The Feasibility of Using Small-Sized Mica

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Abstract. The valuable technical properties of mica have attracted attention for a long time. Currently, mica is widely used in various industries, primarily in the electrical and radio engineering ones. Two types of mica are used in modern technology: muscovite and phlogopite. In addition, vermiculite, lepidolite and biotite are used as well. Mica is one of the best dielectrics, it has properties that other dielectrics lack: high dielectric strength, heat resistance, chemical resistance, moisture resistance, mechanical strength and flexibility. Muscovite and phlogopite are indispensable electro-insulating materials used in powerful generators and other high-volt machines.

1. Introduction
The aim of the work is to develop a theory of enrichment of small-sized mica ores using the waste-free technology. On the basis of theoretical generalizations of the basic laws of mica ore enrichment, we seek to create a combined scheme for small-sized mica raw materials enrichment, find ways to rationally use mica concentrates, and solve important economic problems. The solution to the problem of extraction and disposal of small-sized mica raw materials allows us to consider this category of mica as industrial and produce off-balance mica raw materials, which will significantly increase the raw material base of the main mica-bearing regions. To solve the tasks, the following research methods were used: mineral enrichment; gravitational enrichment; the selective method for extracting the useful area of a mica crystal; granulometric and mineralogical analyses, electrical and mechanical methods for determining micalex quality indicators.

2. Problem statement
Mica has specific properties that distinguish it from the host rocks, but it is not possible to distinguish these properties. Large-sized mica, which is the raw material for the production of sheet mica, which accounts for about 65-70% of the total volume of mica, cannot be crushed. This position makes it necessary to identify such distinctive properties of mica that could be used for enrichment provided that the natural state of crystals is extracted.

3. Theoretical background
The only distinctive property of crystals is their lamellar shape. The lamellar shape of mica crystals and the rounded shape of rock pieces were the basis for solving the problem of mechanical enrichment of mica-bearing rock mass: slotted drum screens (G.M. Markin), slotted drum separators (E.K. Nashev), screw on-board separators (V. M. Arkhangelsky) [1], tray separators (M.F. Lavrov and V.M. Arkhangelsky) [2]. The screw airborne separator was designed by V.M. Arkhangelsky [3], whose
work is based on the difference between the overturning moments of mica crystals and gangue. However, friction enrichment did not find industrial application due to the insufficient development of technological schemes and apparatuses. The Giproninemetallorud Institute developed a so-called belt separator based on the principle of a plow ejector [4]. Production tests have yielded some positive results. At the same time, this separator is characterized by significant drawbacks and low productivity, low mica recovery and high operating costs. The Institute “VNIIasbestcement” [4-6] suggested using vibrating screens with a special design of flat grate sieves [7-9]. For these purposes, screens of the GUP and CM-I3 type are widely used. I.M. Abramovich [10] identified a number of valuable dependencies between the indicators, but the author considered screening only as a means of classifying crushed products and did not mention the possibility of using screening for enrichment purposes. S.E. Andreeva and M.G. Kuzakov carried out a number of studies on mica extraction with a gangue. [11-13]. Works of theoretical and practical importance were carried out by L.M. Shcherbakova [14]. She has developed a methodology for calculating technological schemes and parameters of processing equipment. However, all the studies relate to the enrichment of large-sized raw materials and do not deal with enrichment of small-sized mica [15]. The number of small fractions (class -20 + 5 mm) is 20 - 25 of the total volume of mined mica. The integrated use of mica raw materials is impossible without involving this class in industrial production. Therefore, studies on enrichment of small-sized raw materials are of interest [16].

4. Results and discussion

Based on the theoretical studies, it was found that the main factors affecting the enrichment process are: particle size distribution of mica and rock, mica characteristics by area and thickness, rock to mica size ratio, crystal shape, and the ability of ore to free crystals from crushing rock [17].

| Deposit   | Reserves of small-sized mica, thousand tons | Content in rock mass, % | Fractions, mm -20+10 Thousand tons | Fractions, mm -10+5 Thousand tons | Fractions, mm -5+0 Thousand tons |
|-----------|--------------------------------------------|-------------------------|------------------------------------|-----------------------------------|----------------------------------|
| Mamsko    | 288                                        | 1,6                     | 18                                 | 0,1                              | 108                              |
|           |                                             |                         |                                    |                                   | 0,6                              |
|           |                                             |                         |                                    |                                   | 162                              |
|           |                                             |                         |                                    |                                   | 0,9                              |
| Chuysky   | 92                                         | 2,7                     | 4                                  | 0,1                              | 36                              |
|           |                                             |                         |                                    |                                   | 1,0                              |
|           |                                             |                         |                                    |                                   | 52                              |
|           |                                             |                         |                                    |                                   | 1,5                              |
| Chupinsky | 120                                        | 3,0                     | 3                                  | 0,1                              | 74                              |
|           |                                             |                         |                                    |                                   | 2,5                              |
|           |                                             |                         |                                    |                                   | 43                              |
|           |                                             |                         |                                    |                                   | 1,4                              |

Table 1. Muscovite.
Of the above factors, the most important is the thickness of crystals and the size of pieces of gangue. In this regard, the choice of grate sieve slits is of great practical importance. In case of incorrect determination of the optimal size of the gap, all technological and economic indicators of enrichment become worse. Consequently, only the processing of dumps and the use of waste-free technology can solve the problem of ground mica reserves.

To determine the content of small-sized mica, we examined and tested dumps at 14 mountain sites of the Mamsko-Chuisky, Ensky and Chupinsky muscovite deposits, Aldan and Kovdor phlogopite deposits.

The industrial reserves of muscovite and phlogopite are presented in tables.

Analyzing the tables, we can conclude that mountain dumps have a high content of mica of small classes, which are valuable raw materials for the production of ground mica. However, the extraction of such mica is associated with great technical and economic difficulties, since it is almost impossible to extract -20 + 0 mica from ore using one enrichment method.

Table 2. Phlogopite.

| Deposit | Reserves of small-sized mica, thousand tons | Content in rock mass, % | Fractions, mm -20+10 Thousand tons | Fractions, mm -10+5; Thousand tons | Fractions, mm -5+0 Thousand tons |
|---------|-------------------------------------------|-------------------------|------------------------------------|------------------------------------|---------------------------------|
| Kovdor  | 380                                       | 4,6                     | 33                                 | 133                                | 215                             |
|         |                                            |                         | 0,4                                | 1,6                                | 2,6                             |
| Aldan   | 290                                       | 3,8                     | 27                                 | 106                                | 157                             |
|         |                                            |                         | 0,35                               | 1,4                                | 2,05                            |

Table 3. Performance of mining enterprises.

| Name     | Location          | Deposit of muscovite   | Specific weight, %, 2005 | Specific weight, %, 2010 |
|----------|-------------------|------------------------|--------------------------|--------------------------|
| Mamsluda | Irkutsk oblast    | Mamsko Chuisky         | 75,0                     | 76,0                     |
| Kovdorsluda | Republic of Karelia | Chupinsky             | 10,0                     | 16,0                     |
| Kovdorsluda | Republic of Karelia | Ensky                 | 15,0                     | 8,0                      |

There may be two cases:
- The size of the gap is larger than the optimal one. In this case, the concentrate is too clogged with waste rock.

To reduce the contamination of the concentrate with gangue and bring it to the conditional state, it is necessary to implement additional screening operations into the technological scheme, especially when enriching small-sized mica.
- The size of the gap is less than the optimal one.

The mechanical extraction of mica is very low. In this case, a significant amount of small crystals of mica enters the tails. In their shape and structure, mica crystals of one deposit are different from each other. Along with crystals of a pronounced lamellar structure, lamellate-pinched, wedge-shaped ones were found. Irregular crystals are more difficult to pass through the slots.

All these difficulties should be taken into account when studying the particle size distribution and determining the size of the slit [18].

In addition, the mica ore dressing process is influenced by the uniformity of the material feed to the
screen, distribution of the material over the entire surface of the screen, the specific load on the screen, the amplitude of the screen, the cross-section of the sieve, the size of the feed and quality requirements of the product.

Consider the influence of these factors on the process of mica ore enrichment. The uniformity of the material feed affects the screening efficiency, and, consequently, the extraction of mica crystals. With an uneven feed of the material, its layer reaches such a thickness that there is no necessary stratification of grains by size and separation of gangue from mica crystals. In addition, the waste rock, due to its rounded shape, occupies the recesses between the tops of the corners, preventing the occurrence of a tipping moment, the movement of crystals to the cracks of the screen and their transition into the sublattice product. The extraction of mica in the concentrate is reduced. If the material is correctly distributed over the screen, the load across all mica traps is the same, with uneven loading, a significant part of the material enters some slots, and the remaining smaller part enters the other ones. This leads to a disruption in the rhythm, a decrease in performance of the screen, a decrease in the extraction of mica in the concentrate, and an increase in the contamination of the concentrate with waste rock. To avoid this, determinants should be installed at the points of ore input at the screens. The optimal specific load on the screen sieve depends on the characteristics of mica, mica content in the ore, the width of slots and their quantity. It is set for each deposit. Depending on the size of the material and the size of the screen slit, the specific load on the grate is determined. The specific load with a slit width of 4-6 mm and screening of the material with a grain size of -20 + 5 mm should not exceed 60%. In order to verify the theoretical provisions, experimental studies were conducted to establish the influence of the size of the grate on the extraction and content of small-sized mica in the concentrate, as well as to develop a technological scheme for the enrichment of small-sized mica of the -20 + 5 mm class.

Experimental works were carried out on the ores of the Mamsko-Chuysky deposit of muscovite and the Aldan deposit of phlogopite. Both in samples of small-sized ores containing muscovite raw materials, and in samples of small-sized ores containing phlogopite raw materials, mica is evenly distributed in all size classes. The maximum mica size is -20 mm. Mica is rather dense, lamellar. The studies have established that mica is presented by plates 0.1-8 mm in thickness; with a decrease in the size, their thickness decreases [19].

The above theoretical provisions show that the size of slits, efficiency of the enrichment process, the process mode are determined by the particle size distribution.

It is necessary to study the particle size distribution of small-sized mica ores and the thickness of mica crystals. The volume of samples of small-sized mica ores was 3-5 tons [20-22].

The methodology for processing samples was the same, which created the prerequisites for comparing the results of studies [23].

In order to obtain more correct results, ore was divided into three fractions on flat sieves with square cells of 10, 5, 3 mm in size.

Two classes were analyzed. The assignment of a large piece of rock to a particular class was carried out by measuring it on the shortest side. In addition, the largest size was measured in each piece of rock. Each class was weighed.

During the sample classification process, all mica crystals were manually extracted. The extracted crystals were pre-sorted according to sizes of the total area of -20 + 10 mm, -10 + 5 mm and -5 + 3 mm. Each group of crystals was classified according to their thickness using a caliper. The following particle size classes were used: + 0-0.5 mm; + 0.5-1 mm; + 1-3 mm; + 3-5 mm; + 5-7 mm; + 7-9 mm; + 9-12 mm.

At the end of the mica classification by crystal thickness, each class was weighed. By dividing the mass of each class of both rock and mica crystals, the fraction of each class (frequency) was determined, which made it possible to determine the total characteristics and construct variational series.

The technological scheme of enrichment of small-sized mica was calculated and the main technological indicators were determined.
Experimental works on the verification of the technological scheme were carried out on vibrating screens.

The results of a study of particle size distribution and calculation of the technological enrichment scheme for small-sized ore from the Aldan deposit with a grain size of \(-20 + 5\) mm are presented in Table 4.

To calculate the mica ore enrichment scheme by shape, we used the data on particle size distribution, in particular, the total characteristics of the particle size distribution of the rock, thickness of mica crystals and their average transverse dimensions. The characteristics are presented for the \(-20 + 10\) mm and \(-10 + 5\) mm classes.

### Table 4. Granulometric composition of small-sized mica.

| Size class, mm | Output, % | Mica content, % |
|----------------|-----------|-----------------|
| \(-20+10\)     | 27,83     | 8,2             |
| \(-10+5\)      | 13,2      | 12,7            |
| \(-5+3\)       | 30,1      | 15,8            |
| \(-3+1\)       | 17,72     | 10,3            |
| \(-1+0,5\)     | 6,9       | 7,6             |
| \(-0,5+0\)     | 3,25      | 6,2             |

### 5. Conclusion

The deposits of muscovite and phlogopite can be divided into the following types. Muscovite deposits are as follows: Pegmatoid. Pegmatites of the quartz-muscovite complex. Fractured pegmatites. Mixed genetic types. Phlogopite deposits are as follows: Phlogopite scattered in crystalline schists. Phlogopite in the form of rims. Phlogopite isolation in metasomatic diopside zones. Mixed genetic types. In the muscovite Mamsko-Chuiskoye deposits, there are two genetic types - pegmatoid and quartz-muscovite. These pegmatite varieties are associated with 71% of balance reserves of raw materials, 77% of industrial raw materials, 90% of large-sized mica, and 91% of high-grade mica. In fractured pegmatites, 22% of the muscovite balance reserves are concentrated; however, when converted into industrial raw materials, this figure decreases to 17%, and the share of large-sized mica is more than 4%. The average natural group composition of mica has the following ratio: Muscovite - Mamsko-Chuiskoye deposit: I group (100 or more cm) - 10.1 II group (from 50 to 100 cm) - 15.2 III group (from 4 to 50 cm) - 34.72.1V group (less than 4 cm) - 40.0. Phlogopite - Aldan deposit: I group (100 or more cm) -11.6 II group (from 50 to 100 cm2) - 7.8 III group from 4 to 50 cmII - 27.4IV group 2V group (less than 4 cm) - 53.2. In the mica industry, up to 30-40% of the total amount of mica are mica with a total crystal area of less than 4 cm (\(-20\) mm class) (small-sized mica). This part of mica raw materials is excluded from the commercial products only in the process of enrichment. There are a number of mica deposits explored, but not exploited, due to the low volume of commercial mica (Kondakovskoy, Biryusinsky) and a significant number of muscovite deposits in the Mamsko-Chuysky deposit and Aldan and Slyudyanka mica-bearing regions. The studies of mining dumps of the Mamsko-Chuysky, Ensky and Chupinsky deposits of muscovite, Aldan and Kovdor deposits of...
phlogopite showed the presence of a large amount of small-sized mica of the -20 mm class with an average content of muscovite - 2.1% 9 phlogopite - 4.1%. This valuable raw material can be used in the production of ground mica. 

Studies show that in mica ores containing small-sized mica, the ratio of the size of mica and gangue allows for the extraction of mica of the -50 + 5 mm class. The theoretical studies allow for the most correct and objective analysis of the enrichment process based on statistical parameters of the granulometric composition of the rock mass and thickness of the mica crystals. The total characteristics of thickness of the mica crystals and the size of pieces of rock make it possible to correctly determine the size of slits, establish the mica content in the intermediate product and determine the enrichment efficiency coefficient. The experimental work confirmed the correctness of the theoretical principles and made it possible to obtain concentrate with a mica content of 90-92% with an extraction of 86-87%, which makes it possible to use valuable mica raw materials.

6. References

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