

1917

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Recommended Citation

Keyes, Charles (1917) "Continental Perspective of American Precambrian Stratigraphy," *Proceedings of the Iowa Academy of Science*, 24(1), 53-60.

Available at: <https://scholarworks.uni.edu/pias/vol24/iss1/10>

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CONTINENTAL PERSPECTIVE OF AMERICAN PRE-CAMBRIAN STRATIGRAPHY.

CHARLES KEYES.

To many of the delegates to the Twelfth International Geological Congress who listened to the papers and discussions on Pre-Cambrian problems and who afterwards took part in the Canadian transect continental excursions into regions where the ancient clastics were displayed in infinite variety, the most valuable feature perhaps, was the field evidences of the amazing taxonomic possibilities which on the American continent the Pre-Cambrian sections were opening up. Few of the travelers had ever seen so deeply into the oldest stratified rocks in so short a time, under such favorable circumstances, or under happier guidance. Some of the participants in the proceedings, pre-eminent in other fields of stratigraphic endeavor, seemed to see in this old American complex exactly the counterpart of conditions that were presented a century ago by the Primary (Paleozoic) rocks when they were awaiting the magic touch of English geologists to unfold the then inextricable maze.

Between the two century-part problems there is one marked difference. In America there appears to be in place of only one grand succession of formations two vast piles of eral rank, either one of which very greatly surpasses in magnitude and time equivalent the entire Paleozoic sequence with which Murchison, Sedgwick and Lonsdale had to deal. As Doctor Walcott astutely remarked in the course of his informal lecture before the members of the Congress when he met them on the evening which they spent at Field Station nearby which was his now famous "Burgess Camp," the Pre-Cambrian sediments of the Rockies present the most fruitful theme that today awaits the young and ambitious geologist.

In the weighing of the evidence supporting the various hypotheses presented to them the visitors on these excursions held superior advantages over the others in that they were singularly free from a certain amount of bias which necessarily possesses those who work long and arduously in a circumscribed field. They were in an exceptionally commanding position

rigidly to test the applications of the explanatory theories and to make impartial comparisons between deduced consequences and generalized records. To a degree of stupidity almost, it seemed at times, they had to be shown in the field the detailed proofs. They not infrequently gave scant consideration to many trivial features of which far too much had been manifestly made. They brought to bear upon intricate problems the invaluable experiences of other lands. They were better able to view things more broadly than is possible in the cases of those who had worked mainly in limited areas. Altogether what they agreed upon was often quite different from what had been presented to them, piecemeal as it were, in isolated localities.

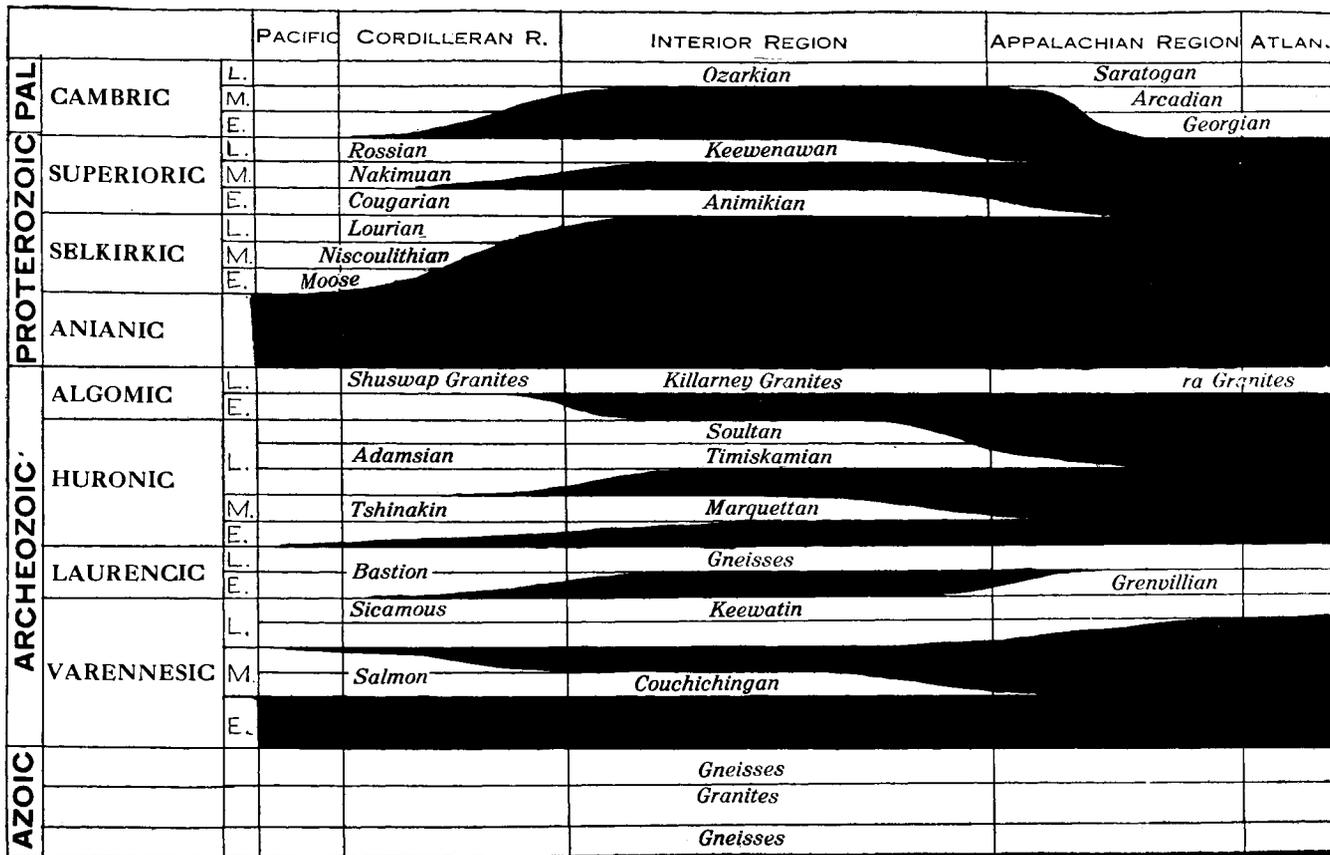
In the various attempts to resolve the most ancient sedimentary successions into their terranal elements the one great drawback is, of course, the more or less highly metamorphosed state of the rocks. This difficulty is even more serious than the one which confronted the student of the Palaeozoics before use was made of fossils. Among very old formations it is often hard to distinguish between rocks which have been altered from igneous masses and those which have been changed from sedimentaries. Moreover, without some scheme of taxonomic location of rock-masses through the consideration of which critical criteria of stratigraphic recognition are proposed, developed and modified, very erroneous notions of mass relationship must prevail. In many places, notably, for instance, on the Atlantic Piedmont plateau, much of the supposed Pre-Cambrian complex recently proves to be merely highly altered Cambrian, Ordovician and even Silurian sediments. On the other hand, thick sections of strata in the Selkirks, for example, long regarded as Palaeozoic in age are found to have beyond all doubt, Pre-Cambrian affinities.

Ever since it has come to be appreciated that there is really a Pre-Cambrian stratigraphy the great desideratum has been the discovery of some spot on earth where the ancient beds still remain but little altered and where a definite terranal sequence may be made out in the same way that it is in the case of the newer sedimentary successions. Several such locations are now known; one on the north shore of Lake Superior, and another in the Rocky Mountains on the boundary between the United States and Canada, are particularly noteworthy. In neither

of these regions are the strata altered scarcely more than it is customary to encounter among the Paleozoics. Since the beds are fossiliferous to depths of more than two miles beneath the typically earliest Cambric, or Olenellus, zone extensive faunas may be expected eventually to be disclosed.

The fact that as yet no long sequences of faunas are determined whereby the rock-sections of the various localities widely separated geographically may be analyzed, compared and grouped into units having definite taxonomic values, as is the common practice among the Paleozoics does not militate against the utilization to their fullest extent of certain physical features which have equal if not superior importance as stratigraphic and correlative criteria. These are the diastrophic features which find their most conspicuous expression in unconformities. Their lateral extent, taxonomic rank and stratigraphic value are best indicated in diagram. These broader stratigraphic aspects of the American Pre-Cambrian complex along a given cross section, as the boundary line between Canada and the United States, are represented on the accompanying chart (Plate II). Both the relative amounts of sedimentation and the magnitude of the important stratigraphic hiatuses also are indicated. The latter mainly represent more or less great erosional intervals—times of notable emergences of the continental tract. The enormous extent of denudation to which they point is no less astounding than the prodigious volume of the sedimentation in comparison with which some of the most familiar Paleozoic sections sink into insignificance.

Considered in their larger, or continental, relations the magnitude of sedimentation and the extent of removal give intrinsic suggestion of the taxonomic ranks to which many of the terranes already recognized should be assigned. Conspicuous features also to be especially noted are the almost uninterrupted degradation in the east; the almost continuous sedimentation in the west; and the sweeping oscillatory movement of the ancient strand-line in the continental interior. Particularly noteworthy also are the three major breaks in deposition marked by unconformities of continent-wide extent. The minor unconformities are likewise significant. Both larger and smaller unconformities are direct expressions of notable diastrophic movements. They are the basal horizons of new cycles of sedi-



Continental perspective of Pre-Cambrian sedimentation.

mentation. They are now so widely known, so well determined, and so numerous that they become prime values in the systematic arrangement of the strata. For purposes of wide and exact stratigraphic correlation they far surpass any service that fossils might perform.

That the primary subdivisions, here designated as Proterozoic and Archeozoic, each have eral rank in the general scheme of terranal classification rather than periodic or serial position as they are often assigned, is amply supported by many considerations. Laying down of a few miles' thickness of strata which each of these divisions represents is surely a time equivalent of that of any known Paleozoic section in the world. The trancontinental unconformity which marks the base of both of these divisions certainly represents diastrophic revolution of the first magnitude, and movement greater than that which characterizes any other recognized eral division. In the relative degree of metamorphism which the several divisions display in the same vertical section is indicated also something of a time measure. Of less taxonomic importance is the comparative amount of deformation exhibited.

The lesser subdivisions¹ which have been recognized in various regions under geographic designations as formations hold only a transitory taxonomic rank. In place of tens or hundreds of feet their thicknesses are often measured in thousands of feet. In the majority of cases doubtless these terranes will be found actually to possess the rank of provincial series, and to permit of further subdivisions into formations, that are comparable to those commonly defined among the Paleozoics.

For classificatory purposes the fossils of the Pre-Cambrian rocks, no matter how plentiful they may occur, are not likely ever to prove so important as they have in connection with the Post-Cambrian strata. Notwithstanding the facts that organic remains have been discovered in both great sections of Pre-Cambrian elastics and that they will be doubtless disclosed in more or less abundance throughout the entire succession, the

¹Varennesic, as a periodic title, was proposed (Proc. Iowa Acad. Sci., XXI, 201, 1914) to take the place of A. C. Lawson's name Ontario, which was preoccupied. It is the old French designation of Ontario Province. It is probably not co-extensive with the term Loganian Series, which a few months after Varennesic was proposed, was adapted for the same purpose by Miller and Knight (Rept. Ontario Bureau of Mines, XXII, pt. II, 127, 1914).

fossils are apt to retain in great measure the characteristics of the oldest Paleozoic forms as we now best know them. Neither are the fossils likely to serve in Pre-Cambrian questions the same stratigraphic purpose that they so long have elsewhere in the geologic column. On this account mainly the real significance of these forms already discovered is commonly overlooked; or their salient features as possible indices to regional stratigraphy are misinterpreted. For these reasons it is that there is such a wide divergence of opinion concerning the taxonomic ranks of the various subdivisions of these oldest sedimentaries.

In arraying the oldest sediments, or those strata lying beneath the commonly accepted base of the Cambrian section, or Olenellus zone, with the younger rather than with the older part of the general sequence undue emphasis is manifestly placed upon certain assumed faunal affinities. This appears to be the chief reason why Dr. A. Rothpletz, for instance, would be inclined to include in the Cambrian section the fossiliferous limestones of Steep Rock lake, north of Lake Superior². In the Beltian section of Helena, Montana, the same observer is even less fortunate in his conclusions relating to the geologic age³ because here he actually worked in recognized Mid-Cambrian strata instead of Pre-Cambrian beds as he supposed, as is conclusively shown by Dr. C. D. Walcott.⁴

Apparently influenced partly by the Rothpletz views Prof. A. C. Lawson⁵ argues for drawing in the Lake Superior region the basal line of the Paleozoic section at the horizon of the great plane of unconformity called by him the Epiarchean interval (Anianic-Selkirkic hiatus); and by severe restriction of the term Algonkian the latter is made co-extensive with Proterozoic. However, the Steep Rock Lake fossils, which are the oldest organic remains known, occur far beneath the level of the break representing the "Epiarchean Interval," and the Algonkian section thus restricted proves to represent an elapse of time equal to, if not vastly greater than, the entire Paleozoic era. So there are grave objections to assigning to such a superior succession of strata so inferior a taxonomic rank.

²Oral communication.

³Die Fauna der Beltformation bei Helena in Montana, pp. 1-46, München, 1915.

⁴Smithsonian Misc. Coll., Vol. CXIV, p. 259, 1916.

⁵Bull. Dept. Geol., Univ. of California, Vol. X, p. 18, 1916.

As Dr. G. Steinman judiciously observes⁷ the discovery of a great fauna in the Steep Rock Lake strata is not likely to acquaint us with forms so very different from those occurring in the typical Cambrie rocks. This also was the opinion of Dr. Th. Tschernychew⁸ who at the same time visited the same localities. Both of these conclusions coincide with the circumstances predicted by Prof. W. K. Brooks⁹ more than twenty years ago—before any Pre-Cambrian fossils were known. Brooks' reasoning was based strictly upon morphological grounds, and on this account has special value. His chief thought was that for some time prior to *Olenellus* time life which was entirely thalassic in nature was just beginning to find the bottom of the sea and was acquiring hard parts in order better to withstand its new shore environment. Hence for long periods previously life changed very slowly; but upon reaching shallow waters and the shore it differentiated with great rapidity. It is with these considerations in mind that the faunal aspects of the Pre-Cambrian rocks should be approached, rather than with any expectation that it is going to be possible to classify the strata according to the same principles that are so universally followed in the case of the later geologic formations.

At the close of the discussions on Pre-Cambrian problems at the Toronto Congress the bewildering variety of suggestions offered in correlation left the impression with the majority of delegates that the subject was in a state of hopeless confusion. More mature reflection showed that this was not really the case. Identical problems were being met in distant parts of the world. Singularly, also, very similar sections had been made out on the different continents. The one feature that loomed largely in the minds of all was the fact that beneath the *Olenellus* level there existed everywhere a vast pile of sediments awaiting taxonomic grouping and systematic adjustment. It was not more intensive local cultivation that was most desired but some classificatory scheme after the plan of that which we have for the later geologic formations. With such a framework upon which to hang all the accumulated facts and fancies negative testimony is as valuable as positive evidence, and the successive

⁷Oral communication.

⁸Oral communication.

⁹Journal of Geology, Vol. II, p. 455, 1904.

problems will be solved as rapidly by disproving terranal relationships as by showing that they exist. Rate of advancement is thus doubly accelerated. Inattention to these circumstances is doubtless the chief reason why progress in Pre-Cambrian geology has been so unnecessarily slow and why so few investigators find the field inviting.

DES MOINES.