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GEOLOGY'S DEBT TO THE MINERAL INDUSTRY[1]

OF recent years it has come to be acknowledged more and more that the science of geology has done and is doing much to advance the mineral industry. On the other hand, it may be of interest to consider briefly what bearing the industry has had on the advancement of the science. In what state of development would geology now be were it not for the assistance it has received from the mineral industry?

In the earlier ages of man the chief interest taken in the components of the earth's crust, in most regions, was, doubtless, chiefly what may be called an economic one. Suitable specimens of flint and other rocks were sought for the manufacture of weapons and utensils. The soft oxides of iron and other paint materials would also early attract attention. In volcanic and earthquake regions other interests would be aroused. Gradually a knowledge of the use of metals would be developed and methods of extracting certain of them from the ores would be discovered by accident. In later ages the economic interest became subordinate to the philosophical. For many centuries little progress could be made in a proper knowledge of the earth's crust until restraining prejudices were gradually thrown aside. It was only at the close of the 18th century that the struggling science began to make real progress. Whatever may be thought of the relative merits of the so-called Neptunists and Plutonists of that time, it cannot but be admitted that Werner was largely responsible for creating a keener and more widespread interest in the proper study of the earth's crust than had existed prior to his day. And this interest was aroused chiefly through his showing that a knowledge of the structural relations of rocks could be applied to economic purposes. Thus, in what

[1] Address of the vice-president and chairman of Section E—Geology and Geography, American Association for the Advancement of Science, Boston, December, 1922.

is acknowledged to be the very beginning of the science of geology as distinguished from cosmogony, credit has to be given to the mineral industry. No less an authority than Lyell makes this acknowledgment when he says in the Principles: "The phenomena observed in the structure of the globe had hitherto served for little else than to furnish interesting topics for philosophical discussion: but when Werner pointed out their application to the practical purposes of mining, they were instantly regarded by a large class of men as an essential part of their professional education, and from that time the science was cultivated in Europe more ardently and systematically." And Sir A. Geikie has said "the devout Wernerian put mines before mountains as a field for geological investigation."

As further illustrating the fact that the founders of geology were much interested in the application of the science, the case may be cited of the "father of geology," William Smith, who lamented "that the theory of geology was in the possession of one class of men, the practice with another." Another example is that of Logan, usually considered to be the father of pre-Cambrian geology, who said of himself: "For many years of my life engaged in the active pursuits of a practical miner for coal, and a practical smelter of copper from its ores, my connection with geology relates more to the application of materials."

A well-known trait in human nature is that when people have become wealthy, especially if they have inherited their wealth and taken on airs more or less aristocratic, they tend to look down on trade and tradesmen. The same characteristic is observed among geologists. Although the science owes so much to its economic aspects, there is a tendency among many men to avoid having anything to do with the applications of the science. This does not apply so much to geologists in North America as to those in older countries, but even on this continent there is a tendency to make two groups, "economic geologists" and "geologists."

The tendency in some countries is exemplified by the case of a well-known professor, who was even a lecturer in a school of mines. In referring to the dangers to be encountered in economic geology he is quoted as saying "You cannot touch pitch without some of it sticking to you." Another distinguished geologist considered it to be *infra dig* for a colleague to give advice on water supply. In another case, a well-known geologist was told by his colleagues that it was not seemly for him to become an officer in a mining society. Further, is it not a fact that if geological papers are published by mines departments, or by mining journals, they usually become known only to those interested in the applied science? Many geologists appear to avoid reading anything that is published under the heading of mines and mining.

A recent writer, referring to work of geological surveys, says that they do provide for some research in pure science, and the by-product of pure science from both public and private work is large. This illustrates the mental attitude which too many geologists have toward government surveys. Are the scientific results obtained from the work, undertaken primarily for economic reasons by the U. S. Geological Survey, in the Lake Superior region, for instance, not entitled to be considered more than mere by-products?

Apropos of the prejudice against economic work, R. W. Brock has said "Geology started as economic geology . . . [But later] it became *infra dig* for a geologist to do anything that would be of value to anybody. He would no more think of applying geology to practical purposes than an artist would of contracting to paint an advertisement. . . . I remember when I was leaving the European university where I had been studying, the old professor under whom I studied said to me, "You are going to America, you will be in great temptation; I know they will try to make use of you in mining; whatever you do, have nothing to do with economic geology."

The advantages accruing to pure science from work undertaken chiefly in connection with the mineral industry is well illustrated in the Lake Huron-Lake Superior region. While Logan made a good start in unravelling the age relations of the Canadian pre-Cambrian rocks, he and his assistants were succeeded by men most of whom have been described by Van Hise, as regards the work of the pre-Cambrian, as "chromatic" map makers, the rocks being mapped largely according to their colors and not according to their age and structural relations. Little

progress was made for many years after Logan's time, or not until some time after the discovery of important ore bodies at Sudbury and later at Cobalt and Porcupine. The finding of gold in the extreme western part of the Province also led to some important work there. If it had not been for the discovery of these valuable mineral deposits in the pre-Cambrian of Ontario, it is doubtful if much more would now be known regarding the age relations of these rocks than was known in Logan's time. Not long after Logan and his assistants ceased work in the pre-Cambrian the science of petrography arose. This science attracted many students of geology who would otherwise probably have done work on the stratigraphy of the pre-Cambrian in Canada. But the fascination of the new branch of science caused work in stratigraphy in regard to these most ancient rocks to be neglected. The students of petrography were interested in the minute structure of rocks, especially those of an igneous nature, and paid little or no attention to the age relations of the great masses of more or less metamorphosed sediments on which the history of the pre-Cambrian is so largely based.

But, while for many years after Logan's time little progress was made in the study of the Canadian pre-Cambrian, good work was being done on the United States side of Lake Superior by Pumpelly, Irving, Van Hise and others whose names will always be associated with the history of the development of these rocks. While the Ontario side was in darkness the lamp was kept burning on the American side, chiefly owing to the great copper deposits of Michigan and the iron mines of that and adjacent states.

Thus, were it not for the mineral industry in these Lake Superior States, probably even there little advance would have been made in the study of the pre-Cambrian beyond what was known in Logan's time. It was only the mineral industry that brought the expenditure of such large sums of money on both sides of the boundary in connection with the study of the pre-Cambrian. It is owing to the work of a large number of men, provided with excellent facilities, during the period of seventy years or more that progress has been made. It is fortunate for the science that these old rocks contain mineral deposits of exceptional value and interest—the greatest iron deposits, the greatest nickel deposits, and some of the greatest copper, silver and gold deposits that have ever been discovered in any country.

Referring to the Ontario side of the boundary it may be said that at Sudbury a knowledge of pre-Cambrian stratigraphy was not so important from an economic point of view as was the distribution and nature of the igneous rocks, more especially the norite, but at Cobalt much depended on stratigraphy, while at Porcupine and Kirkland Lake stratigraphy was again not so important. It may be of interest to add that one important result of the work, during recent years, in these mining areas has been the proving that the commonly accepted dual classification of the pre-Cambrian into Proterozoic and Archeozoic has no basis in fact and should be discarded. There are at least three major groups among these rocks.

The assistance which geology has received from the mineral industry is no better illustrated anywhere than in South Africa. In the early days of settlement in Cape Colony the existence of payable minerals was unknown, and the pioneers had difficulty in making headway with nothing valuable at hand for export or exchange. The discovery of diamonds in 1870 brought about a rapid change in conditions, as did also the discovery of gold in later years in the Transvaal. Had it not been for the discovery of the unsurpassed mineral deposits in the southern part of the continent the Boer farmer would still be occupying it in practically a pristine state. Is not the science of geology greatly indebted to the mineral industry in that part of the continent? Were it not for mining, the character and the wide distribution of those wonderful intrusives, the diamond "pipes," would have remained unknown in our time and for long after. Then, again, what a marvellous series of ancient sediments has been brought to light in the greatest gold field ever known, that of the Witwatersrand. Were it not for mining operations extending to great depths and laterally to great distances, the nature of these sediments, and especially of the comparatively thin beds of conglomerates, could never have been determined. Certain of these beds of conglomerate, that are the most important from a gold miner's point of view, have been proved to be

the most persistent beds of the kind known in the world. But it must be borne in mind that no similar bed has ever offered the same inducement for complete investigation. The comparatively thin bed known as the Main Reef Leader has been proved to be practically continuous over a distance along the strike of at least forty miles and probably has a corresponding extension in the direction of the dip. Its nature could not possibly have been ascertained were it not for the extensive mining excavations and the numerous bore holes that have been put down over a large area in the search for productive gold-bearing rock.

These sediments, with which are associated the gold "reefs" or beds of conglomerate, have a thickness in the central part of the Rand of about 25,000 feet. While the research work which has been done on them was undertaken chiefly for economic reasons, it can be said that no great thicknesses of sediments, fossiliferous or otherwise, have been studied more fully than have these which are considered to be of pre-Cambrian age.

The origin of the gold is such an important factor, both from the economic and the scientific point of view, that the sediments have had to be studied with unusual care. Later workers on these ore deposits appear to be pretty well agreed that the gold was laid down with the conglomerate, forming a placer, but has since been dissolved and re-precipitated. Were it not for the economic importance of these rocks comparatively little would ever have been known about them. The character and origin of the remarkable beds of conglomerate and other features which belong to pure science would never have been determined. The same may be said of many other mining areas.

Another striking example of what the mineral industry has done and is doing to assist in bringing about a knowledge of the geological structure of remote and isolated regions is that of the petroleum geologist, who is often more or less maligned. A knowledge has been obtained of the fossiliferous rocks in remote parts of South America and in other parts of the world through the work of petroleum geologists within a comparatively few years that otherwise would have taken decades. The correctness of the conclusions of these geologists concerning the age and structural relations of these rocks is usually proved or disproved in a short time.

It will be acknowledged that Geological Surveys, supported by governments, have done more for the methodical study and mapping of wide areas than has any other agency, and there would be few, if any, of these surveys were it not that they are supported primarily with the object of describing and developing mineral resources. Even the greatest of Geological Surveys, that of the United States, owes its origin chiefly to economic reasons. The late S. F. Emmons has said that when the first Geological Surveys were established in the west the people had little conception of the advantages and uses of such an organization and a campaign of education of the popular mind was necessary in order to demonstrate its practical value. For ten or twelve years such a demonstration was carried on by the Hayden, King, Wheeler and Powell Surveys, or geological explorations, as they might more properly have been denominated. Most of them appealed to the popular, as well as to the scientific, imagination by their brilliant discoveries of such natural wonders as the geysers of the Yellowstone, the canyons of the Colorado, and the laccolites of the Henry Mountains. The Geological Exploration of the Fortieth Parallel, which alone planned to make a geological map of a definite and limited area, secured its appropriation from Congress on the explicitly economic ground that it was necessary for determining the character of the mineral resources of the mountainous regions to be made accessible by the recently authorized Transcontinental railroads. In furtherance of the plan of popular education, Mr. King, its organizer and chief, pushed to immediate publication the economic results of the work, the study of actually developed mines including the Comstock lode, set forth in a volume on Mining Industry which appeared in 1870, seven years before those embodying the more abstract scientific results which had to wait the completion of the researches of specialists. The final realization of the ultimate object that the geologists of the Fortieth Parallel Exploration had in their minds during the ten years spent on that work came much earlier than had been anticipated, when in 1879 all existing geological explorations were consolidated into a permanent Geological Sur-

vey, which was organized as a bureau of the Interior Department; and there is little doubt that the practical demonstration of the utility of such work furnished by the Mining Industry volume had much effect in rendering Congress favorable to the new organization.

A Canadian may be permitted to say that the geologists of the United States occupy a pre-eminent place in the world, and that the Geological Survey has had much to do in assisting them to achieve this premier position.

From what has been said concerning the geological work that has been done in the mining areas mentioned it seems difficult to draw the line between so-called economic geology and the pure science. Because a geologist is working out the age and structural relations of the rocks in a mining area, primarily with the object of aiding the mineral industry, is there any reason to believe that he has less love for the science or is less enthusiastic in its promotion than is one who spends his time studying the rocks in areas which are of no economic importance? Moreover, does not a man who works in an area where extensive mining operations are being carried on obtain more facilities for arriving at a proper understanding of the problems than he would if no mining was in progress? Undoubtedly some men find it more pleasant to work in areas that are free from economic problems. One of the older writers has said, "There may not always be found a geologist willing to turn away from his delightful studies to avert the ruin which can only fall on those who disregard the plainest truths of geology."

Cosmogony and geology both have had what may be called theological affiliations. While, on the one hand, the progress of geology was retarded by theological prejudices, on the other, theological controversies tended to popularize the science. The popularity of works such as those of Hugh Miller and Sir J. W. Dawson depend to a large extent on the fact that they deal with geology in its relation to theology. There was scarcely a Scotchman in the generation which has just passed away that had not heard of Hugh Miller and read some of his works. Even to this day a geological visitor to lonely Highland glens is likely to meet with a workman or peasant who is surprisingly well read in certain features of geology. Probably one criticism that could be made of the geologists of the present day is that they do not do nearly so much to popularize their science as did their predecessors in the last generation. As an illustration of the popularity of some of these older authors it may be said that even within the last twenty-five years sets of their writings have been found among the books offered to the Christmas trade.

Among those who have greatly helped in the advancement of the science there have been few who were men of independent means, such as Hutton and Lyell, and geology at the present time could not make much progress did it not depend chiefly on financial assistance from governments and those who are interested in the mineral industry. It is true, as has been said, that geology more largely than any other science is regarded as a governmental function.

That applied geology is not a new subject in this country is shown by the fact that in the first annual volume of the proceedings of the American Association for the Advancement of Science reference is made to the "Society for the Development of the Mineral Resources of the United States," which proclaimed that "With unabated admiration for all that part of geology which is strictly scientific we devote ourselves particularly to its æconomical department." From the quotation it will be seen that the objects of that early society were not unlike those of the Society of Economic Geologists organized a couple of years ago.

Since all economic work of importance in geology requires a thorough training in the principles of the science, and since there is such a variety in this work, it does not seem that the training of the man who expects to labor in mining and mineral areas should be different from that of the man who is to pursue the pure science.

In conclusion, if the science is under such a great debt to the mineral industry for facilities and opportunities provided, why should there be a tendency to ostracize the geologist who does work that has an economic value? Why should it be necessary to proclaim the legitimacy of applied geology? Let the man be encouraged who desires "to carry on economic research in a scientific way." Did not Edward Forbes, in the words he used long ago, express the correct attitude towards applied sci-

ence? "When science, provided she be mindful of her honor, and make no sacrifices of her love of truth, serves as the handmaiden of even the humblest of arts, her dignity gains in lustre, and her familiarity breeds respect."

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THE SCHOOLMASTER AND THE TEACHER[1]

IT is very much to be feared that what I have here to say will appear so trite as to be little better than thrashing over of old straw. I am quite sure that much of it has been said (and perhaps better said) many times before. But no student of the problem of science teaching can observe the changes that are taking place in the system of scientific education, and particularly in the character of the results of the teaching of chemistry in our colleges and universities, without feeling that we still have much to learn about how to teach successfully. We cannot regard the subject as being closed. No one has yet discovered the grand secret in its entirety and no teacher of any branch of chemistry, who is both intelligent and honest, can be wholly satisfied with what he observes is going on in the minds of his students, as a result of his contact with them. This is my only excuse for reviving this ancient subject and for adding another bit to the already formidable accumulation of treatises directed toward the solution of such important questions as these.

I do not propose to offer to this section the affront of trying to tell you how to teach chemistry. Many of you have had far more experience in this field than I. Indeed, I frankly confess that I am not an authority on the art of teaching. If I were I should simply write out the recipe, and have it mimeographed and distributed; this you would then properly consign to the waste basket, for each one of you would know of a much better way than the one I would give you. There is no magic word or phrase that is the "open sesame" to the door of success in teaching. Each of us possesses, in some degree, the ability to instruct. But the part that one does well another does poorly. What both fail to attain another will accomplish, and so on. Were it not for this we should not be here to-day, gathered for a mutual exchange of ideas.

For this reason I shall presume upon your time and good nature long enough to say a few things about the general question and about some of the results of my own observations. These may be taken for just what you consider they are worth—no more (of course) and no less (I hope).

Much has been said and written about the necessary qualifications of a teacher. And, after all is said and done, we might finish by saying that the successful teacher of chemistry is one who can teach chemistry. Teaching is not coaxing or coddling, cramming or browbeating. Neither is it the administration of sugar-coated knowledge pills, to those who would cultivate the luxury of sleeping sickness. Our job is so to conduct our classes that our students shall be glad to be in them and that they shall leave them with regret, but carrying with them not only the fullest possible knowledge of the subject but also a deep and abiding respect and love for their chosen science and a boundless enthusiasm for its possibilities. Not an easy job, this, by any means,—as we all know. On the contrary it is one that requires large experience and training and large understanding of human possibilities, human ambitions and human habits of thought.

With this introduction and apology may I begin at what may seem to be the wrong end of the business by saying that the very first requisite for the teaching of chemistry is correct personality on the part of the teacher. This is not a prime necessity for successful work, for example, in chemical research or chemical industry. The researcher *must* have thorough training in fundamentals, thorough knowledge of chemical literature and a logical mind, capable of clear and systematic organization and prosecution of his work and, having these, he may be eminently successful even though his personality may be such as to cause him to be thoroughly disliked by all of his associates. Pray do not understand that I charge the industrial research chemists with such a

[1] Paper read at the Pittsburgh meeting of the American Chemical Society, September, 1922.