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DISTRIBUTION OF PRECIOUS METALS (Au, Ag) IN THE ORES OF THE GEDABEK GOLD-COPPER-PYRITE DEPOSIT

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Abstract

This article presents the features of the geological structure and the patterns of distribution of noble metals in the ores of the Gedabek gold–copper–pyrite deposit. It has been established that mineralization is localized within the volcanoclastic horizons of the Upper Bayasian rhyolitic sequence, which underwent intensive metasomatism, resulting in the formation of secondary quartzites. Atomic absorption spectroscopy data revealed an uneven distribution of gold and silver, with the highest metal concentrations associated with the pyrite–chalcopyrite–sphalerite association in primary ores. Chalcopyrite has been identified as the main mineral hosting gold, whereas native gold mainly occurs in a finely dispersed form within sulfides. The features of the hypergene zone have also been studied; here, as a result of secondary sulfide enrichment and leaching processes, gold accumulations are formed that exceed the size of those found in primary ores.

Keywords: Gedabek deposit, gold–copper–pyrite ores, precious metals, native gold, mineral associations, secondary quartzites, supergene zone, chalcopyrite, rhyolitic sequence, secondary sulfide enrichment.

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INTRODUCTION

The geological structure of the deposit involves Middle and Upper Jurassic sediments, represented by volcanogenic rocks of the Lower and Upper Bajocian, Bathonian, and Callovian stages. The Lower Bajocian volcanics—basalts, andesibasalts, and their tuffs—are intensely hornfelsed within the halo of the intrusive of the same name. The Upper Bajocian is represented by rhyolites that overlie the Lower Bajocian deposits. These rhyolites have undergone hydrothermal alteration and have been transformed into secondary quartzites. The Bathonian stage rocks transgressively overlap the rhyolitic sequence and are composed of basalts, partially andesites and their tuffs, as well as tuff breccias. These, in turn, are covered by tuffaceous-sedimentary and carbonate deposits of the Callovian–Oxfordian stages. The carbonate deposits have a very limited distribution and, due to the contact action of the Gedabek intrusive, are intensely metamorphosed and transformed into vesuvianite skarns.

The deposit is confined to a brachyanticlinal fold (Arydam), inherited by a developing volcanic structure of the central type. The structure is complicated by synvolcanic steeply dipping faults, which were repeatedly rejuvenated and served as ore-conducting channels. The upper volcaniclastic horizons of the rhyolitic rock sequence (Late Bajocian) proved favorable for the localization of pyrite mineralization, being porous, fractured, and chemically active regarding the precipitation of ore matter, near their contact with the overlying andesite porphyrites (Bathonian), which are attributed an enrichment/screening role (Fig. 1).

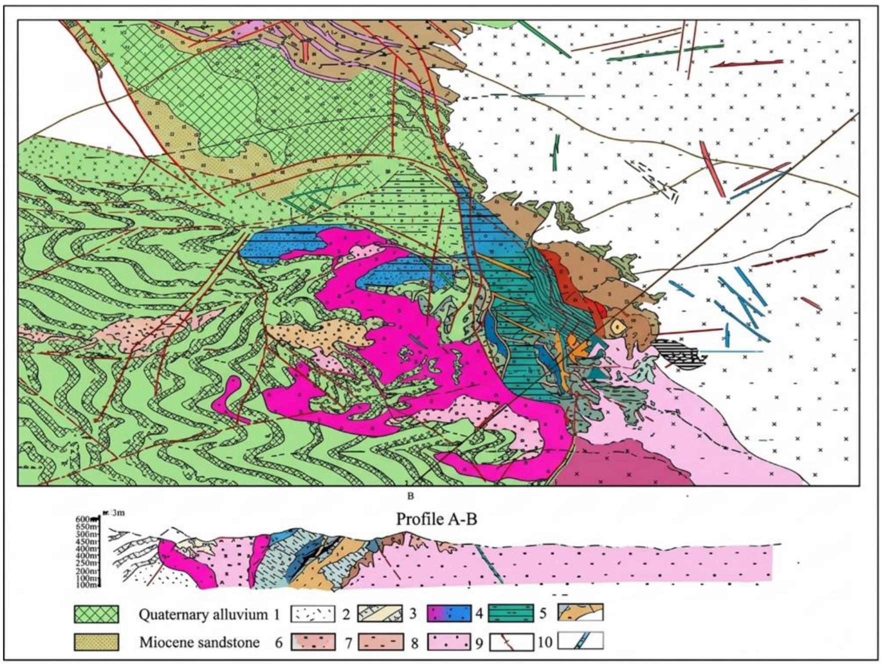

Fig. 1. Schematic geological map of the Gedabek gold-copper-pyrite deposit. (after G.I. Aliev, 1975, 1: 25000)

1 — Oxfordian stage — garnet-scapolite-vesuvianite skarns; 2 — Callovian stage — strongly schistose biotite, epidote, garnet- and pyroxene-epidote hornfels; 3 — Bathonian stage — upper volcanogenic sequence, porphyrites their tuffs and tuff breccias; 4 — Upper Bajocian — strongly ferruginized secondary quartzites; 5 — Middle, Lower Bajocian — lower volcanogenic sequence, porphyrites and their tuff breccias; 6 — Middle Bajocian — lower volcanogenic sequence — epidote-garnet, epidote-pyroxene and garnet-epidote hornfels; 7 — Lower Cretaceous (Pre-Cenomanian) — quartz diorites, locally hybridized; 8 — Middle Jurassic (Pre-Bathonian plagiogranite) — porphyries; 9 — fault lines (faults, normal faults and reverse faults); 10 — dykes

The structural position of the deposit is determined by its location on the extreme southeastern plunge of the Shamkir anticlinorium, at the junction with the Dashkesan synclinorium, and its confinement to the southeastern flank of the brachyanticlinal uplift, which is part of the "Arykhdam" caldera. The most significant tectonic elements are the Gedabek, Fedorovsky, and Western faults of northeastern and sublatitudinal northwestern directions. The Gedabek fault, with a length of 40 km, essentially represents the main ore-controlling structure that determines the position and placement of the deposit's ore bodies. Another major disjunctive primary disturbance is the Fedorovsky fault, which, parallel to the Gedabek fault, is traced in a northwestern direction east of Mount Misdag. The Western fault serves as the western boundary of the deposit, along which the volcanogenic-sedimentary sequence contacts volcanics of andesibasalts composition. [1]

Transverse faults of sublatitudinal strike are the most important structural elements influencing the placement of the vent facies of acidic volcanics and pyrite ore bodies. The primary ore-hosting sediments are Upper Bajocian rhyodacites, transformed, in most cases, into secondary quartzites (monoquartzites, quartz-kaolinite, etc.), within which all known pyrite ore deposits are located. They extend in a wide (500–700m) belt of northwestern strike and are overlain in the west by Bathonian andesite-basalts, which are completely unaffected by metasomatic processes.

Distribution of gold and silver in ores.

Based on factual material, the author studied the gold-bearing potential and the character of the distribution of precious metals (Au, Ag) in the ores. [2,3,6] The results of fire assay and atomic absorption analyses were used. To study this issue, samples were selected and processed from various types of ores (255 samples) and monomineral fractions of the main sulfide minerals (pyrite, chalcopyrite, sphalerite) — 67 samples. According to atomic absorption spectrophotometry data, it has been established that gold is distributed unevenly in various types of ores and monomineral fractions of the main sulfides (Table 1).

Table 1.

Distribution of gold and silver in various types of ores and monomineral fractions of the main sulfide minerals of the Gedabek deposit

Ore Types / Mineral Associations	Number of Samples	Au Content, ppm (Range)	Au Content, ppm (Average)	Ag Content, ppm (Range)	Ag Content, ppm (Average)
Mineral Associations					
Quartz–Pyrite	125	0.1–6.0	0.8	4.8–28.3	13.6
Pyrite–Chalcopyrite–Sphalerite	130	0.1–8.0	2.3	0.9–163.0	36.2
Monominerals					
Pyrite	30	0.01–3.8	1.2	0.3–17.2	3.4
Chalcopyrite	23	0.2–24.1	3.8	1.2–38.7	8.9
Sphalerite	14	0.2–5.4	1.6	1.8–41.2	9.7

As shown in Table 1, the gold content in the quartz-pyrite mineral association is low (averaging 0.8 ppm); its occurrence is noted as fine and finely dispersed. In the pyrite-chalcopyrite-sphalerite association, the gold concentration is more elevated (2.3 ppm), as the primary carriers of gold are chalcopyrite and, possibly, sphalerite, as evidenced by the gold-bearing capacity of the monomineral fractions of chalcopyrite and sphalerite, averaging 3.8 ppm and 1.6 ppm, respectively (Table 1). It is pertinent to note that in pyrite-chalcopyrite-sphalerite ores, an increase in the average particle size of native gold is observed. This is apparently related to the redeposition and enlargement of the early fine and finely dispersed gold from the quartz-pyrite association [4].

Based on the results obtained, histograms of the distribution of gold and silver in various types of ores and monomineral fractions of sulfide minerals were constructed (Fig.2).

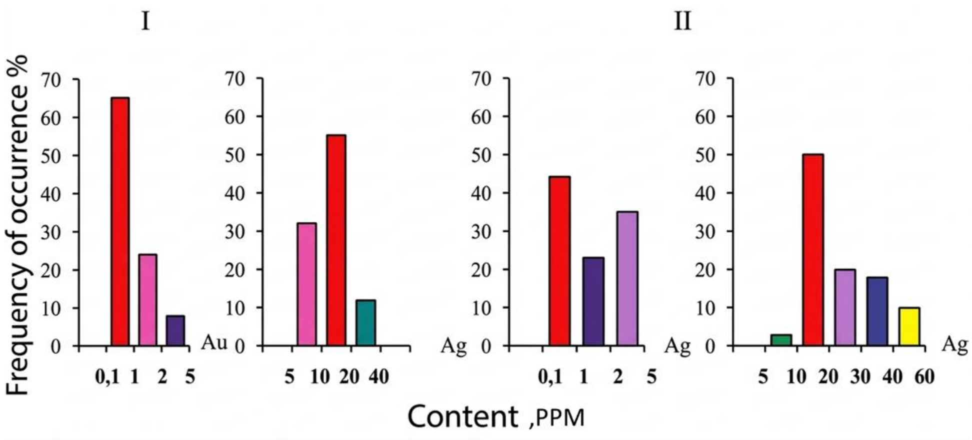

Fig. 2. Histogram of gold and silver content distribution in quartz-pyrite (I) and pyrite-chalcopyrite-sphalerite (II) mineral associations of the Gedabek deposit according to atomic absorption spectrometry data. The abscissa axis represents content classes, ppm; the ordinate axis represents the frequency of occurrence of samples of a certain content class — in relative %.[6,7]

Histograms of gold and silver distribution in quartz-pyrite ores showed that the frequency maxima correspond to intervals of 0.1–1.0 ppm for gold and 10–20 ppm for silver. Ores with such contents account for 50% for gold and 52% for silver. In pyrite-chalcopyrite-sphalerite ores, the concentration of precious metals is higher. Here, the frequency maxima correspond to 0.1–1.0 ppm for gold and 10–20 ppm for silver. Ores with such contents account for 43% for gold and 50% for silver, which is indirectly confirmed by the higher gold-bearing capacity of pyrite-chalcopyrite-sphalerite ores.

As a result of the analyses, it was established that among the sulfides, an elevated concentration of gold and silver is noted in chalcopyrite. Their average contents are 3.8 ppm and 8.9 ppm, respectively. In pyrite and sphalerite, the average gold and silver contents are characterized by lower indicators: in pyrite, Au - 1.2 ppm, Ag - 3.4 ppm; in sphalerite, Au - 1.6 ppm, Ag - 9.7 ppm (Table 1).

Based on the obtained analyses, histograms of gold and silver distribution in monomineral fractions of the main sulfide minerals—pyrite, chalcopyrite, and sphalerite—were constructed (Fig.3).

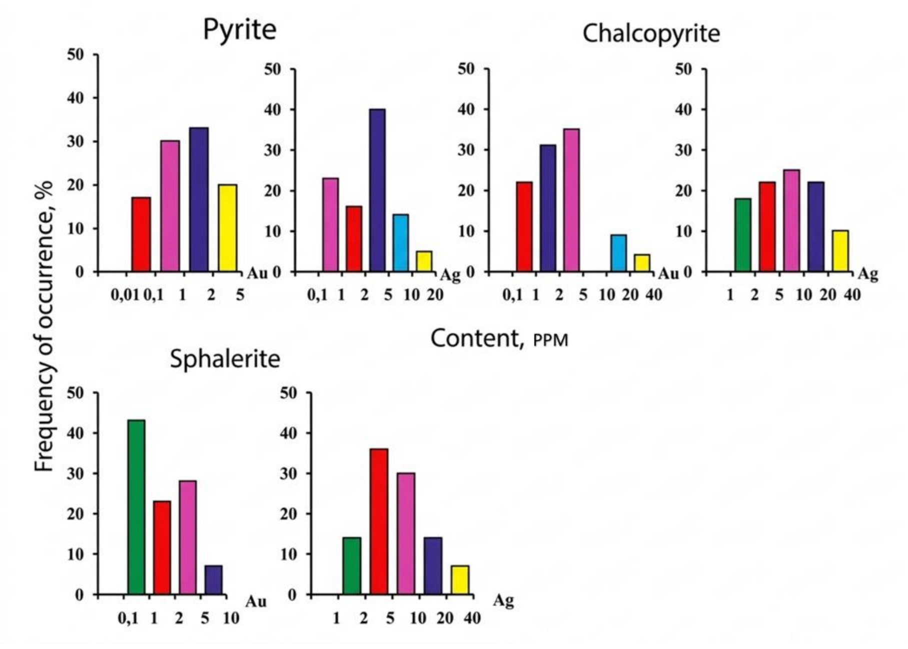

Fig.3. Histogram of gold and silver content distribution in monomineral fractions of the main sulfide minerals of the Gedabek deposit according to atomic absorption spectrometry data. The abscissa axis represents content classes, ppm; the ordinate axis represents the frequency of occurrence of samples of a certain content class — in relative %.[6,7]

Histograms of gold and silver distribution in pyrite showed that the frequency of occurrence corresponds to the intervals of 1.0–2.0 ppm for gold and 2.0–5.0 ppm for silver. Monominerals with such contents account for 34% for gold and 40% for silver. In chalcopyrite, the gold content is higher. In the aforementioned mineral, the frequency maximum corresponds to 1.0–2.0 ppm for gold, while the frequency minimum is noted in the interval of 2.0–5.0 ppm for silver. Monominerals with such contents constitute 40% and 22%, respectively. In sphalerite, the distribution of precious metals (Au, Ag) showed that the frequencies of occurrence correspond to the intervals of 0.01–0.1 ppm for gold (42%) and 1.0–2.0 ppm for silver (33%).

The results obtained for mineral associations and monomineral fractions of sulfide minerals indicated that the bulk of the mass is deposited closely in time with chalcopyrite, possibly forming a structural impurity in the field, and is subsequently released during the cooling of the ores as a product of solid solution decomposition.

Thus, analyses of gold distribution in various ore types and monomineral fractions of the main sulfides, as well as the relationships of native gold with other minerals, testify to the multi-stage deposition of gold from solutions [4]. An insignificant portion of it crystallized synchronously with the early sulfides—primarily pyrite—and is dispersed within them in a finely dispersed state.

The distribution of gold in metasomatites on the surface and at depth is of particular interest. Thus, judging by sampling data, the content of gold and silver in surface metasomatites varies from 0.05 to 2.2 ppm for gold and from 1.0 to 10 ppm for silver. Regarding the drill cores from deep horizons of the Gedabek deposit, relatively high gold concentrations are confined to mono-quartz varieties at and above the level of the ore bodies, while silver is concentrated predominantly in the upper parts in quartz-sericite metasomatites above the ore sequence, which contain a significant amount of pyrite and are of great interest for predicting prospective gold-silver mineralization. This fact, along with other data on the distribution characteristics of precious metals in various metasomatic facies, indicates the redeposition of gold and silver from the copper-pyrite ore zone into the zone of secondary sulfide enrichment.

Currently, one of the most critical issues arising in the study of pyrite deposits is determining the role of the oxidation zone, where a significant amount of gold has accumulated. As is well known, gold accumulation occurs in the upper parts of ore bodies due to the oxidation of gold-bearing sulfides; as a result of these processes, a so-called "gossan" (iron hat) is formed, composed of iron hydroxides (goethite, hydrogoethite), copper carbonates (malachite, azurite), and clay minerals (kaolinite), in which gold and silver are redeposited and subsequently concentrated by acidic mine waters.

Given the above, and in connection with the commencement of mining operations at this deposit, a need arises for a detailed study of the oxidation zone and a reliable assessment of the scale of gold redeposition, which will allow for determining the prospects of the Gedabek deposit at depth. According to fire assay data, gold has been identified in the supergene zone, and its distribution is highly uneven (Table 2). [6]

Table 2.

Distribution of gold in the supergene zone of the Gedabek deposit (G.S. Guseinov, 2012). [6]

Supergene Zone	Subzones	Number of samples	Au Content, ppm	
			Range	Average
Oxidation	"Gossan" (limonites), Quartz-jarosite	85 18	0,8-5,2 3,5-13,2	3,2 7,6
Leaching	Quartz-barite sands with jarosite Quartz-barite sands with native sulfur	32 56	0,5-1,6 4,8-16,5	0,9 9,3
Secondary Sulfide Enrichment	Pyrite sands (friable ore)	20	5,0-26,5	13,8
Primary Ores	Sulfur-pyrite ores	60	0,1-0,7	0,3

According to several researchers, during supergene processes involving the transformation of sulfide deposits, the newly formed minerals and gold retain information about the primary gold content, which allows the use of obtained data for the purposes of predicting mineralization at depth and its affiliation with a specific mineral type. [8]

As seen from Table 2, elevated gold contents (4.8–16.5 ppm, averaging 9.3 ppm) were observed in quartz-barite sands within the leaching zone and in pyrite sands within the secondary sulfide enrichment zone (5.0–26.5 ppm, averaging 13.8 ppm).

It should be emphasized that the character of gold distribution in the supergene zone of the Gedabek deposit remains largely unchanged compared to its distribution in the primary ores. Alteration of the primary distribution likely occurred on a small scale only in specific areas where massive sulfide occurrences predominated.

CONCLUSION

It was demonstrated that industrial concentrations of gold and silver in the ores of the Gedabek deposit are distributed extremely unevenly and are closely associated with sulfide mineral associations.

Chalcopyrite was identified as the predominant mineral containing precious metals, whereas in quartz-pyrite ores, gold was primarily found in finely dispersed form [9]. The critical role of the supergene zone was revealed: as a result of leaching and secondary enrichment processes, significant accumulations of gold form there within gossans and residual products. The established regularities in the distribution of metals by depth and metasomatic facies can enhance the efficiency of prospecting for new ore bodies in the deep horizons of the deposit.

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