive zones of propylitization associated with the early phase, and then superimposed zones of potassium, quartz-sericite and quartz metasomatism and argillization, caused by the influence of more acidic late phases. The formation of a large part of the industrial porphyry copper-molybdenum mineralization followed the intrusion of early generation porphyries. The late porphyry phase is associated with the redeposition of previously formed ores and the formation of rich accumulations in the form of veinlet-impregnated stockwork ores oriented in the latitudinal direction in the fractured zone of the Goshgarchay fault. The late porphyry phase was much less ore-bearing than the first. It was accompanied by intensive silicification, which led to the formation of a “quartz core” in the central part of the field. There is a quartz-sericite zone with rich porphyry copper-molybdenum ores to the north of it, followed by a propylite zone with predominantly veinlet pyrite mineralization [5,9,10].

The zoning of mineralization in porphyry copper fields has been studied by many researchers. I.G. Pavlova et al. provide the following series of ore zoning for porphyry copper fields based on maximum element concentrations: iron → molybdenum → copper (molybdenum) → copper (gold) → iron (gold) → lead → zinc (I); ore minerals: magnetite-molybdenite-chalcopyrite (with gold) – pyrite (with gold) – sphalerite-galena-enargite-bornite-fahlore (II); mineral parageneses: potassium feldspar-magnetite, potassium feldspar-biotite-magnetite, pyrite-sericite-quartz; quartz-molybdenite or potassium feldspar-molybdenite; quartz-chalcopyrite-molybdenite; carbonate-galena-sphalerite (III) (from the center to the periphery and from bottom to top along the rise of ore bodies).

A typical one among the main characteristics for constructing models of porphyry copper fields is a set of zonal metasomatic alterations that have a direct correlation with ore-rich areas. The most prominent examples are potassic, quartz-sericite secondary alteration, extended argillization and propylitization. Usually hypogene extended argillite alteration forms relatively late in the formation of a porphyry system, but can also begin quite early. Some researchers argue that the difference between the metasomatic sets is not related to differences in the porphyry systems themselves [8]. This probably occurs simply because some of the secondary alteration zones formed at shallow depths have been eroded in many cases. As a result, extended argillite alterations are often not included in classical models of metasomatic alteration zoning. Detailed research of porphyry fields have established that early potassium-silicate secondary alterations (potassium feldspar ± biotite ± magnetite with quartz veins) of porphyry systems were formed under conditions of high temperatures (400–600 °C), with the participation of highly mineralized fluids of magmatic origin. And the later sericite veins representing the next stage are associated with colder and less mineralized waters [5,6,12, 15].

The study of many fields, especially those of hydrothermal origin shows that the occurrence of zonality of minerals and chemical elements in ore bodies is inextricably associated with the zonality of wallrock metasomatites. Porphyry copper fields are typical in this regard, in which horizontal and vertical components of zonality are most clearly occurred in the locations of ore-forming elements and various metasomatite formations [12,13].

The metasomatic zoning of the fields indicates that the model corresponds to a typical object of a porphyry copper ore formation. As in many fields of this type, the outer zone of altered rocks is represented by propylites, the intermediate zone is represented by quartz-sericite metasomatites and argillites, and the inner zone is represented by essentially quartz metasomatites [12, 15].

The separation of metal-bearing fluids was repeated during the formation of the Goshgarchay massif, which led to the formation of an extensive zones of propylitization associated with the early phase, and then superimposed zones of potassium, quartz-sericite and quartz metasomatism and argillization, caused by the influence of more acidic late phases. The formation of a large part of the industrial porphyry copper-molybdenum mineralization followed the intrusion of early generation porphyries. The late porphyry phase is associated with the redeposition of previously formed ores and the formation of rich accumulations in the form of veinlet-impregnated stockwork ores oriented in the latitudinal direction in the fractured zone of the Goshgarchay fault. The late porphyry phase was much less ore-bearing than the first. It was accompanied by intensive silicification, which led to the formation of a "quartz core" in the central part of the field. There is a quartz-sericite zone with rich porphyry copper-molybdenum ores to the north of it, followed by a propylite zone with predominantly veinlet pyrite mineralization. Quartz-sericite metasomatites are located within the aureole of biotite-potassium feldspar-quartz rocks and directly above them and accompany porphyry mineralization [11,15].

In connection with the multi-aspect studies of porphyry copper fields, a certain zoning and paragenetic pattern of distribution of mineral associations arising as a result of alteration processes have been established. The description of the alteration processes of intrusion and silicate and wall rocks shows that the products of K-metasomatosis occupy a central position and develop in the intrusion or near it; associations related to phyllitization and argillization are located around the potassium core, and propylitized areas form a wide aureole at the outer boundaries of the action of hydrothermal fluids in the intrusive or host silicate rocks. Two additional types of alteration, represented by quartz+sericite+orthoclase and chlorite+sericite+epidote+magnetite associations, are distinguished [15] as deep analogues of K-metasomatosis and propylitization processes, respectively by Lowell and Gilbert [9]. The ore shell, containing approximately 1 vol. % of all sulfides and almost equal amounts of pyrite and chalcopyrite, is located on the boundary between the zones of phyllitization and K-metasomatosis and extends into the latter zone.

The zoning of mineralization in porphyry copper fields has been studied by many researchers and the following series of ore zoning has been established for porphyry copper deposits based on maximum element concentrations: iron → molybdenum → copper (molybdenum) → copper (gold) → iron (gold) → lead → zinc (I); ore minerals: magnetite-molybdenite-chalcopyrite (with gold) – pyrite (with gold) – sphalerite-galena-enargite-bornite-fahlore (II); mineral parageneses: potassium feldspar-magnetite, potassium feldspar-biotite-magnetite, pyrite-sericite-quartz; quartz-molybdenite or potassium feldspar-molybdenite; quartz-chalcopyrite-molybdenite; carbonate-galena-sphalerite (III) (from the center to the periphery and from bottom to top along the rise of ore bodies) [10, 11,15].

The thickness of the zones of metasomatically altered rocks ranges from several meters to tens, and sometimes even hundreds of meters Within the Goshgarchay OMS (at the intersections of differently oriented faults). Their length is measured from 500-1000 to 2000-3000m. There are three elliptical metasomatic zones, gradually replacing each other in space, surrounding the intrusive massif of porphyry composition around the ore-generating intrusion of the Goshgarchay OMS [5].

Less exposed to quartz-sericite secondary alterations, primary dark-colored minerals such as hornblende are replaced by biotites, sulfides and magnetites on the side. These are already secondary minerals. Plagioclase phenocrysts are partially replaced by sericite, and dark-colored minerals are replaced by quartz and sericite in the zone of quartz-sericite alterations. The contact of quartz-sulfide veinlets with metasomatite with a thickness of 0.5m is filled with sericite and clay minerals. Sericite also fills the intergranular space between crystals in the veinlet.

Hydrothemal-metasomatic alterations, as mentioned above, are developed along faults at the contacts of intrusive rocks, dyke and vein selvages. The initial rocks transformed into metasomatites are intrusive and host volcanogenic formations. Depending on their tectonic readiness, mechanical properties and chemical composition, the intensity of alteration is not the same everywhere.

Three zones of hydrothermalites are distinguished in the structure of the metasomatic column of the Goshgarchay OMS, located around the ore-bearing quartz-diorite porphyry stock, breaking through the vent and near-vent facies of the Bajocian volcanites of medium-basic composition.

The internal zone, covering the endocontact and apical parts of the porphyry intrusion, is represented by intensely silicified rocks, almost entirely transformed into secondary quartzite rocks. The quartz core, which is usually characteristic of many porphyry intrusions with porphyry copper mineralization, is not observed at this field, and its presence in the central part of the intrusion, not exposed by erosion, can only be assumed. The inner zone is represented by secondary quartzites of light gray color with numerous veinlets of quartz of late generations. Judging by the mineral composition, this zone corresponds to the quartz-sericite facies of secondary quartzites.

Ore-bearing of quartz-sericite metasomatite zones is usually weak. The reason for this is the rare impregnation of sulfides, mainly chalcopyrite. However, the sulfide content increases gradually with depth, so the copper content increases from 0.01% on the surface to 0.05% at depth. At the same time, calcite and chlorite occur in the mineral composition of the zone, the sericite content increases. Further, a transition to the quartz-sericite-chlorite facies of secondary quartzites occurs with depth due to a significant increase in the chlorite content in the composition of the rocks, where the copper content also increases, reaching 0.15%. This fact also indicates the presence of vertical zoning in the structure of the metasomatic column.

The middle zone is distinguished as a quartz-sericite-chlorite facies of secondary quartzites. The mineral composition of metasomatites is represented by quartz, chlorite, sericite, epidote, calcite and pyrite, with the first three constituting the bulk of the rocks. The zone occupies a significant area 1.2 km long and 400–600 m wide. Porphyry copper mineralization of the veinlet-impregnated type is clearly superimposed on this facies. Its most intensive development is characteristic of the quartz-sericite-chlorite facies of secondary quartzites, fixing zones of increased fracturing. The amount of quartz and sericite decreases proportionally with depth, while chlorite-epidote-calcite associations increase.

The third, outer zone of the metasomatic column is represented by the propylitic facies of secondary quartzites. Propylitization has an areal distribution here, but its outer boundaries are difficult to define, as the amounts of new formations in the areal zone of weak alterations are represented by chlorite, epidote, zoisite, albite, sericite, biotite, less often actinolite and pyrite. Minor ore intervals, most often of the vein type, characterized by an increased copper content, are occasionally distinguished in this zone, which crowns the metasomatic column. A relatively high silver content has been observed in the ore veinlets, as well as the occurrence of sphalerite mineralization. The zones of the strongest rock transformation are located along the circulation paths of solutions, such as faults of all directions, rock contacts, granitization areas near ore bodies and mineralized zones. Judging by the mineral associations, propylitization occurred in hypabyssal conditions. The occurrence of biotite and albite in propylitized rocks indicates increased alkalinity of hydrothermal solutions. Propylitization is accompanied by the formation of a number of clearly zoning of qualitatively different composition depending on the lithological composition of the original rock. The process occurs according to the principle of infiltration metasomatism under conditions of a temperature gradient, characteristic of contact leaching processes [13].

The following is observed within the Goshgarchay OMS: 1) a clear spatial connection with porphyry intrusions of granitoid composition; 2) alteration of biotite-potassium feldspar – quartz-sericite – propylite metasomatic zones; 3) a veinlet-impregnated nature of mineralization.

Two facies are distinguished among the propylites: actinolite-epidote and chlorite-epidote. Propylitized rocks of the actinolite-epidote facies are observed on average at 0.4–0.8 m from the feeder channel, propylitized rocks and propylites of the chlorite-epidote facies develop from it on average at a distance of 0.1–0.5 m. Breccias of chlorite-epidote-quartz composition are found in tectonic disturbances and ore zones in the internal zones of metasomatic columns.

A significant number of metasomatic zones are observed in propylitized gabbroids of chlorite-epidote facies. There is no actinolite in propylites of epidote-chlorite facies, the number of secondary minerals decreases towards the vein, there is a partial or complete replacement of albite and epidote by carbonate, sericite, chlorite, which are observed in all zones of the metasomatic column. The epidote-quartz-pyrite association is stable in ore zones and tectonic dislocation, and sericite-quartz-pyrite in contacts with ore veins. Propylites of the following composition are observed at a distance from the vein: chlorite, albite, carbonate, quartz, sericite, there is an impregnation of sulphides, various veinlets, both peculiar to propylitized rocks with epidote quartz and syn-ore quartz-carbonate with sulphides, are observed. Sometimes chlorite-epidote-quartz breccias are observed in ore zones and tectonic dislocation, and veinlets of epidote-quartz and quartz composition are found [4,5, 15].

The petrological and geochemical section of the Goshgarchay area (Fig. 2) shows that certain regularity is observed between the petrochemical parameters of metasomatites and the copper and molybdenum contents. It consists in the fact that the maximum content of copper and molybdenum is confined to secondary quartzites of the quartz-kaolinite and quartz-sericite facies in exo- and endocontacts, respectively. While the agpaitic content (al) increases in exocontacts and decreases in endocontacts, then the femic content (f), on the contrary, decreases and increases significantly in relation to fresh granodiorites.

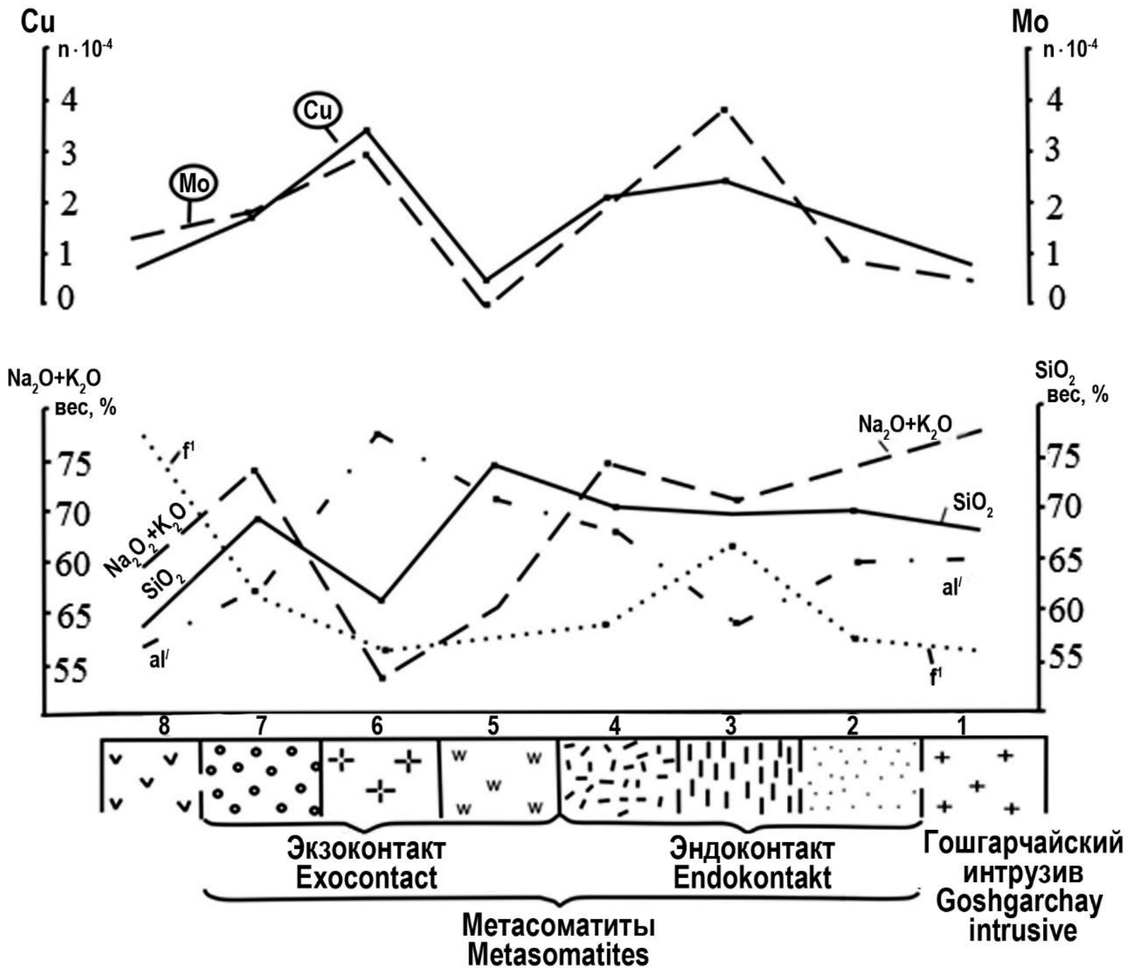

Fig. 2. Petrological-geochemical section of Goshgarchai deposit:

1 – granodiorites unaffected; 2–7 – metasomatites: 2, 7 – propylites, 3, 5, 6 – secondary quartzites; 3– quartz-sericite; 4– argillizites; 5 – monoquartzite; 6 – quartz-kaolinite; 8 – andesite tuffs, unaffected

According to the data from boreholes drilled at the Goshgarchay field, we have studied the ore zoning within its contours and obtained the following series of element zoning vertically (from bottom to top).

Mo→ Cu→ Co → Ni→ Cr → Ag→ Pb→ Zn

The arrangement of elements in horizontal sections based on the values of the zoning index is shown in Fig. 3. As can be seen from the figure, Zn, Pb, Ag and Cr are located in the first horizon, where quartz-sericite-kaolin metasomatites are developed, Ni and Co correspond to the third horizon. Copper reaches its maximum value in the fourth horizon, and molybdenum in the sixth.

According to the analysis of the spatial distribution of hydrothermalites, it is possible to observe the evolution in their formation, namely: the formation of a regional propylitic greenstone alteration of rocks, having a wide area distribution, overlapping of later processes leading to the formation of new pre-ore alterations. These changes differ from the early regional propylitization by a much smaller scale and clear confinement to faults [12, 14]. Ore mineralization is formed precisely in this fragment of hydrothermal activity, it led to the occurrence of polyfacies secondary quartzites, including the main ore-localizing quartz-sericite metasomatites. In general, the evolution of hydrothermal rock alteration led to the zonal structure of metasomatites.

As a result of processing a feature set, complex geological models of porphyry systems began to appear. One of the most successful belongs to R.H. Sillitoe [15], he also defined the place of porphyry copper fields in a series of other fields (Fig. 3).

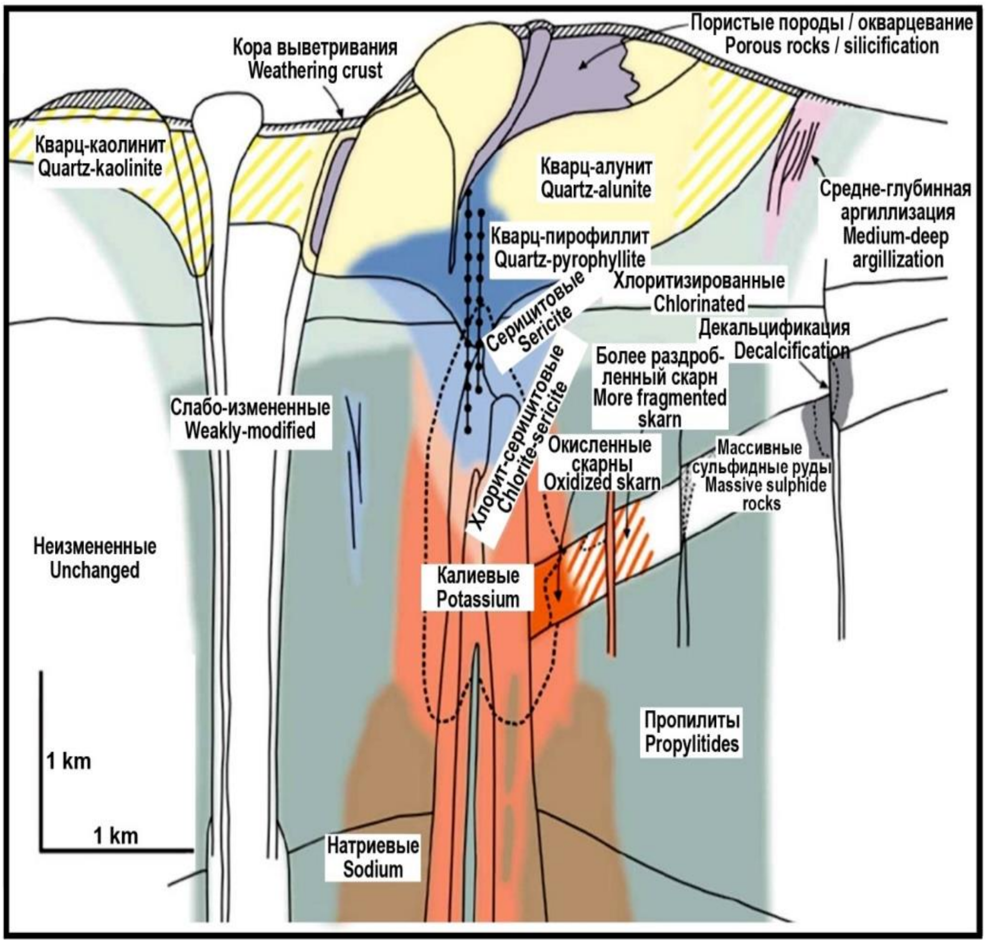

Fig. 3. Model of secondary metasomatic changes on section of idealized porphyry copper system (R. Sillitoe, 2010)

Conclusions. The abovementioned ore-metasomatic characteristics of the porphyry copper fields of the Goshgarchay OMS allow to draw the following conclusions:

1. Goshgarchay OMS is a promising area for porphyry copper, as well as gold ore and polymetallic ores. Intrusive complexes with porphyry copper mineralization according to geological and petrological features belong to the Late Jurassic-Early Cretaceous gabbro-diorite-granodiorite formation. The characteristic elements of the intrusions are Cu, Mo, Pb, Zn, Au, Ag.

2. The separation of metal-bearing fluids was repeated during the formation of the Goshgarchay massif, which led to the formation of an extensive zones of propylitization associated with the early

phase, and then superimposed zones of potassium, quartz-sericite and quartz metasomatism and argillization, caused by the influence of more acidic late phases.

3. Three zones of hydrothermalites are distinguished in the structure of the metasomatic column of the Goshgarchay OMS, located around the ore-bearing quartz-diorite porphyry stock, breaking through the vent and near-vent facies of the Bajocian volcanites of medium-basic composition.

4. Metasomatic formations of porphyry copper fields of Goshgarchay ore field are represented by successively occurred potassium feldspar, greisen, propyllite, secondary quartzite and argillizite formations, which are characterized by superposition of products of subsequent formations on earlier ones.

5. The main components of the model are the host frame (phaneric intrusions), small porphyry bodies such as stocks and dykes (localized, as a rule, in the zones of development of ore-controlling structures and spatially closely associated with mineralization), breccia bodies, ore bodies, ore-metasomatic zoning.

6. The bulk of industrial mineralization is controlled by the porphyry stock and breccia bodies, which sometimes carry a significant volume of ore material.

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