International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081
Online International Journal Available at http://www.cibtech.org/jgee.htm
2022 Vol. 12, pp. 235-240/Sardor and Ruslan
Research Article (Open Access)

MINERALOGICAL AND GEOCHEMICAL FEATURES OF THE PRODUCED GOLD OBJECTS OF THE NORTHERN TAMDYTAU (UZBEKISTAN)

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ABSTRACT
The article presents the results of mineralogical and geochemical studies of explored gold objects of Northern Tamdytau. Numerous gold objects are located in the Tamdybulak-Balpantau ore field of Northern Tamdytau, such as the Tamdybulak, Balpantau, Kyzyltash deposits, the Maisky, Near-Kontaktovy, Taiman, Northern Taiman ore occurrences, the Northern mineralized zone. As a result of studying the mineral composition of ores, it was found that the gold ore objects of Northern Tamdytau have a similar mineral composition, covering the time interval from the early sulfide stage to the carbonate-fluoride stage. The presence of late minerals stibnite, barite, celestine indicates the upper ore section of the studied objects and its prospects for depth.

Keywords: *Gold Deposits, Ore, Mineralogy, Native Gold, Paragenetic Mineral Association, North Tamdytau, Uzbekistan*

INTRODUCTION

The study of the material composition of ores is an integral part of any exploration project. Reliable knowledge about the distribution of useful components and the forms of their presence in various types of ores is a necessary condition for the scientific forecast of the ore potential of objects and the development of technological schemes for their enrichment and extraction.

Uzbekistan is one of the main producers of gold and is among the top ten countries in the world in terms of explored reserves of the metal. Gold reserves in Uzbekistan amount to 1,800 tons and in 2021 entered the top 10 countries in the world by production (Minerals Commodity Summaries, 2022). There are about a hundred gold deposits from small ones to the world-class giant - Muruntau. In the coming years, Uzbekistan plans to increase gold production.

The gold deposits of Uzbekistan are confined to a single Kyzylkum-Kurama metallogenic belt, which includes the South Tien Shan orogenic belt and the Beltau-Kurama volcano-plutonic arc, formed as a result of subduction of the crust of the Turkestan paleoocean under the Kazakhstan-Kyrgyz continent, its collision with the Kara-Kum Tarim continent and subsequent geological processes (Dalimov TN, 2002, Yakubchuk AS, 2002, Goldfarb RJ, 2013).

Numerous gold objects are located in the Tamdybulak-Balpantau ore field of Northern Tamdytau, such as the Tamdybulak, Balpantau, Kyzyltash deposits, the Maisky, Near-Kontaktovy, Taiman, Northern Taiman ore occurrences, the Northern mineralized zone. Recently, exploration work has been actively carried out at these sites in order to expand the mineral resource base of the Republic. This year, development of the Balpantau and Tamdybulak deposits began.

The formation of gold deposits in Uzbekistan took place in the period of 310-220 million years, but the period of maximum ore deposition falls on 280-290 million years, i.e. to the C_3-P_1 boundary (Seltmann R, 2014), which confirms the conclusions about a certain synchronism of gold mineralization and granitoid magmatism (Khamrabaev IKh *et al.*, 1969). It has been established that gold mineralization is superimposed on sedimentary-volcanogenic and igneous rocks of various compositions, from Precambrian to Upper Carboniferous - Lower Permian, and ore formation lasted about 60-70 million years (Koneev RI *et al.*, 2009).

The genesis of Balpantau, according to some researchers, is volcanic-hydrothermal, others - hydrothermal. We adhere to the second point of view. This conclusion is based not only on geological relationships, but also on the results of detailed mineralogical studies of Balpantau, as well as isotope studies of Muruntau arsenopyrite, according to Re-Os-He isotopy data, which is 285.5 ± 1.7 million years (Morelli R and et al. 2007). That is, the age of the main productive pyrite-arsenopyrite with gold paragenetic mineral association at Muruntau is P_1.

Granites in borehole SG-10 have an age of 287.2±3.9 Ma, syenodiorite porphyrites 285.4±5.1 Ma and 284.4±1.9 Ma, adamellites 286.2±1, 8 million years (Kostitsyn YuA, 1993). The dates of igneous formations and arsenopyrite at Muruntau are close, which apparently indicates their genetic relationship.

Zircon U-Pb geochronology of main intrusive massifs of Uzbekistan (CERCAMS data) showed that granitoid magmatism is predominantly of postcollisional age, manifested in the accretionary units at 270-290 Ma, whereas subduction magmatism prevails as characteristic in the volcano-plutonic arc at 300-320 Ma. Determination of sulphide mineralization ages using Os-Re method (CERCAMS data), are respectively 283-289 Ma and 298-314 Ma (Koneev RI, Seltman R, 2014)

MATERIALS AND METHODS

Field geological work was carried out with sampling for further mineralogical work. The mineral composition of the ores was studied under laboratory conditions by optical methods (microscope Nikon Eclipse LV 100Pol). Electron microscopy (Carl Zeiss) and microprobe studies (Jeol JXR8800) were also carried out.

The chemical composition of ores is established by a complex of chemical and physico-chemical analytical methods of research. Including a complete silicate, atomic absorption, spectral, ICP-mass spectrometric, etc.

RESULTS AND DISCUSSION

As a result of mineralogical studies, about 45 minerals have been identified at the ***Tamdybulak deposit***. Some minerals are hypogene, and some are supergene. The mineral composition includes rock-forming, metasomatic minerals, a group of accessory minerals.

Quartz, plagioclase, K-feldspar, sericite, chlorite, ferruginous carbonates, carbonaceous matter, and amphibole are the main rock-forming minerals, rarely pyroxene and epidote. Of the accessory minerals, zircon, apatite, barite, celestite, tourmaline, and monazite have been identified as part of the ore-bearing rocks.

Pyrite and arsenopyrite are the most widespread ore minerals in sulfide (primary) ores. Iron and arsenic hydroxides (goethite, limonite, scorodite) predominate in the oxidation zone.

Native gold is the main valuable mineral in the composition of ores. Also, single grains of chalcopyrite, galena, sphalerite, magnetite, Fe-native, lead sulfosalts, enargite, marcasite, pyrrhotite, melnikovite, jarosite, psilomelane, hematite, copper greens, chalcocite, bornite, anglesite, etc. are found in ore.

The texture of ore minerals is disseminated, nested, veinlet, rimmed in the oxidation zone, substitutions. Sometimes ore minerals cement non-metallic minerals, developing along intergranular spaces. The structure of the ores is hypidiomorphic-granular, fine-, medium-grained, allotriomorphic-granular.

Native gold is found in the form of thin inclusions in the non-metallic mass, in intergrowths with pyrite, arsenopyrite, in the form of inclusions in them. Sometimes it develops along cracks in sulfide minerals (Fig. 1). The shape of the gold particles is determined by the shape of the cavities, there are growths of gold particles on sulfides. Grain size from 0.0n to 0.1 mm. The gold content in pyrite is 11.9 g/t, in arsenopyrite from 4.35 to 646.32 g/t.

Iron hydroxides are widespread minerals of the oxidation zone. Represented by goethite, hydrogoethite, limonite ocher, developed in the form of dissemination, nesting, veinlet accumulations, impregnation of cement of metaterrigenous rocks. The gold content in Fe hydroxides is from 0.6 to 17.76 g/t.

The main non-metallic minerals in the ores of the ***Taiman and Northern Taiman sites*** are quartz, feldspars, sericite, chlorite, carbonates, and carbonaceous matter. Amphibole, biotite, zoisite, epidote are noted in a subordinate amount or in separate types of ores. Of the accessory minerals, zircon, rutile, monazite, and apatite have been identified in the ores (Sayitov S, Tsoi V., 2020).

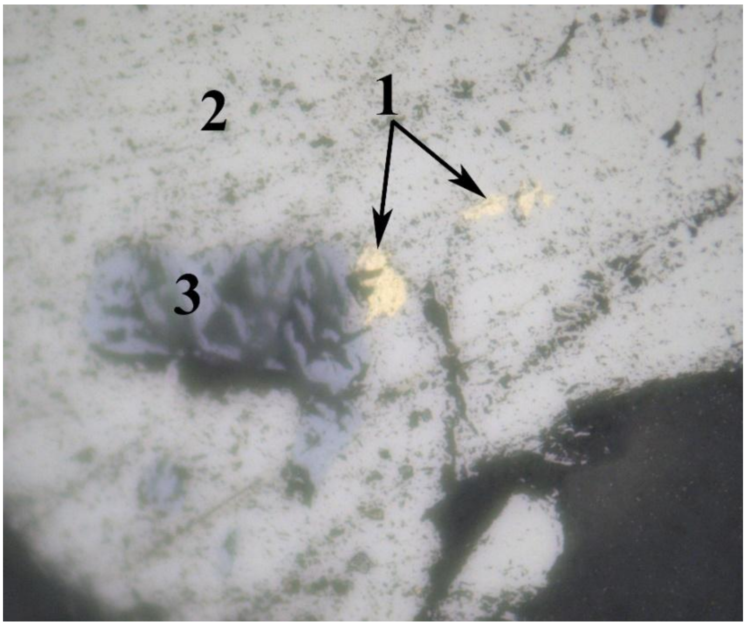

Figure 1. Native gold and enargite in arsenopyrite. 1-native gold, 2-arsenopyrite, 3-enargite. 400^x; without analyzer

The main minerals of primary ores are native gold, pyrite, arsenopyrite. Other ore minerals occur sporadically or in single grains. These include chalcopyrite, pyrrhotite, marcasite, melnikovite-pyrite, galena, sphalerite, antimonite, electrum, bismuthine, cubanite, native copper, magnetite, chromospinelid, scheelite.

In the oxidation zone, ore minerals are replaced by secondary supergene minerals. The group of supergene minerals is represented by iron hydroxides (goethite, hydrogoethite, limonite, jarosite) and arsenic (scorodite), secondary copper sulfides (chalcocite, covellite), copper carbonate (malachite), hematite, etc. Ores of the upper horizons often contain barite and celestite.

The finding form of gold is native form. The size of gold particles is from 0.0n to 0.8-1 mm. The shape is different - from lamellar to xenomorphic, rosette-shaped, curved (Fig. 2). Gold occurs intergrown with quartz, in goethite, and in free form. The composition was determined by local X-ray analysis on a microprobe: Au 58.7-74.98%; Ag 24.11-41.09%; Fe 0.25-0.59. The content of gold in pyrite is from <0.1 to 18.65 g/t.

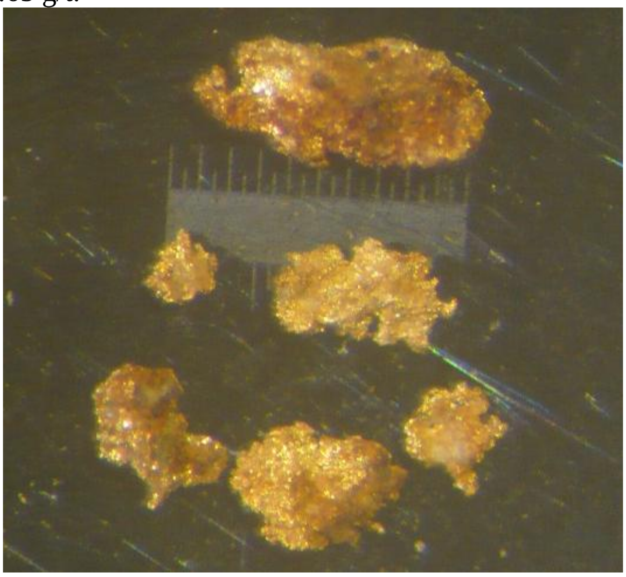

Figure 2. Free native gold from Taiman. Ruler length - 1.0 mm

Goethite and hydrogoethite predominate in the oxidation zone, and scorodite is less common. Develop by pyrite, arsenopyrite, marcasite. Minerals form dissemination, nesting and veinlet accumulations in all types of ore bearing rocks. The shape of the grains is cubic, less often pentagondodecahedral, due to the shape of the primary mineral, pyrite. Gold content in iron hydroxides from 0.1 to 87.85 g/t.
Covellite, chalcocite, hematite, malachite and jarosite from the minerals of the oxidation zone are found in insignificant amounts or in single grains. Accessory minerals are represented by barite, celestine, leucoxene, zircon, monazite, rutile, and apatite.
The following types of metasomatically altered rocks have been identified in the ***Near-kontaktovy*** area: 1) carbonaceous-(chlorite)-mica-feldspar-quartz silt schists; 2) metaaleuropsammites, metapsammosiltstones; 3) meta-effusives; 4) dikes; 5) quartz-vein formations; 6) breccias.
The chemical composition of ores and ore-bearing rocks of the Contact area of aluminosilicate composition (%): SiO_2 48,2-80,21; TiO_2 0,05-0,62; Al_2O_3 3,4-24,9; Fe_2O_3 0,91-6,7; FeO 0,15-0,98; MnO 0,01-0,17; MgO 0,3-2,24; CaO 1,21-12,99; Na_2O 0,14-2,62; K_2O 0,17-3,66 P_2O_5 0,05-0,21; S_{total} do 0,11; lose 4,23-19,4; CO_2 2,6-18,3; H_2O 0,15-1,16 (Tsoi *et al.*, 2022).
The main valuable component in the ore is gold. The content of the element in the ore is up to 48.5 g/t according to atomic absorption analysis. Ore samples with a content of 1-2.0 g/t prevail. Of the associated components, elevated contents of silver, tungsten
The main non-metallic components in the composition of ores are quartz, feldspars, sericite, chlorite, carbonates, and carbonaceous matter. Biotite, amphibole, chalcedony, carbonaceous matter, chlorite, epidote, pyroxene are noted in a subordinate amount or in separate types of ores. Of the accessory minerals in the ores, barite, celestite, spinel, zircon, rutile, monazite, and apatite have been identified.
The main minerals of primary ores are native gold, native silver, pyrite, arsenopyrite, chalcopyrite, scheelite. Other ore minerals occur sporadically or in single grains. These include marcasite, pyrrhotite, sphalerite, galena, and magnetite.
In the oxidation zone, ore minerals are replaced by secondary supergene minerals. The group of supergene minerals is represented by iron hydroxides (goethite, hydrogoethite, limonite, jarosite) and arsenic (scorodite), secondary copper sulfides (chalcocite, copper chloride), copper carbonate (malachite), hematite, etc. Oxidized ores often contain barite, celestine, clay minerals.
The finding form of gold is native form. The main part of native gold is free, rarely intergrown with ore minerals, ferruginous carbonates, and quartz. The size of gold particles is from 0.00n mm to 0.5-1.2 mm. The form of gold grains is varied: rosette-shaped, amoeboid, hooked, lumpy, dendritic, etc. (Fig. 3). The composition of native gold according to X-ray local analysis is as follows (%): Au 91.13-99.98; Ag up to 6.32-7.97; Cu 0.22-1.31; Fe up to 0.7-0.99.

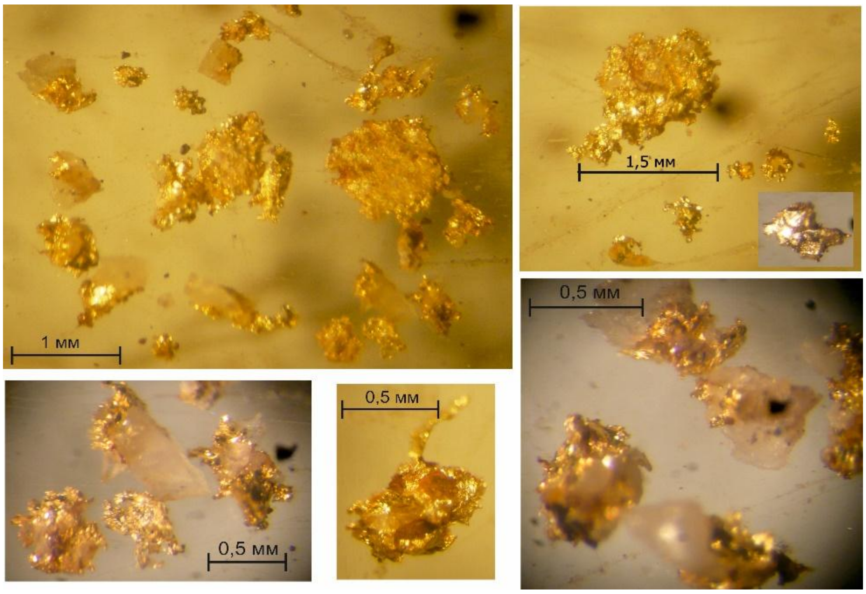

Fig. 3. Form of native gold in Near-kontaktovy area

The form of finding gold in its native form. The main part of native gold is free, rarely intergrown with ore minerals, ferruginous carbonates, and quartz. The size of gold particles is from 0.00n mm to 0.5-1.2 mm. The form of gold grains is varied: rosette-shaped, amoeboid, hooked, lumpy, dendritic, etc. (Fig. 3). The composition of native gold according to X-ray local analysis is as follows (%): Au 91.13-99.98; Ag up to 6.32-7.97; Cu 0.22-1.31; Fe up to 0.7-0.99.

Gold mineralization at the area is associated with a pyrite-arsenopyrite paragenetic mineral association with gold of the early sulfide stage in the scheme of hypogene mineral formation of ore deposits in Uzbekistan (Tsoi, Koreleva, Sayitov, 2021).

Pyrite and arsenopyrite are the main ore minerals of primary ores of ***Maisky*** site. In the oxidation zone, they are replaced by iron hydroxides, such as goethite, limonite, and scorodite. Chalcopyrite, pyrrhotite, and magnetite are found in small amounts. Accessory minerals include zircon, rutile, garnet, celestite, and barite. The non-metallic components are mainly represented by quartz, plagioclase, ferruginous carbonates, calcite, sericite, carbonaceous matter, and less commonly, spinel, epidote, pyroxene, and amphibole (Tsoi *et al.*, 2017).

Native gold is the main valuable mineral in the composition of ores. Occurs in the form of free grains, intergrowths with quartz, siderite, carbonaceous matter. Sizes of gold particles are not more than 0.5-0.8 mm. The shape of gold particles isometric, elongated, drop-shaped.

The composition of native gold and minerals found in intergrowths with gold was determined using local

X-ray spectral analysis. High grade native gold. The content of Au - 77-95.27%, Ag - 3.58-17.6%. In addition, Cu 0.07-0.48%, Fe 0.1-6.77% are noted as impurities.

The main productive is the pyrite-arsenopyrite with gold paragenetic mineral association. Sometimes gold is closely associated with ferruginous carbonates.

The Maisky site is characterized by the following:

The process of mineral formation was long, as evidenced by the finds of early chrome spinels, arsenopyrite and late stibnite, barite, celestite, which indicates the prospects of this ore occurrence.

Elevated contents of Ba, W, As, Au, Ti and locally Cu, Pb, Ni, Cr also indicate the duration of the mineral formation process, including early stages (W, As, Au, Ti, Ni, Cr), medium (Cu, Pb) and later (Ba).

CONCLUSION

Gold is the main valuable component in all studied gold ore objects of Northern Tamdytau. High contents of silver and tungsten have been established as associated components.

The mineral form of gold is native gold. It occurs in association mainly with pyrite, arsenopyrite, and quartz. The process of mineral formation was long, as evidenced by the finds of early chromespinels, scheelite, arsenopyrite and late stibnite, barite, celestite, which indicates the prospects of this ore occurrence. The geochemical features of gold mineralization also indicate the duration of the mineral formation process, since a set of elements characteristic of the early to late stages of hydrothermal mineralization has been established in the studied gold objects.

Thus, the gold ore objects of Northern Tamdytau have a similar mineral composition covering the time interval from the early sulfide stage to the carbonate-fluoride stage. The presence of late minerals antimonite, barite, celestine indicates the upper ore cut of the studied objects and its prospects for depth.

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