JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS

VOLUME 5, ISSUE 05
MONTHLY JOURNALS

ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

DISTRIBUTION PATTERNS OF MAJOR AND ASSOCIATED ELEMENTS IN ORES OF THE SHARYKTY MINERAL OCCURRENCE

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https://doi.org/10.5281/zenodo.20326355

Abstract

This study investigates the distribution patterns of primary and accessory elements within the mineralized zones of the Sharykty ore occurrence. Mineralogical and geochemical studies have established the localization features of ore components and their relationship with tectonic faults and hydrothermal-metasomatic rock alterations. The primary elements are mainly represented by copper, lead, and zinc, while the accessory elements include silver, cadmium, arsenic, and antimony. Analysis of the elemental distribution revealed a zoned mineralization structure, reflecting the multistage nature of ore formation. The results obtained are significant for assessing ore-bearing potential and for guiding further geological exploration.

Key words: Sharykty, minerals, gold, ore occurrences, primary ores, oxidized, area, prospective area, deposits, ore-bearing deposits, suite

The Sharykty ore occurrence is hosted within the metamorphosed formations of the Kosmanachi sequence (formerly the Besapan formation) [6;7]. The sequence is represented by schists of various compositions, siltstones, sandstones of black and dark-gray color, and phyllite-like schists of gray, greenish-gray color on the surface. The composition of the schists is sericite-chlorite-carbonaceous-quartz and sericite-carbonaceous-quartz. Banding is defined by the alternation of thin layers of light, predominantly quartz composition and darker, sericite-chlorite composition. The dark layers are densely impregnated with carbonaceous matter (CM). The combination of layers of different compositions imparts a pronounced plicated texture to the rock [2].

Studying the distribution of principal and associated elements in ores and mineralized zones is a pressing issue, especially in newly explored areas. The mineral composition and geochemistry of gold deposits in the Central Kyzylkum region have been studied by V.D. Tsoi, M.M. Pirnazarov, R.I. Koneev, M.S. Karabaev, M.A. Mirusmanov, R. Khalmatov, I.V. Koroleva, Sh.P. Alimov, and others [4;7; 8;9]. Research results have shown that commercial concentrations of gold in most deposits are due to the development of several productive mineral associations that sequentially replace one another in time and space.

Ore minerals in the heavy fractions of the primary ores from the Sharykty ore occurrence consist mainly of pyrite. Chalcopyrite and arsenopyrite are found in trace amounts. In the total rock mass, sulfides account for 0.8-2%, meaning they are low-sulfide ores of the gold-sulfide geological-industrial type [1]. The resulting ore mineral concentrates were used to make briquettes and for other mineralogical and geochemical studies. The light fraction is

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predominated by fragments of chlorite-sericite-quartz and carbonaceous-siliceous schists, metasandstones and their silicified and chloritized varieties, and quartz.

The majority of gold in endogenous ores is present as dispersed inclusions within pyrite and arsenopyrite. In monomineralic pyrite samples from the ore zones, spectral analysis reveals gold (20-50 g/t) and silver (20-80 g/t) as impurities. Gold content within arsenopyrite reaches up to 180 g/t, and silver up to 60 g/t. Native gold is rarely present in primary ores; it occurs as part of a gold-sulfosalt association with chalcopyrite, sphalerite, pyrite, and silver tellurides (hessite, stützite). The gold grains are lamellar, elongated, and irregular in shape. The gold grains from this association, as identified by microprobe analysis, are very fine, measuring 4-10 μm in size. Microprobe analysis of the gold (electrum) from primary ores reveals elevated concentrations of copper (2.14-5.46%) and selenium (0.86-2.16%).

The fineness of the gold from the primary ores is 592-622‰, which corresponds to electrum.

Most of the native gold in the Sharykty ore occurrence is confined to sulfide oxidation zones and areas of secondary mineral formation. This is a result of the dissolution of fine-dispersed and microscopic gold and its redeposition into larger segregations. The native gold is associated with newly formed minerals (iron hydroxides) or is found in the voids of primary minerals (most often quartz).

It forms rounded, lamellar, and irregular-shaped grains, measuring 2–35 μm, and rarely up to 40x125 μm. Gold segregations in oxidized ores sometimes have a porous structure, which is characteristic of gold particles from an oxidation zone.

In the gold particles of oxidized ores, gold forms an alloy with silver, with varying contents of both components. The fineness of the gold particles from oxidized ores ranges from 645 to 952. Their iron content is elevated (up to 0.76%) and their copper content is reduced (up to 0.18%) compared to gold from primary ores. Gold from oxidized ores is characterized by the absence of selenium in its compositionThe native gold in the oxidation zone is fine-grained (up to 3–10 μm). The fineness varies within the range of 645 to 952.

Higher concentrations of primary and associated components are found in metasomatically altered and vein-quartzified areas confined to rock crushing zones.

According to gamma-activation and fire assay data, the gold content in the ores is 0.9–4 g/t and silver is 0.3–1.3 g/t. In the ores and mineralized zones (according to mass-spectrometric analysis data), the gold content is 0.008–1.12 g/t and silver is 0.18–0.71 g/t. Higher concentration factors are characteristic of selenium (59.5), gold (57.6), arsenic (56.4), and antimony (36).

In ores and mineralized zones, gold forms strong positive correlations with arsenic (0.66), antimony (0.65), silver, and tellurium (0.46), as reflected in Figure 1. Silver is characterized by positive correlations with antimony and gold (0.46–0.54), arsenic and tellurium (0.32–0.37), as well as with a group of polymetals (0.3).

Figure 1. Histograms of the correlation between gold and silver in ores and mineralized zones

To identify changes in geochemical characteristics, the distribution of elements in primary and oxidized ores and mineralized zones was studied.

In the primary ores, the concentration levels of the main and associated mineralization elements are: tellurium (88), selenium (64), gold (59), arsenic (37), antimony (36), tungsten (6.7), and silver (5); the values for other elements are not high (Table 2). The geochemical series for the intensity of element accumulation in the primary ores is: Te-Se-Au-As-Sb-W-Ag-Mo-U-Bi-

Pt-Pb-Zn-Sn-Cu. In terms of distribution, gold forms strong positive correlations with arsenic, silver, antimony, tellurium, and selenium (0.61–0.71), as well as with copper and lead.

This geochemical series, along with the strong positive correlation of gold with arsenic (0.7) and antimony (0.6), indicates the presence of Au-As and Au-Te-Sb-Se geochemical associations. These associations formed during the endogenous mineralization of the Sharykty ore occurrence, which corresponds to relatively low-temperature, near-surface levels of ore formation.

These elemental distribution patterns point to a close geochemical relationship between gold and As, Ag, Sb, Te, and Se, as well as Cu and Pb, during endogenous ore formation processes. They also indicate the presence of gold-arsenic and gold-silver-selenide-sulfosalt associations in this area. The significant correlation of gold with antimony, copper, and lead suggests the presence of the upper-ore, more distal parts of the ore-forming system.

In oxidized ores, the highest degree of element concentration is typical for tellurium (89), arsenic (75), gold (61), selenium (57), and antimony (39), and to a lesser extent, for silver and uranium (5). The values for the remaining elements are not high (Table 1). The geochemical series for the intensity of element accumulation in oxidized ores is as follows: Te-As-Au-Se-Sb-U-Ag-W-Mo-Zn-Bi-Pt-Pb-Sn-Cu.

Contents, average contents, and concentration levels of elements in primary ore samples from the Sharykty mineral occurrence based on mass spectrometric analysis data

No.	Sample No.	Location	Au*	Cu	Zn	As	Se	Mo	Ag	Sn	Sb	Te	W	Pt	Au	Pb	Bi	U
1	50392	well SHK-16, int. 52-54 m	1,7	22,9	99,4	461	3,81	1,13	0,384	3,04	11,2	0,067	10,6	0,007	0,814	25,1	0,329	2,47
2	13317	well SHK-45, int. 23-25 m	1	27,6	59,8	295	4,8	3,06	0,28	3,45	8,92	0,047	8,34	0,006	0,584	12	0,266	2,94
3	50265	well SHK-13, int. 112-114 m	1,7	19,7	99,2	15,3	4,24	1,34	0,19	3,03	5,13	0,093	5,78	0,009	0,092	13,7	0,25	2,54
4	50264	well SHK-13, int. 110-112 m	1,6	14,7	70,4	19,1	0,24	1,8	0,219	2,39	4,91	0,06	9,47	0,006	0,046	9,11	0,199	2,82
5	50430	well SHK-16, int. 128-130 m	1,8	18,6	64,3	19,1	1,21	1,54	0,264	2,98	6,15	0,065	7,66	0,011	0,097	12,1	0,31	2,72
6	51223	Well SHK-18, interval 92-93 m	1,4	15,7	82,4	19,4	3,64	1,44	0,31	2,34	5,31	0,072	34,4	0,013	0,237	24,3	0,178	5,14

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7	50148	Well SHK-15, interval 132-134 m	2,2	12,4	41,5	19,8	1,15	1,28	0,21	2,48	4,2	0,058	9,88	0,009	0,089	13,9	0,229	2,29
8	50525	Well SHK-33, interval 28-30 m	1,6	15,4	76,2	33,2	3,93	1,17	0,297	2,37	7,35	0,108	51,8	0,014	0,231	19,1	0,234	2,9
9	50912	Well SHK-14, interval 150-152 m	1,6	22,8	108	18,9	3,72	61,7	0,368	2,78	8,38	0,05	4,22	0,012	0,076	19,6	0,308	5,31
10	50482	Well SHK-44, interval 92-94 m	1,5	19,5	99,8	19,1	2,91	1,16	0,264	2,64	1,96	0,086	5,37	0,011	0,026	25,5	0,411	2,72
11	50072	Well ShK-41, int. 140-142 m	1,7	26,9	76,2	19,5	5,96	0,97	0,385	3,07	13,5	0,086	7,17	0,01	0,062	14,8	1,31	4,89
12	50604	Well ShK-33, int. 146-148 m	1,5	18,4	58,4	95,8	5,36	0,89	0,291	2,5	6,43	0,086	3,7	0,01	0,545	13,1	0,25	2,38
13	50914	Well ShK-14, int. 152-154 m	2	27,2	162	17,3	4,64	4,32	0,485	2,55	8,02	0,11	1,83	0,007	0,04	14,7	0,237	4,97
14	50147	Well ShK-15, int. 130-122 m	0,8	44	50,7	34,4	2,32	0,84	0,698	1,97	20,4	0,321	4,02	0,004	1,11	32,9	0,3	1,8
15	50391	Well ShK-16, int. 50-52 m	1	16,1	86,5	14	2,91	1,38	0,293	1,82	1,06	0,058	6,68	0,004	0,056	12,3	0,176	3,66
16	50265	Well ShK-13, int. 112-114 m	0,6	14,7	91,1	9,4	2,24	2,53	0,605	2	2,41	0,078	2,25	0,013	0,049	13,6	0,155	4,41
17	50429	Well ShK-16, int. 126-128 m	1,2	43,1	106	10,2	4,08	4,91	0,635	3,14	10,6	0,077	2,35	0,006	0,039	19,7	0,294	12,2
18	50911	Well ShK-14, int. 148-150 m	0,6	23	101	44,8	0,18	2,84	0,258	2,99	5,03	0,064	4,03	0,004	0,082	15,2	0,216	22

Average concentrations	0,97	0,97	85,16	64,74	3,19

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Clarke values	0,004	55	70	1,8	0,05	
Concentration coefficient	241	2	1,2	36,0	63,7	

Geochemical series of the intensity of ele

*according to data from the Dagystau Geological Exploration Expedition**Table 2**

Concentrations, average concentrations, and degree of concentration of elements in oxidized ore samples from the Sharykty ore occurrence, based on mass spectrometric analysis

o.	ample No.	ocation	u*	g*	u	n	s	e	o	g	n	b	e		t	u	b	i	
	0207	-22, int. 239,5-240,5m		,5	8	46	4,2	,76	,62	,25	,44	8,2	,09	,7	,007	,167	8,3	,298	0,6
	0286	-28, int. 86,4-87,6 m	,2	,3	7,6	18	7,5	,22	,71	,265	,07	,33	,115	,44	,006	,143	9,8	,306	3
	1171	-5a, int. 146,8-147,9 m	,1	,9	4,9	3,8	03	,55	,87	,218	,27	,11	,082	,82	,009	,495	1,7	,219	,44
	1416	-6, int.	,1	,6	1	07	7	,4	,65	,281	,94	,33	,131	,06	,00	,104	4,1	,369	,1

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		39,2-40,3 m						5							9				
	0359	-14a, int. 35,7-36,7 m		,5	7	34	7,6	,41	,93	,445	,34	,05	,065	,24	,007	,075	8	,231	
	1131	-5a, int. 101,6-103,0 m	,4		4,9	6,1	66	,59	,29	,19	,08	3,2	,078	,91	,011	,434	6,4	,329	,7
	1133	-5a, int. 104,0-105,0 m		,2	7,1	4	47	,6	,76	,231	,69	1,4	,078	,04	,013	,879	0,1	,479	,93
	0287	-28, int. 87,6-88,6 m		,5	6,6	5,1	8,7	,05	,9	,239	,65	,81	,157	,82	,011	,039	1,9	,321	1,2
	0180	-22, int. 155,3-156,3 m		,9	7,4	1,4	97	,45	,54	,205	,2	,53	,07	,73	,013	,317	1,9	,204	0,4
0	033	-	,2	,4	0	6,	4,	,	,9	,29	,8	,97	,0	,19	,0	,0	9,2	,2	,12

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	2	14a , int. 4,0 - 5,2 m			, 9	7	3	2 5	1	9	2		63		1 2	25		85	
1	030 0	- 28, int. 104 ,7- 105 ,9 m	,2	,5	4 4	8 8	1, 2	, 3 9	8, 5	,42 6	,0 5	,56	,1 8	,03	,0 0 7	,0 76	8,8	,3 78	5,4
2	036 3	- 14a , int. 39, 5- 40, 5 m		,6	1 , 9	1 1	6, 1	, 7 1	,4 1	,30 6	,8 3	0,2	,0 78	,32	,0 0 5	,0 08	0	,3 16	0,4
3	034 1	- 14a , int. 15, 3- 16, 8 m	,5	,5	4 , 7	1, 1	,4	, 2 4	,5 3	,60 5		,41	,0 78	,25	,0 1 3	,0 49	3,6	,1 55	,41
4	140 7	-6, int. 28, 8- 29, 9 m	,1	,3	4 , 4	1	0, 6	, 7 2	,9 4	,42 7	,9 2	,63	,0 94	,99	,0 1 8	,0 23	1,6	,2 55	,27
4	140 7	-6, int. 28, 8- 29, 9 m	,1	,3	4 , 4	1	0, 6	, 7 2	,9 4	,42 7	,9 2	,63	,0 94	,99	,0 1 8	,0 23	1,6	,2 55	,27

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5	0365	-14a, int. 41,5-42,7 m	,2	,4	3,1	06	02	,08	,91	,635	,14	0,6	,077	,35	,006	,039	9,7	,294	2,2
6	0177	-22, int. 152,4-153,3 m	,9	,1	80	215	69	,45	,58	,277	,85	,95	,071	,16	,006	,316	4,4	,24	2,6
7	0176	-22, int. 151,4-152,4 m		,5	3	01	4,8	,18	,84	,258	,99	,03	,064	,03	,004	,082	5,2	,216	2
8	0366	-14a, int. 42,7-44,1 m	,4	,3	6,1	6,5	4	,91	,38	,293	,82	,06	,058	,68	,004	,056	2,3	,176	,66
9	1132	-5a, int. 103,0-104,0 m		,8	0,6	0,8	6,9	,18	,41	,183	,39	5,4	,051	,93	,006	,411	6	,313	,4
0	1420	-6, int. 44,	,5	,4	8,5	58	2,3	,08	,96	,266	,25	,13	,09	1,3	,004	,042	2,3	,404	,89

		2-45,7 m																	
1	1172	-5a, int. 147,9-148,9 m		,1	4,4	01	24	,91	,18	,209	,5	,95	,071	6,5	,006	,572	5,3	,325	2,1
2	0299	-28, int. 103,5-104,7 m	,2	,5	3,5	14	3,1	,08	,43	,356	,74	,65	,064	,5	,004	,147	8,5	,304	1,8
3	1409	-6, int. 30,9-31,9 m		,3	8,7	2,4	1,4	,73	,09	,215	,8	,51	,1	,29	,007	,027	3,2	,36	,65
4	0178	-22, int. 153,3-154,3 m		,9	2,4	2,6	65	,84	,02	,3	,82	,61	,093	,26	,003	,375	,79	,149	,09
25	1130	-5a, int. 100,6-101,6 m		,3	7	7,6	24	,46	,56	,175	,5	0,4	,053	2	,006	,792	5,1	,339	,05
6	0179	-22, int.			4	7,7	40	,01	,73	,349	,19	,22	,147	,69	,008	,634	1,5	,179	,24

154,3-155,3 m																	
Average concentrations	,12	,67	6,60	36,38	35,55	,86	,14	,30	,86	,70	,09	,12	,01	,24	9,14	,29	2,37
Clarke values	,004	,07	5	0	,8	,05	,5	,07		,2	,001	,5	,005	,004	2,5	,17	,7
Concentration coefficient	79	,5	,7		5	7	,8	,5	,4	9	9	,4	,6	1	,5	,7	
Geochemical series of the intens																	

*according to data from the Dagystau Geological Exploration ExpeditionHere, compared to primary ores, the degree of gold concentration increases (61), which is due to the element's geochemical properties, namely its tendency to accumulate in the ore oxidation zone. The concentration degrees of antimony and uranium also increase. This latter circumstance leads to the formation of elevated uranium contents in some parts of the gold ore bodies.

A comparison of this geochemical series with those of other sites we have studied in the Auminzatau mountains (Shokhetau, Karabugut, the NW flank of the Peschanoye deposit, etc.) indicates the significant role of uranium mineralization in the oxidized ores of the Sharykty ore occurrence.

Furthermore, the main elements accompanying gold in the oxidation zone are arsenic, selenium, antimony, tellurium, and silver.

In the oxidation zone, gold exhibits a strong positive correlation with arsenic, silver, and antimony (0.57–0.70), as well as with tellurium (0.36). A significant positive correlation with tungsten (0.47) also appears in the oxidation zone, while the correlations with polymetallic group elements present in the primary ores disappear. This is apparently due to the accumulation of tungsten and the leaching of lead, zinc, and copper from this zone.

An analysis of the main groups of associated elements revealed that the most consistent exploration indicators for gold are arsenic, antimony, silver, and tellurium. Silver's interrelationships are more diverse, including antimony, gold, tellurium, arsenic, zinc, lead, and others. This indicates a stronger connection between the formation of silver mineralization and quartz-carbonate-polysulfide and carbonate-sulfosalt associations.

Thus, it has been established that stable geochemical indicators of gold mineralization in this area are the dispersion halos of arsenic, silver, antimony, selenium, and tellurium, which form significant correlations in both endogenous and exogenous ore formation.

These distribution patterns of the principal and associated elements were identified using mass spectrometric analysis data (CL of the State Committee for Geology). To determine the reliability of these results, a comparative analysis was conducted with data from the Daugyztau

GRE (for the same samples). It was noted that the element distribution patterns largely coincide, which indicates the reliability of the obtained results and the conclusions drawn.

In both oxidized and primary ores, the content of rare-earth elements is below their Clarke values.

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