UDC 553.3/.4.078
DOI: http://doi.org/10.17721/1728-2713.99.07

M. Mansurov, PhD (Geol.- Min.), Assoc. Prof.,
E-mail: mamoy_mansurov@mail.ru,
Baku State University Department of Geology,
23 Z.Khalilov Str., Baku, AZ 1148, Azerbaijan

GEOCHEMICAL FEATURES OF COPPER PORPHYRY MINERALIZATION IN THE GOSHGARCHAYORE MAGMATIC SYSTEM (MUROVDAG ORE REGION, AZERBAIJAN PART OF THE LESSER CAUCASUS)

(представлено членом редакційної колегії д-ром геол.-мінералог. наук, проф. В. М. Загнітком)

The geochemical features of intrusive rocks and the surrounding rocks associated with porphyry copper mineralization in the Goshgarchay magmatic system were studied. Major factors of concentration of copper and copper-porphyritic mineralization in rocks of gabbro-diorite-granodiorite formation has been revealed. It has been established that the structure of this ore region was formed as a result of successive alteration of some deformation stages accompanied by development of fractures in intrusive massive, by dike intrusions, locks displacements along faults and the fractures composed of various mineral associations.

Main ore components were defined and relations hips among elements were considered. Geochemical associations allowing the localization of the development area of mineralization have been analyzed in various formation stages of porphyry copper system according to the results of cluster analysis. In this study, Cu, Mo, Pb, Zn, Ag, Ni, Co, Mn, Ti, Cr, V, and Sr both in the surrounding rocks and in ore-bearing intrusive rocks were considered as stable elements. This group of elements can be regarded as indicator elements in porphyry copper.

The results of the claster analysis show that the elements which are less characteristical for hydrothermal solutions (Mn, Ti, Cr, V, Sr) keep their freedom in all wallrocks and the existence of their grouping is probably associated with their transportation process from silicate rocks with surrounding basic-average content. The elements such as Cu, Mo, Ag, Pb and Zn which form free group are connected with the generation from the magmatic source in the course of crystallization differentiation process and exposure of rocks to the hydrothermal activity which is considered the source of these elements.The identification of reasons of the association of V with Cu and Zn and Pb with Fe group elements in the intrusive facies rocks is characterized with its uncertainty. The analysis of the schedule made according to the results of Cu and basic ore components (Mo, Ag, As, Bi, Gd, Co, Cr, Se, Ge, Li, Nb and etc.) in the ores of Goshgarchay deposit show their dependence on one another equally. The amount of Cu in the ores have Ag, As, Bi, Cd, Ce, Ge, Sr, Mo, Sb, Th and Ti positive correlation relationship, but it has negative correlation relationship with Co, Cr, Cs, La, Li, Pb, Rb, Ni, Nb and Zn. Direct dependence is observed for ore mass between concentrations of Cu, Mo, Pb, Zn, Ag, Se, Te and other elements in the Goshgarchay porphyry copper deposit. Three various mineral associations differing from one another participate in stock work type copper-porphyry mineralization: 1) primary sulfide minerals; 2) oxidized ores; 3) primary sulfide minerals significantly enriched with products of hydrothermal ore carrying solutions.

***Keywords:** copper-porphyry mineralization, Goshgarchay, geochemistry, main ore components, pointed dependence, correlation links.*

Introduction. Porphyry copper deposits form in island-arcs and along the edges of the continent. They are also associated with post collisional volcanism through the frontal part of island. Arcs are compatible to the first type granitoid massif and they are referred to series of magnetite. They compositionally are diorite massifs and subvolcanic mass of shoshonite in the back part of the arc (*Sillitoe, 2010*). The majority of the known porphyry copper deposits are the Mesozoic and Cenozoic in age. The majority of them are conformed to the system of regional decompositions creating conditions to local expansions and providing free movements of fluids. Porphyry copper deposits can be classified into Cu-Mo, Cu-Mo-Au, and Cu-Au deposits (*Titli and Bin, 1984; Sillitoe, 2010*). Porphyry copper deposits are a result of complicated interactions of a number of processes and they are characterized by the following existing signs (*Burgeret al., 2008*): 1) the presence of copper-rich magmas containing stockwork structure conforming to the complicated veinlet system; 2) a genetic relationship of hydrothermal alteration zones and mineralization with magmatic basin at a depth of 1–4 km; 3) direct manifestation of intrusive complexes has caused the formation of porphyry deposits and predominance of vertical stocks and dyke systems; and 4) large-scale hydrothermal alteration zones. Here chlorite-sericite hydrothermal zones derivative quartzite and marginal propylitic zones cover internal calciummetasomatites (*Sillitoe, 2010; Berzina and Borisenko, 2017*).

Great mass of copper ores can be extracted from porphyry deposits worldwide. These deposits are considered main sources of Mo, Au, Ag, Re, Te, and platinum group elements. Porphyry Cu and Cu-Mo deposits associated with volcano-plutonic complexes are developed in most metallogenic zones of Azerbaijanian part of the Lesser Caucasus. Copper mineralization associated with plutonic granitoid massif of the Murovdag ore-bearing region is considered more promising. Several porphyry Cu deposits are located here (Goshgarchay, Goshgardag and etc.), in which reserves of copper can be included in a group of large deposits (*Baba-zadeh et al., 1990; Ramazanov, 1993*).

The Goshgarchay ore district is considered promising deposit and same-name-cognominal copper-porphyry deposit which has been properly studied within the frames of ore-magmatic system, where exploration work has been conducted. Geochemical features of copper-porphyry mineralization within ore-magmatic system have been investigated in this article.

The main purpose of the article is to study geochemical features of copper-porphyry mineralization by analyzing petrographic-petrological features of intrusive and surrounding rocks in Goshgarchay ore-magmatic system. The definition features of major elements and basic ore components have been investigated, their genetic and geochemical features have been studied, the relations between pairs of the element have been defined by the correlation analysis.

Analysis of previous studies. Large sizes and large reserves, as well as the possibility of using rational methods of metal extraction predetermined an increased interest in porphyry copper deposits, which are currently the main raw material base for Cu, Mo. Deposits often contain a number of associated components in industrial quantities among which Au, Ag, Bi, Te, Re and Se play a leading role. Their accounting significantly increases the total value of ores (*Babazadeh et al., 1990; Popov, 1977*). They are accompanied by numerous polymetallic, gold-silver, pyrite satellite deposits and placers. The study of porphyry copper mineralization of the Murovdag ore region began during the period of intensive exploration of porphyry deposits in the Lesser Caucasus (*Baba-zadeh et al., 1990; Pamazanov, 1993*). Endogenous deposits of the Lesser Caucasus are represented by a wide range of genetic and formational types. At present, there is sufficiently substantiated opinion that these deposits form a complex polygenic group with pronounced features of polycyclic development, a variety of tectonic conditions and forms of magmatism manifestations (*Babazadeh et al., 1990; Popov, 1977; Titley and Bean, 1984; Sillitoe, 1996; Pavlova and Sakhnovsky, 1988*). A significant amount of the research as well as their wide geography is devoted to the problems of endogenous ore deposits of the Murovdag ore region. Deposits of different age and different formations of various ores are concentrated there. The features of these deposits are highlighted in monographic summaries, numerous publications (*Baba-zadeh et al., 1990; Ramazanov, 1993; Mansurov, 2013*), such as monographs by Baba-zadeh and others (2005), Baba-zadeh and others (1990). They include articles on geology, mineralogy, geochemistry, formation parameters, isotopic studies of objects of the Goshgarchay ore field (*Mansurov, 2014*). In the work on the Porphyry Copper Formation of Azerbaijan, V.G. Ramazanov (1993) touched upon a number of geological and geochemical features of the Goshgarchay porphyry copper deposit, its connection with magmatism and other issues. Later, we conducted research in this area and published a number of articles in various journals (*Baba-zadeh et al., 1990; Ramazanov, 1993; Mansurov, 2013; Imamverdiyev et al., 2018*). At the same time, studies devoted to the compilation of geological-genetic models of porphyry copper and polymetallic deposits were incomplete. This is explained by their rather large diversity, the idea of their formational affiliation, connection with magmatism and peculiarities of ore components and impurity elements distribution (*Popov, 1977; Abdullayev et al., 1988*). The results, presented in the works, indicate the exceptional relevance of this issue. When processing the materials, the author used both classical literature (Mineral-raw resources of Azerbaijan, 2005; Geology of Azerbaijan, Magmatism, 2003; Ramazanov, 1993) and modern publications (*Baba-zadeh, et al., 1990; Mansurov, 2013, 2021; Imamverdiyev, et al., 2018*). The distribution features of the main ore components in the host rocks and ores of the Goshgarchay deposit have not been sufficiently studied in these works. The value of porphyry copper deposits primarily lies in the fact that they have been discovered in geologically well-studied areas. The ores, with a relatively low content of the main (Cu, Mo) and associated components (Au, Ag, Bi, Re, Se, Te), in them, are characterized by more areal distribution and significant reserves. These features of porphyry copper deposits make them potentially promising. Therefore, a comprehensive geological study of them, including the distribution features of the main ore components of the Goshgarchay deposit, is very relevant. Our goal here was to study these distribution features of ore-generating components by means of mathematical – statistical calculation of analytical data. The obtained results can form the basis for geochemical criteria for direct prospecting and forecasting of hidden porphyry copper ores.

Factual materials and research methods. The basis for the factual material was a collection of samples (about 150 pieces) taken inside and around the stockwork with vein – disseminated mineralization and on its flank to a depth of more than 500 m from the surface. Data from geochemical sampling of ore – host rocks and ores in mine workings and core samples from boreholes were used for this along sections directed perpendicular to the strike of ore – concentrating structures. The collection includes samples taken from gabbroids, quartz diorites, quartz veins with galena – sphalerite – chalcopyrite mineralization. Atomic absorption analysis on a Perkin Elmer device allowed to quantitatively determine such elements as Cu, Mo, Au, Ag, Se, Te, Cr, Ni, Co, Pb, Zn, Sr, Cd, As, Bi. The geochemical data for the wells were processed in the STATISTICA program, using the factor analysis of the main components. Methods of semi – quantitative spectral analysis were applied to study the contents of chemical elements in the host rocks and porphyry copper ores. The main ore samples were taken from the vein – disseminated stockwork type ores. The rock samples were examined by inductively coupled plasma mass spectroscopy (ISP -MS). Silicate chemical analysis was carried out in the laboratory of Izmir University, Turkey. The rock samples were examined by inductively coupled plasma mass spectroscopy (ISP -MS). Analytical studies were performed at the USGS Analytical Laboratory of the United States Geological Survey (Denver).

Geological setting and deposit geology. Peculiarities of geological aspects of Goshgarchay copper-porphyry deposits have properly been described in earlier published works (*Abdullayev et al., 1988; Baba-zadeh et al., 1990; Geology of Azerbaijan. Magmatism, 2001; Geology of Azerbaijan. Tectonics, 2005; Mansurov, 2014*).

Murovdag ore district including Goshgarchay deposit, being a component of Lok-Agdam peninsula arc (Fig. 1) occupies NW uplifted part of Murovdag anticlinorium of asymmetrical structure consisting of the rocks of Lower Bajocian volcanogenic layer in the core and Upper Bajocian and Bathonian strata of basalt-andesite-rhyolite successively differentiated formation in the flanks. The ore district consisting of intrusives is Goshgarchay complex of granitoid intrusions (Goshgardag, Ojagdag, Balaja Goshgardag) and their dyke formations which break through the thick complex of effusive pyroclastic formation impacting contact action on them. Intrusive complexes with copper-porphyry mineralization according to geological-petrological features belong to gabbro-diorite-graniodiorite formation of Later Yurassic-earlier Cretaceous ages (*Abdullayev et al., 1988; Geology of Azerbaijan. Magmatism, 2001*).

Copper-porphyry mineralization cover Goshgarchay, Goshgardag, Kyzylarkh, Kechaldag, Eric-Manuk and other deposits and ore manifestations in the ore district where it's located in tight special and genetical relations with Murovdag granitoid massif (*Abdullayev et al., 1988; Babazadeh et al., 1990*). According to geological setting and special distribution, intrusive formations of Murovdag group are divided into Goshgardag and Gyzylarkh groups (*Geology of Azerbaijan. Magmatism, 2001*).

Goshgarchay ore-magmatic system is located in the uplift part of the south-west of Murovdag anticlinorium with (of) asymmetrical structure which is a main component part of Lok-Agdam islands-arc.The core of the anticlinorium is represented by lower Bajocian volcanogenic layer, but its wings are represented by consistently differentiated basalt-andesite-rhyolite formation layers of Bajocian and Bathonian ages. Fault structures of different directions with overthrust features developed widely within ore-magmatic system, giving it block structure. Fault structures of the north-west and near-meridional direction prevail and intrusive massives occur in their intersection junction (*Geology of Azerbaijan. Tectonics, 2005; Geology of Azerbaijan. Magmatism, 2001*).

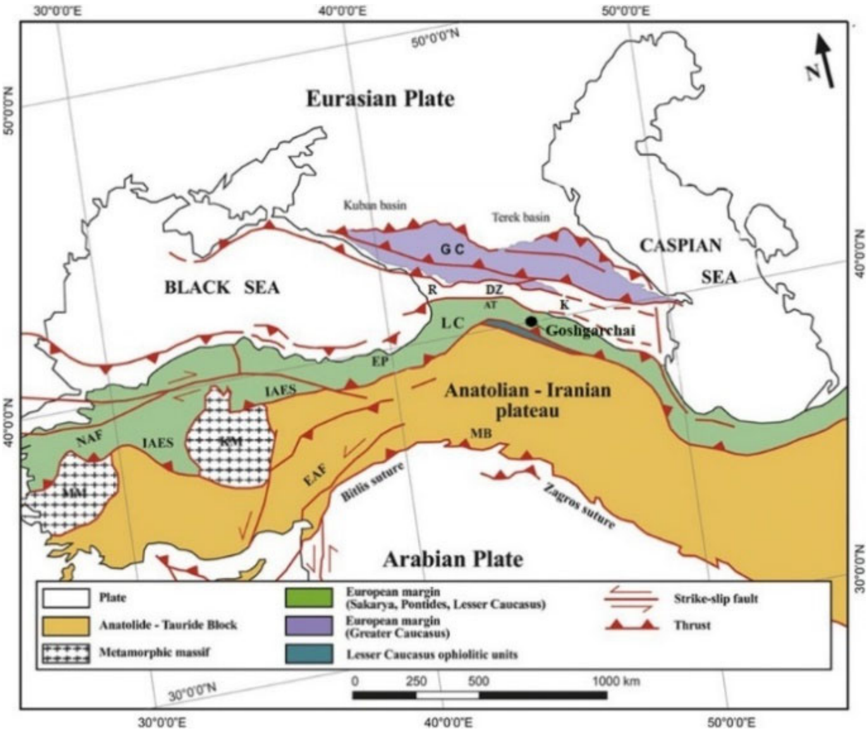

Fig. 1. Tectonic map of the Arabia-Eurasia collision zone. Location of the Goshgarchay deposit is shown by a filed circle (modified from Sosson et al., 2010)

Abbreviations: GC – Greater Caucasus; LC – Lesser Caucasus; AT – Achara-Trialeti; R – Rioni; Dz – Dzirula; K – Kura; MB – Mus Basin; EP – Eastern Pontides; KM – Kirsehir Massif; EAF – Eastern Anatolian Fault; NAF – North Anatolian Fault; IAES – Izmir-Ankara-Erzincan Suture; MM – Menderes Massif

Copper-porphyry mineralization surrounding Goshgarchay, Goshgardag, Gyzyl-arkhach, Kechaldag and other deposits and manifestations forms an association with spatially-genetically same-name granitoid intrusive within Murovdag region. The intrusives comprising ore-magmatic system consist of Goshgarchay complex granitoid intrusives (Goshgardag, Ojagdag, Small Goshgardag) and their dyke systems forming effusive-pyroclastic complex and making contact-thermal relationship with them. Only near meridional Small Goshgardag anticlinal zone located in the southern part of Murovdag anticlinorium takes part in the structure of ore-magmatic system. Anticlinal is composed of volcanogenic-pyroclastic formations represented by steep dip layer (50–80°) of Lower Bajocian (*Geology of Azerbaijan. Tectonics, 2005; Geology of Azerbaijan. Magmatism, 2001; Baba-zadeh et al.,1990*).

The fault structures of different directions which form the block structure of ore-magmatic system in the spatial definition of copper-porphyry and copper-polymetallic mineralization are of significant importance in Murovdag ore district. On the one part they are conditioned with dominating fault structures of north-west direction (Goshgarchay, Alkhanjalli, Chanakhchi), on the other part – with the combination of fault structures of latitudinal (Khoshbulag) and submeridional (Bala Goshgarchay) directions. Larger tectonic rupturings are considered Goshgarchay, Alkhanchalli and Chanakhchi faults of north-west directions (280–330°) lying under 45–85° angle towards the north-east (*Geology of Azerbaijan. Tectonics, 2005; Baba-zadeh et al.,1990*).

Out of latitudinal faults, Goygol-Khoshbulag latitudinal curving fault which is supposed to pass through the central part of Goshgarchay ore-magmatic system is considered to be much larger.

The fault structures of small order are considered mainly latitudinal, sublatitudinal (25–300°), meridional and near meridional (10–40°) directions (*Geology of Azerbaijan. Tectonics, 2005*). Of them, faults of small Goshgarchay near meridional direction arouse great interest. Extending along the same-name river, this fault cuts the ore-magmatic system from the south-west to the north-east and then it is followed up to Ojagdag range. Within Goshgarchay ore-magmatic system, directly second, third and fault systems of higher order are of great importance in comparison with basic ore controlling structures (small faults, intersection areas with surface contact of their different phase intrusives, brecciation zone) for the localization of copper-porphyry mineralization (*Baba-zadeh et al.,1990; Ramazanov, 1993*).Fracture systems in endo and exo contact zones of intrusives define the morphology and measure of ore stockwork. Such fracture systems develop mainly along the contacts of stocks and depend on the form, occurrence depth and structural features of intrusives.

Above-mentioned petrographical component of intrusive massif differs with significant complexity which is related with intrusive activity of multiphase. So, the intrusions of Goshgardag district is mainly presented with gabbro, gabbro-norite, insignificant gabbro-pyroxene consisting of gabbroid phase of intrusions and quartz diorites, granodiorites, granitoid phase formed by sharp intrusive contact with gabbroids (*Geology of Azerbaijan. Magmatism, 2001*).

Gabbro-norites are medium-grained, almost black rocks consisting of plagioclase, pyroxenes, small amount of biotite, protobase, olivine, as well as secondary and accessory minerals.

The mineral composition of gabbroids, along with the main plagioclase, includes pyroxenes and hornblende, some varieties of these rocks may also contain small percentage of quartz (up to 3–4 %). Plagioclase (37–69 %) ranges in composition from labradorite to bitovnite (54–83 %). According to the composition and morphology of crystals, the rocks consist of two generations of plagioclase: plagioclase feldspar of the early generation has more basic composition, then the second generation one, which is represented mainly by labradorite. Mostly the plagioclases are characterized by intermediate Al-Si ordering state. Pyroxenes (18–25 %) are represented by hypersthene, less common enstatite, augite, and even less common diopside. They are, to one degree or another, biotitized or chloritized along cracks or along the edges; replacement of the plagioclase by epidote is quite frequent. Compositions of the pyroxenes are W_{45-52}, En $_{28-42}$, $Fs_{3-26\ 26}$.

Accessory minerals are presented by magnetite (4,6 %), ilmenite (up to 0,4 %), apatite (up to 0,29 %), zirconium (up to 207 g/t). The minerals of ore and rare elements and volatile components occur sporadically in small quantities (*Geology of Azerbaijan. Magmatism, 2001*).

The stratified bodies of Gyzylarkh area are presented by quartz diorites, gabbro-diorites and insignificant amount of diorites, gabbro banatites. Getting closer to the endo contact the rocks acquire more basic character. Gabbro-norites are medium-grained, almost black rocks consisting of plagioclase, pyroxines, small amount of biotites, protobase, olivine, as well as secondary biotites and accessory minerals. Quartz diorites are finely grained, full crystalline rocks, represented mainly by plagioclases, hornblende, biotite, quartz, sometimes mixed with pyroxene, potassium feldspar and albite (*Abdullayev et al., 1988; Geology of Azerbaijan. Magmatism, 2001*).

Plagioclases are represented by andesine and often exhibit typical zoning pattern: a core has a composition of labradorite. Mineral alteration usually affects the core of plagioclases with a high anorthite content. The plagioclases can be classified according to their Al-Si degree of ordering: high, intermediate, low. In terms of chemical composition, plagioclases of various intrusions do not differ significantly (*Abdullayev et al., 1988; Geology of Azerbaijan, 2001*).

Potassium-sodium feldspar often occures in the rocks in small amounts (1–5 %) as xenomorphic grains with characteristic opacity. Amphibole is represented mainly by hornblende, however hastingsite, paragasite, tremolite are also present in the rock.

Magnetite (up to 2 %), ilmenite (up to 0,15 %), apatite (1256 g/t), zircon (190 g/t), sphene (65 g/t) dominate the accessory mineral assemblage. Epidote, orthite, tourmaline, monazite, molybdenite, and a number of others in small amounts were also observed.

The rocks on classical diagram ($Na_2O + K_2O$)–SiO_2 occupy the field of the rocks with normal alkalinity which allows to take them to the normal petrochemical row (Fig. 2). Described classified diagrams of rocks are mainly concentrated in gabbroid fields. It is seen from diagrams that they are compactly located. Other petrographic types of rocks or differentiates are located in the field of quartz diorites and here according to normative mineralogical composition the content of albites increases in compliance with it, basic plagioclase reduces.

The chemical compositions of the rocks of these massifs are given in table 1, according to which graphic images were compiled reflecting particular petrochemical features of the rocks.

The structure of the ore district was formed as a result of succession of several stages of deformation accompanied by fracture formation in the intrusive massif, by intrusion dyke, by block move on the tectonical fault and by cavity filling of fractures with different mineral associations. Sublateral or common Caucasian orientation of disruption become ore conduit, but faults along NE strike feathering Goshgarchay faults by its side wall become ore localization structure which is explained by: 1) the localization of ore zone in the underlie; 2) by similar directions of dipping of ore zone and faults in a steeper angle of the latter; 3) localization of ore zone in small systems of fractures and disruptions; 4) confinedness to basic faults of subvolcanic bodies and dykes, zone of intensive hydrothermal change of rocks and impregnated sulphide mineralization (*Geology of Azerbaijan, 2005*).

Goshgarchay deposit is located in the merge of Boyuk Goshgarchay district and Balaja Goshgarchay at 10–12 km towards the south-west from Khoshbulag village. It consists of basic Bajocian volcanogenic formations broken by granitoid Goshgarchay massif (*Geology of Azerbaijan. Magmatism, 2001*).

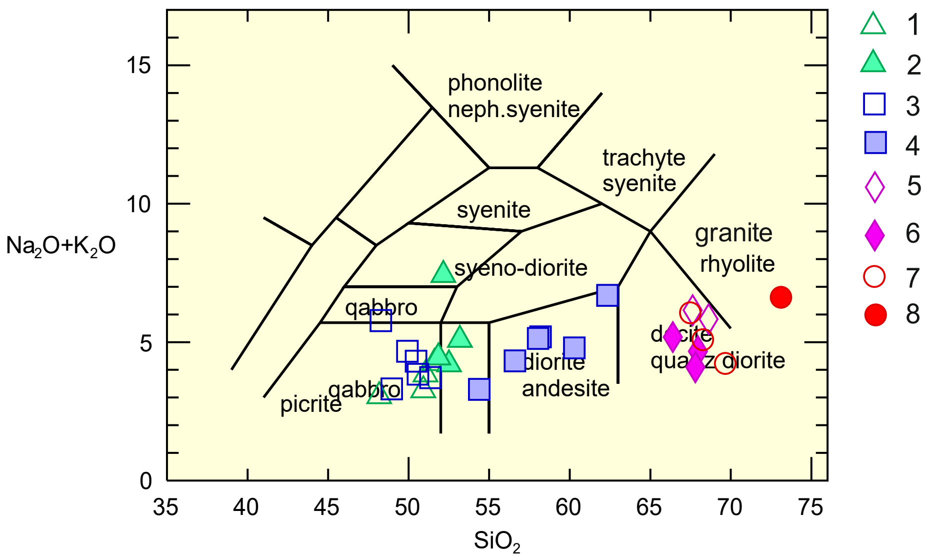

Fig. 2. The location of rocks of magmatic complex in classified diagram (Na_2O+K_2O)-SiO_2 Murovdag anticlinorium:
1 – gabbro norites; 2 – gabbroids; 3 – gabbro; 4 – quartz diorites; 5 – graniodiorites; 6 – dacites; 7 – rhyodacites; 8 – rhyolites

Table 1

The chemical composition of intrusive and effusive complexes of the Murovdag anticlinorium

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SiO_2	48.17	50.91	51.05	51.6	53.18	52.51	52.16	51.85	51.36	50.58	50.47	49.93	48.95	48.28	54.39	58.19
TiO_2	0.54	0.5	0.46	1.03	0.37	1.47	0.45	1.69	0.28	0.63	0.3	0.5	0.29	0.4	0.65	0.65
Al_2O_3	19.62	17.77	19.1	16.88	16.49	17.88	21.87	17.46	16.56	12.38	18.16	12.99	16.67	21.79	14.38	18.23
Fe_2O_3	10.25	3.8	3.45	3.76	5.75	2.86	3.15	4.46	7.19	10.5	5.06	7.51	9.19	5.39	6.76	2.24
FeO	3.05	5.5	5.01	4.43	5.08	5.06	4.85	4.82	6.22	7.42	4.62	8.89	4.36	3.61	5.05	2.64
MnO	0.12	0.1	0.13	0.08	0.09	0.04	0	0.12	0.11	0.14	0.05	0.13	0.1	0.08	0.05	0.1
MgO	3.42	6.02	5.7	5.4	4.2	3.92	3.44	5.01	2.81	3.97	5.41	3.35	5.05	4.01	5.04	3.68
CaO	12.13	10	9.22	10.78	9.64	9.49	5.4	8.03	10.32	9.62	7.14	10.54	10.65	6.12	6.96	7.14
Na_2O	2.26	2.55	3.43	3.64	4.52	3.44	4.54	3.73	3.35	3.11	3.42	4.07	2.72	3.89	2.29	3.97
K_2O	0.78	0.7	0.4	0.6	0.56	0.75	2.88	0.71	0.37	0.73	0.89	0.6	0.59	1.89	1	1.22
P_2O_5	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0.43	2.07	1.06	2.11	0.61	2.36	1.65	2.04	2.21	1.74	4.01	2.05	1.28	4.27	3.1	1.31
Σ	100.8	99.92	99.05	100.3	100.5	99.78	100.4	99.92	100.8	100.8	99.53	100.6	99.85	99.73	99.67	99.37

	17	18	19	20	21	22	23	24	25	26	27	28	29
SiO_2	56.6	58.04	60.29	62.34	68.62	67.63	67.96	67.8	66.4	69.65	68.26	67.48	73.11
TiO_2	0.47	0.1	0.42	0.24	0.2	0.55	0.26	0.25	0.28	0.38	0.38	0.38	0.38
Al_2O_3	16.51	15	15.62	13.84	16.33	15.37	15.11	16.81	16.99	14.5	14.64	14.9	13.15
Fe_2O_3	2.5	5.67	3.36	4.41	1.95	2.02	2.29	2.27	2.22	1.74	1.8	1.69	2.16
FeO	4.95	4.09	3.72	2.72	2.53	2.57	1.46	1.99	1.76	1.55	1.29	1.87	0.97
MnO	0.14	0	0.05	0	0.1	0.1	0.06	0.01	0.08	0.08	0.05	0.06	0.05
MgO	4.7	2.3	2.8	3.1	0	1.05	1.76	1.79	2.42	1.72	1.88	2.69	1.65
CaO	7.1	6.94	5.36	8.66	4	3.53	5.15	3.6	4.28	5.1	4.82	4.21	0.81
Na_2O	3.2	3.3	3.47	6.2	3.65	3.66	3.29	2.61	3.45	2.97	3.45	3.37	6.02
K_2O	1.12	1.83	1.32	0.49	2.18	2.49	1.38	1.48	1.73	1.26	1.64	2.69	0.6
P_2O_5	0.09	0	0	0	0	0	0.07	0.08	0.07	0.07	0.08	0.08	0.08
I	2.2	3.03	2.3	0.87	0.55	0.75	0.99	1.04	0.94	0.71	0.98	0.89	0.69
Σ	99.58	100.3	98.71	102.9	100.1	99.72	99.78	99.73	100.6	99.73	99.27	100.3	99.67

Note. 1-4 – gabbro-norites; 5-8 – gabbroids; 9-14 – normal gabbro; 15-20 – quartz diorites; 21-25 – dacites; 26-29 – rhyodacites

Structural-morphological features and mineral composition of the deposits. Veinlet impregnated stock work ore predominantly develop in the deposit. The vein type of mineralization is of secondary significance and it is confined to the crush zone and hydrothermal changes zone among diabase porphyrites. The mentioned type of mineralization is presented by quartz and carbonate veins and veinlets, impregnated by pyrite, chalcopyrite and molybdenite.

Stockwork body composing the central part of Goshgarchay deposit is confined to apical and peripheral part of the cognominal (the same-name) intrusive, to be more accurate, to its endo and exo contact zone and in sublateral direction occupies approximately 0,8 km^2 area.

Copper contains 0,4 % at a cut-off grade in the margins of stockwork on the surface and ten ore columns were selected. The interpretation of the results of analysis of kern materials allows considering these enriched areas as merging in the depth, in a single ore body forming stockwork with complex morphology. The surface of stockwork body is particularly complicated. The fractures of north-western, submeridional and sublateral directions filled with non-ore and quartz-sulphide substance develop in the stockwork. Veins presented by quartz-carbonate fillings have sublateral strike. They are confined to the crush zone with the thickness of 30–60 m among diabase porphyrites.

More intensive ore mineralization is observed in the central part of stockwork which gradually flattens with distance from the centre towards selvage. Outlines of ore body are windering and orthomorphic in the relation to the morphology of ore generating porphyry intrusive. In conclusion, according to the above-mentioned facts, ore body analogically to intrusion has south-western decline.

Copper is basic useful component. Its content is unsteady in the margins of stockwork body and fluctuates (hesitates) in a wide range from 0,2 to 2,5% comprising in average 0,41%. Among series of ore minerals having major influence on the significance of deposits, molybdenium and noble metals should be mentioned. In some intervals the average content of gold comprises 2,0 g/t and more. Along with gold, increased content of silver was also defined where its significance reaches 30-40 g/t which can positively impact on the value of deposit. Basing on structural-morphological features, we can say that ore mineralization is stockwork veinlet-impregnated type in the deposit of Goshgarchay where impregnation prevails over veinlets and veins.

In the deposits the mineral composition of the ore doesn't differ with great variety and it is characterized by small amounts of ore minerals, their tight intergrowth. As a result of studies of the polished thin sections, the following ore minerals were defined: pyrite, chalcopyrite, sphalerite, arsenopyrite, melnicovite-pyrite marcasite, fahl ore, cobalt-pyrite, enargite, bismuthine, bornite, ilmenite, hematite, chromespinelide, chalcosine, covelline, malachite, azurite, limonite and etc. Among them basic ore minerals of the deposit are chalcopyrite, bornite, pyrite, molybdenite, tenantite, chalcosine, enargite, native copper, gold and rutile. Veined minerals are presented by quartz, calcite, epidote, caolinite, sericite, chlorite, biotite, muscovite and etc (*Baba-zadeh et al.,1990; Mansurov, 2014*).

Results of the research. The samples of rocks were explored by the method of mass-spectroscopy with inductive-connected plasma (ISP-MS). Analyticial researches were carried out in the analytical labs USGS Geological service of the USA (Denver).

Petrological features of the magmatic rocks of ore district were studied by up-to-date methods. Silicate chemical analysis were carried out in the labs of the faculty of Geology of the University of Izmir, Turkey. Atom-absorbtion analysis in the devices (appliances) of the company Perklin Elmer allowed to define series of elements quantitively (Cu, Mo, Pb, Zn, Ni, Co, Sr, Ag, Cr and etc). The study of microelements were conducted in Switzerland in the devices XRF at the University of Lausanne.

Genetic and geochemical features of intrusive rocks and the surrounding rocks associated with mineralization in the Goshgarchay magmatic system were determined by mineralogical and geochemical analyses. The number of testing points within ore-magmatic system has been nearly 1000. Their distribution has been conducted equally within the area. Fundamental vents have been tested both on natural openings and exploration mountain drillings (ditches, wells, pit holes). All testing points have been accompanied by geological and petrographic descriptions. Experiments have been applied on the elements, such as Ag, Au, As, Bi, Ca, Cd, Cr, Cu, K, Mg, Mn, Mo, Na, Ni, P, Pb, Se, Sr, Ti, and V. Primary materials on the results of mineral analysis and the surrounding rocks stand, on the basis of the solution of the raised questions. Statistical parameters of the definition of elements of ore origin on the ore-magmatic system are given in Tables 2 and 3. The development of statistical results of geochemical information through the obtained results was carried out according to the programs of "Statistics" and "MINITAB 16".

Table 2

Statistical parameters of the definition of elements of ore origin on the surrounding rocks of the Goshgarchay magmatic system

№	Ti	Al	Fe	Mn	Mg	Ca	Na	K	P
G-72	667	22100	73200	1340	174000	4.5	493	772	78.2
G-73	689	22000	76600	1350	183000	4.5	502	698	75.1
G-74	891	27600	72200	1220	161000	36600	648	649	95.9
G-75	1230	41300	63000	1260	114000	60900	10400	778	115
G-76	886	28200	70100	1210	152000	52700	738	316	78
G-77	949	29600	73300	1280	159000	43200	721	504	83.8
G-78	770	24400	74400	1260	172000	40500	732	797	54.4
G-79	890	30600	72500	1260	155000	50600	576	296	81.2
G-80	6750	89000	39800	588	20900	23300	49400	14400	1310
G-82	2520	64900	52900	744	18200	56800	18800	384	324
G-84	1500	85500	33700	186	22600	24200	21600	1630	174
G-85	819	88400	26500	198	18300	26000	31100	1790	21.5
G-86	1090	75400	36700	181	19700	24000	17200	1220	340
G-87	1180	89000	30300	206	20200	25800	21800	1700	156

Table 3

Statistical parameters

№	Pb	Zn	Cu	Bi	Sb	As	Mo	Cr	Ni	Co	V	Sc
G-72	11.1	83.7	105	0.12	0.59	1.9	0.9	1260	2.2	0.61	127	<0.04
G-73	5.52	1120	248	0.06	0.42	1.4	0.83	1340	20.8	21	120	0.8
G-74	3.68	130	149	0.07	0.45	2	0.77	1530	534	84.9	151	27
G-75	51.8	173	88.4	0.13	0.95	2	2.2	1520	321	59.2	202	33.3
G-76	3.64	77.2	104	0.06	0.21	4.1	0.45	1780	519	85.8	161	27.2
G-77	3.88	124	66.2	0.06	0.2	<1	0.69	2210	539	88.7	156	27.8
G-78	68.1	636	334	0.1	0.88	4.6	1.3	2260	597	95.2	159	27.1
G-79	3.08	68.8	116	0.06	0.26	2.2	0.67	2360	492	83.7	196	29.4
G-80	13	90	214	0.14	1.1	5.6	2.1	261	17.9	17.4	102	10.8
G-82	7.91	60.1	49.6	0.06	0.22	4.9	1	203	26.8	20.2	323	23.6
G-84	6.71	106	15000	0.88	1	5.9	4.6	719	34.9	9.5	180	25.4
G-85	9.5	49.6	10900	0.44	2.1	12,6	4.5	738	34.8	8.4	123	34.6
G-86	6.93	79.3	20300	0.32	1.2	7.5	4.2	251	46.4	13.2	158	27.2
G-87	6.78	35.3	1350	0.08	0.52	1.3	7.2	421	15	10	92.2	12.4

Notes. G-72-gabbro; G-73-gabbro; G-74-gabbro; G-79-gabbro;G-80-diorite; G-82-basalt; G-75-andesite; G-76-andesite; G-77-andesite; G-78-secondary quartzite; G-84-secondary quartzite; G-85-copper-porphyry ore; G-86-87- ore-bearing secondary quartzite.

The geochemical features of the surrounding rocks. Elements, such as Ag, Al, As, Ba, Bi, Ca, Cd, Ce, Cr, Cu, F, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Se, Sr, Ti, and V were revealed in the Goshgarchay magmatic system and also in the surrounding rocks by spectral analysis. All were not regarded in statistic processing, because their contents were changeable. Elements that are almost stable both in the ores and in the surrounding rocks were included. Among the aforementioned elements, Cu, Mo, Pb, Zn, Ag, Ni, Co, Mn, Ti, Cr, V, and Sr are considered. There is a positive correlation among the trace elements Ag, As, Ba, Bi, Ca, Cd, Cr, Cu, Mo, Ni, Pb, Zn, Mo, Co, Ti, and Cr in the surrounding rocks. Geochemical analyses indicate that contents of elements in the ores are slightly different from those in the surrounding rocks. According to it, we can note that all ore surrounding rocks are participants of ore generating process and in this case, carrier source of ore mineralization is considered later porphyry intrusives (*Baba-zadeh et al., 1990; Titley and Bean, 1984*).

As shown in Fig. 3, elements in the surrounding rocks of the Goshgarchay magmatic system were divided into two clusters. Cluster I was also categorized into three groups. They are as follows: group I: Ag and Cu; group II: Bi, Cd, and Pb; and group III: Cr and Mo. Cluster II was categorized into four groups. They are as follows: group I: Al, Ca, and Mn; group II: Mg, V, Sc, and Ti; group III: Na, Sr, Ce, Ni, Te, Zn, As, and P; and group IV: Ba, K, and S.

As shown on dendrogram of cluster analysis in Fig. 6, a series of elements in the surrounding rocks of the Goshgarchay porphyry deposit were considered as stable elements. They are Cu, Mo, Pb, Zn, Ag, Ni, Co, Mn, Ti, Cr, V, and Sr. They can be considered as indicator elements in porphyry deposits (*Baba-zadeh et al., 1990*). Results of cluster analysis indicate that elements that are less characteristic of hydrothermal fluids showed no dependency in the surrounding rocks. They include Mn, Ti, Cr, V, and Sr. The availability of their grouping is associated with transportation process from surrounding silicate rocks with fundamental average content. The elements, such as Cu, Mo, Ag, Pb, and Zn are genetically associated with amagmatic source and are concentrated in ore-bearing fluids (*Titley and Bean, 1984*). The clarification of the reasons of association of V with Cu and Zn and Pb with Fu group of elements in the intrusive facial rocks is characterized by its uncertainty here (*Nikolayev et al., 2016*). Geochemical analyses indicate that there is a relationship between Cu and trace elements Mo, Ag, As, Bi, Gd, Co, Cr, Se, Ge, Li, and Nb in the Goshgarchay deposit. Copper shows a positive correlation with Ag, As, Bi, Cd, Ce, Ge, Sr, Mo, Sb, Se, Th, and Ti, but has a negative correlation with Co, Cr, Cs, La, Li, Pb, Ni, Nb, and Zn. In order to determine normality of elements, histograms of significant trace elements from the intrusive rocks and the surrounding rocks are presented. Copper, Mo, Ag, Pb, Zn, Se, Te, As, Sb, Sr, Co, and Cr were selected, on the basis of results of group testing. They were obtained from the ores, and also from non-mineralized and weak-mineralized rocks, as shown in Figure 4. Copper, Pb, Sr, Zn, Co, and Cr display an abnormal distribution in the surrounding rocks. Whereas, Ag, As, Mo, Pb, Sb, and Cr display a normal distribution in the ore-bearing mass from the Goshgarchay porphyry deposit. Therefore, we can conclude that elements display two different patterns in the ore-bearing intrusive and the surrounding rocks: a normal definition in the former and lognormal definition in the latter (*Mansurov, 2021*).

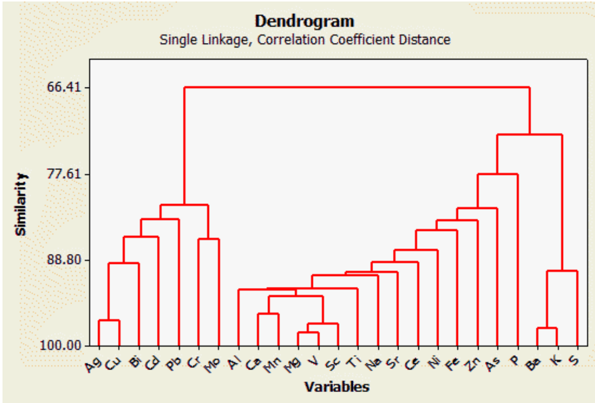

Fig. 3. Cluster analysis of elements in the surrounding rocks of the Goshgarchay magmatic system

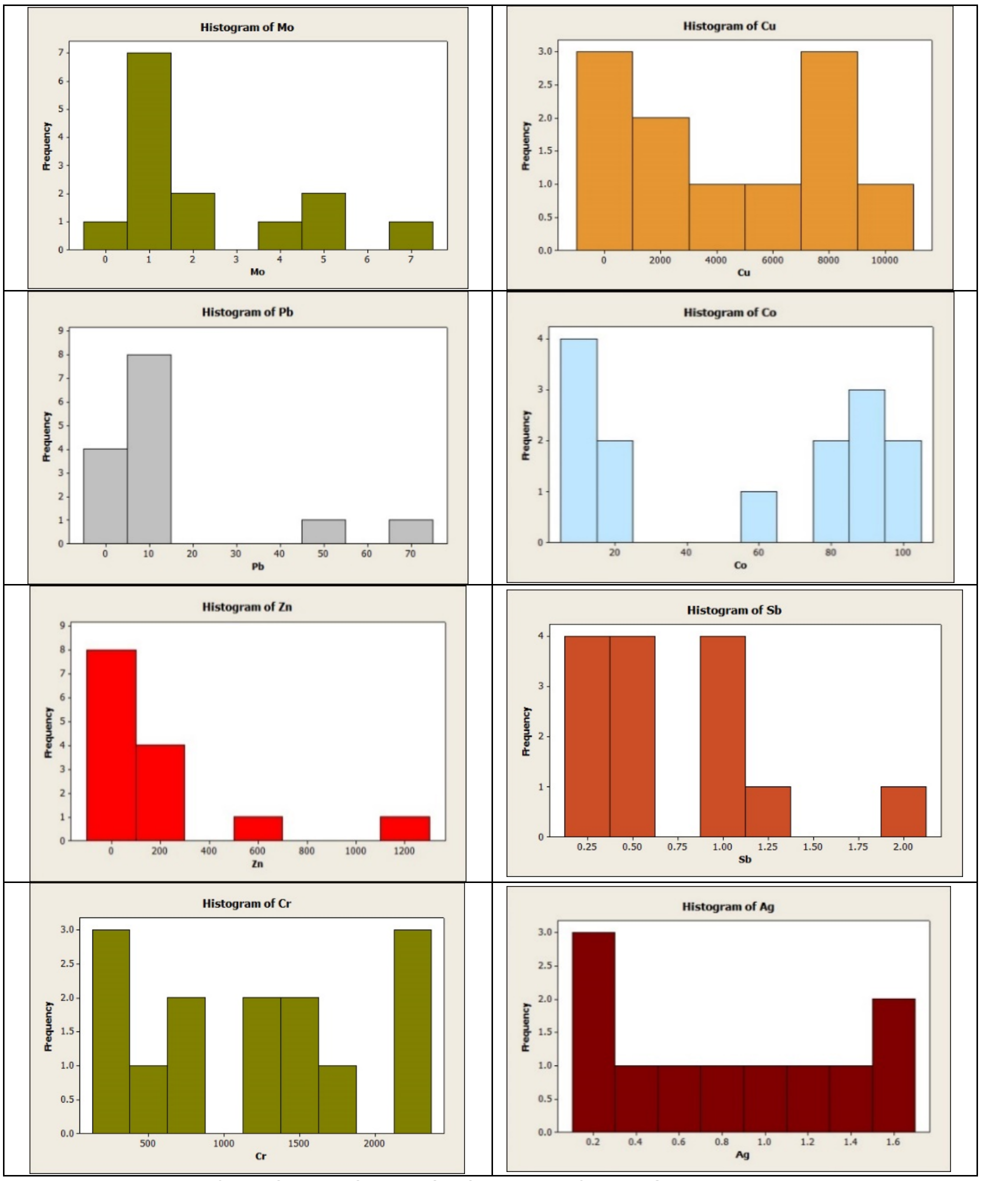

Fig. 4. Histograms of Mo, Cu, Pb, Co, Zn, Sr, Cr, and Ag for the Goshgarchay magmatic system

ISSN 1728-2713

According to the properties of the definition of indicator elements, the associated elements have been studied more than ore elements which are from porphyry copper deposit ores and their scattering areas. Deposits with different contents are characterized by steadiness of the selection of indicator elements. These elements-Ba, As, Sb, Ag, Pb, Zn, Au, Bi, Cu, Mo, W, Sn, Co and B are considered for porphyry copper deposits. Series of the mentioned elements have been generalized and they are not always constant for all porphyry copper deposits (*Rekharskiy et al.,1983; Mongush and Lebedev, 2013*).

For the solution of the advanced problem, behavior features of chemical elements have been investigated in mineral associations and ore surrounding rocks and a few point dependence graphics reflecting dependence relations between elements have been set up. In order to study definition features of indicator elements, the interaction between them was investigated and on the basis of them statistical analysis of geochemical properties of the deposits was made. As shown in the analysis, the dependence of element pairs is symmetrically repeated with respect to diagonal. Dependent variables are shown in the vertical axis and independent variables are shown in the horizontal axis. Point clouds were drawn in the precise direction for separate elements. It's explained so, the ore mass has undergone sharp enrichment in the upper part of the deposit due to oxidation process. Therefore, an increase in frequency of Cu-bearing minerals was observed in the surface. Newly formed sulfides (chalcocite, covellite, bornite, and malachite) appeared in the oxidation zone. The products of both hypogene and hypergene minerals are selected. There is appositive relationship between X and Y. Most part of all point clouds are located along the straight line in the relations graphic of Cu and Mo with other components. But a part of point clouds is located beyond the line. It is a normal case in the definition of elements and contents of elements are not dependent of this straight line. It confirms that all aforementioned elements are the product of geochemical processes.

Discussion. Correlation of Cu and Mo with chalcophile elements, such as As, Sb, Cu, Bi, Cd, Ga, In, Ge, Au, Ag, and Te, and siderophile elements, such as Co, Ni, Mo, Te, and Cr is given in Fig. 5 and 6. The definition of element mixtures in various type of ores and ore metals is inequal and their concentration varies a thousand times more than their contents of Clarke and coefficient of concentration (*Babazadeh et al.,1990; Mansurov, 2013*). There is a positive correlation between Cu and Ag, As, Bi, Cd, Ge, Co, Mo, Cr, Ni, Pb, and Rb, as shown in Fig. 6. Whereas, Cu has a negative correlation with Co, Cr, Cs, La, Li, Pb, Rb, Ni, Nb, and Zn (*Mansurov, 2021*).

According to Grabejev and Chashchukhina, (1985), the interpretation of geochemical information helps us to determine relationship among elements. Geochemical relations between ore elements within the deposit and separate spheres of the deposit is explained by significant features of the studied elements.

It should be mentioned that maximal concentration zone of Cu, Mo, Pb, Zn, Ag, Se, Te and other elements can be different in the evolution of differentiation of postmagmatic solutions which has a series of copper-porphyry deposits containing complicated formation condition. Similar case is possible to observe in the deposits owing to repetition of inclusion of hydrothermal fluids (*Bortnikov et al., 2008*).

Rekharski et al. (1983) noted that the existence of direct (straight) relations between the price of ore value and the price close to Clarke amount of the studied elements is considered essential indicator.

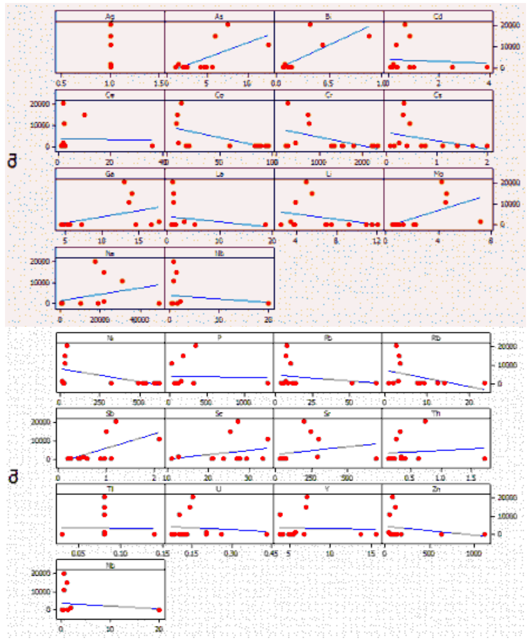

Fig. 5. Correlation Cu with Ag, As, Bi, Cd, Ce, Co, Cr, Cs, Ga, La, Li, Na, Nb, Ni, P, Pb, Rb, Sb, Sc, Sr, Th, Tl, U, Y, Zn, and Nb in the Goshgarchay porphyry copper deposit

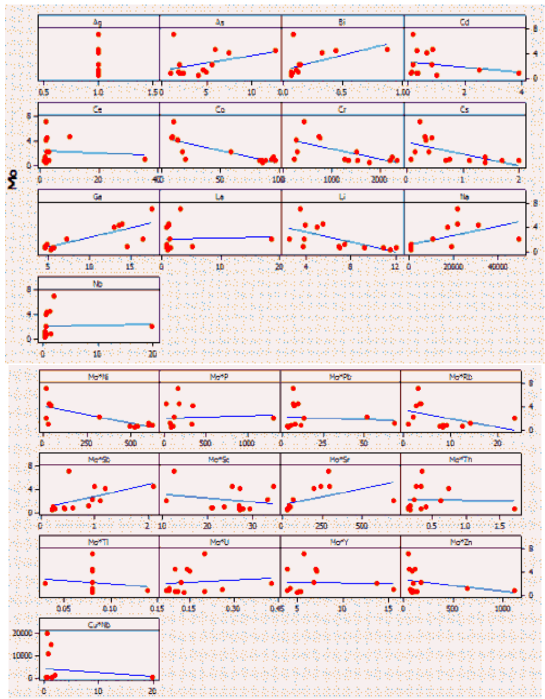

Fig. 6. Correlationof Mo with Ag, As, Bi, Cd, Ce, Co, Cr, Cs, Ga, La, Li, Na, Nb, Ni, P, Pb, Rb, Sb, Sc, Sr, Th, Tl, U, Y, Zn, and Nb.in the. Goshgarchay porphyry-copper deposit

Direct dependence is observed for ore mass between concentrations of Cu, Mo, Zn, Ag, Se, Te, and other elements in the Goshgarchay porphyry Cu deposit. This dependence confirms that these elements occupy place in the same hydrothermal column in space and time evolution of solutions within ore-magmatic system and in the transportation of these elements along with deposit zone. Three various mineral associations differing from one another participate in porphyry copper mineralization: 1) primary sulfide minerals; 2) oxidized ores; 3) primary sulfide minerals significantly enriched with the products of hydrothermal ore-carrying solutions.

Conclusions.

1. Granitoid intrusiveness associated with porphyry copper mineralization in the Goshgarchay magmatic system belong to the later Jurassic-early Cretaceous gabbro-diorite-granodiorite.
2. There is a positive correlation among the studied elements, representing a similar geochemical behavior.
3. Cloud of points extend in completely clear direction for separate elements (especially Cu, Mo, Pb, and Zn). It is due to the fact that the upper part of ore mass in the Goshgarchay deposit has undergone sharp enrichment owing to oxidation process during the progress of abrasion shell sphere.
4. As seen from correlation relation between elements copper-porphyry mineralization is characterized by the mixture of elements in a wide spectrum. Here include both chalcophile elements (As, Sb, Cu, Bi, Cd, Ga, In, Ge, Au, Ag, and Te) and siderophile elements (Co, Ni, Mo, Fe, and Cr).
5. Direct dependence is observed for ore mass between concentrations of Cu, Mo, Pb, Zn, Ag, Se, Te and other elements in the Goshgarchay porphyry copper deposit.
6. Three various mineral associations differing from one another participate in stock work type copper-porphyry mineralization: 1) primary sulfide minerals; 2) oxidized ores; 3) primary sulfide minerals significantly enriched with products of hydrothermal ore carrying solutions.

References

Abdullayev, R.N., Mustafayev. G.V., Mustafayev, M.A. (1988). Mesozoic magmatic formations of the Lesser Caucasuses and associated endogenous mineralization. Baku: Elm. [in Russian]

Baba-zadeh, V.M., Makhmudov, A.I., Ramazanov, V.G. (1990). Copper and molybdenum porphyry deposits: Baku: Azerneshr. [in Russian]

Borisenko, I.D., Borovikov, A.A., Borisenko, A.S., Gaskov I.V. (2017). Physicochemical conditions for the formation of ores at the Samolazovskoe gold deposit (Central Aldan). *Geology and geophysics,* 58 (12), 1915-1927. [in Russian]

Bortnikov, N.S., Simonov, V.A., Bogdanov, Yu.A. (2008). Fluid inclusions in minerals from modern sulfide structures: physicochemical conditions of mineral formation and fluid evolution. *Geology of ore deposits,* 46 (1), 74-87. [in Russian]

Geology of Azerbaijan. Magmatism. (2003). Baku: publishing house Nafta-Press. [in Russian]

Geology of Azerbaijan. Tectonics. (2005). Baku: publishing house Nafta-Press. [in Russian]

Grabezhev, A.I. Chashchukhina, V.A. (1985). On the correlation between the elements of porphyry-copper deposts. *Geochemistry,* 12, 1792-1794. [in Russian].

Imamverdiyev, N.A., Baba-zadeh, V.M., Mansurov, M.I., Abdullayeva, Sh.F. (2020). Rare-Earth elements in magmatic and metasomatic rocks of Murovdag ore area (Lesser Caucasus). *Geochemistry Intenational,* 2, 229-234.

Mansurov, M.I. (2013). Geological-genetical genetic model of Goshgarchay ore-magmatic system of Murovdag uplift. (Lesser Caucasus, Azerbaijan). *Journal of News of ANAS. Earth Sciences*, 4, 16-22. [in Russian]

Mansurov, M.I. (2014). Models of ore-magmatic systems of copper-porphyry of deposits of Goshgarchay ore field (Lesser Caucasus, Azerbaijan). *Journal of News of the Siberian department of the section of earth Sciences of the Russian Academy Natural of Sciences. Geology, Exploration and Development of mineral deposits*, 4(47), 29-42. [in Russian]

Mansurov, M.I. (2021). Distribution peculiarities of basic ore components in Goshgarchay porhyrous cpooer deposit (Lesser Caucasus, Azerbaijan). Visnyk of V.N. Karazin Kharkiv National University, series "Geology. Geography. Ecology", 54, 96-105. DOI: https://doi.org/10.26565/2410-7360-2021-54-07.

Mansurov, M.I. (2021). Location Peculiarities and evolution of Goshgarchay copper-porphyre field (Lesser Caucasus, Azerbaijan). *Visnyk of Taras Shevchenko National University of Kyiv. Geology*, 2 (93), 41-51. DOI: https://doi.org/10.17721/1728-2713.93.05.

Mineral-raw resources of Azerbaijan (Formation conditions, distribution patterns, scientific basis of predicition). (2005). Ed. by V.M. Baba-zadeh. Baku: Ozan, 808. [in Russian]

Mongush, A.-D.O., Lebedev, V.I. (2013). Ak-Sug copper-molybdenum-porphyry deposit: material composition of rocks and ores. *Bulletin of the Siberian Branch of the Earth Sciences Section of the Russian Academy of Natural Sciences. Geology, prospecting and exploration of ore deposits*, 1(42), 22–29. [in Russian]

Nikolaev, Yu. N., Baksheev, I.A., Prokofiev, V.Yu., Nagornaya, E.V., Marushchenko, L.I., Sidorina, Yu.N., Chitalin, A.F., Kalko, I.A. (2016). Au-Ag mineralization of porphyry-epithermal systems of the Baim zone (Western Chukotka, Russia). *Geology of ore deposits*, 58 (4), 319–345. [in Russian]

Pavlova, I.G., Sakhnovsky, M.L. (1988). Models of ore-magmatic systems of molybdenum-copper porphyry deposits as a basis for their prospecting and forecasting. Ore formation and genetic models of endogenous ore formations. Ed. By A.A. Obolensky, V.I. Sotnikova, V.N. Sharapova. Novosibirsk: Science. [in Russian]

Popov, V.S. (1977). Geology and genesis of copper-molybdenum-porphyry deposits. Moscow: Science. [in Russian]

Ramazanov, V.G. (1993). Porphyry- copper formation of Azerbaijan. Baku: Elm, 45. [in Russian]

Rekharsky, V.I., Varyash, L.N., Kapsamun, V.P. (1983). On the genesis of molybdenum and copper mineralization of copper-molybdenum deposits. In the book "Genetic models of endogenous ore deposits". Vol.1. Novosibirsk: Nauka,135-143. [in Russian]

Sillitoe, R.H. (1996). Granites and metal deposits. *Episodes*, 19, 126–133.

Sillitoe, R.H. (2010). Porphyry Copper Systems. *Society of Economic Geologists. Inc. Economic Geology*, 105, 3-41.

Titley, S.R., Bean R.E. (1984). Porphyry copper deposits. Genesis of ore deposits. Moscow: Mir. [in Russian]

Надійшла до редколегії 21.05.22

М. Мансуров,
E-mail: mamoy_mansurov@mail.ru,
Бакинський державний університет,
вул. З. Халілова, 23, м. Баку, AZ1148, Азербайджан

ГЕОХІМІЧНІ ОСОБЛИВОСТІ РУДНО-ПОРФІРОВОЇ МІНЕРАЛІЗАЦІЇ У МАГМАТИЧНІЙ СИСТЕМІ ГОШГАРЧАЙ (МУРОВДАРСЬКИЙ РАЙОН, АЗЕРБАЙДЖАНСЬКА ЧАСТИНА МАЛОГО КАВКАЗУ)

Вивчено геохімічні особливості інтрузивних і вміщуючих порід, пов'язаних із мідно-порфіровим зруденінням у Гошгарчайській магматичній системі. Виявлено основні фактори концентрації мідної та мідно-порфірової мінералізації в породах габро-діорит-грандіоритової формації. Установлено, що структура цього рудного району сформувалася в результаті послідовної зміни кількох етапів деформації, що супроводжувалися розвитком тріщин в інтрузивному масиві, упровадженням даєк, зсувами по розломах і тріщинах.

Визначено основні компоненти руди та розглянуто відношення між елементами. За результатами кластерного аналізу проаналізовано геохімічні асоціації, що дозволяють локалізувати область розвитку зруденіння в різних стадіях формування мідно-порфірової системи. Як стабільні елементи розглянуто Cu, Mo, Pb, Zn, Ag, Ni, Co, Mn, Ti, Cr, V, Sr як у вміщуючих породах, так і в рудоносних інтрузивних. Цю групу елементів можна розглядати як елементи-індикатори в мідно-порфірових породах.

Результати кластерного аналізу показують, що менш характерні для гідротермальних розчинів елементи (Mn, Ti, Cr, V, Sr) зберігають свободу в усіх навколожильних породах, а існування їхніх асоціацій, імовірно, пов'язане із процесом їх перенесення із силікатних порід. Такі елементи, як Cu, Mo, Ag, Pb і Zn, утворюють вільну групу і пов'язані з утворенням із магматичного джерела у процесі кристалізаційної диференціації та впливу на породи гідротермальної активності, яка вважається джерелом цих елементів. Аналіз графіків, складених за результатами вмісту Cu та основних рудних компонентів (Mo, Ag, As, Bi, Gd, Co, Cr, Se, Ge, Li, Nb тощо) у рудах Гошгарчайського родовища, показує їхню залежність один від одного в однаковому ступені. Кількість Cu в руді має позитивний кореляційний зв'язок з Ag, As, Bi, Cd, Ce, Ge, Sr, Mo, Sb, Th і Ti, а з Co, Cr, Cs, La, Li, Pb, Rb, Ni, Nb, Zn – негативний. Для рудної маси спостерігається пряма залежність між концентраціями Cu, Mo, Pb, Zn, Ag, Se, Te та іншими елементами мідно-порфірового родовища Гошгарчай. У мідно-порфіровому зруденінні штокверкового типу беруть участь три різні мінеральні асоціації: 1) первинні сульфідні мінерали; 2) окиснені руди; 3) первинні сульфідні мінерали, значно збагачені продуктами гідротермальних рудоносних розчинів.

***Ключові слова:** мідно-порфірове зруденіння, Гошгарчай, геохімія, основні рудні компоненти, точкова залежність, кореляційні зв'язки.*