POLSKIE TOWARZYSTWO MINERALOGICZNE – PRACE SPECJALNE
MINERALOGICAL SOCIETY OF POLAND – SPECIAL PAPERS
Zeszyt 22, 2003; Volume 22, 2003

Antoni MUSZER[1], Henryk KARAŚ[2]

APPLICATION OF MICROSCOPIC MINERALOGICAL ANALYSIS OF COPPER CONCENTRATE AFTER BIOLEACHING PROCESS

ABSTRACT

The main aim of this paper was the use of microscopic mineralogical analysis to evaluate the course and results of biotreatment process of bornite-chalcocite flotation concentrate. The comprehensive qualitative and quantitative examinations of the product samples enabled the fairly good evaluation of the entire process. The lab tests in bioleaching were made with the use of low grade copper concentrate. Bacterial leaching of the concentrate was carried out with the use of *Acidothiobacillus thiooxidans* and *Acidothiobacillus ferroxidans* strains. Results of the mineralogical analysis of ore minerals showed a positive effect of bioleaching process of sulphides. Microscopic images showed the influence of mutual intergrowths on the range and depth of bioleaching activity in grains of ore minerals. This factor appears to be the most important in selecting suitable bacterial strain and process temperature. This method, mostly used in special petrographic-mineralogical examinations, can be utilised in the evaluation of the bioleaching process as well.

INTRODUCTION

The main goal of mineralogical examinations was the use the ore mineralogy to analyse the effect of bioleaching process onto bornite-chalcocite copper concentrates. The qualitative and quantitative examinations of the feed and obtained processed products enabled the good evaluation of the entire process carried out on the laboratory scale. With the use of the comprehensive ore microscopy techniques we were able to evaluate the bioleaching process carried out. The sample of low copper content concentrate to be tested by bioleaching was taken out from the KGHM Polska Miedź S.A. Company (Poland).

1 University of Wroclaw, Institute of Geological Sciences, amus@ing.uni.wroc.pl
2 CBPM CUPRUM, Wroclaw, h.karas@cuprum.wroc.pl

MATERIAL AND METHODS

The mineralogical examinations of low copper content concentrate tested in the process (Fig.1) were made for each stage of the laboratory tests, which included the pre-treatment of the feed with the use of sulphuric acid and bioleaching operations in the temperatures 25^{o}C (K-25 sample) and 45 ^{o}C (K-45 sample). The aim of pre-treatment process was liberating the ore mineral grains from carbonates and lowering pH factor needed for creating the suitable bioleaching conditions when using bacteria strains.

Four examined samples corresponded with the each stage of the process (feed, pre-treatment, bioleaching in both temperatures). The samples representing each stage of the process were sifted to separate them into three classes, i.e. 125-250 μm, 63-125 μm and below 63 μm in grain diameter. The polished specimens have been made for each class for investigation in the reflected light. Grinding and polishing of specimens were made according to the standard procedures on the Struer-polishing cloths with the use of the matched diamond paste (Muszer 2000). The examinations of concentrate samples were carried out with the use of the Optiphot 2-Pol NICON microscope. The aim of examinations was the profile and identification of all minerals as well as investigations of intergrowth types between them.

Additionally, for each stage of tests the qualitative and quantitative analysis of ore minerals has been carried out with the use of microscopic analysis programme called “Lucia-M”. To identify minerals the basic methodology for ore mineral microscopy has been used (Ramdohr 1975; Picot, Johan 1982, Piestrzyński 1992, Muszer 2000).

MINERALOGICAL DESCRIPTION OF CONCENTRATE SAMPLE

Sieve analysis showed that almost 80% of the volume of sample were located in the grain fraction below 63 μm (Fig. 1a). The coarsest fraction i.e. 125-250 μm in diameter barely came to 1.5 % of the sample volume. The grain intergrowth analysis showed that 34% of ore minerals were unlocked and the rest of ore minerals (66%) made up overgrowths with quartz, clay and carbonate minerals. The further investigations of the concentrate sample revealed the increasing number of intergrowths in smaller grains of ore minerals.

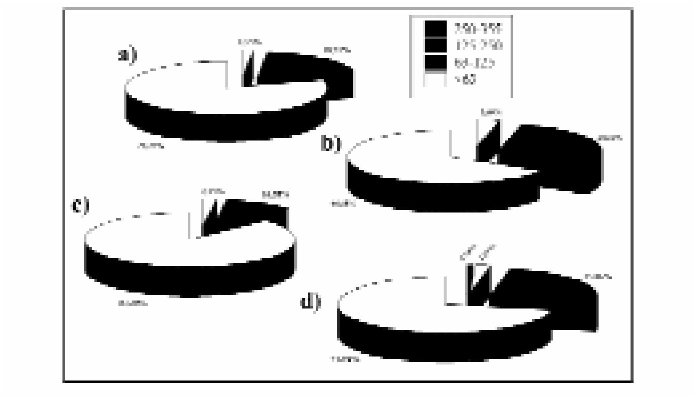

Fig.1. Grain size distribution: a) feed copper concentrate, b) feed after acid leaching – carbonate dissolution, c) bioleaching, temperature 25°C, d) bioleaching, temperature 45°C.

The main ore minerals identified in the concentrate sample were bornite, chalcocite (digenite), chalcopyrite, pyrite, the next ones were covellite and Ni-Co arsenides (rammelsbergite, safflorite, cobaltite, gersdorffite), sphalerite, tennantite and native silver.

GRAIN AND INTERGROWTH ANALYSES AFTER ACID LEACHING WITH H_2SO_4

The acid pre-treatment of concentrate sample was not focused on total carbonate dissolution, assuming 40%-50% carbonate dissolution in the feed. The obtained results of the grain size distribution after acid leaching are shown in Fig. 1b. The volume of coarser fractions (i.e. 125-250 and 63-125 μm in diameter) has increased when comparing it with Fig.1a. The crystallisation process of gypsum and its ability to join smaller grains of carbonate, clay and ore minerals explained this increase. Microscopic observations confirm the next obvious fact: the smaller grains the more effective dissolution process of carbonates (bigger surface exposure of ore grain).

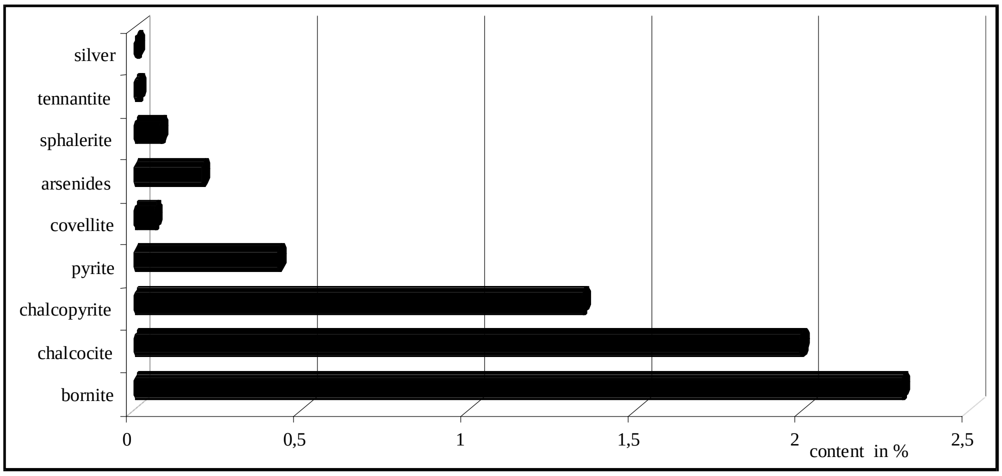

Fig. 2. The contents of ore minerals in concentrate samples after acid leaching.

The content of ore minerals after acid leaching of concentrate sample is shown on Fig. 2. Planimetric analysis of microscopic image has revealed the increase of ore minerals in the leached concentrate sample. The average content of ore minerals increased from 3% to 8.33% owing to acid leaching which exposed more ore minerals.

After acid leaching the entire number of intergrowths in concentrate sample has decreased from 66% (feed) to 40.2%. In the finest grain fraction (below 63 μm), that included 66.15% of the total concentrate volume, the content of ore minerals with no intergrowths (unlocked) was 77.5%. Before acid treatment the grains in this fraction were more intergrown with carbonates than with quartz.

CONCENTRATE DESCRIPTION AFTER BIOLEACHING IN TEMPERATURE 25 ^{O}C (SAMPLE K-25)

After the bioleaching process the finest grain fraction (below 63 μm) in concentrate sample K-25 surged significantly to 87.30% of total volume (Fig.1c). Before bioleaching this fraction was 66.14% of the total one (Fig.1b). The main cause of this surge was the breaking up of porous and brittle gypsum aggregates into smaller grains during bioleaching operation. Maybe, it was done by bacteria strains penetrating deeply aggregate structures. It can be stated that the process of gypsum aggregation of ore grains had no negative influence on bioleaching of copper concentrate. In the K-25 sample the decrease of ore minerals has been observed in particular grain fractions. The volume of ore minerals fell down from 8.33% to 3.91% of total sample volume. The important feature of the K-25 sample examined was a relative drop of ore mineral contents in 125-250 μm and 63-125 μm classes. An insignificant increase of ore minerals content in the finest grain fraction was observed. It seems that it can be attributed to bacterial activity (dissolution of ore mineral grains by bacteria strains).

When comparing mineralogical content found out in samples before bioleaching process (Fig.2) and after that operation (Fig.3) the decrease of chalcocite (digenite), bornite and chalcopyrite content was observed.

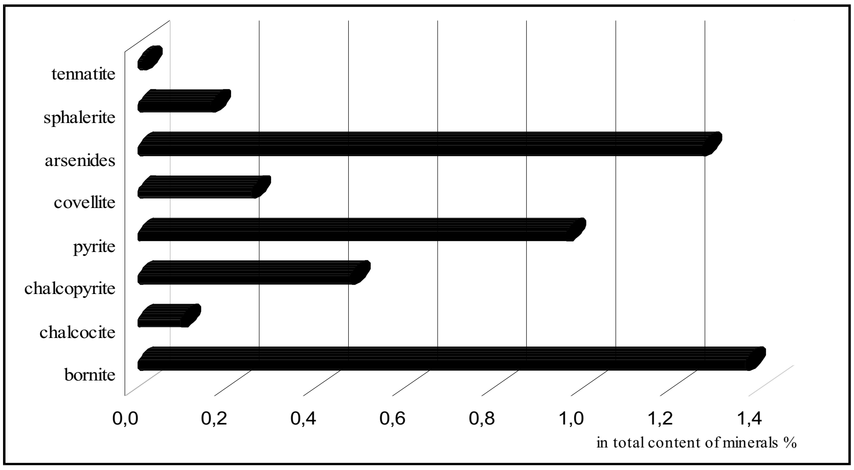

Fig. 3. Contents of ore minerals in K-25 sample after bioleaching in temperature 25^{o}C.

Unlikely the general drop of copper minerals content in concentrate sample after bioleaching the relative „increases" of covellite and Ni-Co arsenides content in the sample were observed. Ore mineral analysis in particular grain fractions showed that in the finest class such minerals as: bornite, pyrite and Ni-Co arsenides were dominating. It seems to be natural because grain sizes of Ni-Co arsenides mostly do not exceed diameter of 63 μm in the ore. The relative surge of Ni-Co arsenides in the entire content of minerals in K-25 sample confirms lack of mineralogical disintegration of arsenides by the bacterial activity. The same phenomenon can be observed in case of pyrite. Pyrite visible as strawberry-shape grains was inserted entirely into bornite and covellite grains. Lack of visible bacterial activity in pyrite crystals was attributed to no free access to them.

CONCENTRATE DESCRIPTION AFTER BIOLEACHING IN TEMPERATURE 45 ^{O}C (SAMPLE K-45)

When comparing figure 1d for K-45 sample with Fig.1c obtained for K-25 sample the different shape of grain size distribution after screen classification was seen. The appearance of additional 250-355 μm class of clayey-gypsum aggregations was caused by the more advanced pre-treatment stage carried out in the concentrate sample. The carbonates present in concentrate feed were nearly entirely dissolved. In the K-45 sample the quantity of ore minerals fell down from 8.33% to 1.23% of sample volume. The result was more significant than in the case of K-25 sample.

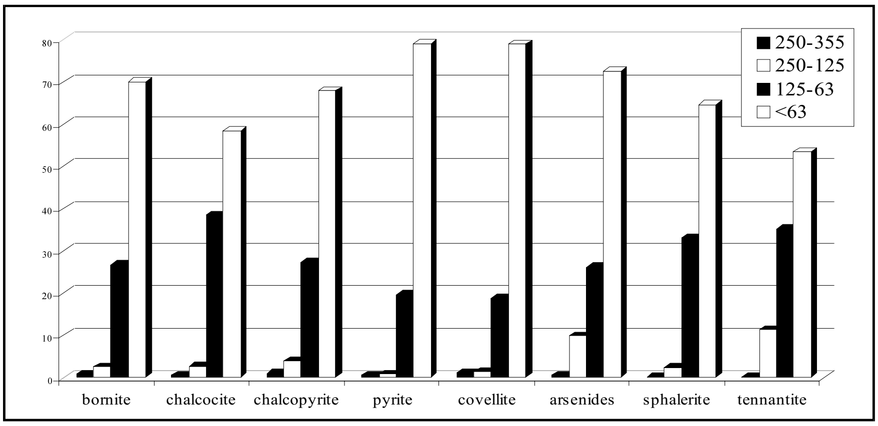

Fig.4. Distribution of ore minerals in particular grain fractions after bioleaching in temperature 45^{o}C.

The most important grain fraction in K-45-sample became the finest class (Fig.4) where all ore minerals participated in it. In 125-250 μm grain class the gypsum aggregates were noticed. The coarsest grains of ore minerals were chalcopyrite grains that amounted to 200 μm in diameter. We could find out very often chalkocite particles inserted in chalcopyrite grains. Most of big mineral grains in both 63-125 μm and below 63 μm grain class were unlocked. However fine ore mineral grains (<10 μm) inserted in clayey-gypsum or clay aggregations were observed. When comparing bioleaching process in both temperatures 25 and 45^{o}C better results were obtained in higher temperature. The contents of main copper minerals except chalcopyrite and covellite fell down more significantly in K-45 sample than in K-25 one. The lowest drop of mineral content was in case of bornite, pyrite and Ni-arsenides. It confirms stronger bacterial activity in case of higher temperature.

In case of arsenides the promising results of bioleaching of Co arsenides (safflorite and cobaltite) have been confirmed. The content of chalcopiryte has not been changed substantially. It confirmed bad results of bioleaching for this particular copper mineral present in concentrate. The same phenomenon can be attributed partly to the results of bioleaching of covellite.

CONCLUSIONS

Screen and mineralogical classification results of the obtained products from bioleaching of copper concentrate confirmed very promising final effect of this process despite unfavourable conditions created by gypsum aggregates in solution.

Ore microscopy proved that this phenomenon couldn't be significant obstacle in the bioleaching process. It can be assumed that bacteria strains were able to disintegrate the clayey-carbonate-gypsum aggregates. When using ore microscopy to compare results of bioleaching process for both temperatures 25^{o}C and 45^{o}C it can be concluded that:

1. growing population of bacteria strains made use of those copper minerals which had the highest copper content,
2. the highest temperature of the process the more promising effects of bioleaching,
3. bacteria strains used in the process were able to dissolve nearly all amount of chalcocite and digenite.
4. undissolved remnants of those easily leachable minerals were "hidden" inside other copper mineral grains i.e. in chalcopyrite, covellite or bornite which were more difficult to leach.
5. due to bacterial activity and higher process temperature (K-45 sample) complete dissolving Co-arsenides has been noticed in grain classes below 63 μm and 125-63 μm, however the content of Ni arsenides relatively increased in K-45 sample,
6. the size of diameter of chalcocite-digenite grains in the process tested was meaningless for bacteria strains used.
7. the most important factor stimulating or slowing down the process of bioleaching of copper minerals is the kind of intergrowth (mutual surface relationship) between easily leachable (chalcocite, digenite) and hardly leachable ore minerals (chalcopyrite, bornite). The same can be attributed to the intergrowth between ore and host rock minerals.

REFERENCES

MUSZER A., 2000: Outline of ore microscopy. University of Wroclaw. (*in Polish*).

PICOT P., JOHAN Z., 1982: Atlas of ore minerals. Elsevier, Amsterdam.

PIESTRZYŃSKI A., 1992: Materials to laboratory of ore microscopy. Krakow. (*in Polish*).

RAMDOHR P., 1975: Die Erzmineralien und ihre Verwachsungen. Akademie-Verlag, Berlin.