Gold-containing mineral associations in copper-pyritic deposits in the Lesser Caucasus (Azerbaijan territory)

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Abstract: In this paper there have been considered gold-containing mineral associations of copper-pyritic deposits in the Lesser Caucasus (case study of the Gyzylbulag field). Detailed studies of the mineral composition and texture-structural peculiarities of this deposit, enabled the authors to identify the following mineral associations in the studied field: quartz-pyritic, quartz-pyritic-chalcopyritic, quartz-chalcopyritic, chalcopyritic-sphaleritic and quartz-carbonaceous one. There has been determined that the above mentioned mineral associations contain gold but the commercial gold potential is determined in two stages of mineralization: quartz-chalcopyritic and partially quartz-pyritic-chalcopyritic stages. However, the gold in some mineral associations differs in form and size of its seepage as well as by its content in different types of ores. The results of investigations demonstrate that in ores of the Gyzylbulag field, gold exit in two generation: 1- The gold of the first generation is linked with the early mineral association (quartz-pyrite). 2– The gold of the second generation shows linkage with the late mineral association (quartz-pyrite-chalcopyrite and quartz-chalcopyrite).
[Gamet Guseinov. **Gold-containing mineral associations in copper-pyritic deposits in the Lesser Caucasus (Azerbaijan territory).** *J Am Sci* 2012;8(12):1077-1081]. (ISSN: 1545-1003). http://www.jofamericanscience.org. 144

Keywords: Gold mineral, Copper-pyritic, Azerbaijan territory

Introduction

As it is known, within the Lesser Caucasus and especially in its northeast part, there have been located a number of pyritic and copper-pyritic fields and ore seepages. Different investigators in their time thoroughly studied the mineralogical composition, texture-structural peculiarities of ores and stages of mineralization in the studied region. However, specific features of the gold-containing mineral associations of the copper-pyritic ores have not been presented in the literature well enough. At the same time, detailed studies of the gold particles which are in close concretion with sulfide minerals, are of interest in the purpose of the improvement of the technology of gold recovery. Taking into account that in the northeast part of the Lesser Caucasus there exist a number of gold-containing pyritic and copper-pyritic-fields, the urgency of the problem becomes obvious. With account of the above mentioned we have studied the gold-containing mineral associations of the copper-pyritic ores in the Lesser Caucasus following the case study of the Gyzylbulag field on the base of rich factual data gathered by the author during the exploration works in the field.

Method of investigation

To study the gold potential and character of the distribution of gold in different mineral associations of the Gyzylbulag field, we used the results of laboratory chemical analyses of samples. We also used special collection of polished specimens and mounted polished specimens made of monomineral fractions of basic sulfide minerals (pyrite, chalcopyrite and sphalerite). All the mineralogical and analytical investigations were conducted in the laboratory of the Central Scientific-Research Institute of Geology of the Russian Federation (CSRIGRF).

Geology

The Gyzylbulag field is located in the zone of conjugation of the Agdam and Garabakh anticlinoria and it is related to the Drombone volcanic-domed structure representing itself the eroded stratovolcano. The geological structure is composed mainly of lava-pyroclastic deposits of the Bathonian age of andesite-basalt composition and less of dacite-rhyodacite composition.

The deep Gyzylbulag fault with submeridional strike is the main ore-controlling structure of the field. The ore deposit has a form of the concave lens and it is located among the hydrothermally modified sulfidized lavas of dacite-rhyodacites which are replaced by propylitized andesibasalts and andesites in the lower horizons (Fig. 1). Copper-pyritic ores in the studied deposits formed due to the differentiated natrium sulphur of the basaltoid volcanism went through a long and complex evolution of their formation and repeated transformation during the multistage hydrothermal-metasomatic process and further metamorphism and regeneration of ores. For this reason the ores are characterized by complex texture-structural correlations of the composing mineral aggregates,

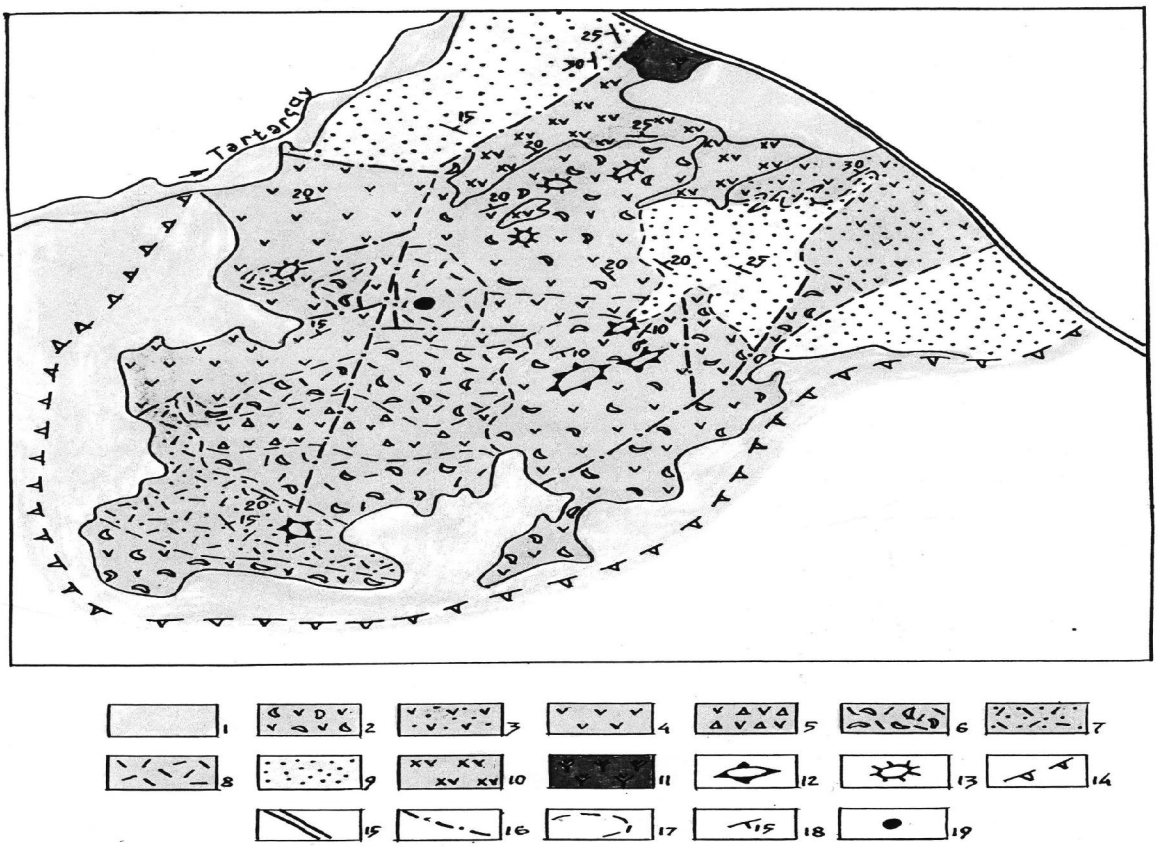

Fig. 1. Schematic geological map of Gyzylbulag field.
1 – Quaternary deposits, 2 - agglomerate and blocky tuffs, 3 - microfragmental tuffs 4 - lavas, 5 – lava-breccia; volcanic formations of dacite-rhyolite-dacite composition, 6 - agglomerate and blocky tuffs, 7 - microfragmental tuffs, 8 - lavas; 9 - volcanomictous sandstones, 10 - subvolcanic intrusive of diorite-porphyrites; 11 - subvolcanic intrusive of rhyo- porphyries, Bathonian volcanoes eruption roots, 12 – extrusive formation, 13 - vent breccia, 14 - supposed boundary of Drombon volcanic-dome structure, 15 - deep boundary fault, 16 - other faults, 17 - facies boundaries, 18 - elements of bedding, 19 - Gyzylbulag field.

some mineral associations and generations of main ore-forming minerals. It is also characterized by a complex character of the distribution of gold in the ore body. The copper-pyritic deposits within the fields are represented mainly by the massive bodies as well as by impregnated ores. The latter form linear ore zone extended in the near-meridional direction. The compact ore forms are the basic mass of the ore material, whereas the impregnated ore forms, according to their spread and amount of economic components play the subordinate role. Among the ore minerals pyrite, chalcopyrite and sphalerite are the main ones, and quartz, calcite and barite (in a low amount) are the gangue. Textures of the ores are mainly massive and impregnated, foliated and brecciated with veinlets. The structures are hypidiomorphic grained and very often with signs of a decay of solid solutions. Detailed studies of the mineral composition and texture-structural peculiarities of the copper-pyritic ores in the Gyzylbulag field enabled the authors to identify the following stages of the formation of minerals:

- quartz-pyritic mineral association
- quartz-pyritic-chalcopyritic mineral association
- quartz-chalcopyritic mineral association
- chalcopyritic-sphaleritic mineral association
- quartz-carbonaceous mineral association

According to the data of the testing and detailed observations during the microscopic examinations there has been determined that all the above mentioned mineral associations contain gold. But gold content and distribution of gold in every type of ores are different. At the same time the gold in different mineral associations dramatically differs

by the form and sizes of its seeps and by the interrelation with the surrounding minerals.

A) The quartz-pyritic mineral association

In the Gyzylbulag field the quartz-pyritic ores were the early formations. Pyrite is represented by isomorphic and bunch-like impregnations accompanied by chalcedony-like thin-porous quartz. The earliest thin-disperse gold is linked with the pyrite of this stage. To study gold potential of quartz-pyritic ores, there have been used results of the testing as well as polished specimens and mounted polished specimens made of monomineral fractions of pyrite. We could not manage to discover gold in pyrites of quartz-pyritic ores at the maximum magnification of 800 times (the examination was conducted in the mineralogical laboratory of the CSRIGRF). However, the monomineral fractions analyzed by atomic absorption methods, contained gold in amount of 0.01 to 1.6 g/t [3].

The results of investigations enabled us to suppose that the absence of microscopic visible inclusions of gold proves the existence of thin-disperse gold in the ores and its even distribution in the early pyrite. There also exists an oblique confirmation of the existence of gold in the above mentioned mineral association. There has been studied the correlation between the noble metals (Au) and sulphur and positive correlation (k.k.= 0.353 at Rkr=0.338) has been determined. Existence of the positive correlation between these elements may be considered as the evidence of simultaneous seep of the thin-disperse gold with the early generation of pyrite [4]. The results of investigations have been confirmed by the data of relevant literature. Some investigators proved that in pyritic deposits, gold is linked with the early generation of pyrite and it is situated in the crystal lattice of pyrite in a thin-disperse state. On the whole, the investigations enabled to get new objective data confirming the notion on the location of submicroscopic gold in sulfides in the form of unevenly distributed mechanical admixture. Results of the investigations could have practical importance for the development of new rational ways of recovery of disperse gold out of the quartz-pyrite concentrates.

B) The quartz-pyritic-chalcopyritic mineral association

The quartz-pyritic-chalcopyritic stages of mineralization are dependent to the zones of location of veinlet-impregnated ores. There occured new generation and deposition of pyrite of the first generation. Moreover, we can observe the event of regeneration, i.e. redeposition of pyrite of the first generation. Partly, gold was deposited in site of the first generation of pyrite. This association was formed at the second stage of ore formation, when the redeposition of gold turned out to be a leading process promoting the gold potential of the copper-pyritic ores. The previously formed quartz-pyritic ores which were crushed and recrystallized later, probably were the source of gold [1].

It should be emphasize that in quartz-pyritic-chalcopyritic ores the unbalance of gold distribution becomes higher with growth of copper content. There occurs violation of even distribution of the thin-disperse gold linked with the early pyrite in the quartz-pyritic ores. Probably, this is due to the occurrence of the thin-disperse gold and submicroscopic inclusions of silver-containing minerals, unevenly distributed in pyrite and chalcopyrite[4]. As a result of analytical investigations there has been determined that the quartz-pyritic-chalcopyritic mineral association was a relatively gold productive association. According to data of the laboratory analysis, in the ores there has been recorded higher amount of gold (3.8 g/t) as compared with the quartz-pyritic ones. Unlike the quartz-pyritic ores, at this stage of mineralization there occurred visible gold. Thus, in the mounted polished specimens made of the quartz-pyritic-chalcopyritic ores, we can observe different forms of its occurrence. Sizes of the gold particles vary 0.001 to 0.015 mm.

C) The quartz-chalcopyritic mineral association

The quartz-chalcopyritic mineral association is the gold-productive one. It is widely spread directly near the supposed ore-feeding channels in the form of stockwork consisting of chalcopyritic veinlets with jasper-like quartz. It is superimposed on the previously formed pyritic ores after the multy-stage crushing, foliation and metamorphism of ores. In the ores, the role of pyrite becomes insignificant at account of the growth and sometimes at account of the prevalence of the quantitative importance of chalcopyrite [2]. In comparison with the above mentioned stages of mineralization, in the quartz-chalcopyritic ores there has been recorded the increased concentration of gold. According to the data of the laboratory analysis, in the quartz-chalcopyritic ores the average amount of gold is 9.1 g/t. It should be mentioned that in the quartz-chalcopyritic ores, there has been recorded the growth of the middle size particles of the native gold. This is probably due to the redeposition and coarsening of the early fine and thin-disperse gold of the quartz-pyritic association [1]. Compare to the above mentioned mineral associations, at this stage of mineralization there has been recorded the visible gold. Its sizes vary in a rather wide range (0.01 to

0.025 mm). The gold particles have various forms include rounded, incorrect, teatrop and irregular (Fig. 2). Alongside with the visible gold, in the quartz-chalcopyritic ores there also exists the submicroscopic gold. It was discovered by the atomic absorption analysis of the monomineral fractions of chalcopyrite (6.2 g/t according to 26 definitions).

The quartz-chalcopyritic mineral association is not linked with the formation of any new systems of fractures. It took place during weak repeated adjustment movements along the dislocations controlling the location of mineralization of the quartz-pyritic and quartz-pyritic-chalcopyritic stage. Probably, this is the reason why the above mentioned association with the visible gold manifests itself in the very same areas of mineralization of the previous two stages. In the mentioned ore, the gold is located mainly in chalcopyrite and in the concretion of chalcopyrite with quartz and in the concretion of chalcopyrite with pyrite. The gold which is in a close concretions with the above mentioned minerals is of interest both for the identification of the difference between the gold in the pyritic ores and the gold deposits in the gold containing formations and for the improvement of technology of gold recovery.

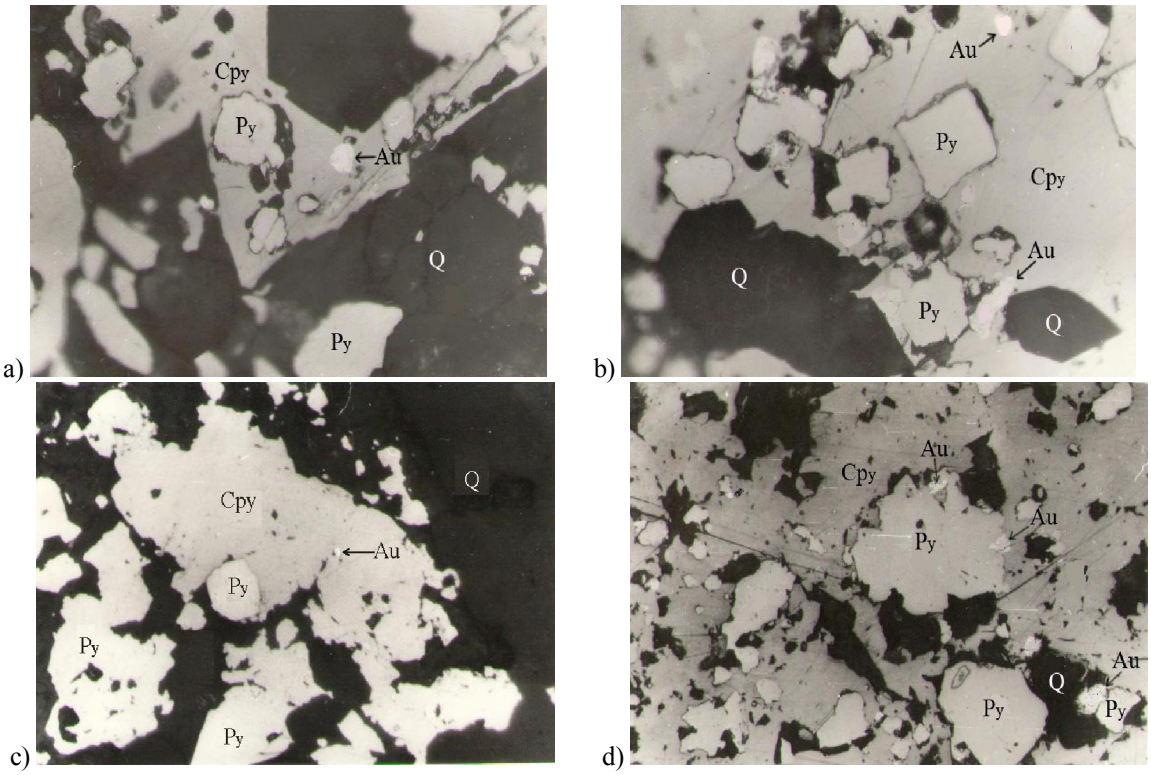

Fig. 2. Various forms of the gold. Anshlif × 250. a) rounded, b) incorrect, c) tea trop, d) irregular

D) The chalcopyritic-sphaleritic mineral association

Compare to the previous mineral associations, in the chalcopyritic-sphaleritic ores concentration of gold becomes lower and occurrence of silver in the ores becomes significantly higher. This demonstrates that alongside with silver which is among the ore composition of gold, there exist minerals of silver and silver-containing sulfides ore, galenite, tetradimite etc. Probably, the wide spread of the latter determines the silver potential of the sphaleritic association [4]. It should be mentioned that zones of disseminated chalcopyritic-sphaleritic ores occupy a transversal position as related to the zones of quartz-pyritic associations. They fix the weakest zones along the contacts of acid subvolcanic dykes or they use easily permeable areas in the zones of the foliation and crushing [5]. The gold-containing aggregates of sulfides, accompanied by high amounts of quartz, occurred in the zones of brecciation of the quartz-pyritic ores in the lower (725 m) horizons of the ore bodies. In these zones, accumulations of the early pyrite contain numerous cavities and fractures of the intraore leaching, healed by the coarsened crystals of pyrite, chalcopyrite and sphalerite. The native gold occurs in the form of finest inclusions in

chalcopyrite and in the form of recrystallized differences of pyrite. According to the data of the laboratory analysis, in the chalcopyrite-sphalerite ores there has been recorded high concentration of gold (5.9 g/t). Gold content of the monomineral fractions of sphalerite (2.8 g/t according to 13 definitions) determined by a method of the atomic absorption spectrometry, once again confirms the relation of gold mineralization with the late ore deposits in the field. Under the microscope we can observe different forms of gold seeps with the prevalence of irregular, angular and foliated forms. Sizes of the visible gold vary 0.01 to 0.03 mm. It should be mentioned that extent of gold potential of the above mentioned mineral association, its mineral composition and terms of the localization in the ore bodies, make it closer to the manifestations of gold-containing polymetallic mineralization.

E) The quartz-carbonaceous mineral association

Process of hydrothermal formation of minerals ends in the deposition of the quartz-carbonaceous stage. They are widely spread and possess distinct features of the superimposed, late character of the mineralization. There has been determined the transversal character of calcite veinlets. In the zones of dislocations represented by stripes of breccias, minerals of the quartz-carbonaceous stage cement and sometimes replace fragments of previously pyritized diabases. In most cases in the quartz-carbonaceous cement of such breccias, there exist a low amount of sulfides. The main mass of the gold-containing late pyrite of this stage is linked with systems of fine quartz-carbonaceous veinlets, subparallel to the basic dislocation. Thus, it is quite obvious that the gold has been seeping in ores of the Gyzylbulag field for a long time and repeatedly, starting from the formation of the earliest pyrites of the quartz-pyritic ores and participating in the deposition of late productive associations.

Conclusion

In the ores of Gyzylbulag field there have been identified the following mineral associations:

- quartz-pyritic
- quartz-pyritic-chalcopyritic
- quartz-chalcopyritic
- chalcopyritic-sphaleritic
- quartz-carbonaceous

All the above mentioned mineral associations are gold-containing ones. The commercial gold potential is determined by two stages of mineralization:

- quartz-chalcopyritic
- partially quartz-pyritic-chalcopyritic

However, the results demonstrated that gold of mineral complexes in different age, dramatically differs by its forms and sized and by the interrelation with the surrounding minerals. The results of investigations enable us to suppose that in ores of the Gyzylbulag field gold exist in two generation:

- The gold of the first generation is linked with the early mineral association (quartz-pyrite).
- The gold of the second generation shows linkage with the late mineral association (quartz-pyrite-chalcopyrite and quartz-chalcopyrite).

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8/12/2012