

## DISCUSSION

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This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

### *THE TEACHING OF ECONOMIC GEOLOGY.*

*Sir:* In entering the discussion opened by Mr. Stewart, the importance of the subject justifies a consideration not only of the courses in geology but also of the entire course to be prescribed for students of mining engineering. The necessity of a thorough discussion of this matter becomes apparent upon looking over the catalogues of the schools giving courses in mining engineering and finding the required work differs from one extreme where no mineralogy is given, and an introductory course only in geology, to the other extreme where it is possible to take geology almost to the exclusion of other engineering subjects. Further even among members of the profession there is some difference of opinion as to the definition of a "mining engineer." Some would not consider the consulting specialist in ore deposits as a "mining engineer" but as a geologist only, making mining engineering as a branch of civil or mechanical engineering applied to mining, while others would allow the expert accountant employed in mining to be designated a "mining engineer." Further, the variety of work that may fall to the mining engineer is great, and the training of the engineer practicing coal mining, busied with the problems of mechanical engineering and the methods of coal extraction and needing a minimum of geology, or that of the one

who has specialized in open pit mining in northern Michigan, and who should be really a railroad engineer, differs as much from the studies that best prepare a man for exploring and mining a metalliferous deposit in the west, as the training of a mechanical engineer ordinarily differs from that of a civil engineer.

Speaking of the mining engineer who is training for practice in the west, he should have a knowledge of general engineering with a special training in the science of ore deposits, and the methods of mining them. With a field as broad as this it is evident that a man can only get a foundation in school on which he must build afterwards. His further education is to be obtained in the offices of the mining companies or in the mine stopes, and he must return for his instruction and his pay, accurate, but generally elementary and routine engineering. For this reason, and because the boy must get a start and earn bread and butter, too much stress cannot be laid on drafting, simple designing, surveying and assaying, lines along which he will find his opening in the mines. It is highly desirable of course, for the mining engineer, to take at least a bachelor's degree in civil or mechanical engineering, with the addition of the introductory courses in mineralogy and geology, and then get his degree of "engineer of mines" after two years' advanced work.

The prospective young mining engineer should choose whether he will devote himself largely to engineering (civil and mechanical) studies, getting at least something more than the rudiments of these, and taking the minimum of geology, sufficient to give him some foundation for his later practical study of ore deposits, learning at least enough to call in an expert along these lines when he gets beyond his depth, or whether to learn thoroughly the rudiments of civil and mechanical engineering, and devote himself to getting a geological foundation, that will enable him, after the practical experience, to carry out a modern geological research of an ore deposit. To do this however will require more than the ordinary four years' course leading to the bachelor's degree in mining engineering.

Finally the question arises as to what difference is to be

made between the training of the mining engineer and the metallurgist. Theoretically there might seem to be but little in common in the mining of and evaluating of an ore deposit, and the reduction of the ore from the same. A metallurgist in an eastern copper refining plant for instance might have little need of the knowledge of the geology of copper deposits or the methods of mining the same, but even here, success in the refining of copper will make him a mining man in the eyes of his friends, and they may even induce him to come west and examine a mine, which will probably end in disaster for himself and friends as occurred in a case I have in mind. It is self evident that the mining engineer should have some knowledge of the principles of ore dressing, milling, and smelting. The young metallurgist will rarely get into a smelter or mill and stay there. If successful later he may be called on to manage both mine and mill and to examine and value mining properties. The majority of courses laid out for the B.S. in metallurgy are open to the severe criticism that the student is required to spend much time in mechanical and manipulative details, which can be better learned outside, and these are given to the exclusion of the study of principles of other branches, without the knowledge of which he will be handicapped in his advancement in the profession. I believe that the time is ripe for a revolt against the common practice of training artisans and calling them engineers.

With the above introduction in mind, we may consider the work in geology that should be given the mining engineer under the two following cases. (I.) For the student studying civil and mechanical engineering in order to apply it to mining, or metallurgy, with a minimum of geology. (II.) For the student studying the fundamentals of general engineering, and covering the science of ore deposits more thoroughly.

For both classes geological instruction may begin in the Sophomore year. This may consist in a course in blow pipe analysis for the first term, and some introductory course in geology for the second term. The writer does not believe in a course for the beginner in identifying minerals by physical tests. It becomes

a course in guessing and teaches the student inaccuracies. Our experience with students who have taken such courses is that they do harm instead of good. The geology course can introduce the student to a few salient facts regarding physiographic and geologic processes, to rocks and their occurrences and to some features of ore deposits. During the Junior year crystallography and descriptive mineralogy will form a year's course. The student should handle and learn to recognize as large a number of minerals as possible, and the geological occurrence of the minerals should be emphasized. However the course in mineralogy should be given from the mineralogical standpoint rather than the geological standpoint, and not by the man who gives the later courses in ore deposits. This is for the purpose of broadening the methods of presenting the subjects relating to ore deposits, and widening the viewpoint of the student. The year's course in Junior geology would be one of the heavy courses of that year. Laboratory courses should form an important part of the work including studies of topographical and geological maps, stereography applied to structural geology and graphic solution of problems in faulting, classification and identification of rocks, etc., etc. Physiographic and structural geology, the study of underground water, and metamorphism can be taken up in some detail during the first 3 months. Historical geology can be cut down to two months and the last four months devoted chiefly to chemical geology and ore deposits. Certain important applications of chemistry and physical chemistry should be discussed here. For instance it should be shown by numerical calculation how the theory of dilute solutions and mass action, explain all the various phenomena of metasomatic replacement. Hydrolysis and its geological application should be discussed in detail, as well as some of the geological applications of the phase rule. A brief study of ore-forming processes, such as replacement, secondary enrichment, etc., with a classification of ore deposits will finish the course.

The above-mentioned work is all that can probably be required of students not going any farther than the bachelor's degree and

under the first group mentioned above, although if possible the senior course in the study of nonmetallic products and ore deposits should be taken. The field geology trip should be given either between the junior and senior year or during the latter. In schools in the west with field problems close at hand, it can be given during the senior year with some advantages over the former plan. During the senior year the usual courses in type fossils, in the economic geology of the nonmetals and of ore deposits, and in microscopic crystallography and petrography should be given. The nonmetallic products in the economic geology course, can be taken the first term. The "Mineral Resources" is the most satisfactory textbook for this, and statistical and graphic methods of investigation can be emphasized. The course in ore deposits is the one specially discussed by Mr. Stewart. If the student has not had his attention directed to the subject in the sophomore and junior years, and especially in the case of an eastern boy who has never seen a mine or ore deposit, there is much force in the arguments for more emphasis on ore-forming processes. Further, the attempt is hopeless to follow the condensed descriptions given in such a book as Thomas and MacAllister's "Geology of Ore Deposits," which is an artificial arrangement of condensed paragraphs with geology left out, on a large proportion of known ore deposits.

The attempt to classify ore deposits under certain definite groups, such as magmatic segregations, contact deposits, vein deposits of various types, etc., is neither very satisfactory from the scientific or the teaching standpoint, especially because any one mineral district or even deposit may show a number of these varieties of ore deposition, modified by a variety of secondary changes. The writer has found a combined geographic and geological basis of classification preferable. Since a large proportion of the American students do not have the command of foreign language to make the study of foreign occurrences satisfactory, attention has to be confined to American examples. Further, the older (and unfortunately some that are not old) descriptions are written by those not trained in the science of ore deposits, so that

the literature studied will be largely that of the government survey, some of that published by the state surveys, and a few contributions of engineers of standing not connected with geological survey organizations.

The selection of the groups of ore deposits will gradually develop a genetic and geological classification. A study of the Mother Lode group of quartz veins, extending up into Alaska will bring out the characteristics of gold quartz veins of the deep-seated kind connected with Mesozoic—early Tertiary granitic intrusives. The many interesting structural details of this group can only be brought out by a study of the detailed geological maps of the ore regions, and the correlation of the group as a whole by a study of the geological map of the country. The writer believes that it is not too much to say that a satisfactory study of the ore deposits of the United States has now been made possible by the publication of the geological map of the country just issued.

The study of the great group of Arizona-New Mexico copper and lead-zinc deposits around monzonite and more acid intrusives, must be prefaced by a structural study of the region. The rôle of the zone of structural weakness skirting the plateau province, running from northwest to southeast in Arizona and curving to a direction from southwest to northeast in New Mexico in governing intrusion and ore deposition will be remembered by every student who has discovered the fact for himself by study of the map. The various complicated phases of ore deposition induced around these intrusions can only be mastered after a thorough study of many of the occurrences.

The details of ore deposition in any region are so closely related to structural details brought out by the geological map, that the suggestion to lay less stress on the geology of the ore occurrences meets with the decided disapproval of the writer.

Towards the close of the senior year, the student will have some idea of magmatic differentiation, etc., and the study of maps and rock descriptions of selected regions, will bring out the occurrence of progressive differentiation, and the occurrence of later satellitic dikes cutting the ore deposits may locate the metal-

lization as one of the series of events in the rock differentiation. In the Lake Superior-Canadian region for instance, it is difficult to see how the relation of ore deposits to progressive differentiation can be appreciated at Sudbury without a study of geological maps and descriptions, or the still closer relation of the ore solutions that formed the original veins at Cobalt, to the pegmatite differentiate of the Keweenawan diabase; and finally with the help of the last Monograph of Van Hise and Leith, and the general geological map of the region, the varied ore deposition of the Keweenawan period, including iron, copper, nickel, cobalt, and rich silver ores, can be worked out by the student in a way that will leave a lasting impression on him.

Further discussion of this method of attack is unnecessary. Towards the end of the course condensed descriptions of foreign occurrences and relations can be introduced by the instructor. In the course outlined the student cannot take up in a satisfactory manner the microscopic examination of ores and gangues during the senior year, but he can learn much from polished hand specimens, with assistance of the binocular microscope, and the study of the numerous microphotographs in the government's publications. The graduate and research courses are arranged to fit the student and subject and need not be discussed here.

In closing, it may be remarked that the writer has met a large number of civil, constructing, and electrical engineers, who have come to the western mining districts to practice their profession. Almost without exception, these men have expressed regret that they had not studied the rudiments of geology and the science of ore deposits, and therefore it would be a good thing if the eastern engineering schools would suggest to those students who have any idea of practicing in a mining country to take the elements of geology.

C. F. TOLMAN, JR.