Disintegration of geomaterials in ore pretreatment–The role and significance

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Abstract. It is shown that all ore pretreatment processes including the stages of crushing and grinding, depending on the structural and texture features of geomaterials, have two interconnected sides: destruction and disintegration. Disintegration is considered as a process of selective separation of geomaterials by their weakest bonds and as a process concomitant with mechanical destruction. The paper justifies the methodology for determining the degree of geomaterial disintegration by the example of impact crushing using grain size composition of crushed products. The proposed procedure is based on isolating the fraction of material that is predominantly accumulated in the form of a mode, which depends on the energy of mechanical effect that is responsible for the process of actual geomaterial destruction and is determined as a lognormal distribution. In this case, the degree of disintegration is determined by subtracting the fraction of geomaterial formed directly by mechanical destruction (in percent or unit fractions) from total distribution sum of grain size composition. Examples of calculating the degree of disintegration for some ore geomaterials are given. Assessing the degree of disintegration according to the developed procedure can become an important characteristic of ore pretreatment and operating performance factor of crushing and grinding devices.

1. Introduction
Disintegration of geomaterials in ore pretreatment is significant, since it determines release of useful mineral components before their dressing. It is shown that all processes of ore pretreatment including crushing and grinding, depending on structural and textural features of geomaterials, have two interrelated sides: disintegration and destruction. If destruction of lumpy geomaterial can be generally presented as reduction in size under mechanical effect, then disintegration is selective destruction mainly by the weakest mechanical bonds. For lumpy ore geomaterials representing conglomerates of a polymineral type, selective destruction occurs, as a rule, along the existing defects, voids and cracks, as well as along the boundaries of mineral phases. The latter is important in the release of useful mineral components and is the ultimate goal of ore pretreatment process. The disintegration mode most closely corresponds to the “golden rule” of ore pretreatment - not to crush more than necessary. Moreover, there is a need to maximize the preservation of the released mineral substance in its natural state, i.e., to minimize overgrinding of minerals to be released. This problem is very common in diamonds and other brittle and soft minerals. Thus, the process of ore pretreatment in disintegration mode is of key importance. The scientific literature gives a general understanding of disintegration process, but the quantitative parameters have not yet been determined, and there are not even clear criteria for which ore pretreatment process can be considered disintegration?
2. Geomaterial disintegration methods

The most studied are the processes of selective destruction of geomaterials caused by the difference in physical and mechanical properties of various ore components, determined by individual crushability index [1]. Theoretically, if a low content of useful components having the same strength properties as the ore matrix is present in geomaterials, then selectivity of crushing the disclosure is out of question. In fact, even in these conditions, a large difference in the degree of crushing the components can be observed, considering the difference in size (dissemination) of mineral components.

The selectivity of destruction of mineral components was quantitatively estimated by MD Krasnov, who used Henry’s washability curves to derive the index of crushing selectivity. The basis for the destruction selectivity index is the excess of any component in one or more size classes compared to its weight, which should be present in this size class at the initial content of the same component [2].

According to VI Revnivtsev, selective disintegration is a process of rock failure which proceeds geometrically and energetically selectively [3]. Geometric selectivity is understood as the destruction of an object along the phase boundaries, and energy selectivity is the minimum energy consumption during destruction.

Also known are the works on the release (liberation) of minerals (useful components), in which the degree of release of minerals is usually determined by mineralogical studies, and it is one of the requirements for the quality of ore pretreatment before dressing. Currently, various methods and techniques for assessing the degree of release have been developed and are used, the main ones are: visual-macroscopic, microscopic, gravity-optical, and separative-analytical [4]. In particular, by analogy with [5, 6], finely disseminated ore is released using the coefficient of intercrystalline grinding, which is the ratio of newly formed material surface obtained due to the destruction of intergrowth contacts of minerals to general newly formed surface obtained during grinding at the same time. In practice, it is difficult to determine the selectivity of release by specific surface area of intercrystalline fracture, precise research methods are required. The value of release selectivity largely depends on the size and structural features of the original material and is ambiguous due to the heterogeneity of geomaterials of even one type or even an individual sample.

The releasability, in turn, is related to useful component dissemination in ore. The minimum value of mineral dissemination is often the main requirement for the depth of geomaterial grinding during ore pretreatment, the selectivity of release is not taken into account.

From the viewpoint of release selectivity of mineral phases, impact methods of crushing and grinding are most effective due to their possibility of volumetric destruction when applying point dynamic mechanical actions. It could be said that this process includes destruction in the mode of disintegration, i.e. rupture of the weakest mechanical bonds of geomaterial. However, there is no universal procedure for determining the degree of disintegration.

This paper aims at developing a relatively simple technique for quantitatively estimating the characteristics of geomaterial disintegration during ore pretreatment. In a first approximation, this information can be obtained from the characteristics of grain-size composition of crushing and grinding products. It is known that each geomaterial, depending on the method of ore pretreatment, has its own specific grain-size characteristics of products. However, multiple experiments show that there are still certain regularities. First of all, the formation of grain-size characteristics depends on the impact energy (mechanical impulse), as well as textural and structural features of geomaterial. As a result, grain-size characteristics of crushing products have a polymodal form. Moreover, polymodality, i.e. accumulation of materials in certain size classes is clearly manifested not at single, but at multiple mechanical actions.

The formation dynamics of a bimodal granulometric polygon for the distribution of specially selected samples of gold-bearing ore from the Nezhdaninskoye deposit with a uniform dissemination of sulfide monomineral particles predominantly of \(-0.63 + 0.315\) mm size is graphically shown in Figure 1 on a dimensionless scale for 10 crushing cycles in a rotary crusher of active impact type.
For the case under consideration, the VM Kuznetsov’s theory [7] is the most suitable. According to this theory, when a rock consisting of strong grains (in our case, monocrystals of sulfide minerals with a visible dissemination of \(-0.63 + 0.315\) mm fractions) located inside a less strong binding mass is destructed, the grain-size distribution of crushing products will be described by a curve with two maxima. One of these extrema corresponds to the average size of strong grains (-2.5 + 1 mm size) inaccessible to destruction under the active impact energy, the second – to the average size of fragments of disseminated inclusions of sulfide minerals (-0.63 + 0.315 mm size). Thus, there is a combination of two distributions: one is set by the degree of geomaterial destruction depending on the applied mechanical actions, the second is caused by structural and textural features.

The second case is the release of disseminated mineral grains - sulfide minerals and destruction of the binding mass. At the same time, conditions are created for the selective disclosure of sulfide monominerals and all this causes the formation of a characteristic mode in the \(-0.63 + 0.315\) mm size in grain-size characteristics of disintegration product.

Figure 1. Dynamics of material redistribution by sizes with respect to crushing cycles.

Thus, the experimental studies helped to determine the facts of selective destruction of rocks depending on the textural features that have disintegration character, i.e. volumetric destruction of geomaterials in zones with the weakest mechanical bonds and which are mainly manifested when multiple dynamic actions are applied. In this regard, it is necessary to develop a technique that could quantitatively determine the degree of disintegration in general crushing pattern.

The main idea of developing such a technique is quantitative determination of two distributions based on impact energy and textural features of geomaterial.

In the first case, distribution in the region of large sizes can be described by a certain law, for example, a lognormal distribution, also known as Kolmogorov distribution [8]. The validity of logarithmically normal distribution law for powdered monomaterials for the case of long-term mechanical grinding was theoretically proved by Kolmogorov. The applicability of this law for many types has been confirmed by a number of experimental studies. Something similar can be admitted in
our case, bearing in mind the type and statistical processing of distribution form of the corresponding mode forming due to multicycle crushing.

The procedure for calculating the degree of disintegration is shown in Figure 2, where grain-size characteristic of crushing products has two modes, one in the region of fine sizes and the other in the region of coarse sizes. As determined, the second mode has the form of a lognormal distribution (shaded part) and represents the fraction of material destroyed due to disintegration, i.e. spontaneous dispersion of the weakest part of geomaterial depending on the texture features. Thus, the ratio of the shaded area to the total weight of crushed material is the desired degree of disintegration.

![Figure 2. Procedure for determining the degree of disintegration.](image)

The calculation part of the procedure is as follows. The parameters of mode region in the region of coarse fractions limited by its size $lgd_1$ and $lgd_2$ and the yield value $\gamma_{\text{max}}$ are found. The area is determined:

$$S_0 = \int_{lgd_1}^{lgd_2} f(x)dx$$  \hspace{1cm} (1),

where $d_1, d_2$ is the size of crushed material.

From the condition: $S = f(x)$ equated to the function of lognormal distribution:

$$e^{-\frac{(\log(x-a))^2}{2\delta^2}} = f(x)$$  \hspace{1cm} (2),

where $x$ is yield of crushing product of a given size, $a$ is average value of crushed material size.

$$e^{-\frac{(x-d_1+d_2)}{2\delta^2}} = f(x)$$  \hspace{1cm} (3)

the value of $\delta$ is the root-mean-square deviation, then the area under lognormal distribution function is calculated on the interval $(n_i, N_i)$:

$$S = \frac{1}{\sqrt{2\pi}\delta} \int_{n_i}^{N_i} e^{-\frac{(\log(x-a))^2}{2\delta^2}} dx$$  \hspace{1cm} (4),

where $n_i$ is the logarithm of the minimum size of crushed material, $N_i$ is the logarithm of the maximum size of crushed material.

Then, the degree of disintegration is determined:

$$D = 1 - \frac{1}{\sqrt{2\pi}\delta} \int_{n_i}^{N_i} e^{-\frac{(\log(x-a))^2}{2\delta^2}} dx$$  \hspace{1cm} (5)
The graphical part of determining the disintegration degree of quartz-antimonite ore from the Sentachan deposit is shown in Figure 3.

![Figure 3](image)

**Figure 3.** Diagram of determining the disintegration degree of quartz-antimonite ore from the Sentachan deposit.

### 3. Conclusions

The developed technique makes it possible to quantify the degree of disintegration that occurs in the processes of ore pretreatment (during crushing and grinding) as an accompanying mechanical destruction due to the presence of phases with the weakest bonds conditioned by textural and structural features in real geomaterials. The heterogeneity of geomaterials results in formation of grain-size composition of crushing products, which, as a rule, has a modal character that is clearly manifested when multiple dynamic actions are applied. The degree of disintegration determined by isolating the fraction of materials formed directly by mechanical destruction from the total share of distribution of grain-size composition of crushing or grinding products is an important characteristic of ore pretreatment process and operating performance factor of crushing and grinding devices. For example, the degree of disintegration of quartz-antimonite ore from the Sentachan deposit determined by this procedure is 0.743, which means that ore is prone to active disintegration, or more than 70% of reducing the geomaterial size during crushing occurs in the disintegration mode.

### References

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