МІНЕРАЛОГІЯ, ГЕОХІМІЯ ТА ПЕТРОГРАФІЯ

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Mamoy MANSUROV, PhD (Geol. & Mineral.), Assoc. Prof.
ORCID ID: 0000-0001-8673-3034
e-mail: mamoy_mansurov@mail.ru
Baku State University, Baku, Respublic of Azerbaijan

GEOCHEMICAL CHARACTERISTICS OF THE MAIN ORE COMPONENTS IN THE GOSHGARCHAY PORPHYRY-EPITHERMAL SYSTEM (LESSER CAUCASUS, AZERBAIJAN)

(Представлено членом редакційної колегії д-ром геол. наук, доц. С.Є. Шнюковим)

The article deals with the determining characteristics of ore elements in the Goshgarchay porphyry-epithermal system. The genetic and geochemical characteristics of the main ore components were studied, and close positive and negative relationships between pairs of elements were determined by correlation analysis on the selected elements. According to the results of the cluster analysis, the geochemical associations that allow the localization of the development area of mineralization at different stages of formation of the porphyry-epithermal system were analyzed. The following series of stable elements, which are typical for hydrothermal deposits, are distinguished among the ore elements of the host and ore-bearing intrusive rocks: Cu, Mo, Pb, Zn, Ag, Ni, Co, Mn, Ti, Cr, V, Sr, etc. This group of elements is considered to be the indicator elements of the copper-porphyry deposit within the porphyry-epithermal system. It has been determined that correlations between elements in copper-porphyry mineralization are characterized by a wide range of element impurities. It includes both chalcophile (As, Sb, Cu, Bi, Cd, Ga, In, Ge, Au, Ag, Te) and siderophile (Co, Ni, Mo, Fe, Cr) elements. The range of values of vertical geochemical zonality on individual sections of the deposit allows to assess the level of the erosion truncation of occurrences in the porphyry-epithermal system.

Keywords: *Goshgarchay, porphyry-epithermal, geochemical, main ore components, correlation relationship, genetic characteristics.*

Introduction. Porphyry-epithermal systems that contain copper-porphyry deposits are formed in the conditions of continental margins and island arcs. These deposits are associated with postcollision volcanism on the frontal part of the island arc adapted to the I-type granitoid massif and belong to the magnetite series in individual cases. The back part of the arc is related to diorite massifs and subvolcanic bodies of shoshonites (fig. 1) (Sillitoe, 210). Most of the known copper-porphyry deposits are of Mesozoic and Cenozoic age. Most of them are adapted to the system of regional divisions that create conditions for local expansions and ensure free movement of fluids. Cu-Mo, Cu-Mo-Au and Cu-Au subspecies are distinguished among copper-porphyry systems (Titley et al., 1984; Sillitoe, 2010).

Copper-porphyry deposits are the product of complex interactions of some processes and are characterized by the following features (Berger et al., 2008): 1) the presence of ore bodies with a stockwork structure adapted to a complex veinlet network and related to rich copper-sulphide mineralization; 2) genetic relationship of metasomatic changes and mineralization with the magmatic basin at a depth of 1–4 km. The predominance of medium and acidic magma adapted to the subduction zone where multiphase focuses with complex structures are formed; 3) the direct occurence of intrusive complexes led to the formation of porphyry deposits and the dominance of vertical contact stocks and dyke systems; 4) presence of large-scale metasomatic alteration zonation. Here, chlorite-sericite metasomatite zones, secondary quartzites and marginal propylite zones cover or surround the internal potassium metasomatites (Sillitoe, 210; Titley and Bean, 1984).

The main mass of copper ores is extracted from copper-porphyry deposits by the countries of the world, and these deposits are also considered the main sources of molybdenum, gold, silver, rhenium, tellurium and platinum group elements. Copper-porphyry and copper-molybdenum-porphyry deposits and occurrences related to volcanic-plutonic complexes have been developed in most metallogenic zones of the Azerbaijan part of the Lesser Caucasus. Copper-porphyry mineralization related to plutonic granitoid massif of Murovdag ore field is considered more promising. There are some copper-porphyry types of deposits and occurrences (Goshgarchay, Goshgardag, etc.) here that can be included in the group of large deposits of copper reserves (fig. 1) (Babazadeh et al., 1990; Mansurov, 2013).

The Goshgarchay porphyry-epithermal system is a part of the Lok-Aghdam island arc and covers the uplifted northwestern part of the Murovdag anticlinorium with an asymmetric structure, which includes a Lower Bajocian volcanogenic layer in its core, and a layer of Upper Bajocian and Bathonian successively differentiated basalt-andesite-rhyolite formations in its wings. The intrusive complexes of the porphyry-epithermal system were represented by the Goshgarchay granitoid intrusions (Goshgardag, Ojagdag, Balaja Goshgardag) and their dyke formations, which intersected the thick effusive complexes. Intrusive complexes with copper-porphyry mineralization belong to the Late Jurassic-Early Cretaceous gabbro-diorite-granodiorite formation according to their geological and petrological characteristics (Abdullayev et al., 1988; Geology of Azerbaijan, 2003). The main part of copper and molybdenum mineralization in copper-porphyry deposits within the porphyry-epithermal system is related to various ore-bearing hydrothermal-metasomatic formations. Copper mineralization is associated with quartz-sericite-chalcopyrite, and molybdenum mineralization with feldspar-quartz-molybdenite formation (Babazadeh et al., 1990; Mansurov, 2014).

The Goshgarchay copper-porphyry deposit is a well-studied, explored and promising deposit within porphyry-epithermal system of the same name. Correlation between the main components of copper-porphyry mineralization within the porphyry-epithermal system has been investigated in this article.

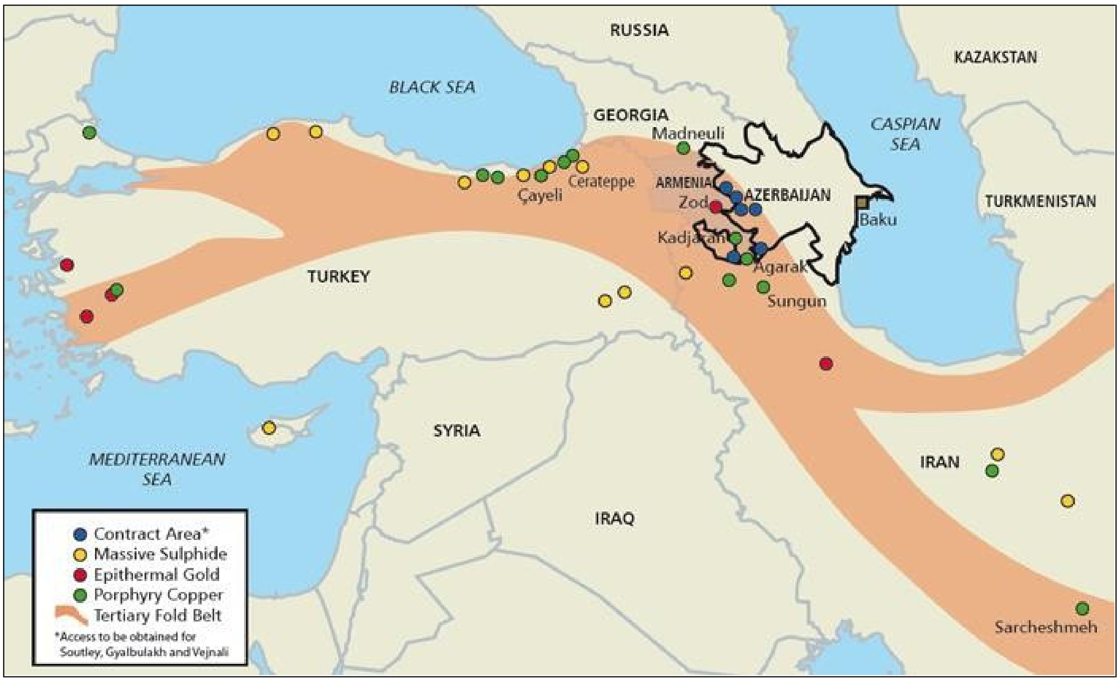

Fig. 1. Porphyry Cu, Au, Mo, Ag deposits in the Tethys metallogenic belt
(http://www. angloasianmining.com/operations/overview, 2018)

Factual materials and research methods. The basis of the factual material was a collection of samples (about 150 pieces) taken inside and around the stockwork with vein- impregnated mineralization and on its flank to a depth of more than 500 m from the surface. The collection includes samples collected from gabbroids, quartz diorites, quartz veins with galena-sphalerite-chalcopyrite mineralization. The samples were used to make petrographic thin sections and plates polished on both sides for the study of fluid inclusions, and the rest of these samples were clustered and dispersed on sieves. Atomic absorption spectrometry on a PerkinElmer instrument allowed to quantify elements such as Cu, Mo, Cr, Ni, Co, Pb, Zn, Sr, As, Bi. Rock samples were studied by inductively coupled plasma mass spectroscopy (ISP-MS) (Turkey, Izmir). Analytical studies were performed at the USGS Analytical Laboratory of the US Geological Survey (Denver).

The results of spectral, atomic absorption and chemical analyzes were used when solving the issues of determining the main ore components and its genetic and geochemical properties in the Goshgarchay porphyry-epithermal system. The number of testing points within the porphyry-epithermal system was up to 1000. Their distribution was equal within the area. Rooty exposures were tested by natural outcrops and exploratory mountain excavations (trenches, pits, wells). All testing points were accompanied by geological-petrographic descriptions. Tests were conducted on Ag, Au, As, Bi, Ca, Cd, Cr, Cu, K, Mg, Mn, Mo, Na, Ni, P, Pb, Se, Sr, Ti, V and other elements. The solution of the issues is based on the primary materials of the results of the analyses of the host rocks and minerals. The processing of the statistical results of the geochemical data on the results was carried out by the "STATISTICA" and "MINITAB-16" programs (Belonin et al., 1982). SPSS statistical package was used to calculate the factor analysis.

Determining characteristics of the main ore components in the Goshgarchay porphyry-epithermal system. The method of factor analysis was used when solving the determining issues of the main ore components, its genetic and geochemical characteristics in the Goshgarchay ore-magmatic system. As it is well known, the factor analysis method is considered one of the modern multivariate statistical methods and is widely used in solving a number of statistical problems in various fields of geology, including ore geology (Belonin, 1982). The method of factor analysis allows a deep understanding of its importance and is considered very important when developing the geological basis of prospecting and exploration of mineral deposits.

The results of the chemical analyzes of well cores, which were dug up to an average of 180 m in the studied area, and surface mountain excavations were used in order to clarify the geochemical and genetic characteristics of the copper-porphyry system in the Goshgarchay ore-magmatic system. Correlation matrix, load factor, factor weight and specific value were calculated by the use of factor analysis for the selected elements (Mansurov, 2018). The main ore elements are combined into two groups to solve the issue. Elements such as Cu, Pb, Zn, Sb, As belong to the first group, and elements such as Ni, Co, Ti, V, Cr, Bi belong to the second group. As a result of the processing, two factors reflecting the correlation relationship between the six ore components were obtained (Table 1).

All factors are considered ore-bearing, or rather, the elements characterized by the maximum charge in these factors took part in the process of ore formation.

The load factor, specific value and factor weight shown in Tables 2 and 3 show that the characteristics of Cu, Pb, Zn, Sb and As elements are determined by the F_1 factor. The analysis of the main components of the F_1 factor shows that there is a significant positive correlation between this load factor and Cu (0.819067), Mo (0.694623), Sb (0.927197) and As (0.87989), a significant negative correlation with Zn (–0.24141), and a weaker but positive correlation with Pb (0.097005). Such a selection of the main components and their behavioral characteristics allow to conclude that the F_1 factor reflects the process of ore deposition by introducing Cu, Mo, Sb and As elements (Belonin, 1982; Mansurov, 2018).

Table 1

Amount of Cu, Mo, Pb, Zn, Sb and As elements in Goshgarchay porphyry-epithermal system

Sınaq-Lar	G-72	G-73	G-74	G-79	G-80	G-82	G-75	G-76	G-77	G-78	G-84	G-85	G-86	G-87
Koordinatlar	40.414	40.415	40.415	40.412	40.25	40.411	40.414	40.414	40.414	40.412	40.410	40.410	40.409	40.409
	45.929	45.929	45.929	45.929	45.93	45.932	45.929	45.929	45.929	4.928	45.934	45.934	45.936	45.936
Cu	105	248	149	116	214	49.6	88.4	104	66.2	334	15000	10900	20300	1350
Mo	0.9	0.83	0.77	0.67	2.1	1.0	2.8	2	2.1	1.6	4.6	4.5	4.2	7.2
Pb	11.1	5.52	3.68	3.08	13.0	7.91	51.8	3.64	3.88	68.1	6.71	9.5	6.93	6.78
Zn	83.7	1120	130	68.8	90	60.1	173	77.2	124	636	106	49.6	79.3	35.3
Sb	0.59	0.42	0.45	0.26	1.1	0.22	0.95	0.21	0.2	0.88	1.0	2.1	1.2	0.52
As	1.9	1.4	2.0	2.2	5.6	4.9	2.0	4.1	<1	4.6	5.9	12.6	7.5	1.3

Note: *G-72-74-gabbro; G-75-77-andesite; G-79-gabbro; G-80-diorite; G-82-basalt; G-78-secondary quartzites; G-84-ore-bearing secondary quartzites; G-85-copper-porphyry ores; G-86-87 ore-bearing secondary quartzites*

Table 2

Load factors of elements

No. of samples	F_1	F_2
G-72	–0,58899	0,243737
G-73	–0,89294	–1,201
G-74	–0,72568	0,451854
G-75	–0,00621	–1,26353
G-76	–0,70914	**0,581864**
G-77	–1,01748	**0,57006**
G-78	0,142963	–2,60776
G-79	–0,83928	**0,638302**
G-80	**0,253752**	–0,01659
G-82	–0,5422	0,490929
G-84	**1,06751**	**0,608548**
G-85	**2,28486**	–0,02201
G-86	**1,531631**	**0,604217**
G-87	0,041206	0,92138

Note: *in bold background – the significant value of the load factor is shown*

Table 3

Load factor, specific value and factor weight on elements

Elements	F_1	F_2
Cu	**0,819067**	**0,24515**
Mo	**0,694623**	**0,253405**
Pb	0,097005	–0,85986
Zn	–0,24141	–0,71234
Sb	**0,927197**	–0,20243
As	**0,87989**	0,018338
Special price	2,854961	1,41241
Factor jack	0,475827	0,235402

Note: *in bold background – the significant value of the load factor is shown*

The analysis of F_2 load factor shows that it has a significant positive relationship with the elements Cu (0.24515) and Mo (0.253405), a negative relationship with the elements Pb (–0.85986), Zn (–0.71234) and Sb (–0.20243), and a weaker but positive relationship with the element As (0.018338). Such a state of the F_2 factor suggests that the migration and concentration of Cu and Mo elements in the main mineralization process took place under different conditions (fig. 2). The data of the behavior of Mo and Cu under different physico-chemical conditions suggest the presence of small amounts of Cu in molybdenum-bearing ore solutions and Mo in copper-bearing solutions (Nikolayev, 2016; Mansurov, 2018).

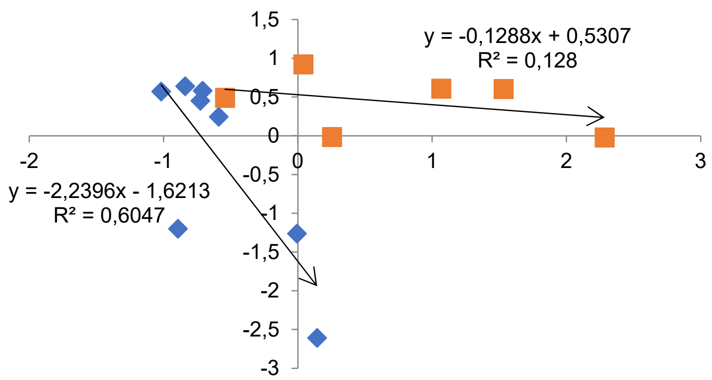

Fig. 2. Dependency graph of factors F_1 and F_2 on the results of factor analysis (on Cu, Mo, Pb, Zn, Sb and As elements)

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The importance of factor F_1, which corresponds to Cu (Mo) association, is statistically related to the retention of chalcopyrite and molybdenite in Cu-Mo porphyry mineralization (chalcopyrite-molybdenite) (Belonin, 1982; Nikolayev, 2016). The positive correlation between the F_2 factor and the amount of Pb, Zn, Sb and As elements confirms indirectly the overlay of copper-porphyry mineralization on the porphyry and subepithermal stage of the ore deposition process (Belonin, 1982, Mansurov, 2021).

14 of the samples taken from the host rocks within the Goshgarchay copper-porphyry deposit were analyzed in order to determine the amount of elements such as Ni, Co, Ti, V, Cr and Bi in the ore-magmatic system of the same name. As a result of processing the analysis results of these samples, 3 factors reflecting the correlation relationship between 6 ore elements were obtained (fig. 3). The concentration of these elements in the samples is shown in table 4, and the load factor, specific value and factor weight are shown in Table 5.

As can be seen from Table 5, the F_1 load factor has a complex character and there is a significant positive correlation between the F_1 factor and Ni (0.94983), Co (0.959018), Cr (0.903098) and a significant negative correlation between Ti (–0.30861) and Bi (–0.61712).

There is a significant positive correlation between the F_2 factor and Ni (0.94983), Bi (0.555844), a negative correlation between Ti (–0.30861) and a weaker but positive correlation with Co (0.042407), V (0.007864) elements.

The results of the correlation matrix of the elements are shown in Table 7 and the following positive and negative correlation relationship between the elements is determined.

Table 4

Amount of Ni, Co, Ti, V, Cr and Bi elements in the Goshgarchay porphyry-epithermal system

Trials	G-72	G-73	G-74	G-79	G-80	G-82	G-75	G-76	G-77	G-78	G-84	G-85	G-86	G-87
Coordinates	40.414	40.415	40.415	40.412	40.25	40.411	40.414	40.414	40.414	40.412	40.410	40.410	40.409	40.409
	45.929	45.929	45.929	45.929	45.93	45.932	45.929	45.929	45.929	4.928	45.934	45.934	45.936	45.936
Ni	2.2	20.8	534	492	17.9	26.8	321	519	539	597	34.9	34.8	46.4	15.0
Co	0.61	21	84.9	83.7	17.4	20.2	59.2	85.6	88.7	95.2	9.5	8.4	13.2	10
Ti	667	891	3.68	990	6750	2520	1230	886	949	770	1300	819	1090	1160
V	127	120	151	196	120	323	202	161	156	159	180	123	158	92.2
Cr	1260	1340	1530	2360	261	203	1520	1780	2210	2260	719	738	251	421
Bi	0.12	0.06	0.07	0.06	0.14	0.06	0.13	0.06	0.06	0.1	0.88	0.44	0.32	0.08

Table 5

Results of factor analyzes of elements

No. of samples	Factor 1	Factor 2	Factor 3
G–72	–0,49629	**0,284595**	–0,7402
G–73	–0,2031	0,113155	–0,84754
G-74	0,976721	0,0241	–0,13388
G-75	0,400452	0,033848	**0,685826**
G-76	**1,060658**	0,05588	–0,00529
G-77	**1,263956**	**0,121979**	–0,15025
G-78	**1,359442**	**0,311581**	–0,07493
G-79	**1,194637**	**0,13958**	**0,497577**
G-80	–0,77459	–2,781	–0,87924
G-82	–0,75298	–1,01647	**2,852318**
G-84	–1,49069	1,745758	**0,530589**
G-85	–0,94606	0,882604	–0,60155
G-86	–0,95203	0,335893	0,055853
G-87	–0,64012	–0,2515	–1,1893

Table 6

Load factor, specific value and factor weight of elements

Elements	F_1	F_2	F_3
Ni	**0,94983**	**0,123226**	0,088395
Co	**0,959018**	0,042407	0,129709
Ti	–0,30861	–0,84415	0,003185
V	0,057914	0,007864	0,994674
Cr	**0,903098**	0,29171	–0,07573
Bi	–0,61712	**0,555844**	0,042269
Special price	3,116917	1,123695	1,021545
Factor jack	0,519486	0,187282	0,170258

Table 7

Correlation matrix

Elements	Ni	Co	Ti	V	Cr	Bi
Ni	1	0,990867	–0,30908	0,121217	0,859261	–0,38713
Co	0,990867	1	–0,24878	0,164289	0,846999	–0,44446
Ti	–0,30908	–0,24878	1	–0,04683	–0,47416	–0,03899
V	0,121217	0,164289	–0,04683	1	–0,01001	–0,02715
Cr	0,859261	0,846999	–0,47416	–0,01001	1	–0,36232
Bi	–0,38713	–0,44446	–0,03899	–0,02715	–0,36232	1

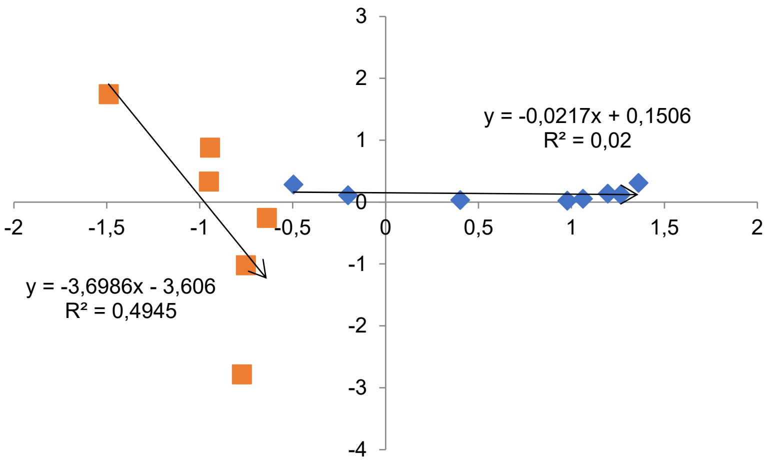

Fig. 3. Dependency graph of factors F_1 and F_2 on the results of factor analysis (on Ni, Co, Ti, V, Cr and Bi elements)

A positive relationship was determined between Ni-Co (r = 0.990867), Ni-V (r = 0.121217), Ni-Cr (r = 0.859261), Co-V (r = 0.164289), Co-Cr (r = 0.46999) pairs, and a negative relationship was determined between Ni-Ti (r = –0.30908), Ni-Bi (r = –0.38713), Co-Ti (r = –0.24878), Co-Bi (r = –0.44446), Ti-V (r = –0.04683), Ti-Cr (r=-0.47416), Ti-Cr (r = –0.03899), V-Cr (r = –0.01001), V-Bi (r = –0.02715) pairs during correlation analysis (R 5 %).

The analysis of the correlation matrix of the elements allows to clarify the interrelationship of the elements and this is shown graphically (fig. 4).

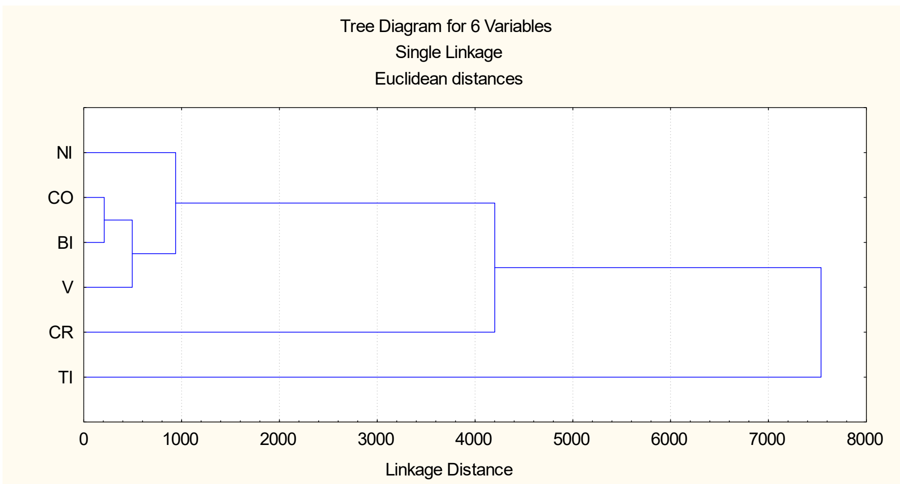

Fig. 4. Dendrogram of cluster analysis of elements

As can be seen from the results of the analysis shown in Table 7 and the dendrogram of the correlation coefficient and cluster analysis in fig. 3, the elements are concentrated in two groups: 1) Ni-Co-Bi; 2) Cr-Ti.

It can be concluded from the abovementioned materials that the elements are grouped in factors or geochemical associations comparable to the mineral paragenesis of the main ore deposition stage. According to M.D. Belonin et al., this grouping is confirmed by the correlation coefficient between geochemical and mineral properties, factor importance and main ore elements (Grabejev et al., 1985).

The results of the factor analysis, correlation matrix and load factor on elements Ba, Sr, Rb, Li and Cs are shown in tables 8, 9 and 10. As it can be seen from here, a positive relationship was determined between Ba-Sr (r=0.718825), Ba-Rb (r = 0.597813), Sr-Rb (r = 0.410724), Sr-Cs (r = 0.49621), Rb-Li (r = 0.207225), Rb-Cs (r = 0.00467), Li-Cs (r = 0.4801) pairs, and a negative relationship was determined between Ba-Li (r = –0.36623), Ba-Cs (r = – 0.27263), Sr-Li (r = –0.6264), Sr-Cs (r = –0.49621) pairs during the correlation analysis (R 5 %).

Table 8

Results of factor analysis on Ba, Sr, Rb, Li and Cs elements

Trials	G-72	G-73	G-74	G-79	G-80	G-82	G-75	G-76	G-77	G-78	G-84	G-85	G-86	G-87
Coordinates	40.414	40.415	40.415	40.412	40.25	40.411	40.414	40.414	40.414	40.412	40.410	40.410	40.409	40.409
	45.929	45.929	45.929	45.929	45.93	45.932	45.929	45.929	45.929	4.928	45.934	45.934	45.936	45.936
Ba	50.2	170	57	120	864	26.8	106	59.2	93.5	48.8	456	95.7	46.4	112
Sr	39.9	42.4	35.6	33.7	699	50	69.7	29.9	30.6	41.1	240	249	196	290
Rb	9.1	8.2	12.4	7.5	23.6	0.73	1.9	8.2	12.3	14	3.3	3.5	2.6	3.0
Li	6.9	7.0	151	10.9	2.4	3.7	3.8	11.5	12.1	7.4	5.5	3.9	4.9	0.23
Cs	0.75	0.68	1530	0.14	0.08	0.31	1.4	1.7	1.4	1.1	0.44	0.33	3.4	0.42

Table 9

Correlation matrix

Elements	Ba	Sr	Rb	LI	Cs
Ba	1	0,718225	0,597813	–0,36623	–0,27263
Sr	0,718225	1	0,410724	–0,6264	–0,49621
Rb	0,597813	0,410724	1	0,207225	0,004672
Li	–0,36623	–0,6264	0,207225	1	0,4801
Cs	–0,27263	–0,49621	0,004672	0,4801	1

Table 10

Load factor, specific value and factor weight

No. of samples	Factor 1	Factor 2
G-72	–0,45585	–0,01598
G-73	–0,29831	–0,02739
G-74	–0,37886	–0,41237
G-75	–0,57507	**0,616692**
G-76	–1,28333	–1,13431
G-77	–1,0357	–1,45335
G-78	0,169205	–1,32235
G-79	–0,46452	–0,0926
G-80	**2,919129**	–1,24843
G-82	–0,21838	**1,472201**
G-84	**0,539637**	**0,477966**
G-85	0,275756	**1,118647**
G-86	**0,445845**	**0,862301**
G-87	0,360446	**1,158973**

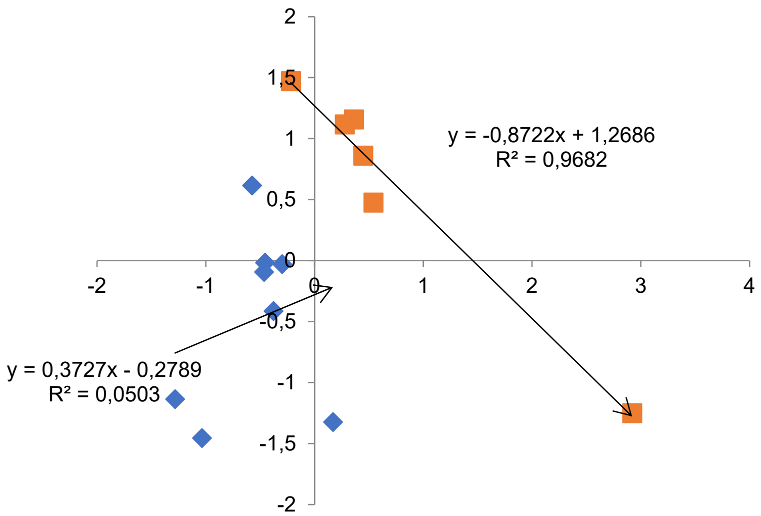

Fig. 5. Dependency graph of factors F_1 and F_2 on the results of factor analysis (on Ba, Sr, Rb, Li and Cs elements)

A geochemical mineral association, which provides conditions for the localization of the development area of mineralization at different stages of the formation of the copper-porphyry system based on the results of factor analysis, was found. The Goshgarchay copper-porphyry deposit is characterized by an upper ore erosional truncation, and a significant amount of copper-porphyry mineralization is predicted to the depth *(Mansurov, 2014)*.

It can be noted on the basis of the abovementioned data that according to (Rekharsky et al., 1983), elements (Ni, Co, Bi, Cr, Ti) that are less typical for hydrothermal solutions retain their independence in all rocks, and their grouping is probably related to the differentiation of magma crystallization (Khitarov, 1977). Also, the elements such as Cu, Pb, Zn, Ag and Mo have specific places in the mineralization process, and their presence in one or another group is related to the degree of hydrothermal activity of the rocks, which are considered as sources of these elements (Khitarov, 1977; Mansurov, 2021).

Conclusions

1) The investigation of the cluster analysis results shows that the elements (Mn, Ti, Cr, V, Sr) that are less typical for hydrothermal solutions retain their independence in all host rocks, and the presence of their grouping is most likely related to their transport processes from the host basic-intermediate silicate rocks.

2) The total of all analyzed tests represents two combinations of determination of major ore components: normal determination in ores and lognormal determination in host rocks.

3) As it can be seen from the analysis, correlation relationships between elements in copper-porphyry mineralization are characterized by a wide range of element impurities. This includes chalcophile (As, Sb, Cu, Bi, Cd, Ga, In, Ge, Au, Ag, Te) and siderophile (Co, Ni, Mo, Fe, Cr) elements.

4) The analysis of the main components of the F_1 factor shows that this load factor is determined by a significant positive correlation between the values of Cu, Mo, Sb and As factors.

5) The positive correlation relationship between the F_2 factor and the amount of Pb, Zn, Sb and As elements confirms indirectly the overlay of copper-porphyry mineralization on the porphyry and subepithermal stage of the ore deposition process.

6) The elements are grouped in factors or geochemical associations comparable to the mineral paragenesis of the main ore deposition stage. Geochemical and mineralogical characteristics are confirmed by factor importance and correlation coefficient between main ore elements.

7) The element-indicators for various factors are following: 1 – Zn, Cu, Co, Ni – for the composition factor of rocks; 2 – Cu, Mo, Co, Ni – for geochemical specialization and primary magma type factors; 3 – Mo – for the depth factor; 4 – Pb, Mo, Zn and Cu – for ore-bearing factor.

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Мамой МАНСУРОВ, канд. геол.-мінералог. наук, доц.
ORCID ID: 0000-0001-8673-3034
e-mail: mamoy_mansurov@mail.ru
Бакинський державний університет, Баку, Республіка Азербайджан

ГЕОХІМІЧНА ХАРАКТЕРИСТИКА ОСНОВНИХ РУДНИХ КОМПОНЕНТІВ ГОШГАРЧАЙСЬКОЇ ПОРФІРОВО-ЕПІТЕРМАЛЬНОЇ СИСТЕМИ (МАЛИЙ КАВКАЗ, АЗЕРБАЙДЖАН)

Розглянуто визначальні характеристики рудних елементів Гошгарчайської порфіро-епітермальної системи. Вивчено генетичні та геохімічні характеристики основних рудних компонентів, а також визначено тісні позитивні та негативні зв'язки між парами елементів за допомогою кореляційного аналізу на визначених елементах. За результатами кластерного аналізу проаналізовано геохімічні асоціації, що дають змогу локалізувати зону розвитку мінералізації на різних етапах формування порфіро-епітермальної системи. Серед рудних елементів вмісних і рудовмісних інтрузивних порід виділяють такі ряди стійких елементів, характерних для гідротермальних родовищ: Cu, Mo, Pb, Zn, Ag, Ni, Co, Mn, Ti, Cr, V, Sr та ін. Цю групу елементів вважають елементами-індикаторами мідно-порфірового родовища порфіро-епітермальної системи. Встановлено, що кореляції між елементами в мідно-порфіровій мінералізації характеризуються широким спектром домішок елементів. Він включає як халькофільні (As, Sb, Cu, Bi, Cd, Ga, In, Ge, Au, Ag, Te), так і сидерофільні (Co, Ni, Mo, Fe, Cr) елементи. Діапазон значень вертикальної геохімічної зональності на окремих ділянках родовища дає змогу оцінити рівень ерозійної зрізаності проявів порфіро-епітермальної системи.

Ключові слова: ***Гошгарчай, порфіро-епітермальні, геохімічні, основні рудні компоненти, кореляційний зв'язок, генетичні характеристики.***

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