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THE MICROSCOPE AND THE STUDY OF THE CRYSTALLINE SCHISTS.

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IN some preliminary pages from the Twentieth Annual Report of the Geological Survey of Minnesota, Professor N. H. Winchell has recently circulated some considerations on the structures and origin of the crystalline rocks.[1] In so far as these are the expression of a sincere desire to advance this difficult line of inquiry by summarizing results secured and by striving toward a more precise definition of terms to be employed in descriptions of crystalline terranes, they are worthy of appreciative consideration by all geologists. Certain of Professor Winchell's statements relative to the comparative value of microscopical and field evidence seem, however, liable to cause misapprehension, and it therefore appears to the writer worth while to call attention to these, at least in so far as they involve his own work on the so-called "greenstones" and "greenstone-schists" of the Lake Superior region.

No problems of geology are more intricate and at the same time more attractive than those presented by the pre-Cambrian formations. The stratigraphy, correllation, and genesis of these vast rock masses must be deciphered mostly without the aid of fossils; hence any kind of evidence, however slight, which throws real light on the questions at issue must be welcomed by the geologist and must be so thoroughly studied by him that it can be accorded its full significance.

The sub-division of the pre–Cambrian rocks into distinct formations has long been recognized as a desideratum in geology but one unattainable without minute and detailed work. General theories have proved futile for its accomplishment. Only now has the problem begun to be attacked by methods which are a stimulus for the present and a promise for the future. In Great Britain, Germany, Norway, Russia, Canada, and the United States facts are being rapidly gathered whose ultimate correlation will surely bring order out of chaos. Field study, areal mapping on a large scale, and the detailed study of stratigraphy must always be the first and most important means of deciphering a crystalline terrane. But the structure planes of the rocks are so often secondary and their original character so obscured by alteration, that stratigraphy, and indeed all field evidence, may prove inadequate to the task set for it. Then it is that help from other sources is required, and none has thus far shown itself more efficient than that furnished by the microscope.

In the history, which in the future will be written of the pre-Cambrian formations, the work already accomplished in the Lake Superior region must occupy a most honorable place. Many pioneers have there pointed out methods and secured results which the world will recognize as fundamental. There the large number of workers have stimulated discussion and has led to a constant re-examination of the same points in the light of accumulating evidence; there repeated surveys have carried on detailed mapping and the field study of stratigraphy; and there, if anywhere, the value of uniting out-of-door and laboratory methods has found demonstration.

In his present communication, Professor Winchell first summarizes the results reached by the Geological Survey of Minnesota in regard to the classification of various pre-Cambrian formations distinguishable within that State. Upon this subject the writer wishes to express no opinion. In the second section of the paper the use of terms is dealt with. A generally accepted distinction is made between constructive (metamorphic) and destructive (weathering) processes of rock alteration, and a plea is entered for some "middle ground" between the interpretations given to the various parallel structures in crystalline schists by those who hold too exclusively to either a sedimentary or a dynamic theory of their origin.

In the third division of his paper Professor Winchell discusses the comparative value of microscopic and field evidence, and it is here that the writer would take issue with his conclusions. He says: "It is in the nature of the problem involved in the study of the complicated structures and relations of some of the Archæan rocks, that the differences between the microscopic evidence and that derived from their macro-structure shall gradually fade out and that one or the other shall usurp the whole field." Later he does indeed allow that "this is not intended to shut out any individual geologist from exercising the right to employ any and all lines of research for the solution of all the problems that he has to solve," (!) but in spite of this generous permission the implication is that, after all, the ordinary mortal must be satisfied to be *either* a field, or a microscopical geologist.

Now, the writer is not aware that the most ardent advocate of the study of petrography (microscopical or otherwise) considers this branch as more than an aid to geological research. Divorced from field observation it becomes unreliable and trivial. As a supplement to field-work it is most serviceable, as the beautiful results of Iddings, Cross, Van Hise, and many others in this country (not to mention European investigators) fully show. The microscopical study of isolated hand-specimens as mere mineral aggregates once served a useful purpose, but this stage in petrography has now passed.

If, then, it be the acknowledged duty of every petrologist to be at the same time a field geologist, and to study his material in the laboratory in the light of his own observations in the field, is it at the same time too much to expect that the field geologists at work on the crystalline rocks will thoroughly inform themselves of the methods, progress, and aims of petrographical research, at least before they complain of their tendency to mislead? The microscope is now but one of the elements in modern petrographical investigation. Progress made by many workers is constantly advancing the point of view, as well as multiplying methods. Is it fair that the field geologist should remain more one-sided than the petrologist would allow himself to be? Between results obtained in the field and laboratory there is no discrepancy, except to one who incompletely comprehends one or the other method of work.

Professor Winchell says that "the sedimentary structure in a rock is one of those characters which the field geologist only can be allowed to pronounce upon with authority." If this be so, it does not follow that he who is *only* a field geologist possesses in such cases the greatest authority. If he has microscopical and other petrographical methods to aid him, it stands to reason that his opinion will be worth more. If he is certain in the field, he may, it is true, be brought to doubt by laboratory study, but this doubt is itself a gain, since there are some crystalline rocks whose origin can perhaps never be put beyond doubt.

Professor Winchell then proceeds to discuss what he calls a concrete case from the greenstones of the Lake Superior region and gives what he thinks would be the conflicting conclusions obtained by a microscopical and field study. To illustrate this case, he reproduces two figures taken from the writer's Bulletin (U. S. Geological Survey, No. 62) on the Lake Superior greenstone schists, and says: "These figures could be repeated many times in the course of a brief examination in the field. These cases present the issues fairly. It remains to be decided whether the

[1] The Crystalline Rocks, some preliminary considerations as to their structures and origin.—N. H. Winchell, Twentieth Ann. Report Geol. Survey of Minnesota, 1891.

testimony of the student who relies on his microscope and starts out with the idea of subordinating his facts to the answers it may give, or that of the field-observer, who only studies the grander structures and has a predisposition to explain such as the foregoing by referring them to sedimentation, shall here be received with the greater credence."

The Bulletin here quoted embodies the results of portions of two seasons' field-work, as well as a large amount of laboratory study of the greenstone schists. However fairly the figures may "present the issues," it is unfortunate for Professor Winchell's argument that he did not select some of the many similar examples with which his field experience has made him personally acquainted. The fact is, that the two occurrences selected by Professor Winchell from Bulletin No. 62 demonstrated in the field the dynamic origin of their structures so convincingly, that no microscopical examination was ever made of them. It would never have occurred to Professor Winchell or to any other "field geologist" to explain the particular features which, in the Bulletin, these two figures represent, by sedimentation, if they had observed the natural exposures. A single narrow shear-zone, crossing a great wall of massive diabase 60 feet in height, makes it certain, without help from the microscope, that the chlorite schist which borders the zone is the result of the fraying-out of the rock by the motion. Nor is there less certainty that the wide gaping gashes in the basic eruptives are due to some mechanical strain. There are cases without number, as every one who has worked in the crystalline schists well knows, where their is doubt as to whether a parallel structure is due to sedimentation or to dynamic metamorphism; but why Professor Winchell should select two cases as clear as these, it is difficult to understand. In the text descriptive of the original figures, it is plainly stated that the first is unsatisfactory because it represents only a *hand-specimen*, whereas the structure, to be appreciated, must be seen on the face of a high rock-wall. In regard to the second figure, it is also stated that it is only a diagramatic representation of an *area* on the rock-wall about three feet square. If there is difficulty in arriving at correct conclusions from the study of natural exposures, all the more caution is necessary in interpreting another author's figures, especially when these are distinctly described as inadequate.

In reality, what are known in the Lake Superior region as "greenstones" and "greenstone-schists" are not one thing, but a great variety of different things. Some of them are massive lavas, others accumulations of ash material stratified by gravity or water. They possess structures of diverse origin, which may to the field geologist appear very much alike. These must be studied first and foremost in the field, but to avoid confusion and misinterpretation we need all the help available, even from the microscope. Here we may see plainly that what macroscopically looks alike is in reality different. In fine, there is no discrepancy between the results of field and laboratory work, and if he who is *only* a field geologist find his conclusions at variance with those of a field geologist who is also a student of the microscope, it behooves him to revise these conclusions before he casts asice the results of modern petrographic research.

WORCESTER SCHOOL CHILDREN. — THE GROWTH OF THE BODY, HEAD, AND FACE.

BY GERALD M. WEST, CAMBRIDGE, MASS.

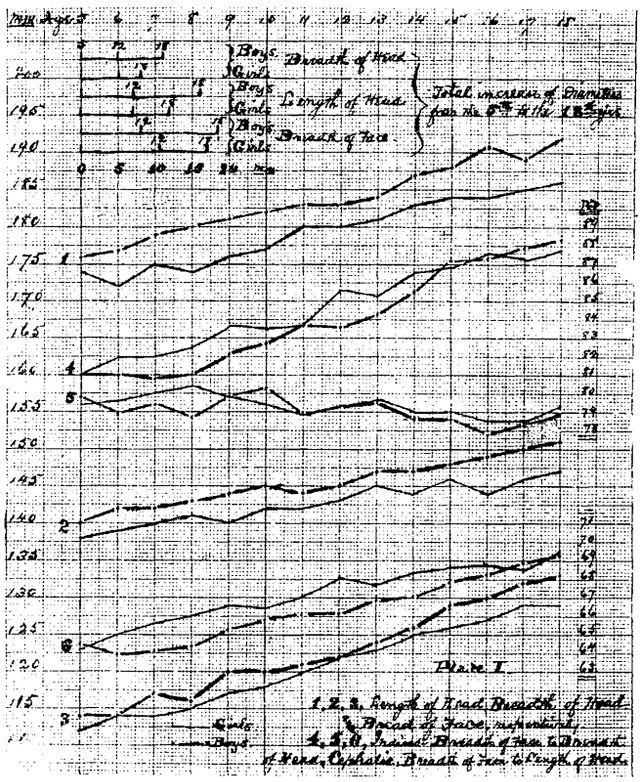
AN investigation into the laws governing the growth of various parts of the body was instituted in the Worcester schools in the spring of 1891, and a short notice of the growth in width of the faces of girls was published in *Science* (July 3, 1891). I now propose to give a summary of some of the other results obtained.

The observations were made in the primary, high and normal schools, and in two of the private schools in the city of Worcester. The number of individuals examined was 3,250, the ages ranging from 5 to 21 years. The nationalities were numerous, but about 66 per cent were of American parentage, 20 per cent of Irish, 7 per cent of English and Scotch, and 6 per cent scattering.

Plate I. contains the curves of growth of the diameters of head and face, with their indices.

Absolute measurements.	1. The maximum length measured from the glabella.	Head.
	2. The maximum breadth.	
	3. The " " of the face.	
Indices.	4. The proportion of the breadth of the face to the breadth of the head.	
	5. The proportion of the breadth of the head to the length of the head.	
	6. The proportion of the breadth of the face to the length of the head.	

Length of Head (1). — In absolute length we see that the girls' length of head is less than that of the boys throughout its whole period of growth, and consequently throughout life. We find, however, that this difference in length does not remain the same year by year, but varies considerably, being, for example, 3 millimeters at the ages of 11, 12, and 13, and rising as high as 6 millimeters before, and 7 millimeters after, that age. We find also



that the annual increment is very irregular in both sexes. We have periods of growth alternating with a cessation of growth.

In girls the greatest length of head is reached at about the beginning of the eighteenth year. In boys the head continues to grow until at least the age of twenty-one. The period of greatest irregularity in the annual increment seems in the case of girls to be before, in the case of boys after, the eleventh and twelfth years.

Breadth of Head (2). — The breadth of head presents phenomena very similar to those of the length of head, i.e., periods of alternate growth and cessation of growth. The girls' width of head is less than that of the boys, but the difference diminishes markedly about the eleventh year, from this age until the fourteenth year the curves are parallel, then this again becomes more widely separated. The age of maximum width in girls is about seventeen, in boys the maximum is not yet reached at the age of twenty-one.

Breadth of Face (3). — Here again we meet with similar phenomena; the breadth of face of the girls increasing rapidly with irregular annual increments until the seventeenth year, when the maximum growth is reached. The faces of the boys continue to grow until the eighteenth year and probably beyond.