# Application of X-ray absorption method to evaluate the separation of poor tin

## INTRODUCTION

Tin is a characteristic element of the upper part of the Earth's crust, where it forms industrial concentrations of tin and complex ores under certain geological conditions.

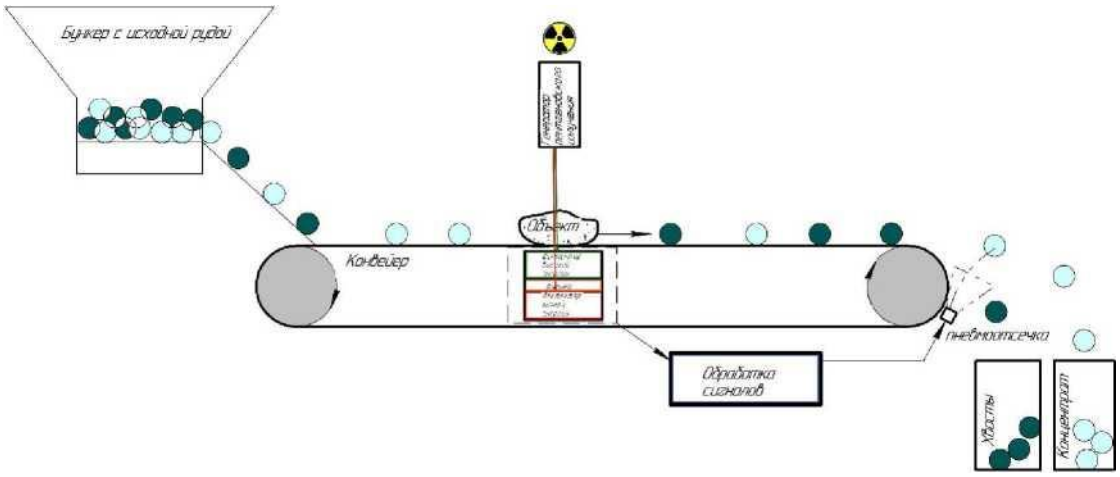
World reserves of tin contained in the subsoil of 19 countries amount to about 5 million tons; resources estimated in the subsoil of 32 countries amount to 16.9 million tons. Production of tin in concentrates is carried out in 22 countries of the world, in 2021, according to preliminary data, it amounted to 329 thousand tons, half of this amount was provided by China and Indonesia.

The development of relatively accessible tin deposits is limited by insufficiently high quality of ores and/or their difficult enrichment, which, given the existing technologies for processing tin raw materials, negatively affects the profitability of production.

## 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 separator

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

## RESEARCH

Bourevestnik JSC carried out works on evaluation of enrichment of three samples of poor tin-containing ore with expected concentrate yield not exceeding 6-10%, preliminary crushed to the size of minus 50 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 recording and evaluation in X-ray absorption analysis is that X-rays passed through pieces of minerals and rocks are recorded on a scintillation detector. 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 by 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

In the first stage, representative samples of up to 100 pieces from each machine size class, each sample, and each sampling location were generated for contrast and enrichment studies by X-ray absorption separation. Pieces for each sample were selected by random selection method, which determines the representativeness of the sample. Each piece was numbered and weighed, and visual analysis was performed in the visible range of optical radiation with assessment of the nature, intensity and phenocrysts of minerals and substances, color characteristics.




Sample material: greisen paragenesis minerals and sulfides (arsenopyrite, pyrite, chalcopyrite, pyrrhotite, stannite) distributed in the form of veins and stockworks in intrusive hidden crystalline rock.

To assess the enrichability of tin-bearing ores by radiometric separation methods, we studied their geological and mineralogical features (visual analysis in the visible range of optical radiation), elemental and material composition (X-ray fluorescence and X-ray diffraction analysis, respectively), chemical composition (determination of rare-earth and trace elements by alloying with borates before acid dissolution and subsequent ICP-MS determination of Sn), non-uniformity of pieces by content of main and associated components (X-ray absorption analysis) and their correlations (static analysis). The data make it possible to establish the principal possibility of applying the methods of lump separation and to estimate the efficiency of the selected separation feature and the limit values of separation by tin content.

The obtained data allowed at the preliminary stage to choose the type of separator and separation modes for preliminary enrichment, to determine the technological indicators of piecrust enrichment.

Evaluation of contrast and maximum possible ore separation indices by X-ray absorption pre-separation method was carried out for -15+0 and -25+15 size classes in total amount of 150 pieces (poor oxidized -15+0 - 5 pieces, -25+15 - 45 pieces; poor primary (core) -15+0 - 5 pieces, -25+15 - 45 pieces; poor semi-oxidized -15+0 - 5 pieces, -25+15 - 45 pieces). According to the data of tin content in separate pieces the fractional composition of samples was carried out, which determines the ore contrast. So the general indicator of ore contrast was M = 1,33 and refers this ore to the category of high-contrast.

To evaluate the preliminary enrichment of the investigated sample with lump separation by X- ray absorption separation method, measurements of 2960 marked lumps were carried out on APR in dynamic mode, at operating mode on tungsten anode of X-ray tube - 120 kV, anode current - 2.6 mA, with a pixel of photodiode line 0.4 mm to obtain X-ray images of ore samples and to analyze the results by available PMO.

XCLUSTER application is developed for the test/tuning stage of useful component extraction on X-ray images of a piece of ore, which performs operations with data (.dat) of two channels, data normalization, taking into account the data of dark current (dark), empty carriage (empty), "about" laser line 3d laser triangulation, construction of X-ray images, allowing in real time to select areas of useful component in the ore to form a cloud of points on the graph, the boundaries of which further allow you to set the separation line, tuned to the desired component, with the help of PMO data separator (Fig. below).

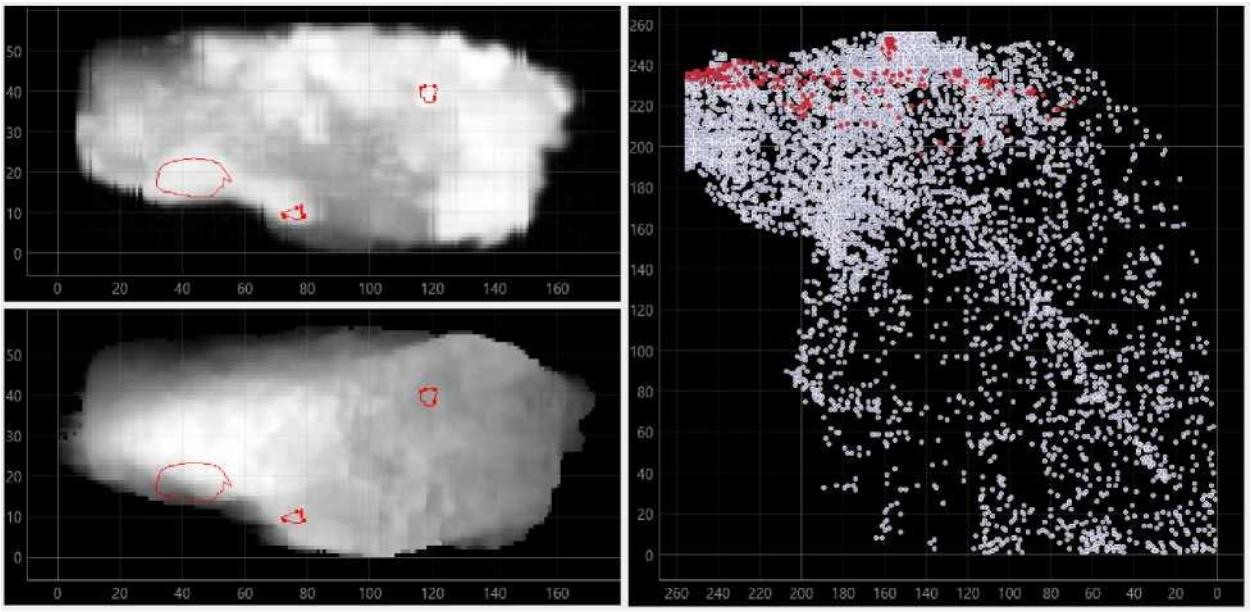


Figure - Visualization of radiographic image (top left), object height (top left) and data cloud in the XCLUSTER application

To adjust the separation line, to calculate the % content of useful components in a piece of ore and to visualize the selected components on X-ray images of the analyzed objects for the whole sample, the XVIEW application (version 2.5) was developed, which allows to perform real-time operations with the data array, to adjust and refine the separation line data, to perform automatic calculations and to generate a calculation file for the whole sample (Fig. below).

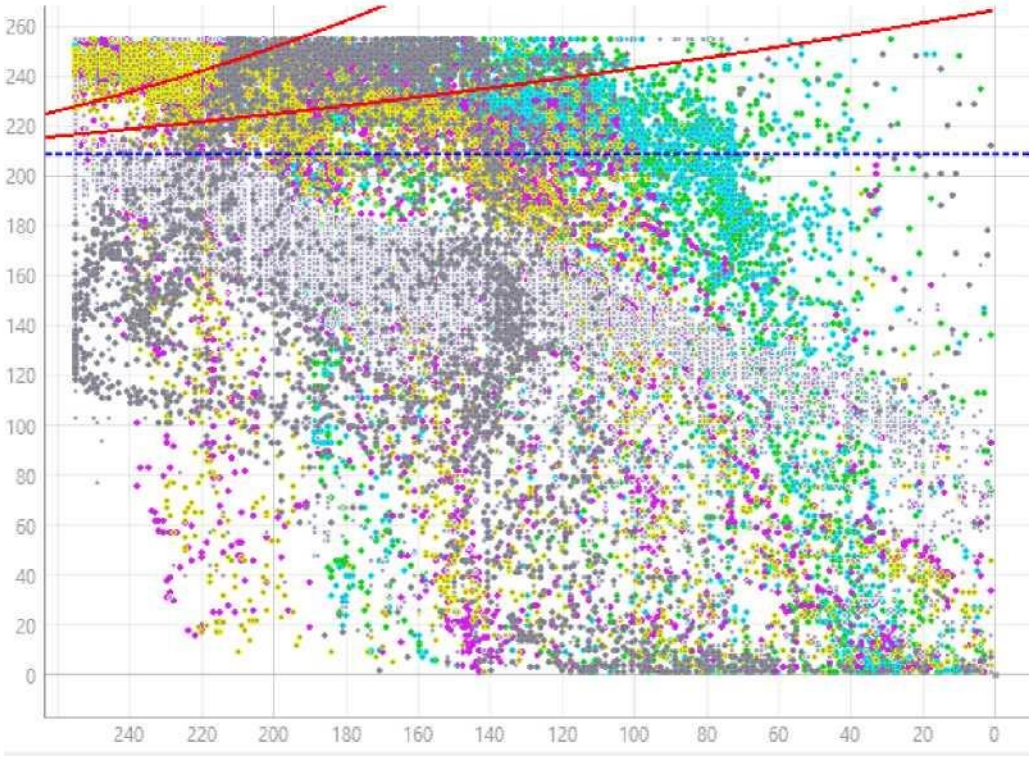
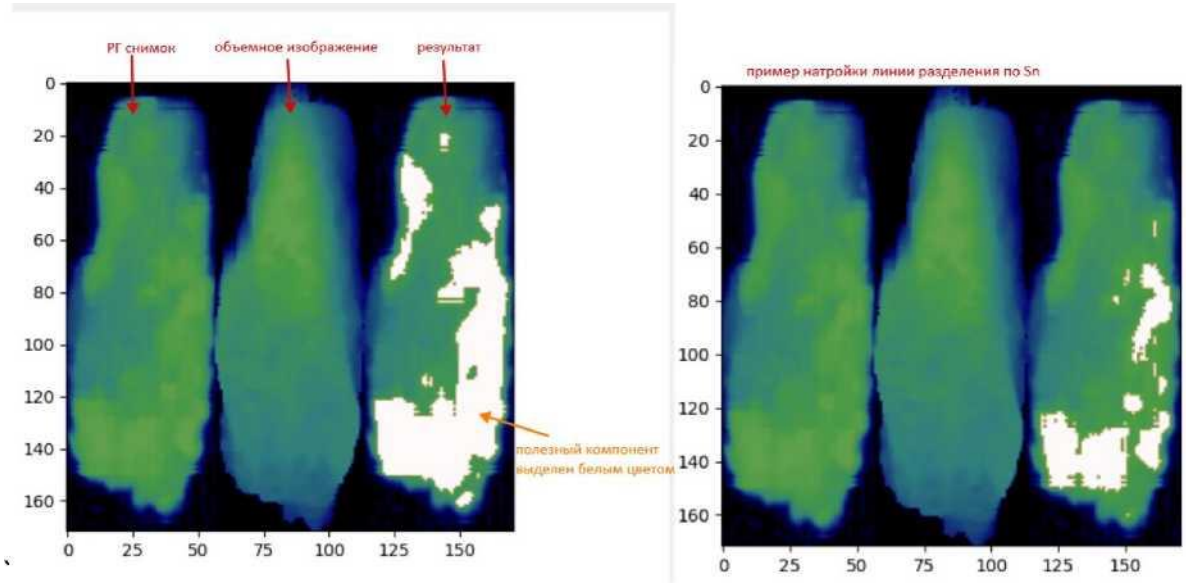


Figure - Example of point cloud (data) visualization in XVIEW application




a b

Figure - Example of data processing results visualization and useful component area extraction in XVIEW application:

a - the separation line is adjusted to the group of minerals of sulfide association,

b - the separation line is set up for Sn minerals - stannite and cassiterite.

Taking into account that according to the results of chemical analysis tin-containing ore is poor, the technological indicators of separation by tailings are sufficient for their separation. The overall separation trait value for the whole sample was 1.31, for poor oxidized tin-containing ore - 1.29, for poor semi-oxidized tin-containing ore - 1.46, for primary tin-containing ore (core) - 1.15.

## CONCLUSIONS

The object of the study was a sample of three types of tin-containing ore (poor oxidized, poor semi-oxidized, primary in the core) of three size classes (-50+25, -25+15, -15+0) in the amount of 2960 samples, from which 150 test representative samples of size classes -25+15, -15+0 were selected for chemical analysis and further adjustment of the separation feature.

Sample material: greisen paragenesis minerals and sulfides (arsenopyrite, pyrite, chalcopyrite, pyrrhotite, stannite) distributed in the form of veins and stockworks in intrusive hidden crystalline rock.

It was found that the sample of poor tin-bearing ore is highly contrasting in terms of Sn content, the total value of contrast index was 1.31 (for poor oxidized - 1.29, for poor semi-oxidized - 1.46, for primary in the core - 1.15).

Chemical analysis identified 30% rich tin-bearing ore samples (>1%Sn), 10% ordinary (10.4% Sn), 15% poor (0.4-0.1% Sn) and 52% miserable (less than 0.1% Sn).

Total fractionation of the sample by Sn content showed a potential possibility of obtaining 74.3 % of tailings containing 0.09 % Sn with losses with them of 9.47 % Sn. At the same time, the concentrate contains 2.41% tin.

The possibility of enrichment of tin-containing ore by X-ray absorption method with application of the developed feature of separation - MD has been analyzed, which allows to establish technological indicators of separation by main tin minerals (cassiterite and stannite) of poor tin-containing ore sufficient for their enrichment and has shown a potential possibility of obtaining 63% of tailings containing 0.11%Sn with losses with them of 9.98% of tin. At the same time, the concentrate contains 1.66%Sn.

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 mineral sorter RGS-6A with throughput up to 160 t/h with the possibility of feeding of size 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.