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Distributions of Noble Metals (Ag, Au) in the Lower Horizons of the Gizilbulag Copper-Cement Deposit

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Abstract

The distribution of gold and silver in various types of ores and monomineral fractions of main sulfide (pyrite, chalcopyrite, sphalerite) minerals is considered. It is established that in various types of ores and monomineral fractions of sulfide minerals, the distribution of noble minerals (Ag, Au) is distributed unevenly. So high gold contents are observed in the quartz-chalcopyrite association, where the average content is 9.2g/t. This is probably due to the fact that the main ore mineral containing gold in the deposit is chalcopyrite, as evidenced by the gold content of monomineral fractions of chalcopyrite, averaging 6.2g/t. High average silver is typical for chalcopyrite-sphalerite types of ores (8.6g/t). Based on the results of the analyses, histograms of the distribution of gold and silver contents in various types of ores and monomineral fractions were constructed. The distribution of gold and silver in lower horizons of the deposit. It has been established that in the 755 m horizon there is a high gold content (20-40g/t), and in the central part of the horizon the silver content is 40-60g/t. At the 725 m horizon the gold content is 30g/t and an increased concentration of silver (20-30g/t) is also noted in the central part of the horizon. The minimum Au:Ag (1:1) ratio is observed in the central part of the 755 m horizon, and at the 725 m horizon the gold-silver ratio is 1:0.8.

Keywords: noble metals, horizon, monomineral, histogram, ore deposit, unimodal, mineral associations.

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Qızılbulaq mis-qızıl-kolçedan yatağının aşağı horizontlarında nəcib metalların (Au,Ag) paylanması

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Xülasə

Qızılın və gümüşün müxtəlif növ filizlərdə və əsas sulfid (pirit, xalkopirit, sfalerit) minerallarının monomineral fraksiyalarında paylanması nəzərdən keçirilir. Müəyyən edilmişdir ki, müxtəlif növ filizlərdə və sulfidli mineralların monomineral fraksiyalarında nəcib mineralların (Ag, Au) paylanması qeyri-bərabərdir. Belə ki, kvars-xalkopirit assosiasiyasında qızılın yüksək miqdarı müşahidə olunur ki, burada orta tutum 9,2 q/t təşkil edir. Bu, çox güman ki, yatağın tərkibində qızıl olan əsas filiz mineralının xalkopirit olması ilə əlaqədardır ki, bunu xalkopiritin monomineral fraksiyalarının qızılın miqdarı orta hesabla 6,2 q/t təşkil edir. Yüksək orta gümüş filizlərin xalkopirit-sfalerit növləri üçün xarakterikdir (8,6 q/t). Təhlillərin nəticələrinə əsasən müxtəlif növ filizlərdə və monomineral fraksiyalarda qızıl və gümüşün tərkibinin paylanmasının histoqramları qurulmuşdur.

Açar sözlər: nəcib metallar, horizont, monomineral, histoqram, filiz yatağı, unimodal, mineral birliklər.

Распределение благородных металлов (Ag, Au) в нижних горизонтах медно-цементного месторождения Гызылбулаг

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Аннотация

Рассмотрено распределение золота и серебра в различных типах руд и мономинеральных фракциях основных сульфидных (пирит, халькопирит, сфалерит) минералов. Установлено, что в различных типах руд и мономинеральных фракциях сульфидных минералов благородные минералы (Ag, Au) распределены неравномерно. Так, высокое содержание золота наблюдается в кварц-халькопиритовой ассоциации, где среднее содержание составляет 9,2 г/т. Вероятно, это связано с тем, что основным рудным минералом, содержащим золото на месторождении, является халькопирит, о чем свидетельствует содержание золота в мономинеральных фракциях халькопирита, составляющее в среднем 6,2 г/т. Высокое среднее содержание серебра характерно для халькопирит-сфалеритовых типов руд (8,6 г/т). По результатам анализов построены гистограммы распределения содержания золота и серебра в различных типах руд и мономинеральных фракциях. Рассмотрено распределение золота и серебра в нижних горизонтах месторождения.

Ключевые слова: благородные металлы, горизонт, мономинерал, гистограмма, рудное месторождение, унимодальный, минеральные ассоциации.

Introduction

The issues of geology and ore formation of the Gizilbulag deposit were dealt with by G.I. Barkanov (1931-1933), A.M. Agakishiev (1979), V.M. Babazade (2003), E.S. Suleymanov (1978), T.G. Hajiev, Yu.R. Shirinov (1980), G.S. Huseynov (1989, 2006) and other researchers.

The deposit is located in the conjugation zone of the Agdam and Garabagh anticlinoriums of the Lok-Garabag structural-formational zone of the Lesser Caucasus and is confined to the central part of the volcano-dome structure of the same name, which is a highly eroded stratovolcano. It is composed of volcanic formations of basalt-andesite-dacite-rhyolite formation of Bajocian age, represented mainly by lava-pyroclastic deposits of intermediate basic composition, and to a lesser extent acidic (Fig. 1).

The structural features of the deposit were caused by the successive formation of discontinuities of varying extent and strike, complicated by shallow multi-oriented fracturing [1].

The Gizilbulag deep fault, which runs along the western flank of the field, is noteworthy among the major discontinuities.

The main ore-bearing sediments are Upper Bayocian rhyodacites, transformed in most cases into secondary quartzites (mono-quartzites), within which are located sinter ores.

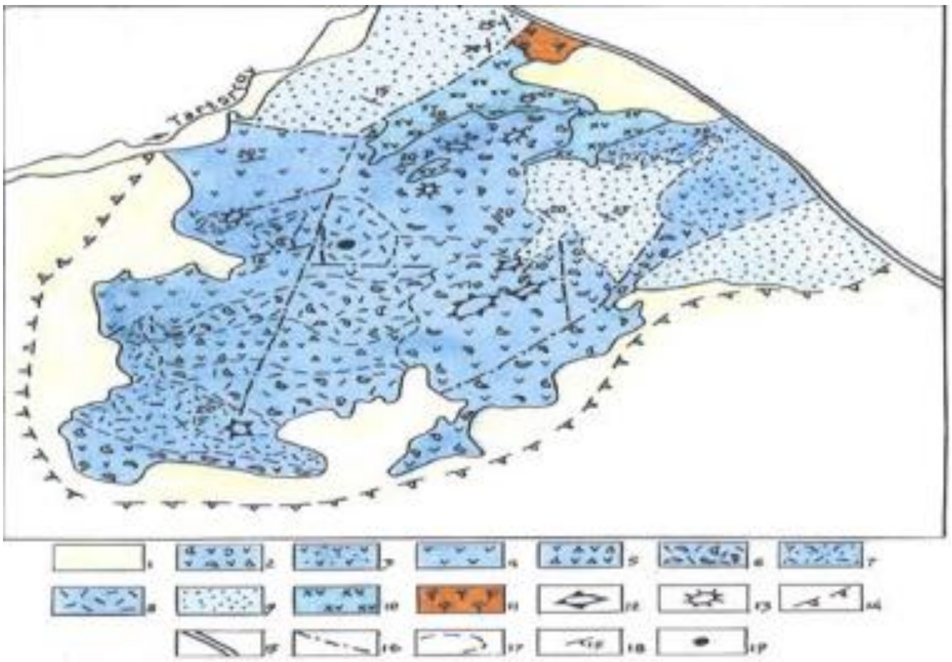

Figure 1 – Geological map of Gizilbulag deposit (according to Y.R. Shirinov, 1981 1:25000)**:**
1 – Quaternary sediments; volcanic formations of andesibasalt composition: 2 – agglomerate and clastic tuffs; 3 – fine clastic tuffs; 4 – lavas; 5 – lavobreccia; volcanic formations of dacite-rhyolite-dacite composition: 6 – agglomerate and clastic tuffs; 7 – fine clastic tuffs; 8 – lavas; 9 – volcanomictic sandstones; 10 – subvolcanic intrusion of diorite-porphyrites; 11 – subvolcanic intrusion of rhyolite-porphyries; roots of outpouring of Bajos volcanoes; 12 – extrusive formations;13 – vent breccias;14 – presumed boundary of the Gizilbulag volcano-dome structure; 15 – deep boundary fault; 16 – other faults; 17 – boundaries of lithologic facies; 18 – elements of occurrence; 19 – Gizilbulag field

The main ore-forming minerals are pyrite, chalcopyrite, sphalerite, galena, arsenopyrite, magnetite, marcasite, molybdenite, pyrrhotite and from vein minerals quartz, calcite. The main minerals of hypergene ores are goethite, hydrogethite, bornite, chalcosine, covelline, malachite, azurite. Quartz-chalcopyrite, quartz-pyrite-chalcopyrite, quartz-pyrite-sphalerite, quartz-carbonate mineral association are distinguished.

To study the nature of distribution of noble metals (Ag, Au) Gyzylbulag deposit, used factual material, the authors collected during research work.

The character of gold and silver distribution in mineral associations and monomineral fractions of the main sulfide minerals (pyrite, chalcopyrite, sphalerite) was established on the basis of analytical studies.

The results of the analyses are shown in Table 1.

Table 1 – Nature of distribution of gold and silver in different types of ores and monomineral fractions of the main sulfide minerals of Gizilbulag deposit

Ore types	Number of samples	Limit Content, in g/t		Average Content, in g/t	
		Au, g/t	Ag, g/t	Au	Ag
Mineral associations					
Quartz-pyrite	46	0,1-1,0	5,0-10,0	0,6	2,2
Quartz-pyrite chalcopyrite	250	0,6-80,0	0,8-77,2	2,8	7,0
Quartz-chalcopyrite	123	3,0-42,0	1,0-26,0	9,2	6,3
Chalcopyrite - sphalerite	152	0,1-80,0	0,4-27	5,9	8,6
Quartz-carbonate	60	-	-	-	-
Monominerals					
Pyrite	28	0,1-11,0	1,0-15,8	1,6	3,9
Chalcopyrite	26	0,3-44,5	0,5-35,4	6,2	6,5
Sphalerite	23	0,1-10,0	0,2-35,0	2,8	7,2

Table 1 demonstrated that in quartz-pyrite ores the gold and silver content is low and is in pyrite in a finely dispersed state.

The highest concentration of gold, as evident from the comparison of average contents, is characteristic of quartz-pyrite-chalcopyrite and quartz-chalcopyrite associations, but the maximum gold content is present in the quartz-chalcopyrite association. Apparently, this is due to the fact that the main ore mineral containing gold at the deposit is chalcopyrite, as evidenced by the gold content of monomineral fractions of chalcopyrite, averaging 6.2g/t (Table 1).

High average silver content is characteristic of quartz-pyrite-chalcopyrite and chalcopyrite-sphalerite associations, and the maximum value of silver is noted in ores of chalcopyrite-sphalerite association (8.6 g/t). This indicates that along with silver, which is a part of nugget gold, there are other silver-bearing minerals and, first of all, faint ore, galena. Probably, the wide development of the latter causes silver-bearing chalcopyrite-sphalerite association.

Based on the results obtained, histograms of gold and silver distribution in different types of ores were constructed (Fig.2).

Histograms of gold grade distribution in quartz-pyrite-chalcopyrite ores showed that the maximum corresponds to the intervals of 1-2 g/t gold and 5-10 g/t silver. Ores with such grades account for 34% gold and 37% silver content.

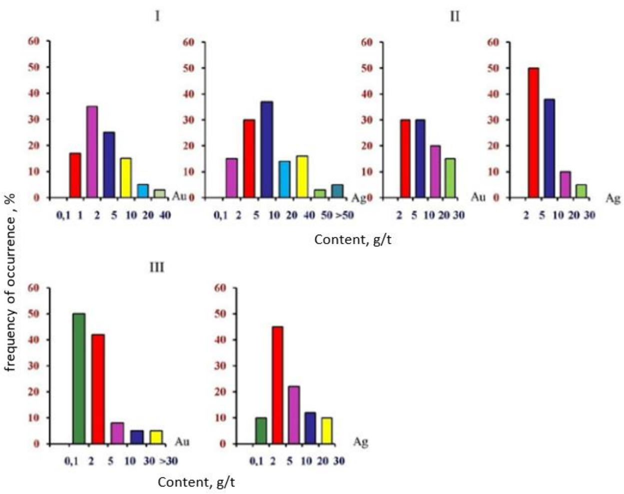

Figure 2 – Histogram of distribution of gold and silver content in different types of ores of Gizilbulag deposit: according to atomic absorption spectrometry: I – quartz-pyrite-chalcopyrite; II – quartz-chalcopyrite; III – chalcopyrite-sphalerite. On the abscissa axis, g/t grades of contents; on the ordinate axis, the frequency of occurrence of samples of a certain class and contents in % RH.

Gold concentration is higher in quartz-chalcopyrite ore types. Thus, there are two maximums (Fig. 2), corresponding to the intervals 2-5 g/t and 5-10 g/t for gold and 2-5 g/t for silver and amounting to 31% for gold and 50% for silver. This once again confirms that at this deposit the main gold carriers are quartz-chalcopyrite ores [2].

The peak of gold and silver content in the chalcopyrite-sphalerite mineral association, according to the histogram, corresponds to the intervals of 0.1-2 g/t gold and 2-5 g/t silver and, as can be seen, is 49% for gold and 43% for silver.

To study the distribution of gold and silver in the sulfides of the Gizilbulag deposit, monomineral fractions of pyrite, chalcopyrite and sphalerite were analyzed by atomic absorption-spectrometric methods. The results of the analysis showed that in the main sulfide minerals (pyrite, chalcopyrite, sphalerite) there is a wide fluctuation of gold and silver content.

This reflects the superimposed nature of the process of accumulation of noble metals (Au, Ag) and indirectly shows that gold and silver are represented by microinclusions of their own minerals [3] and their increase in sulfides is closely related to the belonging of the latter to a particular mineral association and is directly consistent with the increase in the content of the corresponding elements in ores. Therefore, the highest content of gold is characteristic of chalcopyrite, and silver-sphalerite.

Based on the results of the analyzed monomineral fractions of the main sulfide minerals, histograms were constructed.

As can be seen from Fig. 3, the peaks on the histogram are noted at gold contents of 0.1-1 g/t in prite, 1-5 g/t in chalcopyrite and sphalerite, which correspond to 60%, 38% and 43%, respectively. Unimodal distribution of gold in chalcopyrite is noted, which indicates that gold from chalcopyrite belongs to a single statistical population characterized by a single stage of mineral formation. The class of silver content 0.1-1 g/t (in pyrite and chalcopyrite) on the histogram corresponds to the maximum frequency of occurrence and is 42 and 38%, respectively, and in sphalerite-43% (Fig. 3).

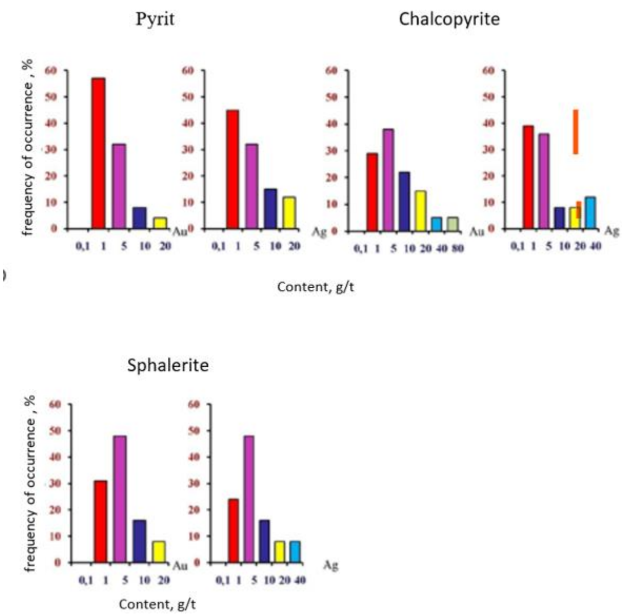

Figure 3 – Histogram of distribution of gold and silver content in the main sulfide minerals of the Gyzylbulag deposit according to the atomic absorption spectrometry data. On the abscissa axis - classes of content in g/t, on the ordinate axis - frequency of occurrence of samples of a certain class of content in % of relative.

Also, the character of distribution of gold and silver in the Gizilbulag deposit was studied by constructing co-centered curves (Fig. 4). For this purpose, the results of assay analyses of samples for gold and silver from the main deposit and ore-bearing metasomatites in two adits at horizons 725 and 755 m were used.

Gold and silver halos at the 755 m (piece 3) horizon display an elongated west-northwestward shape (W-NW) (Fig. 4 "A").

Most of the ore deposit and the surrounding sericite-quartz and chlorite-sericite-quartz and metasamatites are characterized by low gold content. The highest gold content (from 5 to 40g/t) gravitates to the central part of the halo (Fig. 4 "A") and coincide with the halo of high copper content (0.6-2.2%). (Here there are massive copper-cement ores, which are dissected by numerous quartz-pyrite-chalcopyrite veins). From this halo in the west-northwest direction there is a narrow band (5-8m) with gold content of 5-10g/t, coinciding with pre-mining discontinuities [4].

The ore deposit at the horizon of 755 m is characterized in general by low silver grade halos (0.5-5.0 g/t), within which narrow enriched areas on the north-western flank (5-10 g/t) are distinguished, within which narrow enriched areas on the north-western flank (5-10 g/t) are distinguished, gravitating also to pre-mining faults (Fig. 4 "B").

At horizon 725 (Fig.5"A") gold has a slightly different character of distribution. Thus, areas of increased gold content (up to 30 g/t) are concentrated mainly on the northern and southern flanks of the ore deposit, having a submeridional direction, coinciding spatially with the areas of chalcopyrite mineralization development. It should be noted that ore-controlling faults of the Gizilbulag deposit also have submeridional direction.

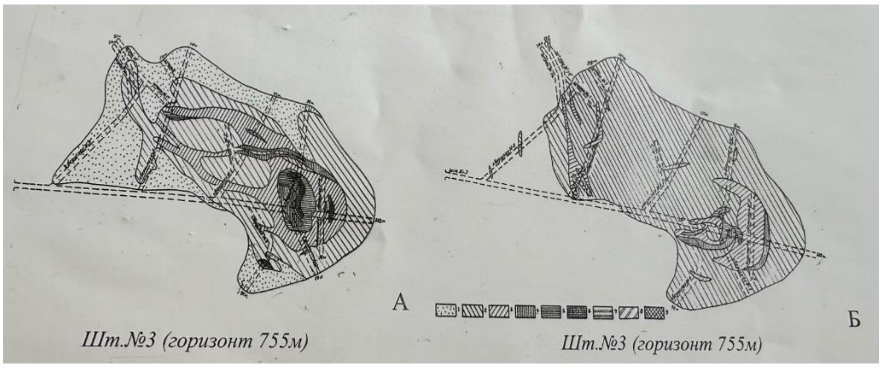

Figure 4 – Distribution of gold (A) and silver (B) on horizon 755 m (piece №3). Gizilbulag deposit. By gold (g/t):1.20-40; 2.10-20; 3. 5-10; 4.1-5; 5. 0.1-1.0; 6. traces. Silver (g/t):40-60;20-40;10-20;5-10;0.5-5.0; 0.1-1

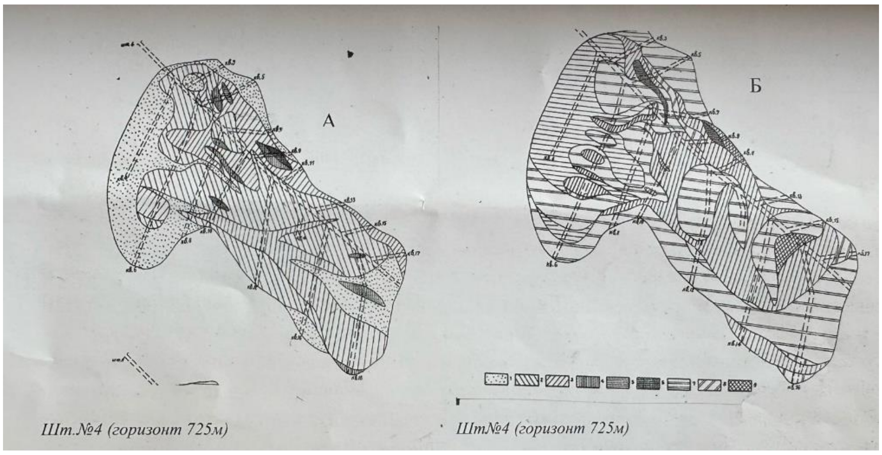

Figure 5 – Distribution of gold (A) and silver (B) at 725 m horizon (piece №4)

Relatively high gold concentrations (5-10 g/t) on the northern flank of the ore body form wider halos of submeridional (north-northwest) direction. Relatively lower (1.5 and 0.1-1.0 g/t) gold contents characterize mainly the contacts of the ore deposit. Low gold grades (0.01-0.1 g/t), characteristic of the central part of the ore deposit, extend in the sublatitudinal direction, coinciding with the development of pyrite ores (Fig.5 "A").

Areas of elevated silver concentrations (20-30 g/t and more) have a limited distribution at the 725 m horizon (Fig. 5 "B") on the northern and northwestern flanks of the ore body. Areas with a range of silver grades (1-10 g/t) are confined to the central part of the ore deposit, usually gravitating towards its contacts. The most common silver grades at the 725 m horizon are 0.1-1.0 g/t. They are relatively uniformly distributed over the area of the ore body. Even lower silver grades (0.01-0.1 g/t) characterize non-ore metasomatites of quartz-kaolinite facies. They are relatively evenly distributed over the area of the ore body. Even lower silver grades (0.01-0.1 g/t) characterize non-metasomatites of quartz-kaolinite facies (Fig. 5 B).

Taking into account the importance of gold-silver ratio as a geochemical indicator of mineral formation environment, we have considered the character of Au:Ag value changes on the surface, in near-ore rocks and in each of the selected productive mineral associations, as well as at different hyposometric levels of 755 and 725 m horizons (Table 2).

Table 2 – Variability of gold-silver ratio at the Gizilbulag deposit

Type of geological formations	Number of samples	Au:Ag ratio
Surfaces	220	1:3
Near-ore rocks	145	1:6
Mineral associations		
Quartz-pyrite chalcopyrite	250	1:2
Quartz-chalcopyrite	123	1:1
Chalcopyrite - sphalerite	152	1:5
Depth levels		
Surfaces	84	1:3
Horizon 755 м	261	1:1
Horizon 725 м	139	1:0,8

As can be seen from Table 2, on the surface the gold-silver ratio is 1:3, and in near-ore rocks the ratio sharply increases due to silver removal in the oxidation zone. The relationship between gold and silver in near-ore rocks is practically lost, and the gold-silver ratio sharply shifts towards silver (Au:Ag=1:6), that is, the ways of accumulation of gold and silver in ore bodies and near-ore rocks are different, and if in ore bodies there is a joint deposition of gold and silver, in near-ore rocks we can assume multiple forms of accumulation. When comparing gold-silver ratios in ores of different mineral associations, it is seen that quartz-chalcopyrite ores (Au:Ag=1:1) are statistically significantly distinguished by this value.

At the 755 m horizon, the minimum gold/silver ratios (1:1) are found in the central part of the ore deposit, generally coinciding with the contours of quartz-chalcopyrite associations and maximum gold grades. The maximum ratios of gold and silver gravitate to the contact strip of the southwestern flank of the deposit, closer to the area of development of lead-zinc mineralization [5, 6].

The areas of maximum gold-silver ratios (1:0.8) at the 725 m horizon also gravitate more to the areas of development of lead-zinc and pyrite components of ores and to a lesser extent - to the areas of distribution at the horizon under consideration, having their main development in the near-contact strip of the ore body and less in the central part.

Conclusion

The high concentration of gold in the Gizilbulag gold deposit is related to the quartz-chalcopyrite mineral association, the main gold-bearing sulphide mineral - chalcopyrite. In the gold-bearing ores of the Gizilbulag deposit, the maximum value of gold was determined in the chalcopyrite monomineral fraction, and the maximum value of silver was determined in the sphalerite monomineral fraction. Among the 755m and 725m depth horizons crossed in the Gizilbulag field, the 755m horizon is considered the most productive for gold.

Conflict of Interests

The authors declare there is no conflict of interests related to the publication of this article.

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