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GRAPHITE-BEARING ROCKS – NEW SOURCES OF PRECIOUS METALS OF RUSSIA AND CHINA

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Abstract: Experimental results on gold extraction by the hydrometallurgy and metal electrodeposition methods from the cap rocks of the Pavlovskoe deposit (south of the Russian Far East) are presented in the article. The suggested principles of the mineral raw material processing will assist in fast developing of gold potential of the coal deposits in Russia as well as in other countries of the world.

1. Introduction

Many researchers assign the high-carbon stratified metamorphic rocks to one of the main sources of growth of the reserves of gold and platinum group metals in Russia and China in the XXI century. Among these objects is the regional graphitization zone in the North Khanka terrane elongated along the Russian Federation and China People's Republic boundary as a submeridional band more than 100 km long and 3 to 5 km wide. The largest deposits of this area are the Tamginskoe (center) and Turgenevskoe (south flank) deposits where the stone material has been sampled for investigations.

2. New sources

Biotite-feldspar-graphite, garnet-biotite-feldspar-graphite, and biotite-muscovite-feldspar shales alternated with graphite-bearing garnet-diopside skarns and conformable injections of the graphitized biotite and leucocratic granite-gneisses participate in the geological structure of these deposits. Along with these rocks, small stocks of the late rare-earth granites as well as thin quartz veins and veinlets are also found. The most significant economical gold concentrations (3-22 g/t) are related with the endogenous carbonization, skarns, and quartz hydrothermalites.

Ore mineralization associated with graphite shows rather complicated polymineral composition and diverse forms of precious metal occurrence – native elements, solid solutions, and intermetallic compounds. Free gold occurs as particles of an irregular form, laminated segregations, and not rare gold flakes of spheroidal contour. The range of the granulometric scale, comprising the visible gold classes, is not large (70-100 mkm). Chemical composition of the metal varies within comparatively narrow limits: content of the main admixture – Ag usually does not exceed 6-8 mass % testifying to the gold high fineness. Among other microelements, copper is found in amounts of 2-3 mass %. In the gold flake, containing microinclusions of carbonaceous matter, concentrations of Au varies from 93.3 to 97.9 mass % and Ag – from 2.1 to 3.5 mass %. In other survey sites of the same particle, Ag is absent, and Cu is 2.1 mass %. In addition, the sites with 100 % Au content were found. Non-uniformity of gold composition within a single grain is, probably, a result of its crystallization from a gas phase.

Segregations of the natural mercuric gold with Au concentrations of 90.88 at. % and Hg – 9.12 at. % are rather widespread. The segregations are about 1-2 mkm in size. Some researchers believe the Hg-bearing mineralization to be related with deep-seated fluid flows. Sometimes, the micron

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segregations of Au-Cu intermetallic compounds are found. The composition of these phases (Au – 65.9 at. % and Cu – 34.1 at. %) is close to the formula of cuproauride - $CuAu_3$.

Rare findings are small grains of intermetallids of gold, silver, palladium, and tin revealed through the graphite ore thermal oxidation. Their chemical composition (without matrix background) is (mass %): Au – 24.5; Ag – 10.53; Pd – 58.1; Sn – 6.87.

In morphology, granulometry, and chemical composition free gold of skarns markedly differs from its analogues from graphite-bearing veinlets. Skarn gold has predominantly clod-spongy forms. Grain sizes reach 1.0 mm. Their chemistry changes essentially – Ag share increases to 10 mass %, and, correspondingly, Au concentration decreases.

On the surface of skarn gold flakes there have been found the carbonaceous micro-nano-structures. Predominating role in their crystallization is played by the film of nano-sized thickness (100-200 nm) that in addition to C(56-60 mass %) and O (19-33 mass %) contains the admixtures of S, K, Ca, Cl, Al, and Fe up to 1-2 mass %. Transformation of carbonaceous film through skarn formation resulted in the appearance of the pipe-like individuals on its surface. Very likely, it is one of the first verification of the presence of the carbonaceous nano-pipes in natural compounds. The nano-material composition at the basement of an individual is close to nano-film, and with distance from the mineral matrix it becomes essentially carbonaceous (about 90 mass %) with an insignificant admixture of oxygen (not more than 10 mass %) that can be considered the illustration of the process of the deep-seated fluid heterogenization for the carbon matter and graphite.

In quartz veins, a low-grade variety of gold – electrum is widespread. The sizes of most of grains usually do not exceed 100 mkm, reaching rarely 1.0 mm. The shape of their segregations is clod-like or tabular. Electrum composition is characterized by the presence of 33 to 34 mass % Ag and 2 mass % Cu. Quite unusual is the constant presence in its composition of high concentrations of Fe (about 34 mass %). Presence of about 3.7 mass % U and 1.26 mass % W is rarely marked.

On the surface of the electrum grains, the isolated magnetite grains and the carbonaceous film fragments are fixed. The fragments' sizes reach 5-6 mkm with a thickness of 100-200 nm. The element composition of the film nano-material differs from their skarn analogues in a higher level of accumulation of Si (7.2 mass %) and Al (4 mass %).

3. Conclusion

Investigations of regularities of gold and carbon distribution and forms of their segregation allowed the recognition of several stages of the formation of polygenic precious-metal mineralization. At the first stage, the graphite ores related with the long-term functioning of the mantle center and intrusive magmatism manifestation are developed. Free gold and carbon of the mantle were transported by dry reduced fluids to the surface. Ore matter was deposited in the reducing medium that is evidenced by a wide set of native elements and intermetallids.

At the second - skan stage the ore matter was crystallized with the formation of new microparageneses of gold, often with the carbon matter participation. Gold often served a base for the carbon nano-pipe formation.

The third - the latest hydrothermal stage is related with the participation of hydrothermal solutions in the emplacement of gold-quartz veins produced by the rare-earth granitoids that essentially influenced the composition of native gold in which the admixtures of W, F, and U appeared.

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