ORE MINERALS UNDER THE MICROSCOPE

By JAMES A. NOBLE

THE student of geology in the course of his training usually passes through three stages of achievement: A first in which he learns to identify the materials with which he works; a second in which he learns to recognize the distribution of these materials in space; and a third in which, from this distribution, he interprets the geologic history of the area of the assemblage of materials. Paraphrasing this generalization into words the student himself might use, he eventualy must answer these three questions: "What is it?," "Where is it?," and "How did it get that way?"

Certainly not all geologic study can be compressed into this simple formula, but the generalization fits several branches of applied geology. In particular, it adapts itself to the study of polished sections of ore minerals as a means of interpreting processes of ore deposition. Though a student may have progressed through the stage of identifying minerals and rocks in hand specimens and with the aid of a microscope, though he may have acquired proficiency in field mapping, and though he may have acquired some skill in the interpretation of the space relations, he is back at the beginning, in so far as the study of ore deposits is concerned, when he sees his first set of polished sections, for he has to learn to identify the minerals all over again.

This change in appearance of even the most familiar minerals when seen on the polished section results from the degree of polish which is needed in the study of opaque minerals. Because most of the ore minerals are essentially opaque in any thickness that can be conveniently handled, it is impossible to study them in the familiar thin section used for the study of rock specimens. As a result, therefore, a smooth surface of the material instead of a thin section is prepared, and all the technique available is utilized to make that surface a true plane devoid of relief. The treatment of the ore sample consists in cutting the specimen and grinding and polishing the cut surface. The grinding and polishing processes call for experimentation with abrasives and for many refinements of method. Accompanying illustrations show the steps used in preparing a specimen for polishing. Current technique by which a surface with a satisfactory high degree of polish is prepared with reasonable expenditure of time and effort is the result of long experimentation by Mr. Rudolf von Huene in the geological laboratories of the Institute.

Although polished sections were first used in the study of opaque minerals in 1864, application of the method was slow in developing, and only within relatively recent years has it come into general use. In consequence, much still remains to be done and the techniques and methods have not outgrown the experimental stage. Parallel with the improved procedures in the study of polished sections has come a specialized technique in the microchemical analysis of ore minerals, made necessary by inherent difficulties in identifying minerals on polished surfaces. Application of this technique and its improvement have progressed in the geological laboratories at the Institute. At present, however, there is need especially for a perfecting of the qualitative chemical analyses, and perhaps of quantitative analyses on a microscopic scale.

In the first step of a microchemical analysis of an ore mineral, a suitable solvent dissolves a tiny grain of mineral scarcely larger than the point of a pin. The single drop of solution is then subjected to chemical manipulations, and the results are observed under the lens of a microscope. These results are for the most part only qualitative, but many of the tests are so sensitive as to afford opportunity to detect traces of impurities in what had been considered to be pure minerals. The frequent occurrence of impurities is of course important. Obviously, it would be still more important to know the exact amount of each constituent, within reasonable limits of error.

However, identifying the minerals is only a means to an end, for eventually the question, "How did it get that way?", must be answered. The second stage of geologic learning, the study of the space relations, moves more rapidly. Long before the student has acquired ability to identify all the minerals, he has noted that they occur in many strange patterns. Interpreting the

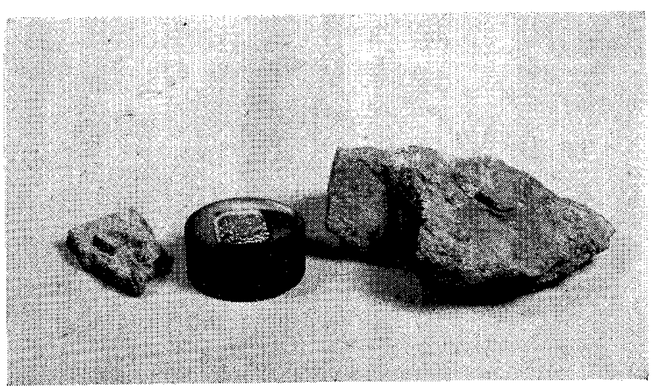

Fig. 1 Successive steps in the preparation of a polished section of an ore specimen. A small chip (on the left)has been cut from the hand specimen (on the right) by the use of a diamond-coated saw. In the center is a finished section of another chip mounted in bakelite and polished.

James A. Noble received his undergraduate and graduate training at Harvard University, stretching four degrees over 19 years. Between A.B. and S.B. degrees in geology and mining engineering in 1920 and 1922, and the M.A. and Ph.D. in geology in 1936 and 1939, Dr. Noble served as mining geologist for zinc mines in Tennessee, copper-zinc-lead-silver mines in Peru, and gold mines in Canada and South Dakota. Before coming to the Institute in 1947 he was for 16 years chief geologist at the Homestake Mine in the Black Hills of South Dakota, one of the large gold mines of the world. Dr. Noble's position at CIT as lecutrer in metalliferous geology represents his first official teaching experience.

During the recent war Dr. Noble did geological work for the Government in a cooperative effort between the Homestake Mining Co. and the U. S. Geological Survey in exploring deposits of vanadium in Idaho and manganese in Baja California.

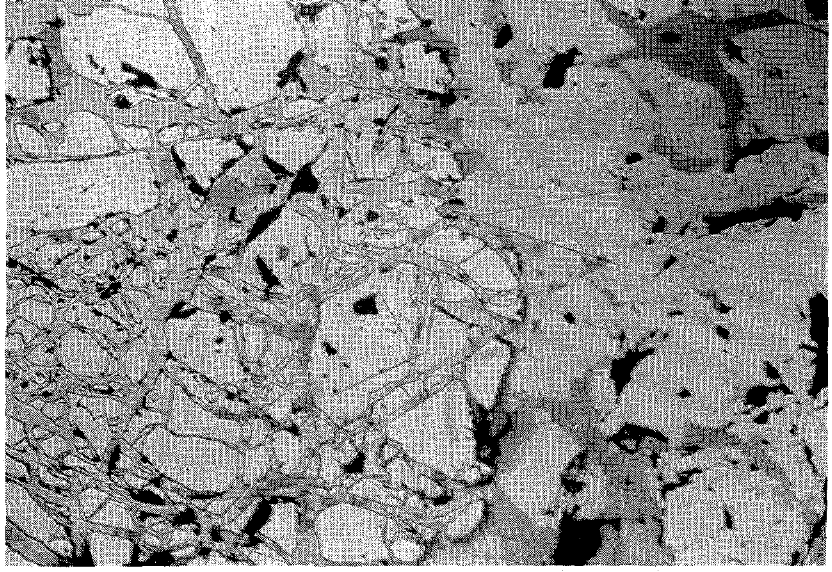

Fig. 2 Photomicrograph of a specimen of copper ore from Magma, Arizona. Light gray areas are pyrite. Intermediate gray areas are chalcopyrite. Dark gray areas are chalcocite. Black spots are holes in the section. Pyrite has been fractured and veined by the other minerals in a pattern sometimes called the "exploded bomb" pattern. There is a suggestion that chalcocite has partly replaced chalcopyrite along cleavage directions. The sequence is pyrite, followed by chalcopyrite, and that probably followed by chalcocite.

space relations is of course handicapped by the fact that in utilizing a plane surface the advantage of the third dimension is lost. Due allowance can be made for this limitation, however, especially if enough material is sectioned to give random sections of all space relations.

As is true for much larger rock units, the identification of the minerals can be made with exactness and their distribution can be shown accurately, but the interpretation of the meaning of these relations is a matter of judgment. The microscope aids in determining the relative ages of the minerals and may likewise afford opportunity to discover something of their mode of deposition. Unfortunately, the relationships are sometimes ambiguous and can be interpreted in various ways by different observers. Other relationships, however, are so obvious in their meaning that they are universally accepted.

The microscopic study of polished sections reveals a vast amount of new information about ore deposits, furnishing as it does not only a means of identifying new minerals present in amounts too small to be seen by the eye or to be detected by analysis, but also a history of deposition of the minerals. An outstanding feature of ore deposits revealed by this study is the extent to which one mineral may be replaced by another. Scarcely a polished section fails to show this process, and in some sections a long succession of replacements can be seen, in which each new mineral in part replaces all the earlier ones. This leads to the disquieting conclusion that still earlier processes of replacement may have occurred of which there is now no evidence, since early minerals may have been entirely destroyed. Such earlier stages in the process of mineralization can only be inferred. The later stages, however, are often indicated in considerable detail and can be accurately discerned if sufficient sampling of the ore deposit is done and the evidence is properly evaluated. Suites of ore specimens like those which comprise the Frederick Leslie Ransome Memorial Collection at the Institute are invaluable in the study of polished sections. It is highly desirable that the Institute collection be enlarged by the addition of specimens obtained from all important ore deposits.

Thus, given a well-chosen suite of ores and rocks, and a set of thin and polished sections cut from these specimens, the mining geologist today can determine the history of mineralization by which a specific ore body has been formed. Since this is an essential step in determining the possibilities of the ore body and in guiding explorations for new ore bodies, it is not surprising that considerable attention is given to the polished section of ore specimens in the geological laboratories of the Institute as a direct approach to an understanding of ore genesis.

Fig. 3 Photomicrograph of a specimen of gold ore from Randsburg, California. Light areas are mixtures of the sulphide minerals pyrite and arsenopyrite. Dark areas are the non-opaque gangue minerals. Pyrite has pseudomorphously replaced an earlier bladed mineral. None of the bladed mineral remains, but a study of other specimens indicates that it was tremolite. Small rhombic crystals of arsenopyrite are perched on the pyrite areas. The sequence of deposition is, therefore, first tremolite, next pyrite, next arsonopyrite.

Fig. 4 Photomicrograph of a specimen of gold ore from the Homestake Mine, South Dakota. Light gray areas are gold. Dark gray areas are specularite. Black areas are non-opaque gangue minerals, mainly quartz. Gold has surrounded and partly replaced the specularite plates, one of which is represented by a line of separate dots.