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QUANTITATIVE ESTIMATION OF DISSOCIATION OF MINERALS USING OPTICAL METHODS OF MINERALOGICAL ANALYSIS

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An ore feed of mineral processing plants is a mixture of barren rocks and ore minerals possessing different physico-mechanical properties, including grinding and dissociation abilities.

In operating experience of process laboratories, the optimized final or intermediate size of ground ore is estimated based on the technology parameters. The optimality range of ore grinding parameters, characterized by the maximum dissociation and minimum overgrinding of valuable minerals, can be predicted at the stage of processing of data obtained in mineralogical analysis using modern image analysis systems.

The integrated mineralogical research conducted by the Mineralogical Laboratory of RIVS, including examination of texture and structure and analysis of dissociation of valuable minerals, using computer-aided microimage analysis systems and mathematical processing of the mineralogical analysis data toward calculation of batch contrast coefficient has allowed, in the authors' opinion, the reasoned estimation of the grinding parameters of feed ore.

This article exemplifies the mineralogical-analytical approach to finding dissociation parameters of minerals in terms of complex ore from Korbalikha deposit. The authors have studied in detail the features of texture and structure of the ore sample, analyzed dissociation ability of valuable minerals and calculated their batch contrast based on the data of mineralogical analysis using the dedicated automated image analysis program Mineral S7.

Key words: *complex ore, structure, texture, mineral dissociation, batch contrast, automated image analysis.*

Efficiency of any mineral processing technology is generally governed by dissociation ability of valuable minerals in the processing feed and by perfection of mineral processing equipment.

Preparing feed for flotation includes determination of mineral grinding optimality range characterized by the maximum dissociation of minerals and by the minimized transition of valuable components in slurry that is difficult to process. These issues are of the high concern in studying grindability and dissociation ability of complex ores that, aside from the multi-component composition of valuable minerals, feature nonuniform intergrowth of minerals, heterogeneous dissemination and variable size of useful mineral grains.

In practice of process laboratories, the optimized final or intermediate size of a ground mineral is selected based on the experimental process variables [1].

The optimality range of mineral grinding parameters can be identified in processing of mineralogical analysis data using advanced microimage analysis systems.

The Mineralogy Laboratory, RIVS, has analyzed material constitution of complex ore from Korbalikha deposit. The mineragraphy study used Leica MZ 16 stereo microscope, Olympus BX51 microscope with SIMAGIS 2P-3C digital camera and Leica DM4500P microscope with Leica DFC490 digital camera. Statistical reliability of the analysis was supported by the dedicated automated image analysis program Mineral S7. On the basis of the available wide range of geometry and morphology information, the data on mineralogy and grain-size can be obtained, such as size of grains, distribution of minerals in aggregates, qualitative–quantitative ratio of minerals in aggregates, percentage of dissociated mineral grains.

Korbalikha ore is represented by hard, sometimes jointy rocks having disseminated, pocket-disseminated (spotty), vein, vein-disseminated and breccias texture.

Structures of the ore are highly variable, differently combined and overlapped. Widely spread are structures unfavorable for flotation — cataclastic, corrosive, colloidal, or decomposed solid solution. Interfaces of intergrown minerals in such structures are uneven, which complicates dissociation of minerals in grinding (**Figs. 1–5**).

The base minerals are pyrite (17.5%), sphalerite (9.6%), galena (2.8%) and chalcopyrite (2.5%). The secondary copper minerals (covelline, chalcosine, bornite) make 0.15%. Nonmetals (67.3%) are mainly dolomite, calcite, magnesium silicates and quartz. Magnesium aluminum silicates and mica are present in small amount; albite, plagioclase, accessory minerals (titanite, rutile etc.) and hydroxides are observed.

Korbalikha ore features complicated, very fine intergrowth of zinc and copper sulfides. This shows itself in the widely spread structure of decomposed solid solution of chalcopyrite in sphalerite, where chalcopyrite has submicroscopic sizes (refer to Fig. 3). Besides, there are fine threadlike intergrowths of sphalerite in aggregates of chalcopyrite (Figs. 2 and 4). For galena, fine-grain poikilitic inclusions are typical, from hundreds of fractions to units of micrometer in size (Figs. 1 and 5). A part of pyrite has nonuniform structure. Such pyrite is observed in fine intergrowths with galena and sphalerite.

Such processing-adverse features of Korbalikha ore impede production of pure concentrates and impose stringent demands on selection of optimized size of ground ore.

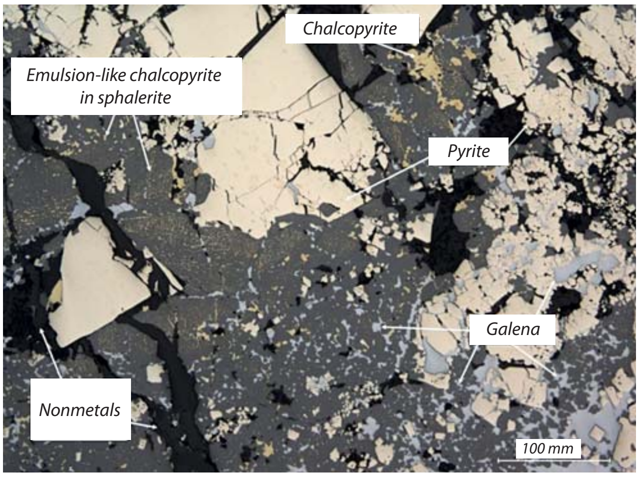

Fig. 1. Characteristic intergrowth of sulfide minerals of Korbalikha ore. Reflected light, parallel nicols

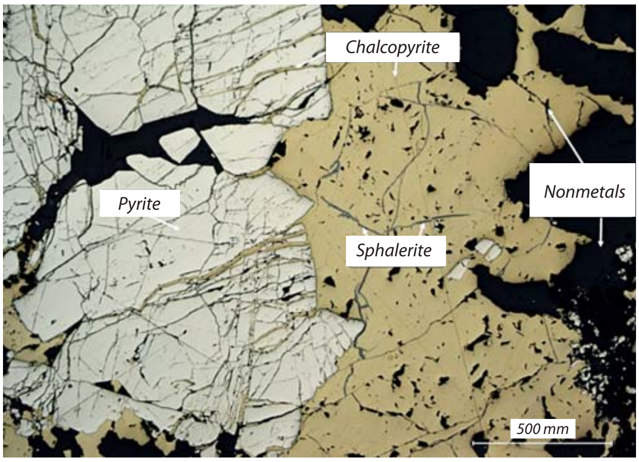

Fig. 2. Combination of structures: cataclastic, replacement (undulose aggregates of pyrite are replaced by chalcopyrite in cracks; in cracks in chalcopyrite, secondary copper minerals of chalcosine and covelline occur), and corrosion (chalcopyrite aggregate is corroded with nonmetals). Reflected light, parallel nicols

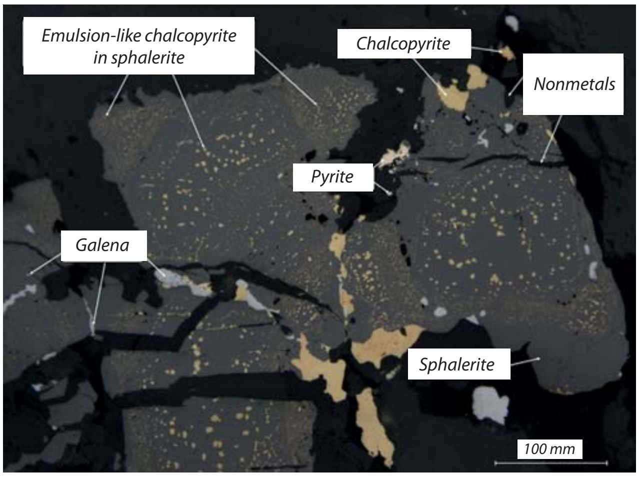

Fig. 3. Structure of decomposition of solid solution (emulsion-like chalcopyrite in sphalerite), corrosion microstructure (sphalerite aggregate is corroded with nonmetals). Reflected light, parallel nicols

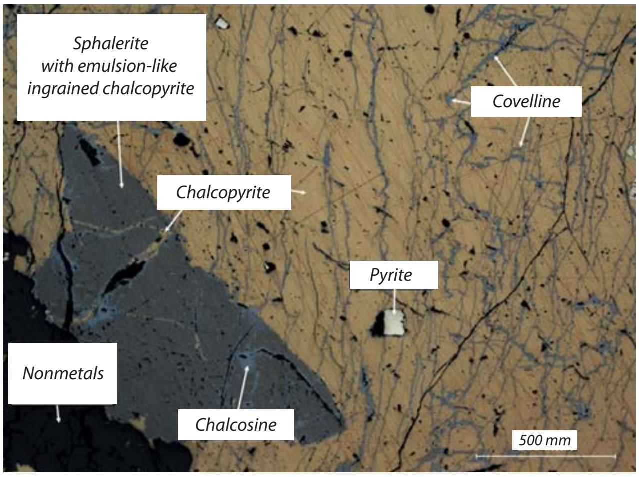

Fig. 4. Corrosion structures: chalcopyrite develops in cracks in sphalerite and is replaced with secondary copper minerals of chalcosine and covelline. Reflected light, parallel nicols

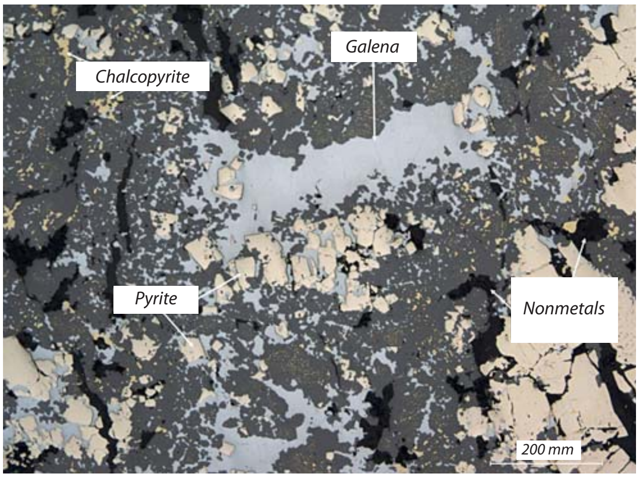

Fig. 5. Corrosion structure: galena "corrodes" aggregates of pyrite and sphalerite. Reflected light, parallel nicols

Table reports the data of the analysis of initial ore ground to the size of –2 mm (15.7 % content of –0.074 mm size) using Olympus BX51 optical microscope and automated image analysis program Mineral S7. As seen, dissociation of minerals in the ground initial ore is not higher than 11% (relative content).

In the course of grinding of the initial Korbalikha ore, dissociation dynamics of mineral aggregates was examined. Relationship of the mineral dissociation and the content of –74 µm size is shown in **Fig. 6**.

Much poorer dissociation of sphalerite is explained by that most of its grains are "saturated" with emulsion-like ingrained chalcopyrite (structure of decomposition of solid solution) (refer to Figs. 1 and 3). Fig. 6 only shows mineral dissociation dynamics without displaying distribution of grains pre size ranges and yield of slime fraction.

It is known that any processing method or machine has individual optimal range of size of initial feed [2]. In particular, mechanical-air machines have the lower limit of the feed size at 10 µm.

It is thought that a promising approach to optimizing parameters of ore pretreatment is the method of quantitative

Amount and dissociation of base minerals in Korbalikha ore sample

Mineral	Content, %		Mineral distribution in size ranges (µm), %				
	Actual percentage	Relative content	<10	10–40	40–74	74–100	>100
Sphalerite	9.65	100					
Free grains	0.27	2.75	25.2	32.6	42.2	0	0
Intergrown with:							
pyrite	0.03	0.3	31	69	0	0	0
galena	0.14	1.46	4.7	9.6	1.9	83.8	0
chalcopyrite	0.6	6.17	3.8	9.7	2,7	5.6	78.2
nonmetals	0.14	1.49	9.2	41.9	48.9	0	0
Polymineral aggregates	8.48	87.83	2.2	14	13.2	4.2	66.4
Galena	2.82	100					
Free grains	0.2	7.14	29	17.8	3	27.3	22.9
Intergrown with:							
pyrite	0.18	6.32	8.7	3.7	87.6	0	0
sphalerite	0.12	4.39	7.8	11.2	0	81	0
nonmetals	0.05	1.87	35	65	0	0	0
Polymineral aggregates	2.26	80.27	12	31.3	11.2	4	41.5
Chalcopyrite	2.45	100					
Free grains	0.27	10.92	1.3	81.8	2.3	4.8	9.8
Intergrown with:							
pyrite	0.01	0.46	1.9	98.1	0	0	0
sphalerite	0.4	16.3	18.3	9	0	0	72.7
covelline (chalcosine, bornite)	0.65	26.38	0	0	4.3	0	95.7
nonmetals	0.04	1.7	8.9	77.7	0	13.4	0
Polymineral aggregates	1.08	44.24	8.2	21.8	8.3	0.6	61.1
Pyrite	17.5						
Nonmetals	67.34						

control of valuable mineral going beyond the lower limit of size range set in accordance with the technology or equipment requirements, using the mineral dissociation criteria represented by a contrast coefficient.

The contrast coefficient is assumed to show the difference in terms of valuable component content between particles. The quantitative characteristic of a sample contrast is the weighted average deviation of a valuable component content of fractions (particles) from the average valuable component content of the sample. Governed by the valuable mineral dissociation, the contrast coefficient varies from 0 to 2 [3]. With the higher degree of grinding, the dissociation of a valuable mineral and, thus, the contrast coefficient is higher. This relationship conditions dynamics and category (class) of grinding and dissociation, but it gives no numerical definition of the optimal parameters of the grinding process.

It was shown in [4] that when calculation of the contrast coefficient unites grains of valuable minerals and barren rocks, having size below the lower limit of the feed size range set under the processing machine standard (10 µm), in a slime fraction where the yield and content of valuable component grow in the course of grinding, the curve of the batch contrast Mb and the grinding duration (or yield of –74 µm size grade) acquires

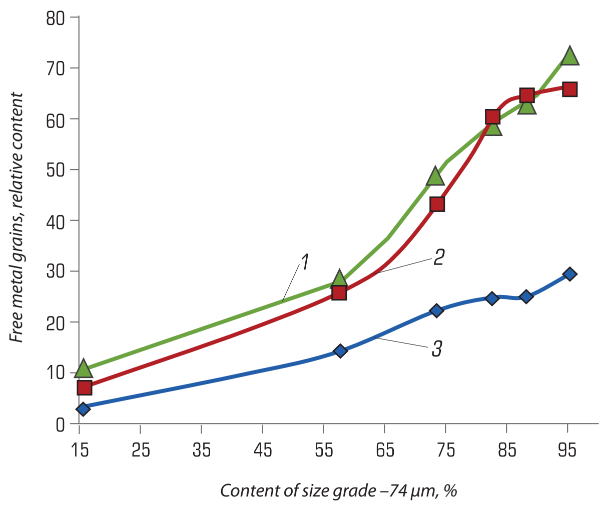

Fig. 6. Free grains of metals (relative content) versus the content of size grade –74 µm, %:
1 — chalcopyrite; *2* — galena; *3* — sphalerite

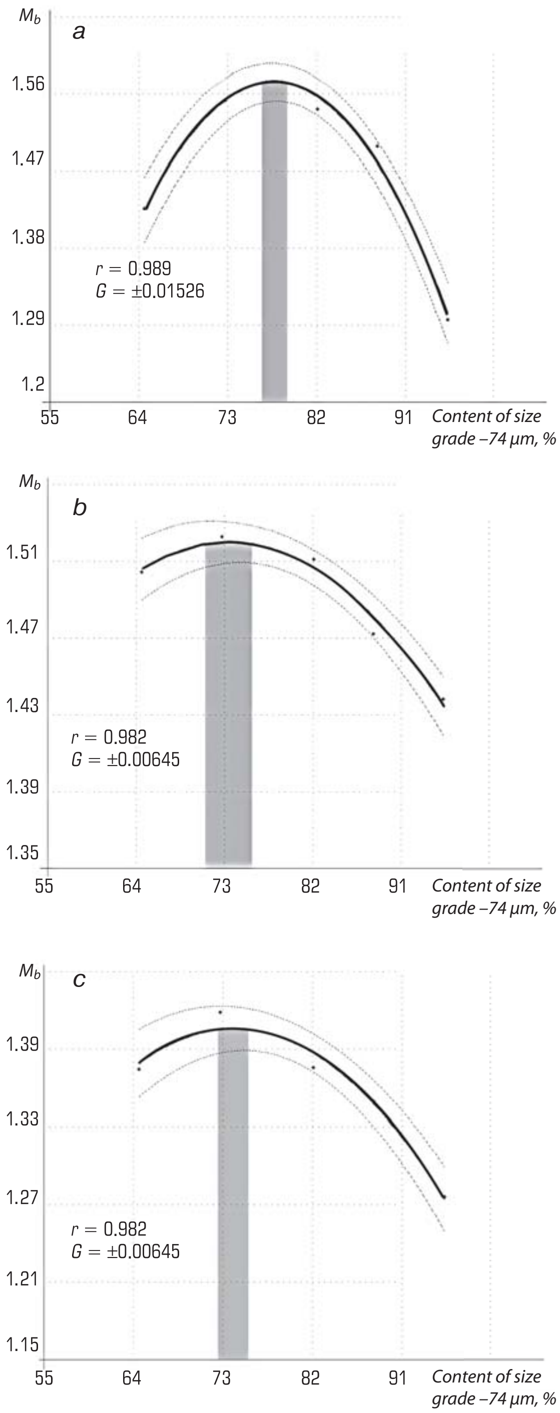

Fig. 7. The change in the batch contrast of (*a*) chalcopyrite, (*b*) galena and (*c*) sphalerite versus the content of size grade 74 µm (dashed lines are the confidence boundaries at Student's probability *P* = 0.95)

an extremum that governs numerical optimal parameters of the grinding process. The calculation uses the formula:

$$M_b = \frac{\sum_1^n |(\beta_i - \alpha)\gamma_i|}{100 \cdot \alpha} + \frac{|\beta_{slime} - \alpha|\gamma_{slime}}{100 \cdot \alpha},$$

where *n* is the number of particles (fractions) making the sample without slime components; α, β_i, β_{slime} are, respectively, the valuable mineral content of the initial sample, fraction and the united slime fraction, %; γ_{slime} is the united slime yield, %.

The relationship between the batch contrast of particles of chalcopyrite, galena and sphalerite and the content of –74 µm size grade in the ground ore is illustrated in **Fig. 7**.

The research has shown that the optimized dissociation of minerals takes place when the content of size grade –74 µm is 76–80% for chalcopyrite, 72–75% for galena and 73–75% for sphalerite. These data are in good consistency with the grinding process parameters selected in development of the efficient processing technology for Korbalikha deposit ore.

Conclusions

Complex ore of Korbalikha deposit features fine intergrowth of sulfide minerals with one another and rock-forming minerals. Prevalent adverse structures and insufficient dissociation of valuable minerals in the initial ore pre-conditions fine grinding of the ore prior to flotation.

Aiming to optimize the relation between the maximum dissociation and minimum overgrinding of mineral particles, the authors have calculated the coefficient of batch contrast with optical methods of mineralogical analysis used for the first time for a complex ore deposit. As the result, the limit for valuable minerals to go to difficult-to-process slimes can be quantitatively estimated, and the optimized grinding process parameters can be found.

In this way, the integrated mineralogical analysis, including texture and structure features and dissociation of valuable minerals, using computer-aided microimage analysis systems and mathematical processing of the mineralogical analysis data for calculation of coefficient of batch contrast has enabled, by the authors' opinion, the reasoned estimation of grinding parameters for complex ore of Korbalikha deposit.

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