

TYPES OF GOLD MINES, PRODUCTIVE MINERAL ASSOCIATIONS AND THEIR COMPOSITION (AS AN EXAMPLE OF BOZTOV, JELSOY AND KASKIRTOV FIELDS)

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ABSTRACT

The article determines the natural species and productive associations through studying the material composition of gold deposits in the areas of Kaskirtov, Boztov, Jelsay in Central Bukantov. According to the results, oxidized and primary types of gold ores are distinguished. They noted that pyrite-arsenopyrite and gold-yarosite-hydrosilicate associations were productive.

Keywords: Central Bukantov, Kuskirtov, Boztov, Jelsay, Endogenous Gold Ores, Hypergene Gold Ores, Mineral Associations, Pyrite, Arsenopyrite, Paragenic Associations

INTRODUCTION

Natural types of ores and evaluation marks of deposits are part of a set indicators which are the same. These characteristics are the basis for the separation of natural types of ores and are specific to each mine, the most important of which are:

- mineral composition of fossils in ores;
- mass fraction of individual components;
- size and properties of spotted minerals (structure and texture of ores).

Separation of natural types of ores is carried out on the basis of various important features, which can affect their industrial viability, in particular the enrichment technology (Bastan *et al.*, 1990; Doroshenko *et al.*, 2005; Krav *et al.*, 2015).

Determining the boundaries of ore types is based on experience gained during the exploitation of similar deposits.

The study of the material composition of ores is one of the necessary tasks in the process of geological exploration, which is especially important for new prospecting areas, as the determination of mineral content of ores is ultimately important for industrial development of gold deposits (Karabaev 2016; Karabaev 2017; Kremenetsky *et al.*, 1995; Trubachev *et al.*, 2016).

Pre-ore altered rocks and mineral composition properties are determined by the conditions of their formation. Because "the distribution of chemical elements on Earth is carried out in accordance with strictly defined geochemical laws", as well as genetic markers of mineral-geochemical complexes in natural systems which are scientific and practical importance (Kremenetsky *et al.*, 1995; Krav *et al.*, 2015)

The following natural types of gold ores have been identified in the Kokpatas deposit adjacent to the study area: spotted gold-sulfide mineralization in metavulcanogenic-terrigenous rocks, vascular sulfide-quartz and oxidized (Tsoi *et al.*, 2015)

Microsondeal (mikrozone) analysis (Superprobe JXA-8800R; Jeol, Japan), chemical analysis, and separation methods are used to isolate natural species of gold ores and identify productive associations.

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The reason for the application of these methods is that ore minerals in the study areas are mainly spread in the form of microseparation.

RESULTS AND DISCUSSION

Mineralization in the south-western part of Central Bukantov differs from mineral composition, morphological features and order of location. The data allows the separation of the above oxidized ore types and the following primary mineralized zones.

The primary ore in these areas consists of mainly of pyrite, rare chalcopyrite, arsenopyrite, galena, sphalerite and a small amount of sulfasols, as well as silver and other minerals (Table 1). The minerals that make up the rock are quartz, albite, sericite, chlorite, kaolinite, and carbonates.

Endogenous mineralization in the field consists of paragenic mineral associations formed in the following sequence:

- Ore mineralization in metamorphic rocks;
- Pyrite-arsenopyrite;
- Polysulfide-silver-sulfosol-gold.

Minerals of metamorphic rocks are pyrite (pyrite-1), in the surrounding rocks this mineral is found in fine-grained form (Figure 1-a, b). Pyrite, formed in the form of grains of almost equal with sparse isometric shape in metaaleurolites and sandstones, is bounded by uneven surfaces. In quartz-mica shales, pyrite sometimes forms flattened grains between layers of rock, the particle size of which varies from 0.00n mm to 1.5 mm. Sparse pyrite particles, their additives, and many aggregates cause irregularly shaped separations. The structure is hypidiomorphic.

The main mass of ore mineralization is associated with altered zones and quartzified rocks under the influence of hydrothermal processes. Such sulfide mineralization is often distributed in the zones of pre-mining change or in the periphery of the quartzation zones (Figures 1- v, g, d, e).

In some cases it can be observed that pyrite, which accumulates in the form of honeycombs and metazars, is located in cracks in quartz veins along a thin, flat surface, which is clearly visible in the fractured fragments along the crack (Fig. 1-e). Sulfides consist of mainly of pyrite, partly of chalcopyrite and arsenopyrite (Table 1).

During the development of sulfide mineralization along the metasomatic quartzation zone, as a result of recrystallization of mica shales, large-particle mica (siritsite-muscovite) -carbonate-containing metasomatic formations are formed. Hydrothermal ore mineralization in the study areas consists of pyrite-arsenopyrite and polysulfide-silver-sulfasol associations.

The pyrite-arsenopyrite paragenic mineral association consists of pyrite-2 and arsenopyrite-1. The intensity of manifestation of this association determines the industrial value of the ores. Pyrite, which is greater than arsenopyrite in terms of its quantitative ratio, is the main preservative of dispersed gold.

In the field of study, gold, which is the main important component of gold-sulfide ores, occurs as a mixture in the composition of sulfide minerals in the endogenous and oxidized ore zones, as well as in pure form (Karabaev, 2017).

In ore bodies, this association has shown to be interrelated with rapidly serrated, quartzized, and chlorinated zone rocks.

Pyrite-2 often forms irregularly shaped metacrystals with a diameter of 0.15–0.5 mm. In the quartzated and altered zones of the rocks, their size ranged from 0.1 to 1.5 mm, forming strata, cells, lenses, and veins. It is more chain-like, spotted, honeycomb-like, clustered, and xenomorphic-grained, and is sometimes observed in the form of separate cubic, pentagondodecahedral crystalline separations. They are differently distributed in the quartz composition. Pyrite crystals formed more dense clusters, and they often have a chain-like property. This cluster of crystals is located at the contact of quartz and layered rocks (Figure 2a).

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In paragenesis with pyrite-2, elongated arsenopyrite and sparse chalcopyrite-1 have been shown. In this case, pyrite formed large (1-2 mm) isometric crystal grains, arsenopyrite - needle, prism-shaped, rhombic aggregates, chalcopyrite pyrite formed irregularly shaped separations.

The *polysulfide-silver-sulfasol* association consists of thin, quartz-carbonate cross-sections containing pyrite-3-sphalerite-chalcopyrite oriented in different directions. They contain arsenopyrite-2, marcasite extracts, chalcopyrite, chalcocite, bornite, sphalerite and rare galenites (Figure 1). This association includes acanthite, a silver sulfide mineral, bleached ore (black ore), and pure gold.

Pure gold has a plate-like morphology and measures up to 0.4 mm in length. It is brighter than pyrite and brighter than chalcopyrite. Gold has a distinct yellow color, with no sulfides grown along with it.

Table 1: Results of separation, chemical and mass - spectrometric analysis of primary mineralized zone ores in Kaskirtov, Boztov and Jelsay fields

Mineral characterization of primary ore samples separation products

Description of the rocks covered (ore-bearing)	Sample weight (gram)			Percent of heavy fraction (%)	Component of mineral	
	Initial amount	Heavy fraction	Light fraction		Heavy fraction	Light fraction
Carbon-sericite-chlorite-quartz meta-sandstones, meta-levrolites, carbonaceous shales in the zone formed during metasomatism, in the form of pyrite halides and aggregates	200	0,5-14	120-167	0.6-7.2	Pyrite (80-95%), less chalcopyrite (0.1%), arsenopyrite (0.2-0.8%), sphalerite, galenite - iron hydroxide (1-3%).	Cover rock fragments (65-90%), quartz (5-40%), carbonate

Results of chemical analysis

Results of mass spectrometer analysis

Components %	B-22	F-76	K-7	Elements	B-22	F-76	K-7
				g/t			
SiO ₂ . %	69.26	63.56	67.14	Au	0.26	0.07	0.06
TiO ₂	0.78	0.66	0.50	Ag	0.80	0.59	0.73
Al ₂ O ₃	11.12	14.26	12.18	Pt	0.04	0.01	0.04
MgO	1.42	1.85	1.78	Te	0.31	0.21	0.57
MnO	0.01	0.02	0.02	Se	7.0	4.60	4.5
CaO	1.26	1.34	1.20	As	6.0	7.5	6.3
Na ₂ O	1.24	1.28	0.76	Sb	110	8.60	14
K ₂ O	2.14	2.40	1.62	Cu	100	63	88
P ₂ O ₅	0.17	0.18	0.15	Pb	31	7.5	9.6
SO ₃ .	1.56	1.65	1.38	Zn	93	43	85
SO ₃ . sulfate	0.12	0.16	0.10	W	0.68	7500	2.10
S. sulfide	0.46	0.58	0.46	Mo	16	900	7.3
Fe ₂ O ₃	3.24	4.06	4.26	Sn	2.30	11.0	1.90

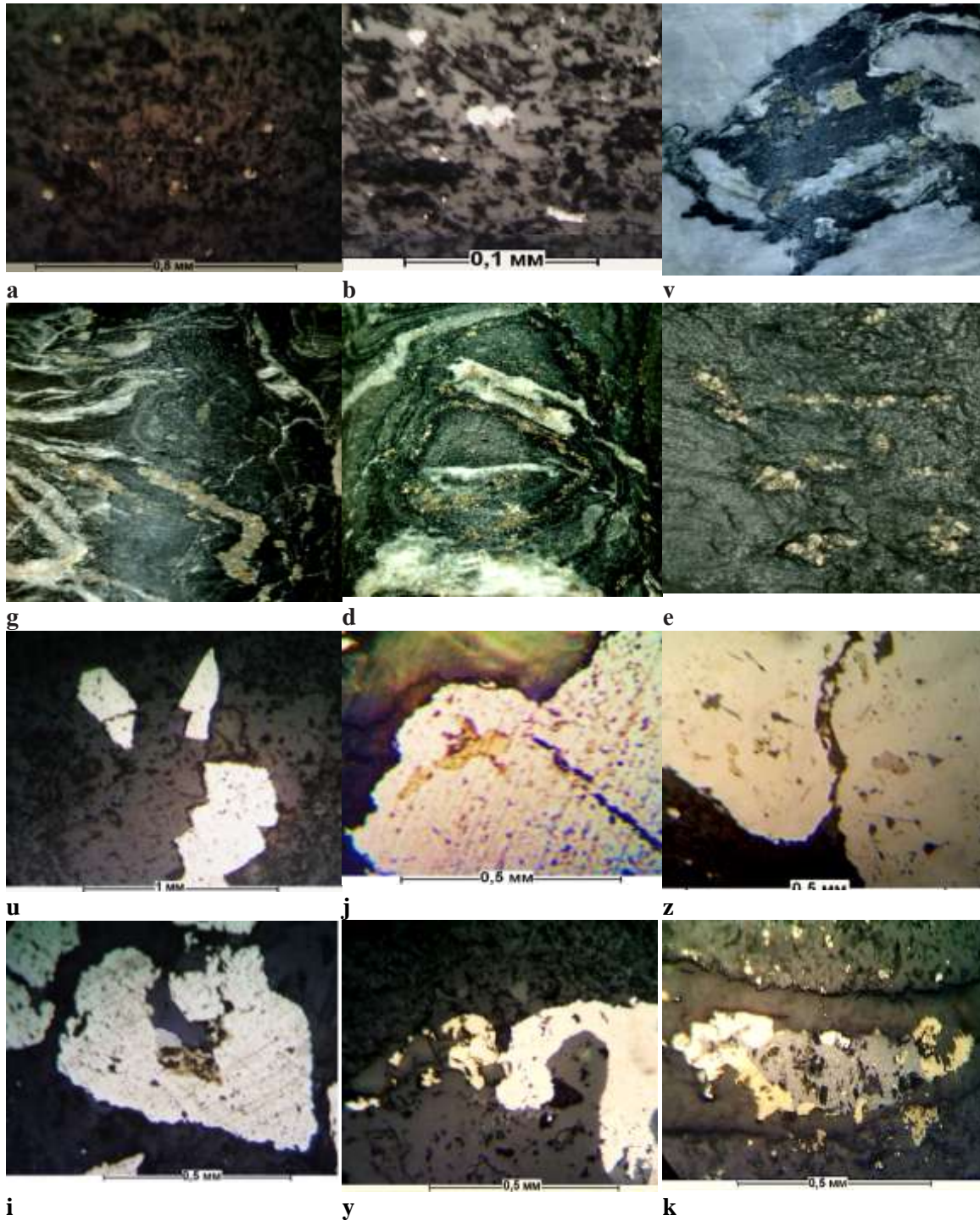


Figure 1: Description of primary ore minerals in various metamorphic, quartzated shales.

The sulfides in the rocks are not oxidized, so in these rocks the gold is primary and associated with changes in the rocks under the influence of metasomatic processes. According to the interaction of paragenic minerals, it can be noted that after gold pyrite-1 (metamorphogenic) and more quartzation zone, paragenic (pyrite-2) mineralization zones are intersected by quartz-pyrite-3-chlorite association.

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Table 2: Mineral characteristics of oxidized ores of Kaskirtov, Boztov and Jelsay fields

Mineral characterization of oxidized ore samples separation products											
Description of the covered rocks	Sample weight (grams)			Percent of heavy fraction (%)	Mineral composition						
	Initial amount	Heavy fraction	Light fraction		Heavy fraction	Light fraction					
Ironized, quartzified rocks formed under hypergenic conditions in fractured zones	200	0,4-1,40	136-160	0,1-0,63	Iron hydroxide (80-95%), pure gold - separate grains, pyrite-separate grains	Cover rock fragments (75-85%), quartz (5-40%), carbonate (0-10%), gypsum (0-1.0%), iron hydroxide (5-10%)					
The composition of the minerals of oxidized minerals according to the data of the electron microsonde analysis											
№ sample	Mineral	Content of element %									
		SiO ₂	TiO ₂	V ₂ O ₅	K ₂ O	MnO	Fe ₂ O ₃	CuO	As ₂ O ₅	SO ₃	Σ
2	Q-55 Getit	2.30	0.06	0.07		0.24	83.20	0.01	0.38	0.34	86.6
3	B-62 t	2.15	0.05	0.06	0.05	0.27	83.62	0.03	0.34	0.39	86.96
4	J-626	2.45	0.04	0.05		0.26	82.80	0.01	0.36	0.36	86.33
5	B-62 Hyd	3.18	0.06	0.36	0.05	0.01	69.60	0.60	0.60	1.30	75.76
6	Q-62r roge tite	3.36	0.04	0.54	0.03	0.03	70.04	0.26	0.55	3.50	78.35
Dimensions and composition of pure gold in oxidized ores in the research area according to the data of electron-microsonde analysis											
T.p.	Number of sample	Size (mkm)	Quantity of components %								
			Au	Ag	Fe	Cu	Σ				
1	PK -3-1	5	92.08	7.46	0.24	0.1	99.88				
2	PK -3-2a	6	86.12	12.4	1.22	0.06	99.80				
3	PK -3-1-B	8	74.42	25.16	0.34	0.02	99.94				
4	PK -3-3	6	74.56	25.05	0.22	0.12	99.95				
5	PK -3-6	5	68.3	31.4	0.12	0.14	99.96				
6	PK -3-2B	6	64.23	35.2	0.38	0.06	99.97				

The polysulfide-silver-sulfasol association can sometimes be seen crossing pyrite-arsenopyrite veins in quartzation zones. Pyrite is a carrier of micro-supplements of arsenopyrite-2 and chalcopyrite. It can be seen that the densely distributed pyrite in small honeycomb separations grew together with chalcopyrite and sphalerites. In this paragenesis, pure silver is recorded in association with pyrite, sphalerite, chalcopyrite (Fig. 1k). In sphalerite, a large number of circular and irregularly shaped chalcopyrite-2 microns are observed. Pure gold formed a compound with quartz, chlorite, pyrite, and chalcopyrite. Small aggregates like plate formed.

Morphological features of pyrite separations in metamorphic rocks (a, b); spotted and vascular-spotted pyrite-arsenopyrite mineralization in quartzated carbon-mica-chlorite shales (v, g, d) and metaalevrolites

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(e), pyrite-arsenopyrite association chalcopyrite separation in pyrite, separation of chalcopyrite and arsenopyrite in pyrite (z), chalcopyrite, sphalerite and pyrite growths (i), polysulfide-silver-sulfasol association of pyrite and chalcopyrite in paragenesis, association of pure silver (white), pyrite (yellow), chalcopyrite (yellow), sphalerite (gray) in k-carbonate veins (y, k).

Ore texture - spotted, vascular spotted, vascular. Structure - idiomorphic and hypidiomorphic. Complexes of pure gold and various microminerals (selenides, tellurides, sulfasols) are widely used in the polysulfide-silver-sulfasol association.

Carbonate, quartz-carbonate, carbonate - zeolite associations - developed after mineralization of ore in terms of the formation time of small amounts of pyrite grains, but formed more widespread areoles than ore associations.

Ore mineralization of the oxidized type is developed in the zones of rocks with extensive formation of iron hydroxides in the deep sections of the Kaskirtov, Boztov areas from 10-15 m to 30-40 m, and in the Jelsay area from 30-60 m (Fig. 2 a, b).

The mineralized zones discovered on the surface through the help of mountain loams are mainly composed of brecciated, fractured, limonite shales and metaaleurolytes (Table 2), forming quartz veins with a thickness of 8-10 cm (Fig. 2-v, g). The main part of the oxidized type ore bodies is developed in the "tectonic wave" zones of discontinuous devices - almost parallel upright (slightly sloping to the north) and relatively young wavy faults in the sub-latitudinal direction. The convex side of tectonic waves is directed to the north in Jelsoy, less Boztov fields, and to the south in Kaskirtov, and these devices played important role in the location of ore bodies.

The location of oxidized ore bodies in brecciated, quartzized metaelectrolites (a, b); samples from ores (v, g) and their texture-structural properties (d, e, z - nicols in parallel); dispersion of elements in a particle of plasticine gold (j); distribution of elements in pure gold particles in oxidized ores (l microsonde image - raster distribution of elements); morphology of pure gold particles in quartz-getite-hydrogetite associations in oxidized ores (m microsonde image - in returning electrons).

When the oxidized ores are studied using the separation method, the heavy fractions show signs of iron hydroxide (60-70%) and gold. The particles of partially oxidized pyrite can be seen in samples taken from the lower part of the oxidized zone. Light fractions consist of covering rocks (75-85%), quartz (5-40%), carbonates (0-10%), gypsum (0-1%). The presence of gypsum in the samples is associated with hypergenic processes.

Getite and hydrogetite minerals are common in oxidation zones. The main aggregates of these minerals fill the pores of the primary sulfides. In the cracks formed in the quartz veins, iron hydroxides are developed and they are up to 1 mm thick intersections, 3-5 mm veins, and vascular-shaped separations. The amount of iron hydroxide in the oxidation zones is 2-8%, a up to 20% in many stem samples. In heavy fractions, the content of these minerals reaches 70-90%. The sandstone-shale rocks in these zones are composed of limonite and rock-forming minerals that have survived from the primary formations, which make up 35-40% of the total mass. Limonite is formed from a mixture of iron hydroxide and consists of mainly of the minerals getite and hydrogetite (Fig. 2 g).

The main mineral minerals of oxidized ores are iron hydroxide (getite, hydrogetite), yarosite, scorodite and pure gold. They occur in the form of ocher, pseudomorphoses on sulfides, and effluents accumulated as a result of infiltration (Fig. 2d). The color is different, mostly brown. The highest light-reflecting light-gray part of the goitre is dense, the dark-brown part is dull and usually has a hidden crystalline structure. Pale bold gray hydrogetite has a fine porous structure.

They are earthy, loose, powdery, and developed, changing internal reflexes associated with the formation of micro-cavities as a result of displacement processes - that is to say copper-yellow, rusty ocher, brownish-brown in color.

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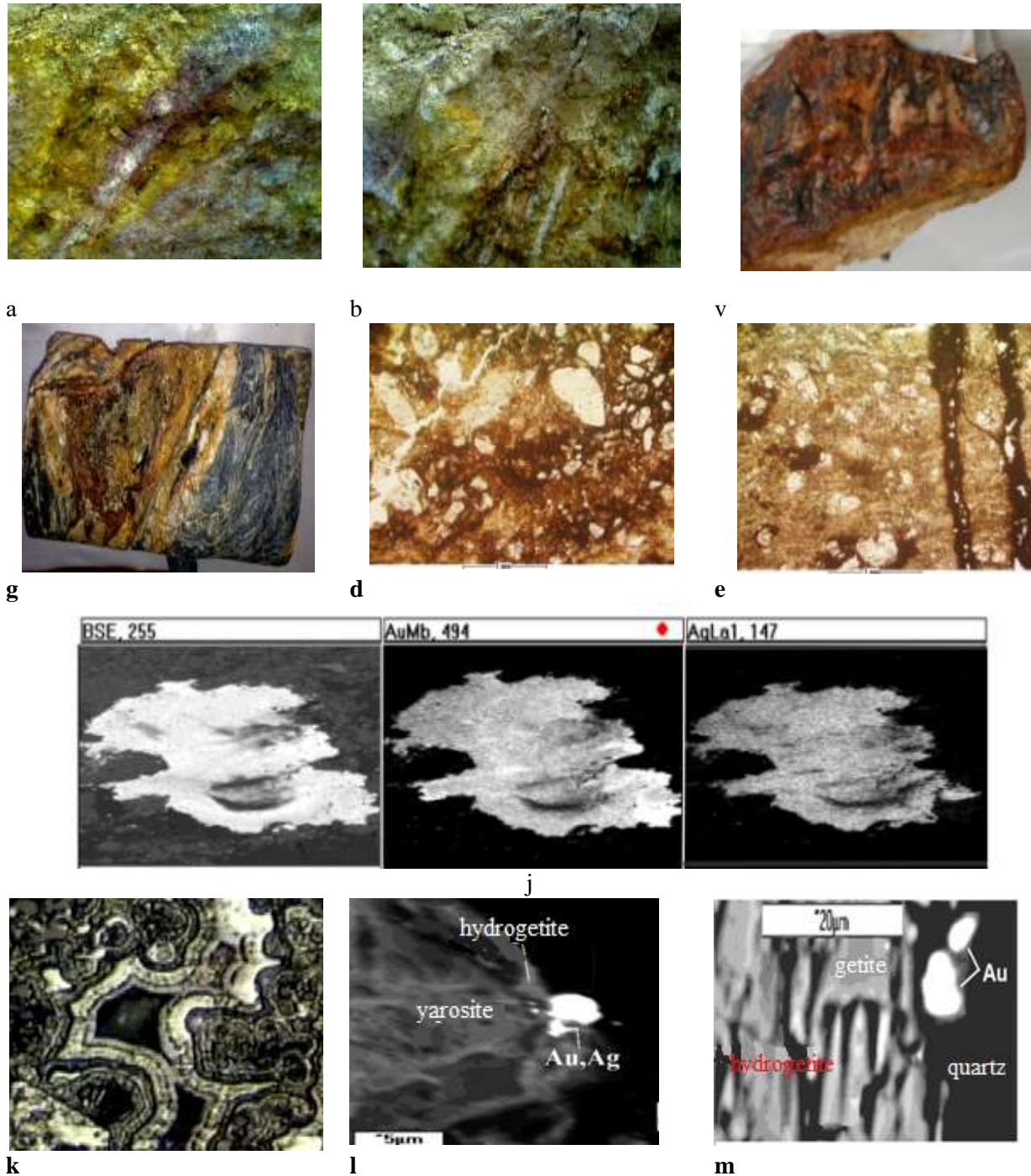


Figure 2: Forms and composition of oxidized ores and gold in their composition

Iron oxides are mainly distributed in chlorite-sericite, shale rocks, forming sufficiently flat, fine cloudy-spotted clusters. Only occasionally are there grains of plagioclase clearly cataclastic around their visible bundles.

Iron oxides sometimes form thin elongated veins 0.15-0.2 mm thick. Oxidized ores consist of a series of associations of gold-jarosite-hydroslide (in the lower part of the oxidized ore zone) and gold-hydrogetite-kaolinite (in the upper part of the oxidation zone). The zonal locations of these associations are formed as

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a result of the downward absorption of surface waters (hypergenic solutions). Due to the infiltration and diffusion of these solutions, the sulfide minerals of the primary ores are broken down to form various sulfates (yarosite, scorodite, etc.). Very fine-dispersed gold, on the other hand, is free from sulfides and forms a pure, congenital, gold-yarosite-hydrosilicate association. The exchange of minerals in the sulfide-sulfate-hydroxide and feldspar-hydroxide-kaolinite series reflects the evolutionary properties of hypergenic compounds.

Much of the amount of pure gold falls on oxidized ores, as the finely dispersed and microscopic gold sulphides combine with each other to form aggregates after separation. In the Kaskirtov and Boztov fields, their shape is plate-like, unevenly circular, forming particles with a size of 5-10 microns. The degree of nobility of gold is 643-921 (Table 1), the difference from endogenous gold is in the high content of iron in their composition (up to 1.22%). In Jelsoy, xenomorphic particles of 2–12 m in size are found in pure gold found in getite and hydrogetites. The purity level of gold is 900: Au ~ 90%, Ag ~ 9%, Fe ~ 0.8%.

In oxidized ores, under the influence of the hypergenic conditions that form them, the degree of originality of gold can change abruptly in individual particles, and non-uniform fine-grained, flaky gold particles are observed (Fig. 2, j-i). The particle on the right side of the sample consists of much pure gold (purity level 921, PK-3-1), and the purity level of gold on the left side of the sample is 744 (PK-3-1-v). Iron has a higher iron content (0.34%) and copper has a lower value (0.02%, Table 2).

CONCLUSION

In the study areas, natural species of gold ores are classified according to their mineral composition, spatial location, and morphological properties. Accordingly, the types of oxidized ores on the surface of the Kaskirtov, Jelsoy and Boztov fields and the types of primary mineralized zones below the oxidation zone boundary are identified.

The primary mineralized ore in the study area consists mainly of pyrite, rare chalcopyrite, arsenopyrite, galena, sphalerite and a small amount of sulfasols, as well as silver and other minerals.

The main mass of ore mineralization is associated with altered zones and quartzified rocks under the influence of hydrothermal processes. Endogenous mineralization has resulted in mineralization of ore in metamorphic rocks, pyrite-arsenopyrite, polysulfide-silver-sulfosol gold paragenic associations in the gold sequence. Pyrite-arsenopyrite is the main carrier of pyrite dispersed gold in the paragenic mineral association.

The main minerals of the mineralization of the oxidized type are getite, hydrogetite, yarosite, scorodite and pure gold.

Oxidized ores consist of zonal localizations of gold-jarosite-hydroxide (lower part of the oxidized ore zone) and gold-hydrogetite-kaolinite (upper part of the oxidation zone) associations. For primary gold ores, pyrite-arsenopyrite and for oxidized ores, gold-yarosite-hydroxide mineral associations serve as the main producers.

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