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COPPER SUPER CONCENTRATE PRODUCTION TECHNOLOGY FOR OPERATING COPPER–MOLYBDENUM PROCESSING PLANTS

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Processing plant (PP) of Erdenet Mining Corporation treates complex copper–molybdenum ore from the Erdenetiin-Ovoo deposit and produces copper concentrate (copper content of 23.5 %) and molybdenum concentrate. In view of the change of the copper market trends and the higher cost of shipment, it is of current concern to have a high quality copper concentrate production technology with placement of scavenger circuit within a confined space of the operating PP given the currently used reagent regime is essentially preserved. The laboratory research has shown two feasible approaches to this problem solving: separation of copper "head" and individual flotation of sand and slime fractions. Based on the research findings, a copper concentrate perfection chart has been recommended and is currently used by PP. The offered approach can be extended for similar mineral processing plants.

In dressing of copper–molybdenum ore where copper is represented by primary minerals, the copper content of the concentrate is as rule not higher than 25 %. Given the high shipment cost and the changed trends on the copper market, it is advisable to be able to improve quality of the marketable concentrate. The authors offer the developed technology for high quality copper concentrate production and the related flow chart enabling placement of the required equipment in the territory of the operating plant. The approach is implemented by Erdenet Mining Corporation. The developed technology enables production of copper concentrate with the copper content not lower than 27 %. The approach is applicable at similar processing plants.

Erdenet Mining Corporation preparation plant processes Erdenetiin Ovoo complex copper–molybdenum ore and produces copper (copper content of 23.5 %) and molybdenum concentrates.

At the present time, in view of the change in the copper market trends and the increased concentrate haulage rate, it is expedient to develop a process for production of high quality copper concentrates. The difficulty of the task is conditioned by the requirement to accommodate the aftertreatment cycle inside of the limited area of the operating plant with the adherence to the actual chemical reagent conditions of the given plant.

The laboratory tests showed produceabilty of the copper concentrate (copper content not less than 27 % and copper loss per cycle not higher than 3 %) using two circuits: withdrawal of the first concentrate portion with the highest content of copper (termed "head as against "tailings") from the flotation circuit; separate flotation of sand and slime fractions. From the research evidence, the flotation circuit with the "head" withdrawal and the rest copper concentrate aftertreatment has been recommended and implemented. The project is adaptable at the similar processing plants.

Key words: *Erdenet Mining Corporation, copper–molybdenum ore, flotation, copper concentrate.*

Conventional Cu–Mo ore dressing circute includes bulk flotation with Cu–Mo concentrate production. Then, the concentrate either goes to final concentration for production of bulk concentrate with the copper content in accord with the quality standard[1], or is sent to selective flotation with self-contained process stages of copper[2] and molybdenum scavenging. The former scenario is the base case for porphyry copper processing.

An illustration of the base case scenario implementation is Erdenet Mining Corporation. The final concentration circuit includes thickening and washing of the bulk concentrate (**Fig. 1**). The discharge of the thickener, which accumulates and blends bulk concentrates (copper content of 13–17%, molybdenum content of 0.3–0.5%) received from all 6 circuits, is a feed of the final concentration circuit termed as copper–molybdenum flotation at the Erdenet processing plant. The bulk concentrate thickener discharge is ground in mill MSH-CHTS-3200×4500 in a closed circuit with two cyclones GTS-500 and enters Cu–Mo flotation.

The scavenger flotation froth is a finished Cu–Mo concentrate that goes to the thickener for washing and dewatering. The recleaner Cu–Mo flotation tailings are dumped.

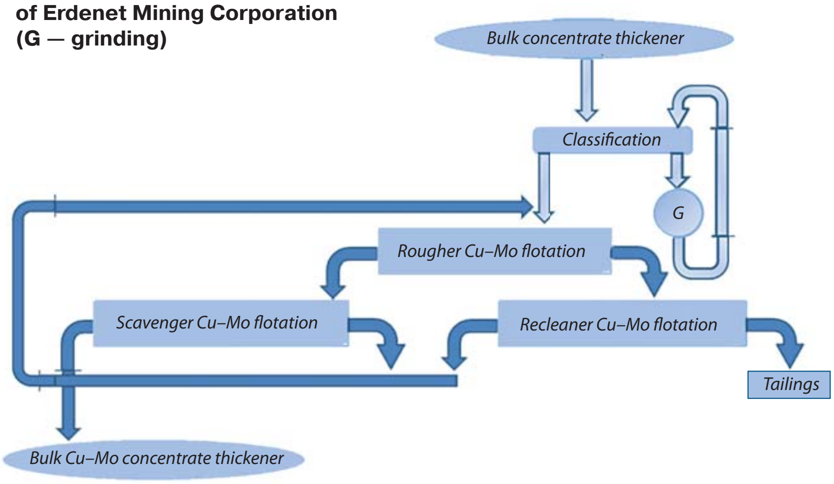
The objective of Cu–Mo flotation circuit is production of saleable Cu–Mo concentrate with the standard copper content (23.5%). The objective is achieved by means of final concentration circuit in lime—the bulk flotation content of CaO is 400–50 mg/l, the scavenger flotation content of CaO is 700 mg/l. Then, Cu–Mo concentrate is sent to selective flotation, and Cu concentrate in that case becomes the middlings of the molybdenum flotation circuit.

In the world, processing plants treating porphyry copper ore with comparable copper and molybdenum content at the similar output produce copper concentrate with the copper content of 25% and higher (**Table 1**).

For all conditional analogy[3], it is possible to state that Erdenet PP has a certain potential to improve its copper concentrate quality. Copper content of the copper concentrate, apart from mineralogical features, is as a rule the function of the

[1] In the next-following selection flotation circuit copper concentrate is obtained from middlings.
[2] It is also possible to include sand and slime copper circuits here.
[3] Primary/secondary copper minerals ratio, nature of impregnation, pyrite content of ore, etc.

Fig. 1. Layout of copper-molybdenum flotation at processing plant of Erdenet Mining Corporation (G — grinding)



next metallurgical process stage. Erdenet PP is a part of the Erdenet Mining Corporation, a steel works is readily accessible, logistics of concentrate transportation is simple—these factors condition production of low-grade concentrates at high metal recovery. On the other hand, high transportation costs incite technologies aimed at production of high-grade and even super concentrates.

Table 1. Work performance of copper–molybdenum processing plants

Processing plant	Content of ore, %		Copper content of concentrate, %	Copper recovery, %
	Cu	Mo		
Island Copper	0.5	0.02	25	85
Gaspe	0.66	0.02	30	90
Granisle Copper	0.43	0.01	25	85
Morency	0.5	0.01	25	85
Twin Butte	0.5	0.02	28	76
Dos Altosa	0.42		28	82
Palabora SA	0.55		32.5	83

Table 2. Element composition of the test sample

Element	Cu	Mo	Fetotal	Stotal
Average content, %	13.1	0.37	22.1	27.9
Content range, %	13–17	0.3–0.4	20–25	25–30

Table 3. Phase composition of the test sample

Copper compounds	Content, %	
	Absolute percentage	Relative amount
Oxidized copper	0.6	4.6
Secondary copper	5.07	38.7
Primary copper	7.43	56.7
Total	13.1	100

The changes in the copper market and the need of diversification of consumers call for technologies[4] that allow production of high-grade concentrates without appreciable capital expenditures. The analysis of engineering solutions accepted at the plants where analogous mineral material is processed shows that in terms of improvement of Cu concentrate quality, the most popular methods are the change of the reagent regime and the use of more selective collectors, which entails the rise in the cost of the marketable product.

The aim of this study is the increase in the copper content of Cu–Mo concentrate up to 27% with no decrease in the metal recovery by means of rearrangement of the currently accepted flotation flow chart.

Material constitution of Cu–Mo flotation circuit feed

The test object was the sample of the bulk concentration thickener discharge. The petrography and mineragraphy analysis of the sample was carried out at the RIVS's mineralogical laboratory. The chemistry and phase composition of the sample are given in **Tables 2** and **3**, respectively.

Mineral composition

Absolute percentage of copper minerals in the sample is,%: chalcopyrite 20, covelline 5.3, bornite 1.5, tennantite 0.5 and chalcosine 0.3. Chalcopyrite and chalcosine are dissociated to 75% or occur in aggregates mainly with covelline and bornite (14.4 and 12.2 in relative amount, respectively). Secondary copper minerals are dissociated to 50% (bornite) and 40% (covelline), or they may occur in aggregates with one another, or with chalcopyrite (**Fig. 2**). Free and aggregate copper minerals mainly have grains +10 µm in size. Molybdenite occurs as free grains, more often as elongated flakes, seldom tabular shaped. Free grains of pyrite make 80% of pyrite content of the sample, major portion of aggregates is with copper minerals.

Grain size composition examined on Mastersizer analyzer is shown in **Fig. 3**.

Finally, the analysis of the bulk concentrate sample has shown that:

- the sampled ore has a high copper head grade (>50%);
- there are almost no aggregates of copper minerals and nonmetals, a specific feature is intergrowth of sulfide minerals;
- primary copper minerals are dissociated by 75%;
- dissociation of secondary copper minerals ranges between 40% (covelline) to 75% (chalcosine);
- grains vary in a wide range of sizes (from 0.01 to 0.3 mm and larger); fine intergrowth of minerals is observed.

On the whole, both the mineral composition and the degree of dissociation of sulfides are favorable for production of copper super concentrate; the latter factor pre-conditions

4 And for modification of the actual processing charts, of course.

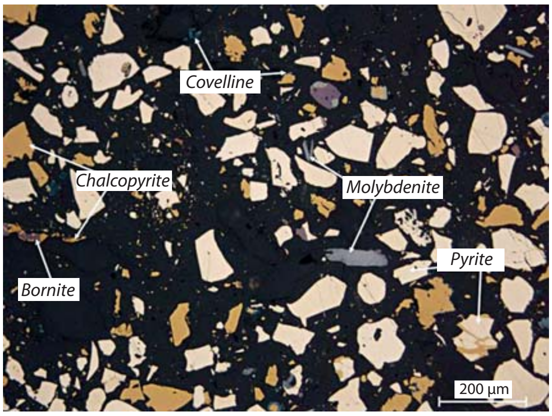


Fig. 2. Sample of the bulk concentrate thickener discharge. Reflected light, parallel nicols. Darker grains with relief — nonmetals

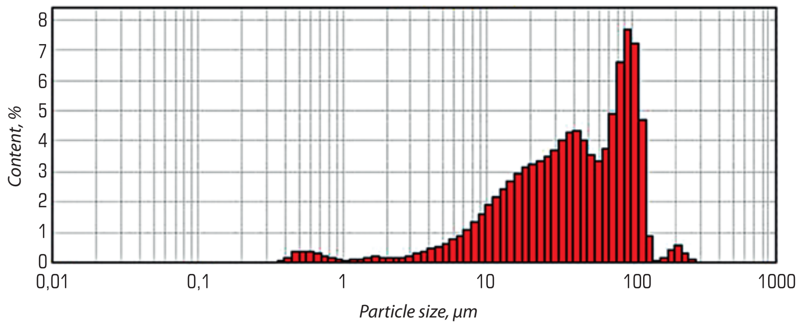


Fig. 3. Sample grain size composition

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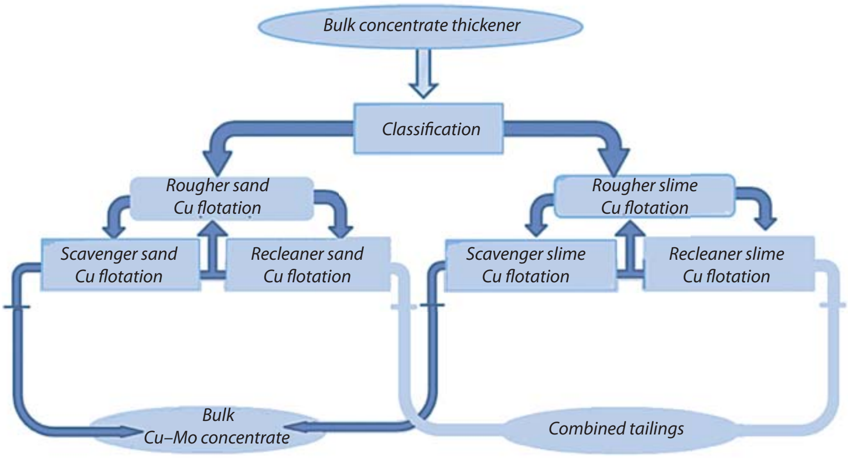

Fig. 4. Flow chart with Cu "head" separation

separate processing of sand and slime fractions of the final concentration circuit feed.

Feasible flow chart alternatives

Taking into account features of mineral dissociation, it seems most rational to carry out final concentration of the bulk cycle using the following charts:

Separation of Cu "head" (**Fig. 4**) with the copper content not less than 25%, regrinding of the middlings and its final concentration in the scavenger circuit up to the copper content of 27–28% and production of Cu–Mo concentrate with the copper content not less than 27%; a key problem — selection of a turn point where from middlings return in the processing cycle;

Dividing initial bulk concentrate into sand and slime fractions (**Fig. 5**), individual processing of the fractions and, then, blending of the discharges.

The highroad to complete dissociation of aggregates is regrinding of concentrates down to the size grade specified based on the mineralogical analysis results and the canonical chart flotation[5] afterwards. This circuit produces copper concentrate with the copper content under 25.0–25.8%. It is impossible to produce a higher quality Cu concentrate using the flow chart currently accepted by PP due to low (not more than 50–60 mg/l) residual content of CaO, which conforms with the bulk flotation index. Aiming at simplification of reagent regime in the final concentration curcuit, it was decided to adhere to the flow chart accepted at the plant. High activity of pyrite of Erdenetiin Ovoo porphyry copper ore in a weakly alkaline environment predetermines high yield of pyrite in froth and, as a consequence, low content of copper. The basic method used by the processing plant to increase copper content of the froth product is flotation in a lime environment. Regular content of CaO in the fi-

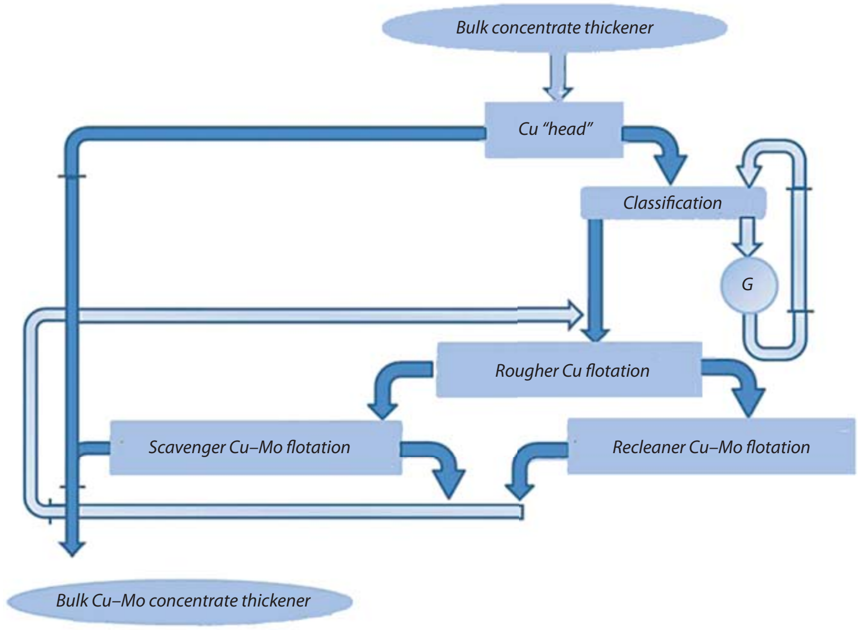

Fig. 5. Flow chart with separate flotation of sand and slime fractions (G — grinding)

[5] This circuit has been implemented at the final concentration phase at Erdenet PP.
[6] Molybdenite loss in the final concentration circuit is up to 30% (relative amount).

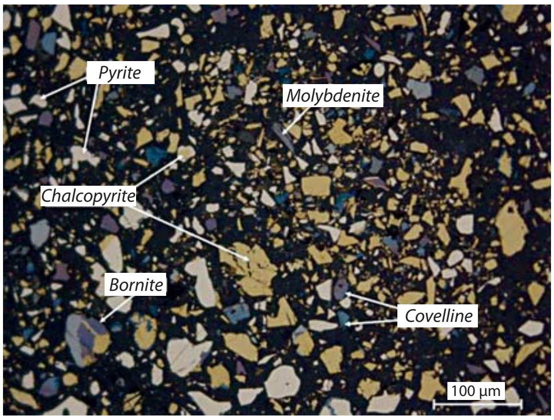

Fig. 6. Sample of Cu "head." Reflected light, parallel nicols. Darker grains with relief — nonmetals

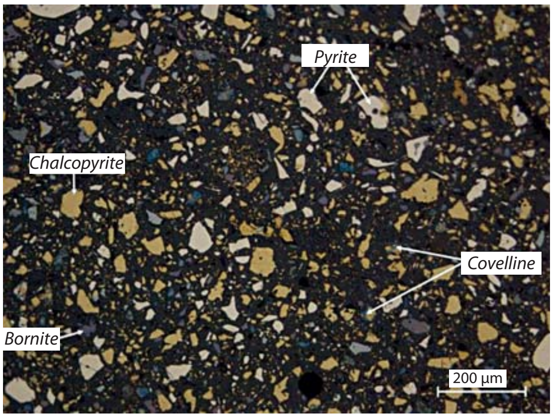

Fig. 7. Sample of scavenger Cu concentrate. Reflected light, parallel nicols. Darker grains with relief — nonmetals

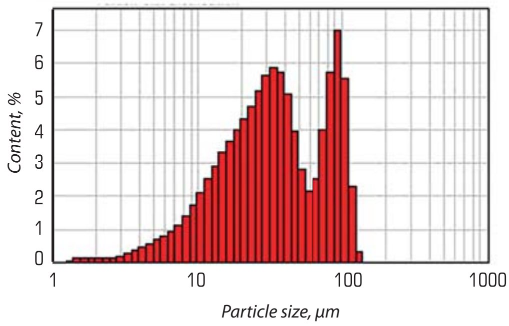

Fig. 8. Grain size composition of Cu "head"

concentration circut is 750–900 mg/l in the bulk flotation and 850–950 mg/l in the scavenger flotation. Nevertheless, based on the data of sampling in the past year, CaO concentration is 500–700 mg/l. It was many times observed that CaO concentration higher than 300–400 mg/l was accompanied by essential depression of flotation of molybdenite[6].

The experiments proved one of the aspects of the final concentration circute, namely, extreme dependence of the content and recovery of copper in the rougher flotation froth on the concentration of CaO. With the higher CaO concentration, the copper recovery and content grow, but the production data worsen in the concentration range from 500±50 mg/l and higher. Besides, it is found feasible to obtain Cu "head" with the copper content of 25–25.5% and more at the copper recovery of ~50% and above.

In conclusion of this section, the key processes in the flow chart with the separation of Cu "head" are:

- flotation in water phase of pulp slurry at the residual concentration of CaO within the range of 400–500 mg/l;
- regrinding of the 3rd thickener charge until the content of size grade –74 µm reaches 95%;
- sending middlings to classification or to feed Cu–Mo bulk flotation;
- introduction, if necessary, of a reagent–modifier to depress flotation of slime particles of aluminum silicates.

Flow charts with separation of Cu "head"

Thus, the keystones of the flow chart arrangement are:

- ratio of copper recovery in the Cu "head" and in the copper scavenger flotation concentrate;
- middlings return point.

It is worthy of saying that selection of the middlings return point in the final concentration circuit is a matter of principle for Erdenet processing plant. For some time past, middlings was returned either in the rougher final concentration, or Cu–Mi rougher flotation, or to the bulk concentrate thickener. As follows from the mineralogical analysis, copper minerals are mainly dissociated, and elimination of the excessive grinding of copper minerals needs that middlings is sent to the rougher Cu–Mo flotation circuit.

Self-contained experiments with intra-cycle water rotation were undertaken to test each of the competing flow charts. The experimental results show that when middlings is returned in the Cu–Mo flotation circuit, the bulk Cu concentrate assuredly has copper content of 27.3% at the recovery of 97.7%; with the alternative flow chart, the concentrate has copper content of 28.5% at the recovery of 96.9%.

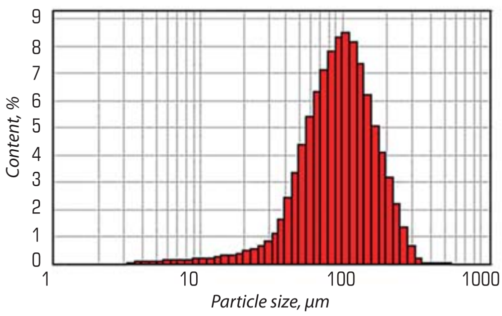

Fig. 9. Grain size composition of sand fraction

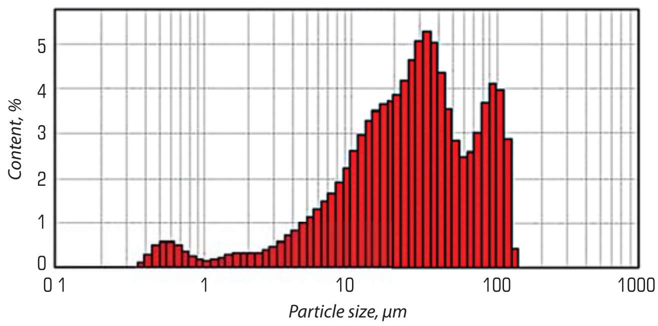

Fig. 10. Grain size composition of slime fraction

The mineralogy of the products of the both flow charts has been analyzed.

Mineragraphy of the products of the self-contained flow chart with Cu "head" separation

Figs. 6 and **7** show pictures of samples of Cu "head" and Cu scavenger flotation concentrate.

Cu "head" is mainly represented by dissociated grains of copper minerals: dissociation of chalcopyrite reaches 92%; bornite — 79%; chalcosine and covelline — 55%. Free grains of pyrite are also present in large amount, to 88%, but total content of pyrite is comparable with the content of chalcopyrite: 35.4 and 42.5%, respectively.

Distribution of minerals in scavenger flotation concentrate I partly conforms with the mineral distribution in Cu "head" in terms of coarseness and content of aggregates; however, there are some differences: free pyrite content lowers from 88 to 52%, which is indicative of a certain efficiency of the scavenger flotation circuit; molybdenite content grows from 0.4 to 0.9%. The grain size composition of Cu "head" is shown in **Fig. 8**.

The mineragraphical data on copper concentrates produced using the flow chart with various middlings return points show nearly the same compositions with the only major difference in terms of bornite aggregates that are mainly represented by fraction of 40–100 µm.

Flow chart with division of bulk concentrate into sand and slime fractions

The alternative to the Cu "head" separation chart is the flow chart where bulk concentrate is divided into sand and slime fractions which are then individually processed. After the processing the final products are joined together (refer to Fig. 5). Zangezur processing plant has implemented such flow chart with division of the bulk concentrate into sand and slime fractions by the grain size of 45 µm.

Grain size compositions of the sand and slime fractions are shown in **Figs. 9** and **10**, respectively. The data on chemistry and phase composition of the final concentration feed with division into sand and slime fractions are compiled in **Tables 4** and **5**.

From the comparison of the data on dissociation of minerals in the fractions of the bulk concentrate (**Figs. 11** and **12**), of interest is the ratio of dissociated grains of primary and

Table 4. Element composition of the bulk concentrate

Element	Cu	Mo	Fetotal	Stotal
Sand fraction	10.1	0.38	24.5	29.9
Slime fraction	15.9	0.38	21.5	27.3

Table 5. Phase composition of the bulk concentrate

Copper minerals	Sand fraction		Slime fraction	
	Content, %			
	Actual percentage	Relative amount	Absolute percentage	Relative amount
Oxidized	0.27	2.67	0.97	6.1
Secondary	3.55	35.15	6.47	40.69
Primary	6.28	62.18	8.46	53.21
Total	10.1	100	15.9	100

Table 6. Self-contained experiment data

Product	Yield, %	Content, %			Recovery, %		
		Cu	Mo	Fe	Cu	Mo	Fe
Sand Cu–Mo concentrate	14.91	32.34	0.612	22.84	34.82	34.35	18.64
Slime Cu–Mo concentrate	31.74	27.17	0.444	27.15	62.3	53.06	47.17
Total Cu–Mo concentrate	46.65	28.82	0.498	25.77	97.12	87.41	65.81
Sand recleaner tailings	32.09	0.64	0.038	14.67	1.48	4.59	25.77
Slime recleaner tailings	21.26	0.91	0.1	7.23	1.4	8	8.42
Total tailings	53.35	0.75	0.063	11.71	2.88	12.159	34.19
Initial feed	100	13.84	0.266	18.27	100	100	100

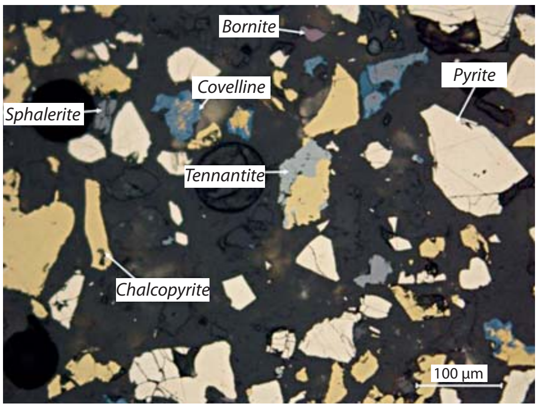

Fig. 11. Sand fraction of bulk concentrate. Reflected light, parallel nicols. Darker grains with relief — nonmetals

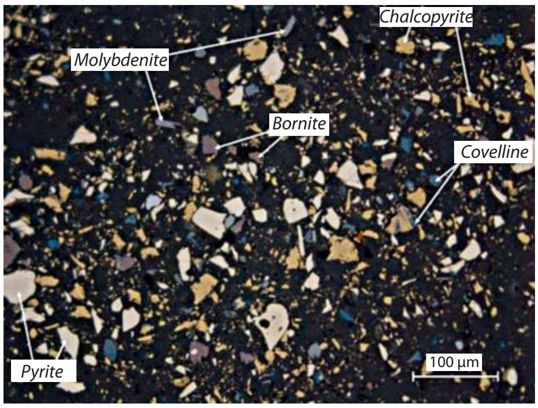

Fig. 12. Slime fraction of bulk concentrate. Reflected light, parallel nicols. Darker grains with relief — nonmetals

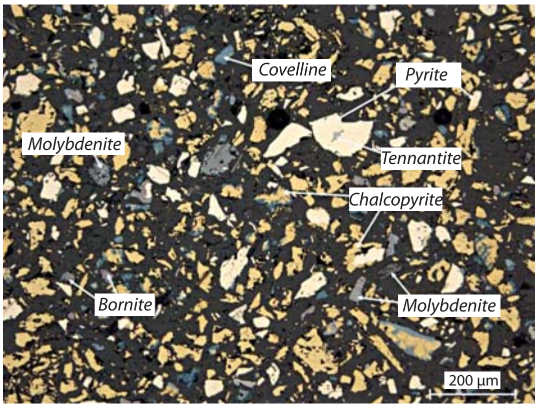

Fig. 13. Sand fraction concentrate. Reflected light, parallel nicols. Darker grains with relief — nonmetals

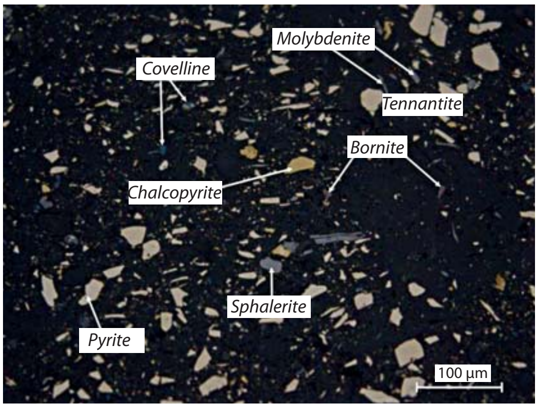

Fig. 14. Slime fraction concentrate. Reflected light, parallel nicols. Darker grains with relief — nonmetals

secondary copper minerals: dissociation of chalcopyrite grains in the sand/slime fractions is 84–93%, while the content of dissociated grains of secondary minerals of copper and pyrite is almost the same. The share of dissociated copper minerals is about 21% in the sand fraction and 31% in the slime fraction. The sand fraction nearly contains no dissociated chalcopyrite of the size grade –10 μm, while its content in the slime fraction reaches 51%. So, it is rather difficult to predict high quality of the copper concentrate in the slime fraction circuit but high recovery of copper in the froth at this stage is guaranteed.

The summarized data of the self-contained experiment on the separate flotation of the sand and slime fractions are given in **Table 6**.

The processing regimes for the sand and slime fractions differ in that:

• the sand fraction is ground to the 90% content of –74 μm size;

• the reagent regime for the sand fraction involves the second collector — diesel fuel;

• the reagent regime for the slime fraction is added with the depressor for flotation of slime aluminum silicates;

• the consumption of the prime collector for the slime fraction is increased to 60 g/t in the rougher flotation and to 30 g/t in the recleaner;

• the content of solid in the rougher slime flotation is twice as little — 15%.

Mineragraphy of concentrates after individual processing of sand and slime fractions

Sand fraction flotation concentrate. With the overall degree of dissociation of copper sulfides up to 60%, there are composite aggregates of copper sulfides with one another and with pyrite and sphalerite, as well as aggregates of chalcopyrite with molybdenite and molybdenite with nonmetals (**Fig. 13**).

Slime fraction flotation concentrate. The actual percentage of chalcopyrite is much lower, by 20%, and the portion of dissociated grains of chalcopyrite is lower as well, by 15% (**Fig. 14**). The situation is opposite in terms of covelline: the portion of dissociated covelline is twice as little in the sand fraction concentrate than in the slime fraction concentrate at the same covelline content. The same is valid for bornite. Appreciable difference is in the degree of dissociation of pyrite grains: 9% in the sand fraction and 33% in the slime fraction. The overall content of dissociated minerals of copper is about 52%.

The analysis of the obtained results shows that:

• the sand and slime fractions have the comparable yields — 47 and 53%, respectively;

• the copper content of the sand fraction and slime fraction scavenger concentrates is 32.3 and 27.17%, respectively, with the yield of the latter twice as much the former—31.74 as against 14.91%;

• the joint Cu–Mo concentrate contains 28.82% copper (at recovery of 97.12%) and 0.498% Mo (at recovery of 87.4%); dump tailings have copper content of 0.75% and molybdenum content of 0.063%.

Conclusions

During development of a technology for production of copper super concentrate (copper content not lower than 27% at the preserved recovery) from a bulk concentrate, the following flow charts were tested (with overall adherence to the reagent regime accepted at the processing plant):

• separation of Cu "head;"

• individual processing of sand and slime fractions and blending of the final products.

The recommended flow chart (with separation of Cu "head") in accordance with the accepted reagent regime allowed for the bulk concentration processing at the copper content of 28.5% in the final concentrate at the recovery of 96.93% (per circuit).

By now, the final concentration circuit with Cu "head" separation has been introduced on the backup floor of the processing plant. The obtained engineering solutions can be used at the similar processing plant given some modifications are made. EM

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