Dissolution and Redistribution Mechanisms of Gold inside the Tailings (Mine Dumps) and their applied Significance

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Abstract

The article presents the forming processes of technogenic and mineral formations (TMFs) – technogenesis and subsequent transformation of the composition and structure of TMFs – technogeogenesis. The authors studied technogeogenesis on the example of gold-bearing technogenic placers. The processes of TMFs conversion lead to the release, transfer, and accumulation of gold-bearing phases inside man-made dumps. Management of the processes of technogeogenesis leads to the creation of nature-like production technologies. Directions on the management of the formation of gold concentrations in TMFs were allocated. Experiments on the accumulation of gold on geochemical barriers were carried out.

Keywords: tailings, tecnogenesis, tecnogeogenesis, gold, accumulation, nature-like technologies, technogenic-mineral formations (TMFs).

Introduction

The present stage of civilization development is characterized by the fact that Humanity is beginning to understand and accept the limitations of its capabilities, the need to change behavior when using the bowels of the Earth. For the first time, this understanding in terms of quantitative indicators and development models was presented in 1972 in a report to the Rome Club "Limits to Growth". Subsequent monitoring of data confirms the general trends of civilization.

Guide for the development of monomineral deposits remains at the present stage. Often, the main mineral is mined in the most accessible form of its location. Solid phases of minerals are preferred. We leave the future integrated development of resources to our descendants, storing by-products in dumps. Consequence of partial extraction of useful components brought environmental problems that arose at the place of mining. The problems are created precisely by those components, the extraction and use of which would bring an essential plus to the economics of field development.

The modern approach of geologists to the multipurpose development of the deposits and the reduction of environmental loads is implemented by the idea of TMFs re-developing. The solution of this problem is possible taking into account modern ideas about the TMFs as products of human geological activity. With this approach to the TMFs, we do not have the right to identify them with production waste. They should be considered as *an intermediate product, technological reserve of the deposit*, suitable for the further usage.

Methods

The structure and content of the TMFs have regular character of the substance distribution in accordance with the system for the formation of technogenic sediments (technogenesis). On the example of gold, we have traced the distribution of its particles that were not extracted for various reasons in the enrichment process; studied the patterns of behavior of gold particles on man-made objects with a wide geography (Ural, Siberia, Yakutia, the Far East, Canada (Yukon Territory, Klondike)) (Kovlekov, 2002; Makarov, 2001; Mirzehanova, Mirzehanov, Debelaya, 2014; Naumov, 1994; Naumov, 2010; Perepelitsyin, Ryitvin, Koroteev, 2013; Naumov, LeBarge, Kovin, 2013).

Technogeogenesis, or processes of

transformation of the gold mineral phases in the composition of the TMFs is considered in detail by analyzing the series: Au - Hg - Cu; Au - Pt (Fe), Au - Pb. Gold technogeogenesis in technogenic formations (dissolution, transfer, accumulation) leads to mobilization and sedimentation, enlargement of gold particles (agglomeration, new formation, sticking of gold particles into a common aggregate) during the interaction of different gold particles (Au - Au).

Management of the formation of gold concentrations in industrial conditions was realized in the development and implementation of modular technologies in one of the placers of the Urals. According to the project Federal Program of the Ministry of Education and Science of the Russian Federation, 6% or 9.24 kg of chemically pure gold was additionally obtained for placers. Analysis of the finding gold forms in the sludge storages of gold ore facilities in the Urals and leaching dumps of the Muruntau deposit (Uzbekistan), facilities of the Yenisei ridge, Yakutia and Canada made it possible to prepare recommendations for increasing the degree of gold extraction in enterprises.

Gold is widely distributed in nature in different sediments, state of aggregation, different forms of finding. **In the solid phase**: free, bound in minerals, in intergrowths, "film" and sorbed on minerals. **In solutions**: mine and underwater waters, brines, oils. **In gases and sublimates**, it is often not seen, forms of finding are not know, therefore they are not removed. Technology of investigation and extraction is aimed on extracting of certain forms of gold finding. It does not take into account other forms. In mining gold (other forms of finding) comes into man-made dumps or man-made mineral formations (TMFs). The best studied is solid phase: free, bound in minerals, in intergrowths, "film" and sorbed on minerals.

The authors study the applied aspect of the physicochemical differentiation of gold within the framework of an international research group with Italian colleagues. The theoretical foundations of the mechanisms of dissolution and re-precipitation of gold have been developed. Gold is dissolved by cyanides of Na or K, acidic solutions of thiourea and chlorine water, humic and fulvic acids, aqueous solutions of $FeCl_2$, Cu_SO_4, NaCl, HCl, H_2SO_4, etc. Gold transfer occurs by ore, waste and subsoil waters. Gold deposition takes place on geochemical barriers.

The experiments on gold accumulation at a number of geochemical barriers were carried out: 1) carbonate (Naumov, 1994) for acidic waters; the restoration of dissolved phases to clastogenic particles of native gold on the carbonate barrier in a concrete settling tank (Ural, Isovskiy mine) was established; 2) electrochemical (Naumov, 1994) on a metal grid; sedimentation of gold from technogenic waters on a copper wire by natural electrolysis was proved (the Urals, the Isov mine); 3) carbon (Naumov V.A., Osovetskiy, 2010), the results of experiments were obtained, allowing to confirm the direction of the process of gold sorption, the mechanisms of its accumulation and the distribution of nanogold particles on the coal surface.

On the territory of Northern Italy and the Urals, the selected man-made model objects were used to study the composition and zonality of man-made and mine waters. One of the objects is a preserved skarn iron ore deposit with the presence of zones of arsenopyrite mineralization, located in the Southern Alps. Another is the dumps of the polymetallic object of the Eastern Urals. Samples of waste, bottom-waste and mine waters were taken in order to determine the magnitude of gold mineralization. Experiments on the formation of artificial carbonaceous barriers in the form of capsule modules are planned.

Main results

Among the geological processes associated with the TMFs are distinguished: 1) the processes of formation of the TMFs, or actually **technogenesis**; 2) geological processes of transformation of the composition and structure, occurring in the TMFs - **technogeogenesis**. Taking into account that the processes of technogenesis and technogeogenesis are manageable (depend on human activity), it is also possible to distinguish 3) the processes of **technogenic ore genesis** - the perceived formation of given characteristics of the structure and directions

of change in the composition of the TMFs (Naumov, 2010; Naumov, Naumova 1997). Technogenic ore genesis has an applied value and is based on knowledge of the processes of technogenesis and technogeogenesis.

Technogenesis or formation of the TMFs occurs as a result of processes of *mechanical differentiation and integration*. The laws of distribution of substance and useful components in the dumps do not depend on the composition of the natural material (loose sediment deposits or crushing products of primary ores). At the same time, technogenic facies of three types are formed: alluvial, dump (bulk) and waste-alluvial (Naumov, 1994). Under the technogenic facies is accepted - the product of accumulation of the TMFs, formed during the technical activities of man in the process of deposits development.

Technogeogenesis appears in the processes of mineral new formations, the transformation of matter and useful components under the influence of internal and external factors of the geological environment. As a geological exogenous process - technogeogenesis is distinguished by the presence of destruction of rocks and mineral phases in the TMFs; transportation of material and transport of chemical elements in dissolved form; accumulation and formation of new mineral and petrographic differences.

The appearance of technogeogenesis in dumps is due to mechanical, physicochemical and biochemical differentiation and integration of the substance, including useful components. Here the role of surface, waste, ore, substernal, industrial waters developed within the limits of the TMFs is great. When saturated with useful components in the process of technogeogenesis, they can be considered as hydromineral raw materials of practical importance. Such waters are formed in the the TMFs formed during the mining of sulphide deposits containing copper, iron, arsenic, mercury, gold, silver, etc.

The concept of "technogenic ore genesis" represents the geological process of the creation by nature or man of new ore objects from technogenic sediments, as a result of the processes of technogenesis and following technogeogenesis (Naumov, 2010).

Gold technogeogenesis in technogenic formations, including the processes of dissolution and destruction, transfer and accumulation, leads to the redistribution of the metal and the formation of concentration zones.

Managing the processes of technogeogenesis has the following main aims:

- accumulation of useful components for the purpose of their subsequent extraction (nature-like production technologies);
- creation of nature-like environmental protection systems.

Conclusions

The processes of technogeogenesis in gold-bearing technogenic-mineral formations lead to the formation of "**beneficiation plants in the subsoil**", where natural processes of redistribution of matter take place inside the technogenic objects. As a result of these processes, the release, dissolution, migration, regeneration and restoration (growth) of gold-bearing phases, including in the form of gravitationally recoverable gold, occurs.

Natural-like or technogenic processes of change in the geological environment are endogenous and exogenous geological processes activated by man. Today they appear everywhere as a new stage in the development of the noosphere, a technospheric stage. However, the study of these processes almost no attention. At the same time, these unconscious processes are controlled by us. The results of the geological activity of technogenic processes (the transformation of matter and space in technogenic formations that occur at the border of the interaction of litho-, bio-, hydro-, atmo- and sociosphere) are amazing. They lead to both negative and positive consequences for a person. Their controllability allows you to create cost-effective concentrations of useful components for mastering or use the laws of their transformation to produce substances with given characteristics of composition and properties. Mankind has launched the mechanisms of the "factories in the depths". The task is to learn how to manage and create the necessary products.

Some ways to control the processes of technogeogenesis and increasing the degree of gold extraction can be outlined:

1) amplification of the technogeogenesis processes (ensuring circulation of industrial waters; activation of decomposition of sulphides, etc.);
2) formation of mechanical and chemical barriers inside man-made structures for the accumulation of useful components;
3) design of construction sites for the placement of the technogenic formations, taking into account the introduction of technologies for the extraction of man-made gold.

In general, **the investigation of the genaration of technogenic-mineral formations** is of great theoretical and practical importance. The correct approach to the application of the TMFs allows one to develop a number of nature-like technologies that will be more *efficient and environmentally friendly* than the extensive way of developing new deposits.

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