International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081
An Open Access, Online International Journal Available at http://www.cibtech.org/jgee.htm
2021 Vol. 11, pp. 158-163/Shukurov and Inatov
Research Article

FORMS OF LOCATION OF GOLD, SILVER AND OTHER VALUABLE ASSOCIATED ELEMENTS IN THE GOLD-SILVER ORES OF KARAKUTAN DEPOSIT (WESTERN UZBEKISTAN)

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ABSTRACT.
In the article the ores of the Karakutan gold-silver deposit were studied. According to results of researches it was found that they are represented by three types of ores: primary oxidized, zones of secondary sulfide benefication and oxidized zones. In addition to established forms of occurrence of gold and silver, forms of occurrence for the other productive elements Pt, Sn, W, Se, Te, Hg, and rare earth elements were also found.

Keywords: *Gold, Silver, Associated Elements, Form of Occurrence of Gold, Karakutan Deposit*

INTRODUCTION
The Karakutan gold deposit is located within the Katyrmay sedimentary-metamorphic sequence (S), which composes the northwestern part of the Ziyaetdin mountains (figure 1). The sedimentary-metamorphic formation is conditionally subdivided into two subformations from bottom to top: 1) calcareous-shale (S_1) 200 m in thick and 2) siltstone shales 1000 m in thick.

Figure 1: Situation of the study area; White rectangle indicates the situation of study area

The deposit belongs to the gold-quartz-pyrite-arsenopyrite minable type. Ores are represented by mineralized zones confined to steep and gently dipping extended vein-vein systems and small stockworks (*Baymukhamedov et al.*, 1969). These systems are cut through by dikes of intrusive rocks (quartz diorite porphyry, granodiorite-porphyry, lamprophyre). The first information on the mineralogical and geochemical characteristics of the Karakutan gold deposit was obtained by the authors. These researchers found that the main concentration of gold is confined to quartz veins and veinlets with sulfide mineralization with native gold and less in silicification zones (not confirmed by researchers' materials), which intensively develop along quartz-hydromica and quartz-chlorite schists. The disadvantage of these studies is the lack of information on the content of organic matter and clay minerals in ores and host rocks and their role in the formation of gold mineralization (*Vasilevsky et al.,* 2012).
The largest amount of ultrabasic rocks (about 10 bodies) is developed in the Kutchi region (in the northeast of the Zirabulak mountains). In the Katarmayaul mountains, trabasites are found only in the southeast (three bodies) and in the northwest (one body). In the Kutchi area, these formations are represented by sheet-like and lenticular bodies with a thickness from the first to 40 m., with a length from the first tens to more than 650 m. Their boundaries with the enclosing shales are more or less distinct and are characterized by a completely consistent occurrence with the surrounding rocks [5, 6]. They are composed of chrysotile, antigorite and bastite-antigorite serpentinite. The apparent thickness of the Katarmay suite is over 3400m. The age of the suite is debatable. Most researchers consider the formation to be Upper Proterozoic. (Korsakov *et al.,* 1993).

MATERIALS AND METHODS

Study methods.

The method of prospecting works in the Karakutan ore field for such a long period of its study has been developed reliably enough. The overwhelming majority of ore bodies of deposits are localized within the Karakutan branch of the Karakutan fault zone and are confined to rupture faults (the length of the first km) of sublatitudinal northeastern, rarely meridional strike, accompanied by crushing, silicification (both rock masses and due to veinlets and veins of quartz) sericitization, chloritization, clarification, carbonatization, sulfidization and, under surface conditions, ferruginization (formation of iron hydroxides). The length of the ore bodies along the strike - the first tens of meters - 500m, most - 100m, along the dip they were traced to a depth of no more than 170m. the fall is steep - 400-900, the average thickness is the first meters, the main useful component of ore bodies is gold, which is concentrated in quartz formations from faults (*Gorev,* 1969). Average grade of gold in ores is 5-15 g / t. associates with gold silver in concentrations sufficient for its associated extraction (average in ores - 5-70 g / t). the rest of the components do not give industrial contents.

In this regard, we provided detailed studies to determine forms of occurrence of ore-forming, gold, silver and other valuable components in various types of ores and products of their technological processing of the Karakutan gold-silver deposit, within the dimension of mineral particles > 1 μm and <1 μm. To identify the forms of finding ore-forming gold, silver, platinoids and other valuable accompanying elements in ores and products of technological conversion, the following analytical laboratory studies were used: the use of modern analytical methods of microprobe and an electron scanning microscope made it possible to analyze and establish the forms of finding gold, silver and related elements in ores and the technological cycle of ore redistribution of the Karakutan gold-silver deposit.

RESULTS

As a result of the study, mineral forms of occurrence of noble and valuable accompanying elements were established: Au, Ag, Se, Te, Cd, Hg, Mo, W, Pt, which are present in various chemical compounds, with dimensions from> 1 μm (microprobe) and less < 1 μm (scanning electron microscope). Noble metals - Au, Ag, Pt: 1 - visible native gold - in terms of the size of its particles, it mainly refers to dust-like (0.01 -

0.06 mm), fine (1 - 10 μm), ultrafine (0.1 - 1 μm) and colloid-dispersed (<0.1 μm) (*Marchenko, 2016*). Native visible gold is found mainly in pyrite, arsenopyrite, goethite, hydrogoethite, quartz, opal and other minerals (figure 2). The composition of native gold is represented by two types of chemical compounds: one hundred percent native gold and gold intermetallic compounds - Au-Ag, Fe-Au (ferroauride) and Au-As (arsenoauride). In addition to gold and silver, native gold contains impurities of Fe, Cu, As, S (Table 1).

In addition to visible gold, we found "invisible" gold in ores and intermediate products of their redistribution. The main concentrators of "invisible" gold are the main productive sulfides - pyrite, arsenopyrite, antimonite and pyrrhotite. In pyrite, the gold content ranges from 100 to 8900 g / t, on average 400 g/t, in arsenopyrite - from 600 to 900 g / t, on average 450 g/t, in antimonite - from 7002 to 7439 g / t, on average - 7177 ppm, in tetrahedrite-tenantite on average 900 ppm, in pyrrhotite on average 600 ppm (Table 1). Such a high gold content in antimonite is explained not by its entry into the crystal structure of the mineral, but by its entry in the form of an impurity or an ultra-finely dispersed mixture of antimonite and native gold. In addition to productive sulfides containing "invisible" gold, similar "invisible" gold is present in clay minerals: in hydromica, the fluctuation of which is from 400 to 4900 g/t, averages 2700 g/t, in hydrobiotite-chlorite - from 900 to 4500 ppm, on average - 3100 g/t, in opal - from 200 to 1400 g/t, on average - 1200 g/t in halloysite - 4500 g/t, in goethite and hydrogoetite - from 0 to 5200 g/t , on average is 950 g / t, in quartz - 1400 g/t, in giolaphan - 1200 g/t (Table 1). The presence of significant concentrations of "invisible" gold in the above minerals is not a refractory gold for cyanidation, since gold is not included in the crystal lattice of these minerals, it is adsorbed or presented in the form of colloidal particles (*Petrovskaya, 1973*).

Invisible gold in sulfides is present in the composition of sulfides iso-structurally and is resistant to further extraction. According to our calculations, refractory "invisible" gold in sulfides (pyrite, arsenopyrite and pyrrhotite) is no more than 25% of its total content, due to the insignificant content of these sulfides in the ore, on average, it is no more than 2.5%. The frequency of occurrence of high-grade gold is 65%, medium-grade gold - 25% and low-grade gold - about 10% (sample of 50 gold grains). Refining of gold occurred due to the hypergenesis of primary ores and their technological processing (roasting).

The form of silver appearance. Silver in various types of ores is represented by: native silver, silver sulfides (argentite, acanthite), silver arsenides (freibergite, matildite), silver antimonides (freibergite, ramdorite, polybasite, nakasaite, tetrahedrite, stephanite, animikite). In addition to its own minerals, silver in the form of "invisible" forms of occurrence is present in pyrite from 100 to 5900 g / t, on average 300 g / t, in arsenopyrite - from 200 to 2200 g/t, on average - 800 g/t, in antimonite - from 500 to 1900 g / t, averaging 940 g / t, in pyrrhotite - 800 g/t . Also, "invisible" silver is present in hydromica from 900 to 4500 g / t, averaging 3100 g / t, in hydrobiotite-chlorite - from 900 to 4500 g/t, on average 3100 g/t, in goethite and hydrogoethite from 0 up to 900 g / t, averaging 18 g / t, etc. Silver is present in significant quantities in productive hypogenic minerals: galena, sphalerite, chalcopyrite, jamsonite, berthyrite, boulangerite, burnatite, gersdorfite, lelengite from 200 to 8500 ppm and in minerals of the secondary enrichment zone: chalcocite, digenite, covellite and mojite up to 25000 g / t . From the above, it follows that the minerals of silver and their "invisible" form dominate over the minerals of gold and its "invisible" forms.

In addition to the above forms of finding gold: native gold, "invisible" gold in minerals concentrators (pyrite, arsenopyrite, goethite and hydrogoetite), gold is possibly associated with organic matter (OM) - the third form of finding gold in the Karakutan gold-silver deposit. This is evidenced by numerous studies of domestic and foreign researchers, but the question of the form of finding gold in organic matter remains debatable, for this it is necessary to have analytical instruments for the determination of gold in organic matter.

Table 1: Chemical composition of gold and platinum and silver minerals (according to scanning electron microscope and microprobe data)

Scanning electron microscope data		Microprobe data					
Au	**Ag**	**Au**	**Ag**	**Fe**	**Cu**	**As**	**S**
100		85.02	12.60	2.06	0.03		
100		83.74	13.37	2.88	0.01		
100		83.77	13.43	2.84	0.03		
100		82.94	14.31	2.60	0.14		
100		81.44	16.25	2.55	0.23		
79.01	20.99	90.17	7.20	2.36	0.28		
87.92	12.10	64.40	34.76	1.02		0.81	
81.50	18.40	62.83	35.37	1.07	0.26	0.47	
86.35	13.55	67.28	31.0	1.08	0.28	0.36	
75.90	24.10	35.60	61.58	2.79	0.03		
62.31	37.69	34.83	62.40	2.78			
74.28	25.65	18.08	80.43	1.42	0.07		
79.01	20.99	35.67	57.40	6.98			
74.30	35.30	17.31	80.66	1.86	0.17		
99.80	0.20	65.33	29.22	5.50			
98.0	2.0	64.97	30.56	4.80			
90.29	19.71	81.96	18.06				
100		81.72	18.34				
81.40	13.70	75.29		22.32	0.05	2.25	
71.50	28.5	76.04		21.78		2.40	
83.30	19.70	99.82			0.18		
		62.88	34.76	4.04			0.14
		63.38	35.37	1.02			
		66.17	31.00	1.07	0.26		
		67.16	31.58	1.08	0.28		
		37.69	62.30				

The presence of a significant amount of free gold in ores is explained by the oxidative processes of sulfuric acid leaching of pyrite and arsenopyrite under hypergenic conditions, which are confirmed by the nonstoichiometry of the chemical composition of pyrite ($Fe_{1-x}S_{2+x}$) relative to the theoretical composition (FeS_2), arsenopyrite ($Fe_{1-x}As_{1+x}S_{1+x}$) relative to theoretical (FeAsS). The underestimated content of iron in the formula of pyrite and arsenopyrite is explained by the initial stage of the oxidation of Fe of the primary sulfides of pyrite and arsenopyrite with the formation of iron hydroxides (goethite and hydrogoethite), with the release of a certain amount of free gold from the crystal lattice of these minerals. According to the scanning electron microscope EVOMA, in the samples of the technological cycle of the processing of ores, in addition to native gold and silver, a number of other native metals have been identified: Zn, Cu, Fe, Pb, Sb, W and intermetallic compounds Zn-Cu, Fe-Ti, etc. formations are explained by their formation in zones of oxidation of hypergenesis or during the technological cycle of roasting ores of the Karakutan gold-silver deposit.

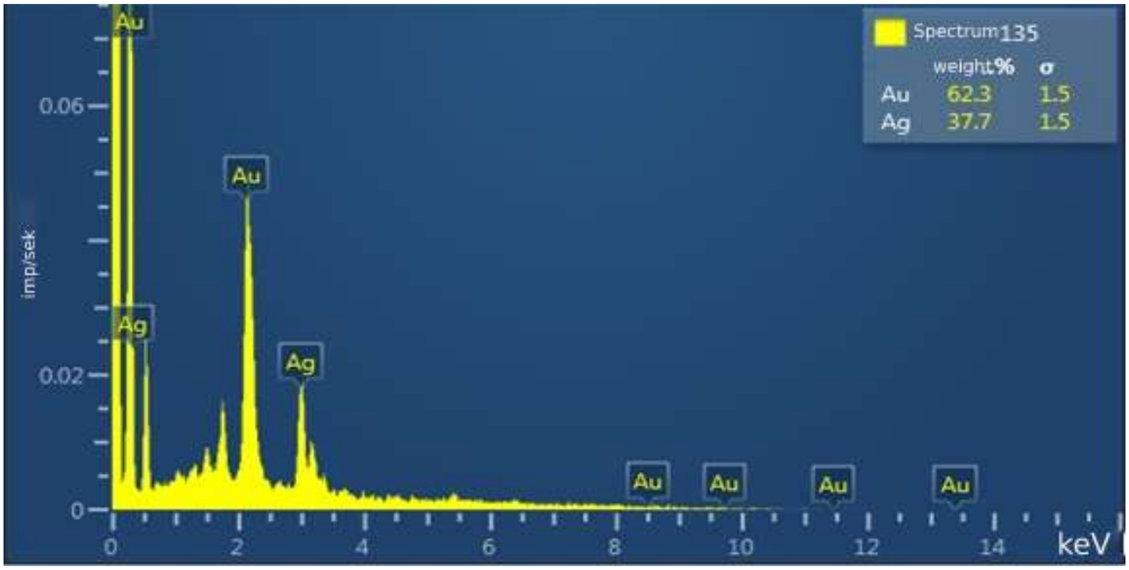

Figure 2: Micron inclusions of intermetallics (Au, Ag)

DISCUSSION

Detailed studies of various types of ores of the Karakutan gold-silver deposit and the products of their technological processing: mineral composition, behavior in various technological processes (natural, modern), identification of the forms of appearance the main productive elements in them: Au, Ag, Pt, Cu, Pb, Zn, Sn, W, Se, Te, Hg, Sb, As, S have shown that also natural technology.

The overwhelming majority of the main minerals-carriers of "invisible" gold are pyrite, pyrrhotite, arsenopyrite, antimonite. Pyrite contains on average about 400 g /t of invisible gold, arsenopyrite - 450 g/t, pyrrhotite - 950 g /t, antimonite - 7177 g /t, which are included in the crystal lattice of these sulfides, except for antimonite, gold is present in them as an impurity. The proportion of pyrite and arsenopyrite containing invisible refractory gold in the total volume of various types of ores is insignificant and amounts to about 2%, therefore, the proportion of invisible gold contained in sulfides (pyrite arsenopyrite and pyrrhotite), according to our calculations, is no more than 25%.

Silver is mainly represented by numerous native minerals or is present as a non-structural impurity in other minerals that are easily ionized and recovered. Part of silver, like gold, is represented by “invisible” refractory silver mainly in pyrite up to 300 g /t, in arsenopyrite up to 800 g/t, included in the crystal lattice, in antimony up to 940 g/t (not structural silver). This silver, as well as gold, is easily extracted with natural technologies (hypergenesis of pyrite and arsenopyrite, and during the roasting of flotation concentrate, in which these minerals are destroyed with their transformation into hematite and pyrrhotite).

In addition to the forms of occurrence of gold and silver established in various types of ores and products of their technological conversion, forms of occurrence for other productive elements were also found: Pt, Sn, W, Se, Te, Hg, and rare earth elements.

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