On the problem of cognition of mineralogy and geochemistry of the landscape of mining territories

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Abstract. A methodology for studying the forms of finding chemical elements in the landscape of mining territories is given. The necessity of mineralogical and geochemical integration of methods is shown, the influence of the forms of occurrence of chemical elements in the landscape on the extent of their absorption by biota, in particular, the coefficient of biological absorption. The dependence of the forecast of the state of mining geosystems on the forms of presence of potentially hazardous chemical elements in them is determined.

The industrial revolution in the last two centuries has caused a sharp increase in the demand for mineral raw materials for the chemical and metallurgical industries, as well as energy. This led to the intensification of the mining activity of man. It was expressed in a multiple increase in the 19th century in the extraction of ferrous and non-ferrous metals, as well as bituminous and brown coal. Since the invention of internal combustion engines operating on both gasoline and diesel fuel, the demand for oil has sharply increased in the 20th century, and then, in the process of development of transport and fuel energy, natural gas.

From the second half of the XX century with the discovery of the possibility of using the phenomenon of radioactivity for energy purposes, the need arose for nuclear fuel. Since the middle of the 20th century, with the development of the aerospace complex and electronics, there has been a sharp increase in the consumption of rare and scattered chemical elements, and a significant part of noble metals also began to be consumed in these areas of human activity. The intensive development of the exploration industry has led to the discovery of a huge number of deposits of these types of raw materials and, accordingly, to a multiple increase in mining production. Without going into consideration of the volume of mining in the world, we will show this progress on the example of the Trans-Baikal Territory.

It is known that Transbaikalia is one of the historical territories where silver (1704), ore gold (1714), fluorite (1746), tin (1811), molybdenum (1915) were mined for the first time in our country, tungsten (1916), bismuth (1916), uranium (1946), one of the first jasper (1717) and aquamarine (1723). The first industrial production of lithium in Russia was also started at the Zavitinskoye deposit in Transbaikalia in the 1940s.

A sharp increase in the production of gold and silver-bearing polymetallic ores can be seen from the analysis of such figures. Most of them were open before 1788. Until 1905, they produced 1,174,214 tons of high-grade ore. Their reconnaissance to depth and on the flanks in 1926–1953 allowed to multiply the reserves of sulphide ores and revive their production. In Soviet times, the
Nerchinsk Polymetallic Combine, before its liquidation in 1993, produced 16 620 thousand tons of ore, which is almost 15 times higher than the production over the previous 200 years. In total, almost 18 million tons of ore were mined and processed. If we take into account that in the best case, the extraction was 85%, then more than 15 million tons were spent in the tailings. Currently, the dumps contain more than 15 million tons of mining waste containing iron, gold, silver, lead, zinc, arsenic, bismuth, cadmium, sulfur, tellurium, selenium, thallium. All of them, with the exception of iron, gold and silver, in certain concentrations pose a significant environmental hazard.

From the middle of the twentieth century. In Transbaikalia, the mining of tin, gold, tungsten, molybdenum, rare metals, uranium (Tulukuevskoe in the Streltsovsky ore region), coal, including germaniferous (Tigninsky opencast) and uranium-bearing (Urtuisky opencast) coal, is intensified. This leads to an abundance of quarries and reservoirs containing high concentrations of ore and other elements. The total number of mines and mines on the territory of Transbaikalia before the 1990s was approaching seventy. The vast majority of mining enterprises in 1993–1995 closed. The exception was made by enterprises that mined coal, uranium and gold, with the exception of its main carriers. The largest Baleisko-Tasveevskoe, Darasunskoe and Klyuchevskoe deposits, whose ore dressing dumps are subject to destruction under hypergenesis conditions, are not being developed.

The total mass of waste only from the development of ore deposits in the Trans-Baikal Territory as of 01.01. 1997 was about 850 million tons. They include 1 million 335 thousand tons of rich slag of the silver smelting plants of the Nerchinsk mining district. The average content of lead in them is in the range of 3.91–7.64%, zinc 1.03–7.59%, indium 0.002–0.02%, gallium 0.002–0.02%, silver 29.93–79, 92 g / t, gold 0.09–0.25 g / t. They also contain copper (0.1%), antimony (1.3%) and tin (0.1%). Waste from the development of all polymetallic deposits amounted to more than 15 million tons.

Taking into account the exploitation of deposits of brown and bituminous coals, fluorite, as well as rare metals (Li, Be, Ta, Nb and Sn) by the Zabaikalsky GOK, the total mass of displaced technogenic massifs is about 3 billion tons.

Therefore, one of the important tasks in the field of geocology has become the need for a comparative study of the mineralogical and geochemical specialization of ore deposits and their mining waste in order to determine the impact on the environment. Since 2005, INREC SB RAS (Laboratory of Geochemistry and Oreogenesis, Geocology and Hydrogeochemistry) and Transbaikal State University (Laboratory of Landscape Mineralogy and Geochemistry) have been studying the processes of concentration and migration of chemical elements in natural and geotechnogenic landscapes of mining regions of Transbaikalia.

In the literature on the impact of mining waste on the environment, ecologists, geographers, physicians and other specialists who do not have a geological education mainly use only information on the gross contents of certain chemical elements in mining waste. But the actual probability of assimilation of these concentrations by living organisms is not considered. Therefore, the concentrations and forms of occurrence of elements that can cause toxicosis remain unknown. Often in the literature, the phrase "heavy metals" is used for chemical elements such as arsenic, tellurium and selenium, which are not metals, or beryllium and lithium, which are the lightest of metals. Therefore, the relevance lies both in the need to understand the probability of the behavior of chemical elements in the landscape, and the correctness of the terminology and forecast of the impact of certain concentrations of chemical elements and their forms on the environment, humans and biota as a whole.

The purpose of this work is a methodology for studying the concentrations and forms of finding chemical elements in mining waste, certain concentrations of which can be toxicogens and have a negative impact on the environment.

The methodology is designed to understand the distribution of the contents of chemical elements that make up the substance of the landscape, and the forms of their presence in it, which determine the probability of migration and stability, ensuring the absence of a significant effect of their concentrations on the state of the environment.
The most important aspect of these studies was the study of the biogeochemical component for understanding the conditions, nature and amount of the capture of chemical elements by certain plant species. At the same time, it is necessary to know the phenological stages of plant development in typical weather and climatic conditions and geomorphological features of the landscape.

In general, the entire system of mineralogical and geochemical study of the landscape occurs in a chain: rock (ore body) → weathering crust (oxidation zone) → soil (upper layer of stale tailings) → plant (plant organs) → domestic animals → humans.

It has been established that all mineral deposits containing recoverable industrially important chemical elements, be it metals (copper, lead, zinc, tungsten, tin, bismuth, cadmium, silver, mercury, rhenium, etc.) or metalloids (arsenic, antimony, boron, tellurium, selenium, etc.) and non-metals (carbon, chlorine, fluorine, sulfur, etc.) are surrounded by geochemical anomalies and their deposits themselves also belong to geochemical anomalies.

Therefore, it is important to know which part of the territory of the mining complex belongs directly to the development zone of the geotechnogenic landscape, and which is a natural geochemical anomaly, where everything is in dynamic equilibrium. This is due to the fact that the probability of the transition of chemical elements into a migratory state is significantly higher due to the greater openness of the grains of mineral particles as a result of grinding mineral aggregates in the course of stripping operations or their preparation for processing at the processing plant. It is important to understand the vertical distribution of chemical elements. Therefore, for this, it is necessary to open the soil horizons and strata of technogenic overburden rocks and tailing dumps, draw up sections and test them taking into account the vertical distribution of visually identifiable layers according to the change in color and granulometric composition.

Due to the periodic movement of the slurry pipe mouth of the concentrator, the distribution of tailings is lateral. This is associated with a change in the distribution of chemical elements, which determines the preferential distribution of various chemical elements, including their toxic concentrations, in the volume of the tailing dump. Therefore, it is advisable to test tailings and areas of natural geochemical anomalies along profiles that cut all landscape facies and zones of distribution of mining waste.

The most important task is to study the forms of finding chemical elements in the landscape, which determine the likelihood of their migration and capture by plants and other biota.

The most important indicator of the likelihood of a plant extracting a particular chemical element, as you know, is the biological absorption coefficient (BAC). It was determined that the BAC of arsenic [1, 2], bismuth [3], zinc and cadmium, lead [4], cerium [5] is insignificant and a significant part of these elements is inaccessible to the root system of plants. It was also found that, in most cases, the content of the element and its BAC is maximal for the roots of plants and their leaves, where photosynthesis takes place. It is significantly less in stems that play the role of transport and is minimal in seeds, possessing protective barriers to maintain the purity of the plant species. Identified barrier and barrier-free plant species with respect to the absorption of certain chemical elements.

Identified barrier and barrier-free plant species with respect to the absorption of certain chemical elements. Determination of these properties of plants is extremely important for understanding and predicting the infection of plants with potentially dangerous for the life of herbivores and humans. Therefore, the most important condition for predicting the probable contamination of plants with potentially toxic elements is to determine the forms of their presence in soils and in the upper parts of technogenic massifs.

Among the forms of finding chemical elements in soils, technosoils and stale tailings, according to the methods developed by soil scientists, the following fractions should be determined: water-soluble, exchangeable cations, specifically sorbed cations associated with organic matter associated with ferrous minerals (iron hydroxides, as well as manganese, which are sorbents many metals) and residual, firmly fixed in the crystal structure of aluminosilicates.

The most important is to determine the proportion of water-soluble forms of chemical elements, which include sulfate, chloride, nitrate, and soluble in organic acids. In most of the cases studied, the
water-soluble forms themselves make up no more than 5% of the total content of chemical elements. Acid-soluble and ion-exchange forms in total reach values up to 10%. Iron and manganese hydroxides are also relatively stable and amount to 1.5–10%. The most resistant to the influence of plant root systems are residual forms, the proportion of which is mainly in the range of 50–70% [2]. The most resistant to the influence of plant root systems are silicates, arsenates and some sulfides and oxides. For example, the bulk of arsenic in soils is in the form of the perfectly stable mineral scorodite, lead, arsenic and chlorine in mimetite, while zinc can be in the form of calamine silicate (hemimorphite). Therefore, to predict the likely proportion of chemical elements capable of migration, it is necessary to conduct a mineralogical analysis of soils, technosols and stale tailings. At the same time, the most likely occurrence of water-soluble sulfate forms of zinc, cadmium, copper, iron, part of manganese is always pyrite and, to a lesser extent, chalcopyrite, sphalerite and bornite. These minerals themselves, in the presence of oxygen and water, are capable of being sources of sulfate anion, which facilitates the dissolution of not only other sulfides, but also silicates.

Conclusions

1. To reliably determine the ecological state of the landscapes of mining areas, it is necessary to know the relationship between natural and geotechnogenic geochemical anomalies.

2. Assessment and forecast of the impact of these geochemical anomalies is impossible without knowing not only the concentrations and distribution of chemical elements in space, but also the mineral and other forms of their occurrence, which determine the extent of their impact on the landscape.

3. The methodology for determining the forms of finding chemical elements that give toxic concentrations includes a mandatory mineralogical and geochemical study of soils of natural geochemical anomalies and geotechnogenic massifs as components of integral geosystems of mining areas.

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