Application of X-ray absorption method to estimate the sorting of silver-bearing ore

INTRODUCTION

Silver is the second most popular metal after gold. According to experts, the total amount of proven reserves of this precious metal in the world now reaches 600 thousand tons. Every year about 20-22 thousand tons of silver are mined in the world.

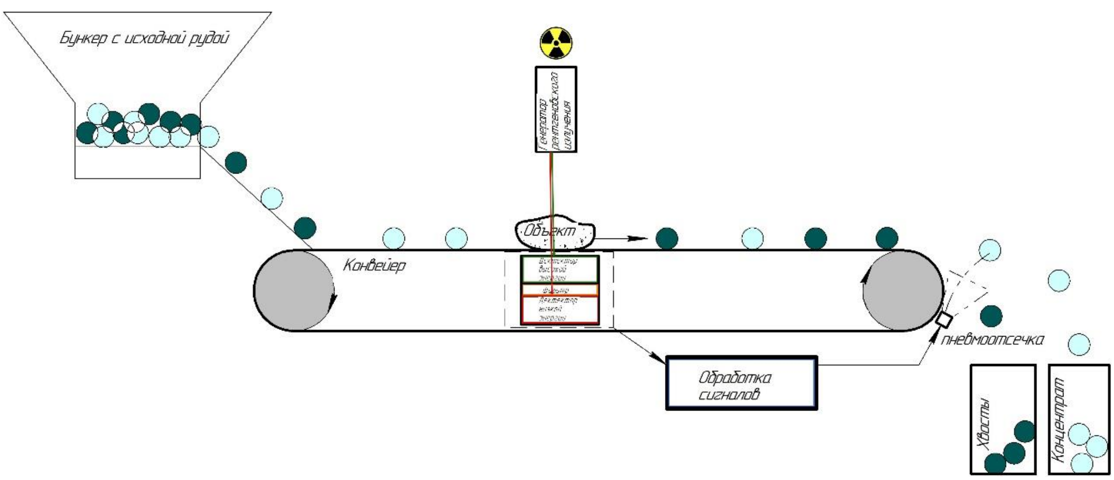
Back in the 19th century, all silver mining was concentrated in South American countries. And now this continent retains the leading position in the world market of "white" gold.

The largest reserves are in Poland and Peru - in these countries there are about 110 thousand tons of the precious metal. However, Mexican mining companies are ahead of the world in terms of production volumes.

METHODS AND PRINCIPLES

The search for an effective method of raw mineral concentration is an important strategic task for the development of mining companies. A special place among the methods used for preconcentration is occupied by a group of information methods. Among them the most widespread are X-ray absorption for primary concentration of mineral ores. For this purpose X-ray absorption separation or X-Ray Transmission method (XRT method) is used with high efficiency.

This method does not require special preparation of raw materials in the form of washing operations and cleaning the surface of rocks from dirt, dust, sludge films. X-ray absorption method is a penetrating method, and allows to recognize hidden mineralization in the rock.



General principle of operation of the X-ray absorption sorting

In general, the principle of operation of the X-ray absorption method can be presented as follows: the higher the atomic number of the elements that make up minerals and rocks, the smaller the number of X-rays will pass through this material. The amount of attenuation of X-ray intensity by the material depends on the atomic number of the object substance, the thickness of the piece and the energy of X-ray quanta.

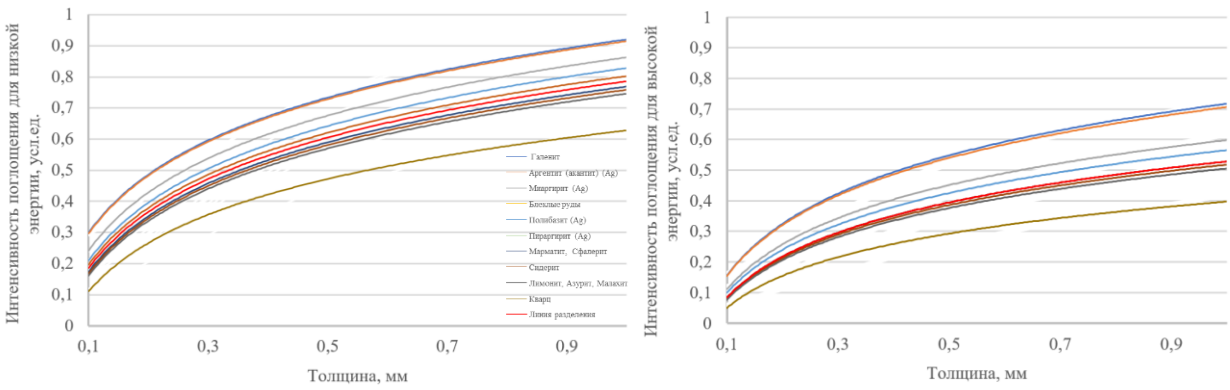
STUDY

Bourevestnik carried out works on assessment of enrichment of silver-bearing ores of Obokha deposit by X-ray absorption method. According to the results of the research, high efficiency of the developed MD separation feature was established.

The principle of registration and estimation at X-ray absorption analysis consists in that the passed X-ray radiation through pieces of minerals and rocks on a scintillation detector is registered. The detector converts the energy of the X-rays that have passed through the pieces of ore into current pulses, which are amplified and recorded by a recording system. The obtained results are digitized, converted into graphic form in the form of raster graphic images and processed by the software of the automated control system according to a special algorithm developed in Bourevestnik. Then they are compared with the values of the specified separation threshold, after which the ratio of the area of the useful component to the total area of the piece of ore in the X-ray image was analyzed and calculated. In the study, the components sought are argentite (acanthite), pyrargyrite, miargyrite, stephanite, prustite, polybasite and faint ores, as well as galena and cerussite, since lead minerals contain isomorphic silver impurities.

RESULTS AND DISCUSSIONS

At the first stage the theoretical calculation of X-ray absorption intensity for each mineral from Table 2 at dual-energy detection was carried out, as well as to obtain a comparative characterization of the contrast of useful components in relation to the host rocks (Fig. below), which is calculated as the ratio of X-ray absorption intensities of the useful product to the host rock.



Theoretical calculations of X-ray absorption intensity by minerals of silver-bearing ore

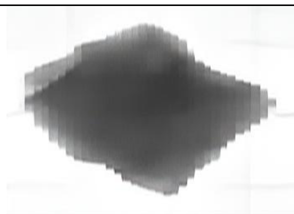
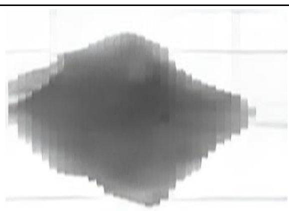
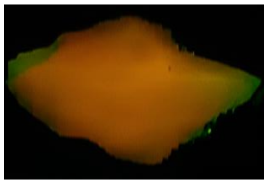
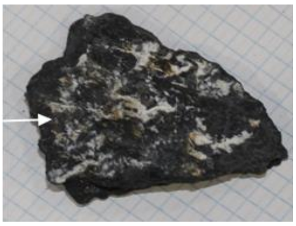
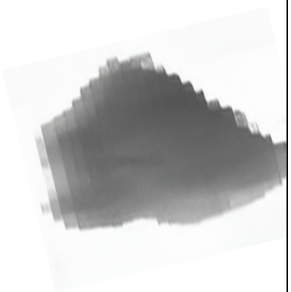
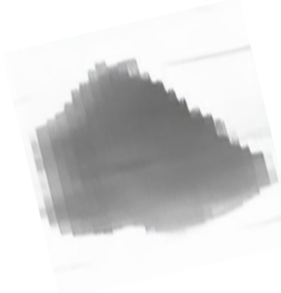
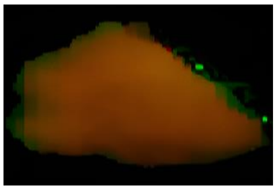
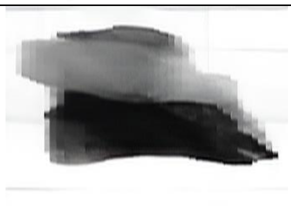
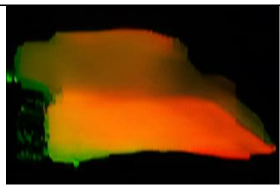
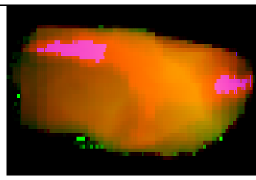
The calculation results showed the division of silver-bearing ore minerals into two groups:

- The first group including the main useful components: argentite (acanthite), polybasite, pyrargyrite, as well as galena, cerussite and faint ores.
- The second group including host rocks: quartz, muscovite, marmatite, sphalerite, siderite, limonite, azurite, malachite.

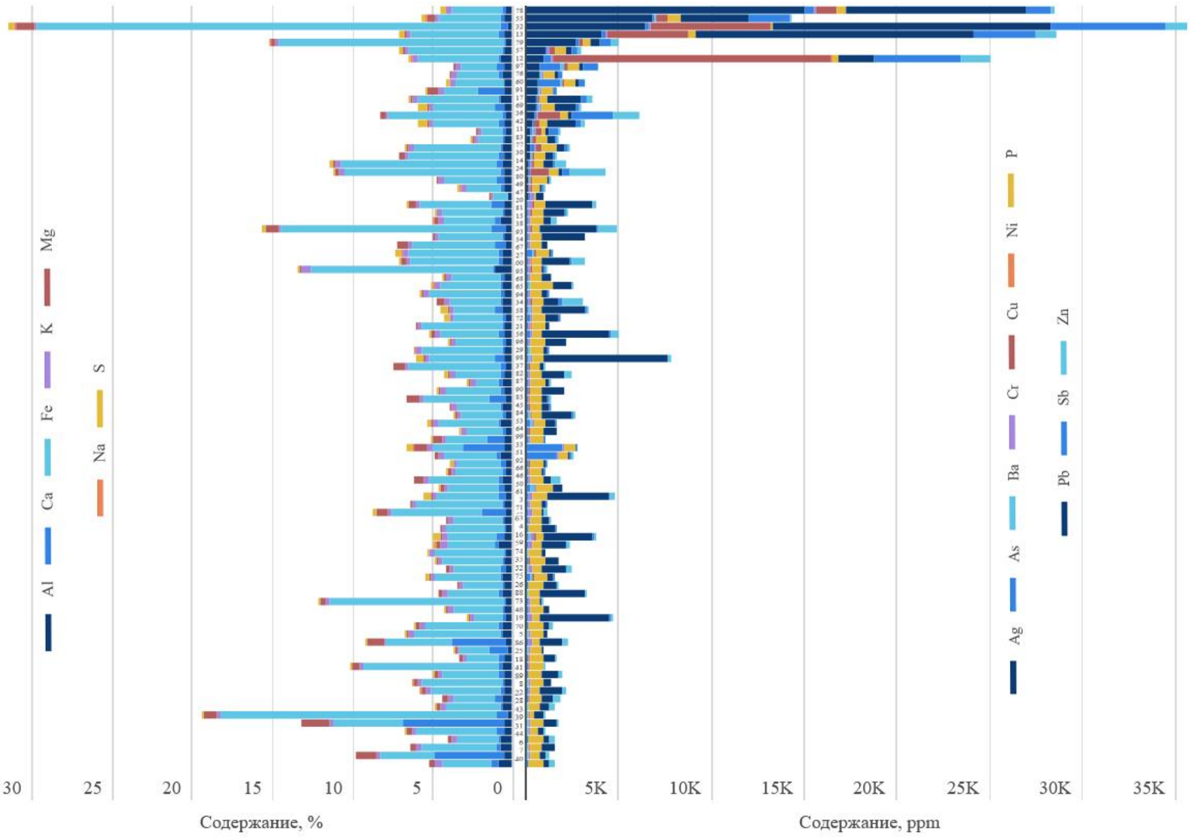
Thus, the theoretical estimation of the sign of separation by the degree of difference of minerals of the main component - the first group - in relation to minerals of the host rock - the second group - at two-energy system of registration of the passed X-ray radiation through pieces of silver-bearing ore was received. The results have shown that at two-energy system of registration the minimum value of contrast at low and high energy, 24% and 15% respectively, is revealed at polybasite and pyrargyrite in relation to marmatite and sphalerite.

In order to develop the separation feature at the first stage of work, namely qualitative and quantitative separation of silver-bearing ore by the ratio of areas of the useful product and the host rock, representative pieces of ore were selected, on the surface of which there are various mineral differences, which were analyzed by the separation feature apparatus. The samples with the highest (samples No. 9 and No. 23 with sulfide minerals on the surface of the piece) and the lowest absorption capacity (samples No. 1 and No. 2, represented with typical host rock) were selected. Using these samples, using the methodology and algorithm developed in Bourevestnik, separation features were developed for the MD algorithm, which allows to identify inclusions of complex sulfide (sulfosol) minerals in the host rock. Further, X-ray images of representative samples of silver-bearing ore with different content of X-ray dense particles were obtained (Table below):
No. 1- 1,22%, No. 2- 0,82%, No. 3- 40,90%, No. 23- 44,22%.

Table - Photographs and X-rays of representative samples of silver-bearing ore from the Obokha deposit

No sample	Photo of samples	Radiographic image		Processing result
		on a channel of low energy	on a channel of high energy	
1				
2				
9				
23				

In order to quantitatively analyze the main chemical elements, 94 samples of silver-bearing ore were measured by inductively coupled plasma atomic emission spectrometry (AES), which revealed 24.4% of samples with high silver content (more than 100 ppm). The results are presented in the figure below.

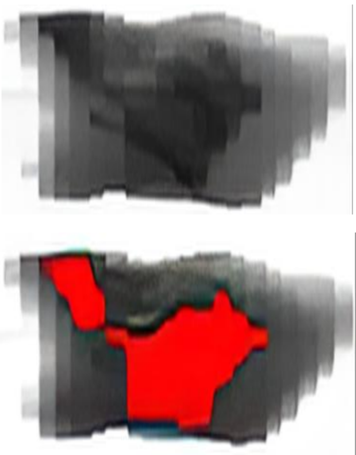
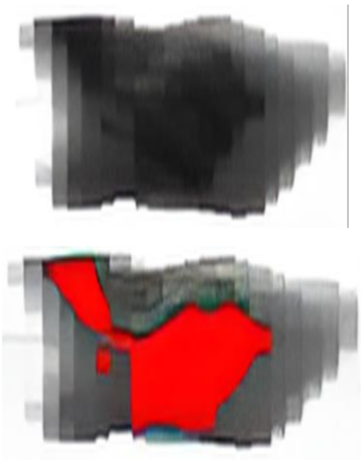


Results of quantitative composition of chemical elements in silver-bearing ore samples obtained by inductively coupled plasma AES method

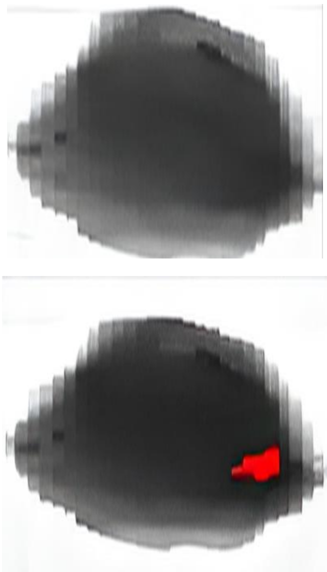
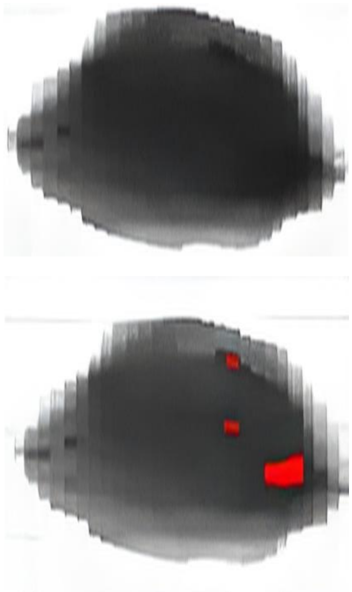
Next, we analyzed the correlations of silver with other components of the rest of the sample pieces, which also indicates the association of silver with lead, which is represented by galena (R=0.72), and antimony, represented by tetrahedrite (R=0.65).

The contrast index ($K'_{п/л}$) was analyzed for the samples with the lowest and highest silver content according to the AES results as the ratio of X-ray absorption intensities of the useful product to the absorption intensity of the host rock. The results of calculation in ImageJ software are presented in the figure.

Sample No. 13 with high silver content, MD=30.10

Photo of samples	on a channel of low energy	on a channel of high energy
		
	$K'_{п/вп}=1,436$	***$K'_{п/вп}=1,316$***
	$S_{пп}=21\%$	***$S_{пп}=26\%$***

Sample No. 8 with very low silver content, MD=4.04

		
	$K'_{п/вп}=1,008$	***$K'_{п/вп}=1,075$***
	$S_{пп}=2\%$	***$S_{пп}=2,6\%$***

Samples with high and very low silver content

The enrichment of silver-bearing ores by X-ray absorption separation method and the efficiency of the developed separation feature were studied, which is defined as the maximum weighted average deviation of silver content in fractions obtained by successive grouping of pieces arranged in ascending order of separation feature from the average content of valuable component in the ore, and the efficiency of separation feature is calculated as the ratio of the separation feature indicator to the contrast indicator.

The analysis of sample separation efficiency showed that the proportion of false pieces in the tails was 5.77% when separating using MD feature, while quantitatively the yield of true tails when using MD feature is 59.04%. This also indicates the high efficiency of the MD separation feature

CONCLUSIONS

Thus, using the methodology and algorithm developed in Bourevestnik, the separation feature for identification of inclusions of complex sulfide minerals (sulfosols) and host rocks was developed. In addition, it was found that samples with the highest absorption capacity have iron, copper, antimony and lead, which are part of galena and tetrahedrite, which are silver indicator minerals. This is confirmed by the analysis of correlations of silver with lead, which is represented by galena (R=0.72), and antimony, represented by argentotetrahedrite (R=0.65).

Fractionation of a selection of samples showed the potential for 52.1 % of tailings containing 66.3 g/t silver with a loss of 9.1 % Ag. The concentrate contains 721 g/t silver.

Quantitative analysis of the separation efficiency of the sample showed that at separation the proportion of concentrate pieces in the tailings was 5.77 %, which also indicates the high efficiency of the separation feature, which is the X-ray absorption method.

Thus, taking into account the obtained results of research of silver-bearing ore of Obokha deposit, the X-ray absorption method of separation, realized on the XRT mineral sorter RGS-6A with capacity up to 160 t/h with the possibility of loading of ore range from 10 to 100 mm, produced by Bourevestnik, allows to significantly increase the recovery rates of useful component at the stage of preliminary enrichment of initial ore due to its inclusion in the technological process chain.