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Review of methods for determining the minimum weight of the initial ore sample

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Abstract
In order to determine the parameters of the raw material processing, it is necessary to know its characteristics. Raw materials for processing are supplied in crushed form and stored in a pile in warehouses. Usually this raw material is tested. The most obvious indicator of such raw materials is the size of the pieces. With this indicator the sample mass taken for analysis is also associated. The purpose of the article is to analyze the methods for determining the minimum weight of the initial sample in the preparation of ore processing. It has been established that the mass of the primary sample is related to the size of the mineral pieces: the smaller the pieces, the greater their number should be taken into the sample. The properties of the material play a significant role in determining the required mass of the sample. Sample mass reduction errors depend on the excess or deficiency of pieces of useful minerals replaced by pieces

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I. INTRODUCTION

Most metal-bearing ores and industrial minerals contain valuable mineral or metal in a small amount, the valuable mineral being embedded in a host rock as a multitude of intergrowths or disseminated throughout it as impregnations. So most raw ores require treatment of some kind to produce a salable product. Any processing process begins with testing, which consists in isolating part of the array (sample), preparing it and measuring controlled properties. The main purpose of testing is to obtain the necessary information about the test product [1]. The patterns of testing depend on the values of mineral processing characteristics and on its texture and structural features. Thus, the object of dressing study is the processing features. To search for these patterns, it is necessary to know the mineral textural and structural features and the most probable value of the content of a valuable mineral. Therefore, the urgent task is to determine the dependence of the processing characteristic variability in the size classes.

1.1 The first research steps

The first attempt to express the connection between the weight of the initial sample and the size of pieces or particles of the tested material belongs to Vezin [2]. He believed that the number of particles (pieces) in the initial sample should be equal to the number of particles in the sample for chemical analysis. Thus, the formula $q=kd^3$ appeared in the literature, where q is the weight of the sample; k is the coefficient of proportionality, determined by the given number of pieces or particles in the sample; d is the size of the pieces or particles. However, the results obtained by this formula turned out to be somewhat overestimated.

The principle of Demond and Halferdahl, which was the basis for numerous works on determining the minimum weight of the initial sample, is based on the fact that the larger the ore particles, the more particles are intergrowths of a useful mineral with rock and, therefore, the greater the content of a useful component in such a particle (piece) approaches the average content of the useful component in the ore. In this regard, it makes no sense to take into the sample such a number of large particles (pieces) as provided by the Vezin formula. In other words, the weight of the sample is proportional to a value somewhat smaller than the cube of the diameter of the largest pieces. The influence of factors that determine the minimum required sample weight must be taken into account by the summing factor k and the variable exponent a in the formula

$$q=kd^a. \quad (1)$$

1.2 Category of ores

According to research and their comparison with practical data, it is established that the exponent a, depending on the properties of the ore, can have values from 1,5 to 2,7. For each ore this indicator should be determined experimentally [3]. In the future, two directions of research were outlined, representatives of which are K. L. Pozharitsky and P. L. Kallistov. Let's consider the main differences between these approaches.

The scheme of Pozharitsky's method [4] is as follows.

1. All ores are divided into three categories according to the uniformity degreeof the metaldistribution and the amount of useful componentimpregnation; each category of ores is assigned an exponent, and in the formula $q=kd^a$these indicators are taken equal to 1,8; 2,0 and 2,25.

2. The initial value is taken as a chemical sample equal to 1 g, with a fineness of 0.1 mm. Then q_1=0.001 kg=const, d_1=0.1mm=const. Then we get $\lg k= \lg q - a \lg d=a - 3$.

3. After substituting the intended $a$value into this expression, the corresponding value of k equal to 0.06, 0.1 and 0.18 are found. Thus, all cases of the initial sample value determining are reduced to the calculation of the sample using one of the three formulas

$$q=0,06d^{1,8}; \tag{2}$$

$$q=0,1d^{2}: \tag{3}$$

$$q=0,18d^{0,25}. \tag{4}$$

The choice of this or that formula is made empirically on the basis of studying the nature of the deposit and ore.

The *first category* of ores, for which it can be used (2), includes:

- ores of rare metals with uniform fine dissemination of useful component, similar copper, polymetallic, arsenic, sulfuric and copper pyrite ores;
- ores with uneven mineralization, in which the valuable mineral tends to be very easily crushed;
- bauxites, iron ores analyzed for iron, calcium, magnesium, etc.

The *second category* of ores, the sampleprocessing of which can be carried out according to (3), includes:

- uneven molybdenum, mercury, copper, porphyry, antimony and lead-zinc ores;
- uneven ores of rare metals, in which the valuable component is prone to easy grinding.

The third category of ores, the processing of samples of which is recommended to be carried out according to the formula (4), includes ores with large and uneven dissemination of molybdenite, scheelite, wolframite, cinnabar, cassiterite and other valuable minerals.

Kallistov's research is differing from Pozharitsky's methodology:

first, establishes the independence of k and a from each other;

secondly, the value of the chemical sample and the final fineness of grinding may not be constant;

thirdly, in tested schemes for processing experimental samples have parameter values of the formula $q=kd^a$not only sufficient, but also the minimum weight of the sample.

Thus, Kallistov's technique consists in determining two or more critical (minimum necessary) sample values q for two or more different tested sizes of the maximum sample pieces, after which the search for k and a is reduced to solving two equations with two unknowns $q_1=kd_1^a$,$q_2=kd_2^a$.

II. RESULT AND DISCUSSION

The review and analysis of Pozharitsky's and Kallistov's works shows that the only thing common to these methods and the Demond-Halferdahl method is only the appearance of the final formula (1), while the interpretation of the meaning and method for determining the values of k and a in all three cases is original and independent from each other.

Figure 1 shows the sample weights depending on the size of the largest pieces or particles of the material tested according to K. L. Pozharitsky (curves 1,3,5) and according to P. L. Kallistov (curves 2, 3, 4), while ores 1, 2 are considered - very uniform, 3 - uneven and medium, 4, 5 - very uneven.

Comparison of calculations shows that for the range of ore size and dressing products tested at processing plants (up to 20 mm), the results of calculating the initial sample weight and reduction schemes according to K. L. Pozharitsky and P. L. Kallistov are almost the same for the size of pieces up to 7 mm .

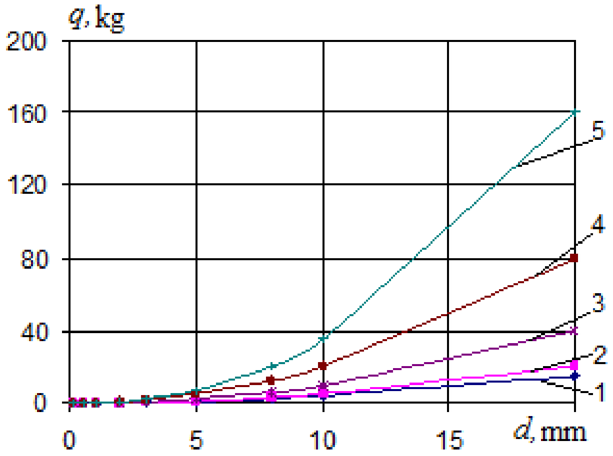

Fig. 1: Sample weight depending on the size of the largest pieces or particles according to K. L. Pozharitsky and P. L. Kallistov

The approaches of other authors differ. So, as a result of the discussion and generalization of a large number of experimental works, the supporters of the formula (1) returned to the Chechott formula, however, proposing a new table of the coefficient kvalues. Brunton's method assumes that there is already some disclosure i.e. there are particles with different content of a valuable mineral in them. However, it expresses such a state through the integral characteristics of the mineral. The disclosure depends on the parameters of the size class and other parameters of the tested massif, on the particle size distribution function. Thus, disclosure is not fully taken into account. These two analyzed methods theoretically substantiate the minimum sample mass based on the texture and structural mineral features, however, their use for practices is difficult.

For initial tests the Richards-Chechott'sformula (1) is usually used. Prof. Richards believes that the principle underlying Vezin's formula of a grainequal number in samples contradicts the mineralogical characterization of the material. In fact, for most ores, large pieces, in terms of the uniformity degree of metal distribution in them, are more consistent with the average rock than small pieces. Therefore, for ore coarse crushing the number of pieces in the sample may be less than for fine crushing.

According toChechott'smethod for any mixture there is a certain limiting material amount, which still retains a composition identical to the original orewith a given size of pieces and a given nature of mineralization. This amount increases with:

1) an increase in the size of the grain (piece);
2) an increase in the degree of mass heterogeneity;
3) an increase in the percentage of a valuable mineral in a mineral with an uneven distribution of it;
4) an increase in the value of a mineral.

Thus, the smaller the piece, the more it differs in properties from the massif. Therefore, it turns out to be natural to associate the sample mass with the size of the mineral pieces. And the smaller the pieces, the more of them should be sampled.

2.2 Dependence of the sample weight on the ore properties

In this work, we analyzed the dependences of the sample weight *q*, particle size *d* on the properties of the material *b/a* (Fig. 2), where *b/a* is the ratio of the content of the valuable component in the sample to the total sample mass.

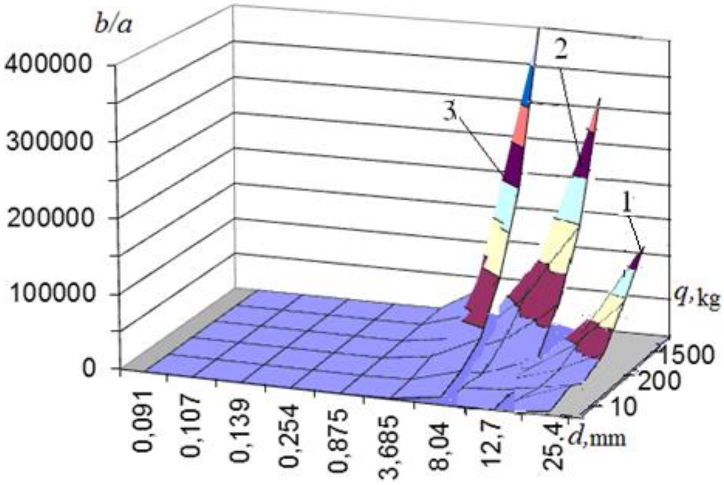

Figure 2: Dependence of sample weight *q*, particle size *d* on material properties *b/a* for pyrite (1), ore with native silver (2) and native gold (3)

Analysis of the data showed that the properties of the material play a significant role in determining the required sample mass for all other things being equal to the size of the particles (pieces).

This dependence is confirmed experimentally. The connection between the amount of sample (q), grain size (d) and the properties of the material was established experimentally in the form of a parabola, where the Richards table is used to determine the coefficient k dividing all minerals into 6 categories according to the degree of difficulty of sampling. When using the table, there is difficulty in determining the coefficient k. Since the value of k depends on the qualitative composition of the mineral, it is quite natural that the subjective factor in assessing its value plays a significant role; therefore, the reliability degree of the selected value depends on the skill and qualification of the operator.

Table 1: Definition of empirical coefficients

Category	**Ore nature**	**Limits of the *k* - factor**	**Average values of *k***
I	ores are very poor very uniform mineralization uniform fine dissemination	016-0,40	0,25
II	poor ores more or less uniform mineralization fine uniform dissemination	0,40-1,50	1,0
III	average ores by richness medium and fine dissemination	1,50-3,00	1,80
IV	average ores by richness uniform, medium and coarse dissemination	3,00-6,00	4,50
V	rich ores mineralization uneven large uneven dissemination	6,00-15,0	10,0
VI	very rich ores highly uneven mineralization sporadic dissemination with orifice inclusions	15,0-24,0	20,0

For example, let's consider the classification of gold-bearing ores. For gold-bearing ores with free gold, the value k = 6-15 can be taken. Gold-bearing ores with visible gold occurring in the cementation zone or presented in the form of nested accumulations should be attributed to category VI with a coefficient k = 15-24. Sulfide gold-bearing ores, in which gold is usually finely disseminated in sulfides, could be attributed to group II with a coefficient k = 0.4-1.5, but due to the possible uneven distribution of gold in sulfides, it is better to attribute to group III or IV, and even to V. According to Chechott's table, the value of the coefficient depends on three factors: 1) the richness of the ore, 2) the degree of uniformity of mineralization, 3) the value of dissemination of useful minerals in the ore. The concept of "wealth" is rather conditional, since it depends on a number of technical and economic factors, and depending on the level of technology development; ores from the poor category can be transferred to the rich category. With an increase in the content of titanium-magnetite in the mixture, the relative error decreases. This confirms the assumption that the errors in sample mass reduction depend on the excess or deficiency of pieces of useful minerals replaced by pieces. The experience of using Table 1 in practice shows that all the coefficients adopted in it for different categories of ores are overestimated.

Sometimes they turn out to be overestimated by several times, due to which the sample weights calculated according to these coefficients turn out to be so large that it is difficult to study them.

2.3 Sample weight for sieve analysis

For determining the minimum sampleweight for sieve analysis the connection between the weight of the sample and the size of tested material pieces or particles is not only the main one, but also the only one. However, research in this area is extremely limited, which can only be explained by the lower value of sieve analyzes compared to chemical analyses. Meanwhile, the importance of sieve analyzes in mineral processing, especially at the stage of preparatory operations (crushing, screening, grinding, wet and dry size classification), is enormous. The most important operation indicators of concentrating plants — productivity and extraction of useful components into concentrates — are closely related to the granulometric composition of the processed raw materials [5].The practice of determining the sample weight for sieve analyzes is expressed by several, often conflicting tables and recommendations (Fig. 3), where 1 is Taggart's results [5]; 2 - practice of the Ural concentrating factories; 3 - Practice of the Mekhanobr Institute; 4 –Evsiovich's results [6].

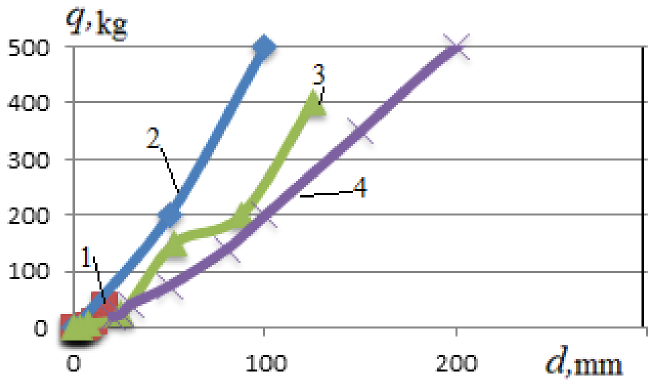

Figure 3: Weight of samples for sieve analysis from various sources

Mathematical processing of disparate data shows that the connection between the size of the maximum piece or particle and the sample weight for sieve analysis obeys the empirical formula proposed by S.G. Evsiovich[6]:

$$q_{min} = 0{,}02\, d^2 + 0{,}5\, d, \tag{5}$$

whereq_{min} is the minimum sample weight for sieve analysis, kg;
d is the size of the maximum pieces or particles, mm.

Considering that the sieve analysis error up to ± 1% of the sample weight is considered quite satisfactory, the size of the sieve holes, on which about 1% of the total material remains, can be taken as the maximum size.

A serious study of the connection between the size of ore pieces and the sample weight for sieve analysis using the theory of probability and the theory of the average size calculating of a mineral grain mixture was carried out by D. A. Krasnov [7], who suggested that the minimum sample weight for sieve analysis can be determined by the formula

$$q = 45 \frac{3-k}{k(r^{3-k}-1)} \frac{d^3 \delta t^3}{P^3} \tag{6}$$

whereδ is the specific gravity of a useful mineral or its intergrowths with waste rock, g/cm^3;
r is the modulus of the geometrically progressive sieve analysis scale;
k is the exponent of the cumulative characteristic of the tested material ($k<3$, usually $k=1$);
P is the given sampling error in relative percentages ($P> 5\%$);
t is the probability parameter (usually $t = 2$).

To use this formula, it is necessary to have a preliminary understanding of the particle size distribution of the tested material. Thus, for practice it can be used the formula (5) [8].

III. CONCLUSION

It was observed that the mass of the primary sample was related to the size of the mineral pieces: the smaller the pieces, the more of them should be taken into the sample. The properties of the material play a significant role in determining the required mass of the sample. Errors in the reduction of the sample mass depend on the excess or lack of useful mineral pieces, replaced by pieces. For sieve practical analysis, the connection between the size of the maximum piece or particle and the sample weight can be described with an acceptable accuracy by the formula $q_{min} = 0.02\ d^2 + 0.5\ d$.

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