SCIENCE

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*RELATIONS OF GEOLOGIC SCIENCE TO EDUCATION.**

INTRODUCTION.

THE custom has been established which requires the retiring President of this Society, as other societies which have for their purpose the advancement of science, to set forth his views concerning matters related to the interests which the association seeks to promote. This custom evidently rests on the reasonable presumption that the officer during his term of service has been led by his duties to consider how the cause which he represents may be promoted, how its store of truth may be enlarged, and in what manner it may best be made to serve the interests of mankind. This task may be essayed either by a survey of the work which has recently been accomplished in the science, with appropriate comment on the trends and results of the endeavors, or the essayist may restrict his undertaking to some one portion of the field with which he is conversant in the hope that he may be able to present the fruits of his own labors in a way which is likely to be profitable to others. For various reasons I have chosen the latter of these alternatives and have taken for my subject the relations of geological science to education. Under this title I shall not only include those questions

* Annual Address by the President, N. S. Shaler, Read before the Geological Society of America, December 27, 1895.

which pertain to pedagogy, but certain larger aspects of the matter which relate to the needs of society, both from the moral and the economic point of view.

RELATIONSHIP OF TEACHING AND RESEARCH DEFINED.

I have been in good part led to take up this subject for the reasons that the title itself is a protest against the modern notion that the work of research should be separated from that of teaching; that natural inquiry should be released from the ancient and profitable connection with education, which in my opinion has advanced and ennobled both these branches of learning. Those who seek to have inquiry endowed are led to the endeavor by a true sense of the importance of the tasks with which the path-seekers in the fields of nature have to deal. They are, moreover, guided to their object by the motive which leads to the division of labor in all work which men do, whether in economics or in pure learning. Undoubtedly a certain kind of success would attend the complete separation of the students of phenomena from those whose business it is to impart knowledge; but there are gains which, though immediate, are not desirable, for the reason that they entail in the long run serious losses. It may well be apprehended that the definite separation of the inquirers in any science from those who are to teach the learning would result, on the one hand, in isolation of the men of the laboratory from the life of their time, and on the other, in a degradation of the instruction to a level where it would become mere formal tutoring, destitute of the penetrating spirit which gives value to scientific thought.

It seems to me that the explorer, if he be animated by the true spirit of his class, finds himself seeking for undiscovered realms, not for personal gains, nor, indeed, merely to add to the store of things known, but always with reference to the enlargement of mankind. His motive is in the highest sense that of the teacher; he limits his opportunities of personal culture if he denies himself the chance of communicating his gains to the youth of his time. It may be held that the investigator has his means of teaching through the press and the learned societies, but I need not tell my brethren of the craft that the opportunities of sympathetic contact with his fellow men which are thus to be had are very limited; that they are quite insufficient to satisfy the natural desire of an ardent student of nature for relations with the life about him. The only way in which a really wholesome situation can be found for the naturalist in any of the realms of nature is to link his work with the tasks of education.

Viewed from the point of view of the student of science, who has to catch the spirit of inquiry from the word of the master if he is to win it at all, we see that the teaching function of the inquirer is of the utmost importance to his science. We all recognize and deplore the evils which arise from the fact that young people have to be introduced to most branches of learning by teachers who have little chance to gain or to preserve the spirit of inquiry. We can at most hope that the scientific motive may come to these instructors through a study of the psychology which properly underlies their work. It is unreasonable to suppose that they will be able to bring to their work the stimulating influence of those who are a part of the learning they convey. Therefore, if men are to be bred in the ways of the naturalist, the task must be done by investigators. It goes, or should go, without saying that while these men may give and receive profit from their positions as teachers, they should not be called on to do the share of this work which is often inflicted on them, as it is on the teaching body of our schools in general. A condition of this combination of inquiry and in-

struction is that the two should be associated so as to give the men of science leisure for their studies as well as an opportunity to influence youths by their teachings.

INTERDEPENDENCE BETWEEN RESEARCH AND INSTRUCTION IN GEOLOGY.

There are good reasons why the connection between research and instruction should be preserved in geology, even if it be abandoned in the case of the other sciences. In those other branches of natural learning the subject-matter can be brought into the laboratory, or, at least, as in the case of astronomy, be in some measure made immediately visible to the student, but in geology only a very small part of the facts can be demonstrated by laboratory means. Even where the teacher finds himself in a field which is rich in illustrations, he is sure to lack examples of the greater part of the important facts which he has to bring to the understanding of his pupils. Under these conditions good teaching depends upon the development of the inquiring spirit without the stimulus of a satisfactory direct contact with phenomena. This task cannot be accomplished by any routine methods or by instructors who are not true men of science. It can only be done by those who have the spirit of the investigator in them, who know the range of fact in the intimate and personal way which will enable them to arouse the constructive imaginations of the youth to the task of picturing the unseen—a task which is at the foundation of the best culture which science has to give.

A capital instance of what can be done by a teacher who is also an inquirer is afforded by the work of Louis Agassiz in extending the interest in glacial geology in this country. His lectures on the subject were so vivid, they so effectively presented the physiognomy of the Swiss glaciers, that they quickened the imaginations of the dullest persons. They aroused an interest in the matter which was so intense and on the whole so well informed that the study of glacial geology in the larger sense of the term developed more rapidly and on better lines in this country, where existing ice fields are lacking, than in European lands, where examples abound. In such work we see the part of the master in instruction. As a contrast I may be allowed to relate a story which gives us a notion of what science teaching is likely to become when it is left to the people of routine.

The professor of mineralogy in Harvard University one day observed two young women examining his mineral cabinet, one of whom was evidently searching for some particular species. Offering his help, he found that the object of her quest was feldspar. When shown the mineral she seemed very much interested in the specimens, expressing herself as gratified at having the chance to see and touch them. The professor asked her why she so desired to see the particular mineral. The answer was that for some years she had been obliged to teach in a neighboring high school, among other things, mineralogy and geology, and that the word feldspar occurred so often in the text-book that her curiosity had become aroused as to its appearance.

It will, of course, be possible to give the routine teachers some practical knowledge of feldspar and of the other matters of fact with which they have to deal in their text-book work, but the motive, or the lack of it, which is indicated by the incident will always have to be reckoned on as inseparable from the millwork of ordinary schools. So far as geology is concerned, the instruction of this text-book kind which may be essayed in the secondary schools is quite in vain. Its only effect is to make the youths on whom it is inflicted quite unapproachable by the teacher who may afterwards undertake to introduce them to

geology. All of us who have taught in colleges know the youth who has had somebody's 'six weeks of geology' rubbed in by a drudge who, if required to do so, would in a like way have applied Sanscrit. We know that the youth who has been so misused is in most cases, provided he is not blessed with a good capacity for escaping the influences of education, utterly unfit for our uses. The most *economical* thing to do, in the large sense of the word, is to give him the advice which the elder Agassiz was wont to give to those of his students who proved impregnable to his methods of instruction: "Sir, you better go into business."

VALUE OF GEOLOGICAL EDUCATION AND METHODS OF TRANSMISSION.

Comprehensive Character of Geology.

Assuming, as we needs must, that as geologists it is our duty not only to extend the learning of the science, but also to take charge of its diffusion among the people, let us consider in general the value of good which we have to deliver and the manner in which the transmission may best be effected. So far, doubtless for the reason that geologists are uncommonly busy people, there has been little note taken of the importance of the store of the science to society or the way in which the knowledge should be handed down. We have been content to harvest and have hardly considered the work of cultivation; therefore the assessment which I am about to give will doubtless need much revision.

In the first place, we should note well the fact that geology differs from all other divisions of natural learning in that it is not limited to a particular group of facts or modes of energy; but is in a way concerned with nearly all the work which is done in and on this sphere. We should, perhaps, except human affairs; but if he is so minded the geologist may make good his claim to a large share in interpreting that group of phenomena also. In fact, the earth lore is not a discrete science at all, but is that way of looking at the operations of energy in the physical, chemical and organic series which introduces the elements of space and time into the considerations and which furthermore endeavors to trace the combination of the various trends of action in the stages of development of the earth. It is in these peculiarities of geology that we find the basis of its value in education and in the general culture of society, which it is the aim of education to create. It should be in its province, as it is clearly in its power, to give to mankind perspectives which will serve vastly to enlarge the evident field of human action.

All observant teachers know that no true success in education is possible until we contrive an awakening of the youth from the sleepy acceptance of the world about him. To rid the student of this benumbing relic of the bone-cave, the spirit of the commonplace, there is no treatment so effective as that which is in the power of the master in geology to give. The story of the ages clearly told, with a constant reference of the bearing of the matter on the appearance and the fate of man, will quicken any mind that is at all fitted to profit by the higher education. Although geology can hardly be said as yet to have made any such general impression on laymen as is justified by the body of truth which it has to deliver, the close observer may notice certain important changes in the state of the public mind which seem clearly to have been due to the teachings of the science. While many things go into the making of the world's judgments, there can be no question that the plain truths concerning the antiquity of the earth and the series of events which have led to the coming of mankind have in this generation been most effective in overturning sectarian bigotry and in

other ways enlarging the spirit of all educated people.

It is evident that the main contribution which geology has to make to those conceptions which may enter into the spirit of our society relates to the position of man; the abstract learning, that which is in and for itself, is for those who have the professional interest. These public values of the science are of two diverse kinds—on the one hand, those which pertain to intellectual enlargement; on the other, to economic development. Therefore in considering our duty by the educational side of our work we should see what the contributions can be to these two modes of endeavor and how they should be presented. First, I shall consider the limitations of that work which may be regarded as distinctly pedagogic.

Divisions of the Science.

It seems to me necessary distinctly to separate the body of the instruction which is to be given in geology into two parts—that which is appropriate to the general public; and that which, though 'caviare to the general,' fits the appetite of the professional-minded. We are indebted to the philosophical pedagogue Herbert for a statement of the self-evident proposition that interest in a matter must exist before information concerning it can be profitably communicated; therefore in our teaching we must take no end of care to provide this foundation for the attention. This care is particularly necessary in the matters of geology, for, as before remarked, the facts cannot often be exhibited in the experimental way, as in the laboratories of chemistry and physics, where the touch of hand or the sight of controlled actions establishes a personal relation with the problems. The teacher of our science has to avail himself of certain antecedent motives which he can presume to exist in any normal youth which may provide the required foundation of interest. What I have to say on this point is the result of nearly a third of a century of experience in teaching geology, and is based on work which has been done with more than 4,000 students. The basis for the induction is sufficiently great to make the conclusions of value. These are in brief as follows: That instruction in geology which is meant for those who have not acquired the professional motive, must find its basis of interest on either of two foundations—on the element of sympathy with all which relates to the fate of man which is native in all of us, or on the love of the open fields, which every youth who is not utterly supercivilized has as a birthright. Each of those interests is in a way primal; both may be separately reckoned on as strong in nearly all youths who are fitted for the higher education.

Class-Room Instruction.

To make use of the motives which may interest the beginner in geology my experience has shown that the first thing to do is to give by means of familiar lectures a general acquaintance with those series of actions which show the long continuous operations of energy in the orderly march of events, taking pains at each convenient opportunity—there are many such— to note how these processes have served to bring about the conditions on which the development of peoples or of states depends. Thus, in treating of volcanoes, the very humanized story of Vesuvius or of Ætna, especially the dramatic episode of the death of Pliny the Elder, is worth much to the teachers for the reason that it serves to bring a sense of human affairs into a subject which for lack of illustration is apt to remain remote and therefore uninteresting. The fact that the story of these volcanoes, especially that of Vesuvius, is inwoven with that of men forms a bond between the mind of the novice and an order of nature which would

otherwise be utterly unrelated to him. Again in treating of seashore phenomena, the history of harbors and their relation to the development of states, affords a basis on which to rest the account of coastline work. Yet again, in the matters connected with the formation of mineral deposits, which from the nature of the subject are apt to be somewhat elusive, it is easy to fix the attention by reference to the relation of those stores to the needs of man. So, indeed, in all parts of this preliminary work of awakening and developing interest in his subject, the teacher of geology, if he is to be successful, must go about his task on the supposition that he has to extend existing interests to his field. When men have for some hundred generations appreciated the earth as we would have them do it, the process of selection or the inheritance of acquired characteristics may give a birthright interest in the large problems of geology; but while here and there a youth may be found with a Hugh Miller's taste for the science, the teacher who reckons on having his class thus inspired will fail to achieve success.

Methods of Field Teaching.

As soon as the teacher through his work in the lecture room has succeeded in extending the natural inborn interests of his pupils to the problems of geology, instruction in the field should begin. In this part of the work there is need of a great change in the methods and aims of the teaching. While in the lecture room the conditions require the didactic method and exclude that of investigation, the reverse is the case in the field. When I first essayed peripatetic teaching I made the grave mistake in endeavoring to lecture with the phenomenon as a text. In time I found that the fatigue and other disturbing conditions of the open made students unable to profit by any such didactic method, and that all such direct instruction should be done while they were in the more receptive conditions of the house. The true use of the field is to awaken in the pupils the habit of seeking for themselves. The teacher may trust in this task to the existence of an observant motive in men which is at its best when they are in the open air. All of us, however dull we may be in the housed state, have when afield a discerning humor which prompts us to learn the reasons for the unexplained occurrences of nature. This precious relic of the savage life, of the original motive of curiosity, which has been the source of man's advance on the most of his intellectual upgoings, is in average youths strong; it requires the deadening effects of a long and misspent life to eradicate it in any normal human being. It is to this element of curiosity, informed by the preliminary instruction of the lecture room, that the teacher of field geology should mainly trust for his success.

In practice it will be found impossible completely to exclude didactic teaching in the field—such arbitrary divisions of methods are generally impracticable—but when in face of an exhibition of any geological phenomena, with the briefest possible preliminary, designed to fix the attention of the class upon the facts, the teacher should at once become a mere questioner, a goad to arouse the men to a like interrogation of the things they see. It is important that the first problems of interpretation which are essayed should be of the simplest order, for immediately successful work in the unaccustomed harness is much to be desired. Thus the determination of strikes and dips, the identification of visible faults, and, above all, the careful recording of such facts, should come first and the work be carried to distinct success before any effort is made to use the results in the larger interpretations as to the attitudes of strata. In my experience it is the most desirable in the early part of the field training to give all

that can be obtained in the way of work which relates to causes of action, and thus, for the reason that men, however great their training may otherwise be, are unlikely to conceive the earth about them as a realm of continuous processes, their geology is thus not brought down to the present period. The beds and banks of the streams, the retreating escarpments, the shores of lakes and of the ocean—above all the, when rightly discerned, majestic phenomena of the soil—all may serve to impress the pupil with the activity of the earth, and thus clear his mind of the natural but blinding conception that after its creation time the sphere entered on an enduring rest.

Difficulties Encountered in Field Teaching.

In my experience the difficulties which have to be met in field teaching, apart from the hard labor involved in the simultaneous exercise of mind and body, consists in the struggle which the instructor has to make with the incapacities which arise from the supercivilization of his pupils. These hindrances are protean in form, but they are most commonly to be found in an inability to think in three dimensions any better than we can in four, and an incapacity to continue any work when alone. As to the first of these defects there seems to be no resource except to revive the natural dimensional sense which primitive people have. If the student has had sound training in solid geometry he may the more quickly recover the capacity to form the special conceptions which are required of the geologist; but the natural solid is quite another thing from the ideal, and while the theoretical view of them is the same the practical experience is very different. Some youths never learn to deal with the earth problems from the solid point of view. They are therefore cut off from the better uses of the field; yet even with this signal disadvantage they may do good work in certain parts of the science. One of the most distingushed of our American geologists, now dead, was, perhaps on account of the fact that he saw from but one eye, quite without the sense of the relations of the solid; yet, while in the field work his success as measured by his talent was limited, his contributions in other departments were great and of enduring value. Nevertheless, though the people who abide in two dimensional spaces may possess abilities of a high order, they should be kept out of the science which more than any other calls for the ability to frame three dimensional conceptions.

An inability to work alone in the field is a rather common, and in my experience an incurable, defect in certain students who would otherwise be fitted for geology. Those who are thus afflicted appear to lose their motive of inquiry when they are parted from their fellow men. Their malady is to be regarded as one of the many defects of body and mind which are due to over-housing—to that absolute separation from the peace of the wilderness which characterizes our city life.

As soon as possible the field student should be brought to the point where he is required to make his own maps, at first as sketches, and then in the more formal way by pacing, with some methodical control, such as by a simple triangulation. One piece of such map work where the delineation of the surface in general ground plan and contour, as well as the geological coloring, is from his own labor will often be sufficient to affirm the working power of the man. In the ideal of the system such instruction should come to every student who undertakes the study of geology, but in practice it will probably be gained by very few. In the department of Harvard University which is devoted to the science 300 men each year enter on the elementary work. Of these not more than the eighth

part continue the study to the point where they may begin to do work which may be regarded as independent; yet fewer essay the training which looks forward to a professional career. As this department has been long established and is favorably conditioned to give instruction, the lack of a large attendance under a system of free election by students may be taken as an indication that while the elementary didactic presentation of the science attracts the greater number of the youths of our colleges, the higher branches are less attractive than the other similarly difficult work of the indoor learning, The conclusion is that geology in the larger sense of the term is, at least in the present condition of culture, an interest for a few chosen spirits who are so fortunate as to be born with a share of the world sense, or at least with an aptitude for studies which demands a measure of the primitive man which is not to be found in the most of our supercivilized folk.

Undesirability of Teaching Geology to Immature Students.

In the demand which is now made for a beginning of all our sciences in the secondary schools it is proposed to include geology in the list and to set boys and girls of from fourteen to seventeen years of age at work upon the elementary work of the learning. For my own part, while it seems to me that some general notions concerning the history of the earth may very well be given to children, and this as information, it is futile to essay any study in this science which is intended to make avail of its larger educative influences with immature youths. The educative value of geology depends upon an ability to deal with the large conceptions of space, time and the series of developments of energy which can only be compassed by mature minds. Immature youths, even if they intend to win the utmost profit from geology, would be better occupied in studying the elementary tangible facts of those sciences such as chemistry, physics or biology, sciences which in their synthesis constitute geology, rather than in a vain endeavor to deal in an immediate way with a learning which in a good measure to be profitable has to be approached with a well developed mind. The very fact that any considerable geological problem is likely to involve in its discussion some knowledge of physics, chemistry, zoölogy and botany is sufficient reason for postponing the study until the pupil is nearly adult.

EXPERT WORK AND ITS INFLUENCE AND REQUIREMENTS.

Besides the relations to society which may be established by his position as a teacher, the geologist is from the character of his studies much called on for another kind of help, that which pertains to the development of earth resources or to the litigation which concerns earth values. In this field the relations are more critical and more perplexing than in that of instruction. The results of blundering are more apparent and their immediate effect on the reputation of the science more unhappy. That this branch of learning has managed to retain a fair place in the esteem of the public in face of the criminal blunders which its prophets have made is indeed remarkable. It shows how much our people are disposed to pardon where they believe that men mean well, however ill they may do. There is, however, a lesson from this unhappy experience which we should all read and inwardly digest. This is in effect that what is called expert work demands other qualities of mind and another training than those which go to make a successful investigator or teacher. We, as well as the general public, need to recognize that fact, that there is as much reason to suppose that a noted teacher of political economy should prove successful in determining the merits of a proposed business project as that his colleague in

geology should be fit to advise in regard to a mining venture. The teacher may be an expert in the economics of the profession, but the proof of the fact is not to be found in his scientific work or in his success as an instructor. If he has not had the other training it may be safely assumed that he will be totally unfitted to wrestle with the tricky fellows who try in amazingly varied ways to deceive him, or even with the tendencies of his own mind, which naturally lead him to see riches where others fancy they discern them.

In the interests of our science it is most desirable that all expert work should pass into the hands of a body of men who should bring to their task so much of geology as is needed for the particular inquiry, commonly not very much, and who can join with it the more important practical acquaintance with the miner's art and the conditions of trade which relate thereto. In certain cases the men of theory may well serve these experts; all their inquiries are likely to be of service in the determinations, but on them should not be the responsibility for the business side of the problems. There is little the geologist does in the way of research which may not have some practical application to the affairs of men, but he should not mistake this possibility of usefulness as an indication that it is for him to give his inquiries an economic turn.

CONCLUSION.

We thus see that geological science, like the most of the other branches of natural learning, has two distinct points of contact with society—that of instruction and that of economic affairs. In each of these fields of usefulness its services to man have been great and are to be far greater in the time to come. As for instruction, the task is to give to men an adequate perspective for their lives. It is to ennoble our existence by showing how it rests upon the order of the ages. In the economic field it is to show the resources which these ages have accumulated in the earth for the service of the enlarged man, who is to attain his possibilities by a full understanding of his place in nature. To do the fit work we need to combine the functions of explorers and guides zealous to open the way to the unknown, and those of teachers who take care that the youth of our time are led into the land which we know to have so much promise for man.

SOME VALUES OF STELLAR PARALLAX BY THE METHOD OF MERIDIAN TRANSITS.

IN this article are presented values of the parallax for thirteen of the list of nearly ninety stars upon which I have been engaged at this observatory the past two years. The results here given include the values presented at the Springfield meeting of the American Association for the Advancement of Science, with some additions. They are the results of preliminary solutions based upon all my observations of these stars available at the time, and equal weight has been given to each observation.

The method employed is that of the differences of meridian transits, and it is believed this is its first application since it was introduced in its present detail by Prof. Dr. J. C. Kapteyn at the Leiden Observatory in 1885–87. He determined the parallaxes of fifteen stars by this method with a high degree of accuracy. The observing consists in noting the successive times of transit of three stars, of which the first and third are comparison stars and the middle star is the one whose parallax is sought. The former should be so chosen as to make the group of three stars as symmetrical as possible in both position and magnitude. Of course, a fine meridian instrument is required, and for the present series the REPSOLD meridian circle of 12.2 c.m. was employed with a power of 180 diameters. To