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MINERALOGRAPHY AS AN AID TO MILLING[1]

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The accurate determination of the opaque minerals present in an ore is very often of prime importance to the mill-man if he would work out the problem of separation intelligently. It is sufficiently obvious that a chemical analysis or an assay will only give him data as to the elements present and will leave him more or less in the dark as to the minerals represented in the ore. Since it has been found that certain sulfides are more amenable to flotation methods than others, the value of accurate mineralogical determination of the ores would appear to be particularly necessary in this form of milling. However, it should also be quite evident that any milling problem would be benefited at its inception by a careful study of the mineral content of the ore, the approximate quantitative proportions of the minerals present, and their mutual inter-relationships.

As far as the writer is aware the only satisfactory method for examining these ores microscopically is by means of polished sections in reflected light. This branch of Mineralogy, known variously as Mineralography or Mineragraphy, may also be applied to the microscopic study of mill-products in the different stages of separation. Where the fragmental material is fairly coarse a thin layer of it may be set in melted sealing-wax and polished in the ordinary way. If the material is fine enough to pass through a 48-mesh screen, before polishing, it must be mixed with a combination of melted sealing-wax and balsam. This may conveniently be accomplished in a small porcelain dish in which the wax and balsam are melted, the powder being poured in and stirred all through the mixture. The grinding operations which are so useful with the coarser powders and with the solid sections, must be eliminated for these finer powders and a good part of the polishing must be done by hand on a rouge-block.

[1] Presented at the annual meeting of the Mineralogical Society of America, Ann Arbor, Michigan, Dec. 29, 1922.

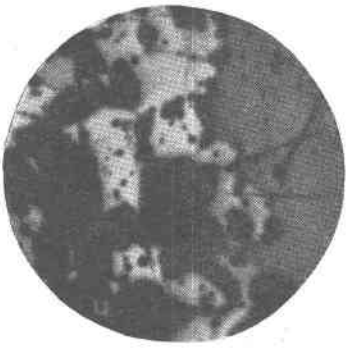

FIG. 1. Solid Section—White, pentlandite; gray, pyrrhotite; black, gangue. Magnification 150 ×.

FIG. 2. Passed thru 20-mesh screen. White, pentlandite; gray, pyrrhotite; black, gangue and wax. Magnification 150 ×.

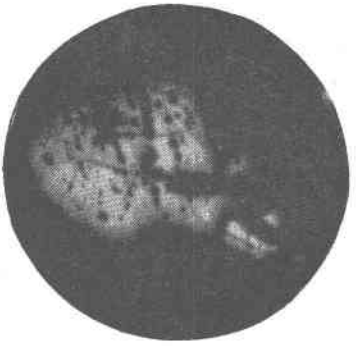

FIG. 3. Passed thru 48-mesh screen. White, pentlandite; light gray, pyrrhotite; black, gangue and wax. Magnification 150 ×.

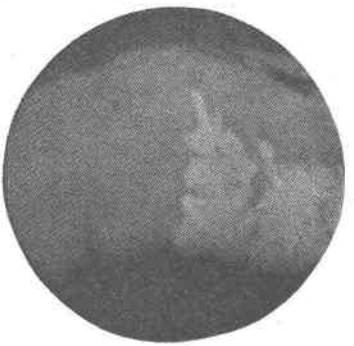

FIG. 4. Passed thru 100-mesh screen. White, pentlandite; gray, pyrrhotite; black, wax. Magnification 580 ×.

Recent investigations carried out by W. J. E. Wyllie, M. A. Sc.,[2] in the Mineralogical laboratories of the University of Toronto, demonstrated very effectively the value of this form of microscopic study, when applied to the examination of mill-products. In the experiments carried out by Mr. Wyllie, the nickeliferous pyrrhotite from the Creighton Mine, in the Sudbury District, was selected as providing suitable material to illustrate the value of this method. It was found from examination of polished sections

[2] Wyllie, W. J. E.—"The Use of the Microscope in the Treatment of Ores." (Thesis for M. A. Sc. Degree.)

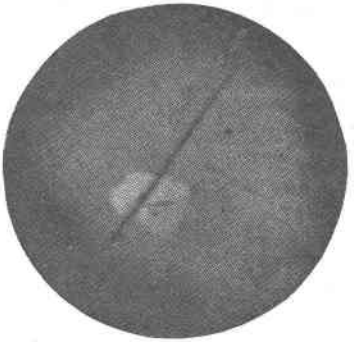

FIG. 5. Passed thru 200-mesh screen. White, pentlandite; gray, pyrrhotite; black, wax. Magnification 580 ×.

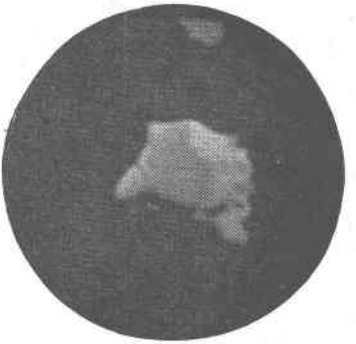

FIG. 6. Passed thru 300-mesh screen. White, pentlandite; gray, pyrrhotite; black, wax. Magnification 580 ×.

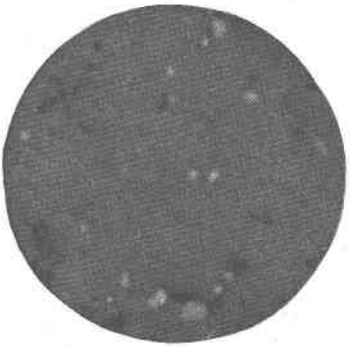

FIG. 7. Fine grained portion. White, galena; gray, sphalerite; black, gangue. Magnification 150 ×.

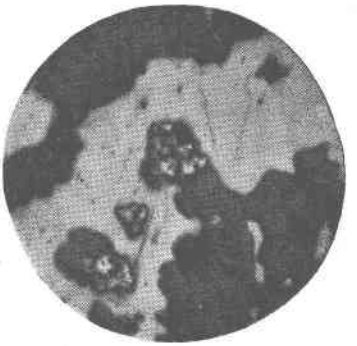

FIG. 8. Coarse grained portion. White, low relief, galena; white, high relief, pyrite; gray, sphalerite; black, gangue. Magnification 150 ×.

of the uncrushed ore that the nickel was present in the form of pentlandite and subsequent experiments with the mill-products demonstrated very clearly that it was present only in this form. A separation by magnetic means was attempted and the magnetic particles were examined in the successive stages of crushing, down to material that would pass through a 300-mesh screen, to determine the amount of pentlandite still adhering to the fragments of pyrrhotite. It was observed that even in the very fine material passing through the 300-mesh screen, some few particles of pentlandite remained. The quantitative proportions of the two

minerals present in the ore powder were determined for two of the coarser sizes, the percentages of pentlandite present being as follows:

Material retained on 48-mesh screen	3.97%
Material retained on 100-mesh screen	3.33%

These results were obtained by careful counting and measuring of the individual mineral grains. This was done on a cross-sectioned ground-glass plate fitted to the mineralographic camera, the measurements of the two minerals giving the relative proportions. It was unfortunately impossible in the time allotted for this work to do more than a few sections of each of these two sizes. Much more accurate work would be possible, given more sections. Nevertheless from the following table of analyses, carried out on the different sizes, it will be seen that these quantitative determinations agree fairly well with the chemical proportions:

Size	% Ni
Retained on 48-mesh screen	1.70
Retained on 100-mesh screen	1.17
Retained on 150-mesh screen	1.06
Retained on 200-mesh screen	1.05
Retained on 260-mesh screen	0.94
Retained on 300-mesh screen	0.82
Passed 300-mesh screen	0.52

In figs. 1-6 the intimate association of the pentlandite with the pyrrhotite is shown in most of the sizes down to material fine enough to pass through a 300-mesh screen. Fig. 4 in particular, which shows material passed through a 100-mesh screen, exhibits an almost dendritic intergrowth between the two minerals. Both from the analyses and the microphotographs it would appear that separation of this ore by magnetic methods would require crushing to too fine a size to make it commercially feasible. The analyses alone would have told half the story and microscopic investigation completed the tale with striking illustrations.

Examples might be multiplied showing the value of the microscope to the mill-man, but it is not the writer's intention to introduce too many illustrations. One or two more cases might, however, be cited as furnishing striking examples of the value of the microscopic method of attack.

In the month of March, 1922, the writer was asked by Prof. L. J. Rogers of the Department of Chemistry, University of

Toronto, to undertake the microscopic investigation of some lead-zinc ores from Burmah. He wished to determine, if possible, approximately the proportions of galena and sphalerite present in the ore, the average size of the individual mineral grains, and their interrelationships. The ore as submitted was of two different types, one part being fine-grained (Fig. 7), and the other fairly coarse in texture (Fig. 8). The minerals present in the ore were chiefly galena and sphalerite, with minor amounts of pyrite, chalcopyrite, and tetrahedrite. By means of a cross-sectioned eye-piece set in the microscope, it was possible to determine fairly accurately the relative proportions of the two principal minerals, the average size of the individual mineral fragments, and the intimacy of their mutual crystallization. The fine-grained mixture was found to occupy 70% of the section, the coarse-grained mixture 30% of it. It was further determined that of the fine-grained portion, representing 70% of the whole, only 16% was occupied by fine specks of galena, the remainder largely by sphalerite; furthermore that of the galena in the fine-grained portion the following sizes occupied the relative areas indicated in the subjoined table:

Diameter	Relative Areas
.0004 in.	26%
.00075 in.	31%
.001 in.	27%
.0015 in.	12%
.002 in.	3%

The data thus collected proved of considerable value in determining the degree of crushing and the methods of separation to be employed generally. Much more complete information could have been collected for this material if the ore had been crushed to various sizes and the fragments examined for the two minerals. Unfortunately time was a prime factor in this case and further investigation of the sort was found impossible.

The ore from the Stemwinder Mine, near Kimberley, B. C., might serve as one more illustration. Costly laboratory investigations were carried out on this ore by numerous experimenters in the hope of arriving at some solution of this particular problem of separation by flotation methods. A very brief preliminary microscopic examination of the ore would have resulted in the elimination of some part at least of this experimenting and the

expense incident thereto. Through the kindness of E. W. Todd of the Department of Mineralogy, University of Toronto, the writer was able to obtain for examination some of the ore from this mine. It is very fine-grained, with the three main constituents, sphalerite, pyrrhotite, and galena so intimately mixed as to require too fine crushing to accomplish a clean-cut separation.

A similar mixture of minerals obtains at the Sullivan Mine in the same district, but the individual mineral grains are larger in this ore making it more amenable to treatment.

From these few examples it would appear that a preliminary microscopic examination of any ore would be extremely useful in determining the kind of milling to be undertaken, that it is possible to examine all classes of fragmental material, down to that passing through a 300-mesh screen, and finally that without such microscopic investigation the mill-man is handicapped in the majority of cases.

AUGITE OF THE ALBAN HILLS, ITALY

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In a continuation of our study of volcanic augites, we have recently examined an augite from the Alban Hills, using material sent to us by Professor F. Millosevich, of the University of Rome, to whom we would express our sincere thanks. The material studied by us was used also by Drs. L. H. Adams and E. D. Williamson, of the Geophysical Laboratory, in their investigation of the compressibility of minerals and rocks.[1]

The augite of the Alban Hills has not been much studied, although it is one of the most abundant and most prominent minerals of the district, and has been known for about one hundred and fifty years. An analysis by Klaproth, made in 1810, gives a remarkably close approximation to its chemical composition. The latest general description (chiefly crystallographic) is that of Zambonini,[2] who gives a full bibliography to 1899. Later papers on Alban augite have been published by Viola and Kraus,[3] and by Parravano.[4]

[1] L. D. Adams and E. D. Williamson, *Jour. Franklin Inst.*, **195**, 482, 1923.

[2] F. Zambonini, *Zeits. Kryst.*, **33**, 39, 1900.

[3] Viola and Kraus, *Zeits. Kryst.*, **33**, 36, 1900.

[4] Parravano, *Rend. Accad. Lincei*, **21**, 469, 1912.