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No. 81

CORRELATION PAPERS CAMBRIAN

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J. W. POWELL, DIRECTOR

CORRELATION PAPERS

CAMBRIAN

BY

CHARLES DOOLITTLE WALCOTT

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF GEOLOGIC CORRELATION,
Washington, D. C., April 1, 1891.

SIR: I have the honor to transmit herewith a memoir by Mr. C. D. Walcott, on the Cambrian of North America, prepared for publication as a bulletin.

The Division of Geologic Correlation was created for the purpose of summarizing existing knowledge with reference to the geologic formations of North America, and especially of the United States; of discussing the correlation of the formations found in different parts of the country with one another, and with formations in other continents; and of discussing the principles of geologic correlation in the light of American phenomena. The formations of each geologic period were assigned to some student already well acquainted with them and it was arranged that he should expand his knowledge by study of the literature, and by field examination of classic localities, and embody his results in an essay. The general plan of the work has been set forth on page 16 of the Ninth Annual Report of the Survey, and on pages 108 to 113 of the Tenth Annual Report, as well as in a letter of transmittal to Bulletin No. 80 of the Survey.

The first of the series of essays resulting from this work, prepared by Prof. Henry S. Williams, pertains to the formations of the Carboniferous and Devonian periods, and constitutes Bulletin No. 80. The present essay is the second of the series, and others will follow.

Mr. Walcott finds that the American Cambrian includes three faunas, of which the first and third are of continental range, and that by the aid of these faunas the formations in the various geologic provinces may be classified into three divisions, an upper, a middle, and a lower. He finds also that these divisions may be homotaxially, and perhaps chronologically, compared with divisions of the European Cambrian.

Very respectfully, your obedient servant,

G. K. GILBERT,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

OUTLINE OF THIS PAPER.

This work is a review, by one who is working in the Cambrian field, of the work of his predecessors, and of the results they and he have thus far obtained as he interprets them. It thus becomes historical and descriptive, and is a general statement of the principles upon which the correlations have been made in establishing the group.

Chapter I gives a statement of the principles upon which the delimitation of the group is based, a few brief remarks upon the nomenclature of the formations, and a list of the books and articles consulted in the preparation of this paper.

Chapter II gives a historical review of the geologic and paleontologic work that has been done in the four provinces in which the sediments of the Cambrian group occur. These are the Atlantic Coast Province; the Appalachian Province, which is divided into the Northern Appalachian and Southern Appalachian areas; the Rocky Mountain Province, and the Interior Continental Province. The latter is divided into the Upper Mississippi Area, the Eastern Border or Adirondack sub-Province, the Western Border or Rocky Mountain sub-Province, and the Southwestern sub-Province of Texas and Arizona. Within each of the provinces the historical data are reviewed by the political divisions of States and Territories, and in British North America by provinces.

The historical review of the geologic work embraces all that has come within the knowledge of the writer of the descriptive geology of the rocks now referred to the Cambrian group. The paleontologic review includes only the mention of the genera and species described by the various authors.

Chapter III is a record of the names that have been employed to designate various formations. It is of an historical rather than a controversial character.

Chapter IV gives a summary of the present knowledge of the formations in each of the four geologic provinces, in the same arrangement as that of the historical review in chapter II. The attempt is made to give a concise statement of the present knowledge of the formations referred to the Cambrian group within each province. The paleontologic references are to the larger subdivisions of the fauna without mention of genera or species. These will be described in special monographs, now in the course of preparation. At the close of this summary there is a synopsis of the Cambrian group, in which it is stated that the group is established by (*a*) the presence in the Rocky Mountain Province of 6,000 feet of limestone with an undetermined mass of quartzite beneath; (*b*) in the Appalachian Province by over 12,000 feet of quartzite, shales, slates, and limestones; (*c*) a continental distribution; (*d*) a characteristic, highly differentiated fauna. A table of the classification of the formations is arranged with the type formation of each subdivision at the head, while beneath are the formations correlated with it.

A map showing the geographic distribution accompanies this chapter; also one on which the sedimentation is illustrated by vertical columns of strata. A section across the continent, with the base of the Ordovician fauna as the upper limit and the columns of strata arranged beneath it, reveals the presence of a great trough along the line of the Appalachians from Alabama to Labrador, and a second trough on the western side of the continent west of the eastern Rocky Mountain ranges. It is claimed that the great interior Continental Province was a land area during

Lower and Middle Cambrian time and that the Cambrian Sea did not enter upon it until the beginning of Upper Cambrian time. A map based (Pl. III) upon this view illustrates the supposed land area at the beginning of Cambrian time.

The base of the group is stated to be where the oldest known fauna that is referred to the Cambrian fauna occurs. The summit of the group is the transition from the Cambrian to the Ordovician fauna, or in the New York section between the Potsdam sandstone and the superjacent Calciferous formation. The rocks or sediments are described and the conclusion reached that there were geographic areas in which different types of sedimentation prevailed, and that as a whole the sediments were deposited in both shallow and deep waters on an ocean bottom that was being slowly depressed in relation to sea level.

The study of the fauna indicates that the group may be conveniently divided into three divisions, lower, middle, and upper. The evidence of the sedimentation and organic remains proves the presence of geographic provinces in Lower Cambrian time that became more strongly differentiated in Middle Cambrian time and less strongly marked in Upper Cambrian time.

The chapter concludes by notes on the Cambrian rocks of Great Britain, Europe, China, India, Australia, and South America.

Chapter V deals with problems for investigation and settlement which are taken up, for the local problems, in the same order of presentation as the matter in chapters II and IV. The general problems respecting our knowledge of the Cambrian group, as a whole, or in large parts, are discussed separately, as are the problems of nomenclature and classification. The latter includes a statement of the problems relating to the name and the limits of the group.

Chapter VI is devoted to the study of criteria and principles used by authors in the correlation of the various parts composing the Cambrian group, with observations on some methods of correlation. The first portion includes the historical notes, and is a review in chronologic order of the principles of correlation used by authors in the United States and Canada, and observations by authors upon correlation of American with European formations. This review shows that many authors have expressed sound views upon methods of correlation and that, with the exception of the additions made since the theory of evolution began to influence paleontologists, the addition to methods has been relatively small. Under the heading of methods of correlation, correlation by superposition, organic remains, lithologic characters, and unconformity are treated of at some length. Under organic remains are considered life zones, stage of evolution, life history, contemporaneity, homotaxis, and percentage of species. Reference is also made to homogeny and topographic features as elements entering into the problems of correlation.

THE CAMBRIAN GROUP OF ROCKS IN NORTH AMERICA.

BY CHARLES D. WALCOTT.

CHAPTER I.

INTRODUCTORY.

This report is an unfinished memoir. It is an account of the present knowledge of a great geologic group that will require prolonged investigation to bring it to the status in descriptive geology already attained by the superjacent members of the Paleozoic system.[1]

The history of the origin and application of the term Cambrian in geologic nomenclature is presented in connection with the description of the names that have been employed in the classification of the various formations characterized by the types of the "First or Primordial Fauna" of Barrande. The basal fauna, as now known, is that of the Olenellus zone; and the upper horizon of the group is drawn at the summit of the series characterized by the Dikellocephalus fauna of North America. The delimitation of the group is based on the principles: (*a*) that the great geologic groups must rest on the broad zoologic characters of their included faunas, and not upon local stratigraphic breaks between certain series of rocks or upon local differences in sedimentation; (*b*) that the most reliable chronologic scale in geology is that afforded by the relative magnitude of zoologic change; and (*c*) that the geologic duration and importance of any system are in strict proportion to the comparative magnitude and distinctness of its collective fauna.[2]

Geologic classification has been largely based upon the imperfections of the geologic record and an arbitrary assumption of breaks in the chain of sedimentation and life that are not of universal extent. Geologic continuity must have been a fact and the sequence of life and deposition continued uninterrupted on some portion of the earth from the earliest Cambrian time to the present day. Such continuity could not have existed in any one province, and it is doubtful if the complete record will ever be regained. In its absence the classification already

[1] In the preparation of the historical portion I received material assistance from Prof. Joseph F. James, who, taking as a basis the bibliographic card-catalogue of Mr. N. H. Darton, prepared a series of brief abstracts which guided me in my historical research.

[2] Lapworth, Charles. Geological Magazine, new ser., dec. II, 1879, vol. 6, p. 3.

established is adopted and then arbitrarily assumed whenever the original basis for it is cleared away by more perfect knowledge.

For convenience of description and geologic cartography, the geologic formation[1] is taken as the primary unit of classification. The combination of these primary units forms the terrane, which may be composed of any number of geologic units. The groupings of the terranes form the groups, and the union of the groups the systems. Thus the Potsdam sandstone of the Adirondacks, the Dutchess County limestone of New York, the upper Knox shales of Tennessee, the Hamburg shales of Nevada, and many other formations unite to form the Upper Cambrian terrane. The union of the Upper Cambrian with the Middle and the Lower Cambrian builds up the Cambrian group. The combination of the Cambrian, Silurian, Devonian, and Carboniferous, forms the Paleozoic system.

The nomenclature of the formations of any group frequently expresses in local terminology the history of the development or evolution of knowledge of the group. For instance, the formations composing the Cambrian begin, in America, with the "Granular Quartz" and then follow the Potsdam sandstone, the St. John shales, the Chilhowee sandstone, etc. The plan of naming the formations from the locality at which they are best developed is a great safeguard and can be frequently adopted. For instance, the Potsdam sandstone of New York has its type locality at Potsdam in St. Lawrence County, where it can be readily identified. To say it is identical with the Upper Cambrian or St. Croix sandstone of the Mississippi Valley, with which it has been identified, and to speak of the latter as the Potsdam sandstone, is to practically state that they are synchronous. The use of the name St. Croix does not imply this. It enables the geologist to mention the formation without assuming a correlation that he may or may not believe in.

[1] Dr. J. J. Bigsby states that "According to Deshayes 'a formation is a space of time represented by a certain number of beds, laid down under the influence of the same phenomena,' or, in other words, a formation is characterized by the constancy of its fossils." (On the Paleozoic basin of the State of New York. Part II. Classification of the Paleozoic strata of the State of New York. Quart. Jour. Geol. Soc. London, 1858, vol. 14, pp. 428, 430.)

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CHAPTER II.

HISTORICAL REVIEW OF THE GEOLOGIC AND PALEONTOLOGIC WORK.

The scope of this review is limited, with a few exceptions, to the notice of papers and memoirs that have added something original to the preexistent knowledge of the rocks and faunas now referred to the Cambrian group.

Several methods of presenting the historical data have suggested themselves.

(1) Chronologic; (2) Geographic and chronologic; (3) Chronologic, geographic, and stratigraphic.

(1) *Chronologic.*—This method necessitates reference to papers in the order of their publication, whether they treat of Cambrian rocks in Newfoundland, New York, Alabama, or Nevada. All is subservient to the chronologic record.

(2) *Geographic and chronologic.*—This method permits of the chronologic grouping of the papers referring to the rocks under consideration in geographic areas.

(3) *Chronologic, geographic, and stratigraphic.*—This third and more comprehensive method arranges the review in the form of a statement of the historical data as in the second method, with the addition of treating of such primary divisions separately as may be thought worthy of such consideration. To this there may also be added, in exceptional instances, the chronologic arrangement of the discoveries and opinions of some of the more prominent investigators and authors.

The second method is adopted in this review in connection with the third, where the latter is necessary in order to present more clearly the evolution of the present knowledge of the rocks and fauna of the Cambrian group.

The Cambrian group can usually be divided into three primary divisions. *First*, the Lower Cambrian; *second*, Middle Cambrian; *third*, Upper Cambrian. This nomenclature will be used throughout the review, when it is necessary to refer to a standard generally known.

Rocks of Cambrian age occur on the North American continent in four principal geographic areas or geologic provinces. In reviewing the literature it is possible, owing to the investigators in each province having limited their work to their respective provinces, to present the history of discovery and publication in each by itself, as follows:

I. *The Atlantic Coast or Eastern Border Province.*

II. *The Appalachain Chain.*

III. *The Rocky Mountain or Western Border Province.*

IV. *The Interior Continental or Central Province.*

The record of paleontologic investigation in each province will follow the geologic review.

ATLANTIC COAST PROVINCE.

The Atlantic coast province includes the deposits on the island of Newfoundland, the provinces of Nova Scotia and New Brunswick and Cape Breton, and the States of Maine, New Hampshire, and eastern Massachusetts.

NEWFOUNDLAND.

Systematic geologic investigation in Newfoundland began with Prof. J. Beete Jukes, who in 1843[1] published a report of his studies in field and office. He describes the relation of the strata at the base of the Paleozoic section (now referred to the Olenellus zone), to the unconformably subjacent crystalline rocks about Conception Bay, and mentions the red shales in which the Olenellus fauna is now known to occur, as well as the green and dark shales of the Paradoxides zone, as subsequently known. A description is given of the upper slate formation as shown on the islands in the bay, under the name of Bell Island shale and grits; and of the lower slate under the name of St. John's slate, 2,000 to 3,000 feet thick, as seen near the town of St. John's; also the superjacent Signal Hill sandstone, about 800 feet thick.[2] In the absence of fossils no attempt was made to correlate the formations with those of England. On the map accompanying the report the geographic distribution is given of the lower slate (St. John's) and of the upper slate (Bell Island) formations about Conception Bay and Smith Sound.

Two years later Capt. H. W. Bayfield[3] described a sandstone with subjacent red and white limestone on the Straits of Belle Isle, which he stated contained a species of Cyathophyllum. This is the first notice of the Lower Cambrian rocks containing Archæocyathus, and it is the second recorded discovery of fossils now referred to the Olenellus zone.

At a meeting of the Boston Society of Natural History, April 20, 1859, Dr. C. T. Jackson exhibited a trilobite from the calcareous slate of St. Mary's Bay, Newfoundland, which he thought identical with *Paradoxides harlani* from Braintree, Massachusetts. He said that this formation could be followed, though in an interrupted line, from Braintree to Newfoundland.[4]

In 1859 Mr. J. W. Salter[5] received a specimen of the genus Paradox-

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[1] General report of the geological survey of Newfoundland in 1839 and 1840, pp. 160, 2 pls., London, 1843.

[2] Op. cit. pp. 55-60.

[3] On the junction of the transition and primary rocks of Canada and Labrador. Quart. Jour. Geol. Soc., London, vol. 1, 1845, pp. 450-459.

[4] On a trilobite from Braintree. Boston Soc. Nat. Hist., Proc., vol. 7, 1859, p. 54.

[5] On the fossils of the Lingula-flags or "Zone Primordiale." Quart. Jour. Geol. Soc., London, vol. 15, 1859, pp. 551-555.

ides, collected from the upper slate of St. Mary's Bay, Newfoundland, which he described under the name of *Paradoxides bennetti*, calling attention to its relation to *Paradoxides spinosus* and *P. bohemicus*, of Bohemia.

In 1862, Prof. Jukes, referring to his work in Newfoundland, stated that he included under the upper slate formation the Bell Isle shale and gritstone and variegated slate; and in the lower slate formation the Signal Hill sandstones and St. John's slate. He says he did not find any fossils in them, but that Mr. C. Bennett subsequently found trilobites of the genus Paradoxides (named *P. bennetti* by Mr. J. W. Salter) in the slates on the west side of St. Mary's Bay. "These slates belong to the group I called the St. John's slate, which is covered conformably by the Signal Hill sandstone. The Variegated slate group, on the other hand, passes up into the Bell Isle shale and gritstone, and near Brigus Harbor, in Conception Bay, may be seen to rest unconformably on the St. John's slate" (as described in 1843).[1] This is the unconformity now recognized between the Cambrian and Algonkian rocks.

Eighteen years after Captain Bayfield had reported on the strata of the north side of the straits of Belle Isle, Sir William E. Logan[2] described the strata resting on the gneiss as red and green sandstones, 231 feet thick, overlain by gray, reddish, and greenish limestone. In the limestone a number of fossils were found which Mr. Billings identified with those found in the "Red Sandrock" of Vermont. The formation was referred to the Lower Potsdam by Logan. Fifteen miles across the straits, on the Newfoundland coast, the rocks are apparently of Calciferous age; and he concluded that the Potsdam sandstone zone was buried beneath the waters of the Straits.[3] In the description of the section at Bonne Bay, on the west coast of Newfoundland,[4] it is compared with that at the Straits of Belle Isle; and on pages 865–867, the section at Bonne Bay is given in detail. Of this 1,711 feet are, by the contained fossils, referred to the Potsdam group.

In the report of the Geological Survey of Newfoundland for 1864[5] a summary is given of the then existing view of the succession of the Lower Paleozoic rocks in North America. For Newfoundland the succession of the rocks now referred to the Cambrian is Upper Potsdam, Lower Potsdam, and St. John's group, and Newfoundland is cited as the locality where the lower portion of the series is complete. The lowest, or St. John's group, is correlated with that of St. John, New Brunswick, and the Paradoxides beds of Braintree, Massachusetts. The lower Potsdam is represented by several hundred feet of limestones and

[1] The student's manual of geology. Second edition. Edinburgh, 1862, p. 457.

[2] Geological survey of Canada. Report of progress from its commencement to 1863. Montreal, 1863, pp. 983, 11 plates. Atlas of maps and sections, with an introduction and appendix. Montreal, 1865. 9 maps and sections.

[3] Op. cit., p. 288.

[4] Op. cit., p. 293.

[5] Logan, W. E., Lower Silurian Rocks of North America. Geol. Surv. Newfoundland, Rep. Prog. for 1864, Montreal, 1866, pp. 45, 46. Revised edition, 1881, p. 49.

sandstones on the Straits of Belle Isle, and on White Bay, Newfoundland, and by the slates of St. Albans and Georgia, Vermont. The Upper Potsdam is that of Wisconsin and Minnesota, represented in the typical Potsdam of New York. This horizon is not recognized in the northern part of Newfoundland, but occurs on Conception Bay, in the southeastern part. The tabulation made by Logan has been followed very largely by all writers upon American geology, and the succession was not changed until 1888, when it was discovered that the St. John group of Mr. G. F. Matthew was above the Lower Potsdam of Billings and Logan.

The Geological Survey of Newfoundland, under the direction of Dr. Alexander Murray, added materially to our knowledge of the Lower Paleozoic rocks. All the strata beneath the Calciferous or Quebec group were referred to the Potsdam group.[1] In the neighborhood of Canada Bay, on the east coast, the entire series referred to the Potsdam has a thickness of 1,153 feet, of which the lower 760 feet belong to the Lower Cambrian zone, as shown by *Olenellus vermontana* occurring in the upper portion.[2] In the report of field work for 1868, Dr. Murray[3] describes the rocks about Conception Bay, in the southeastern portion of the island. Of the lowest bed exposed on Manuel's Brook, a small stream that flows into Conception Bay, he says: "On Manuel's Brook a very coarse conglomerate may be seen, in strong and moderately regular beds, resting directly upon the syenitic gneiss of the valley above. * * * About 400 yards below the bridge the conglomerate is overlaid conformably by a set of dark brown or blackish shales, * * * with some hard calcareous beds interstratified," and this series extends down the stream nearly to the bay.[4] Dr. Murray also describes, in a section at Topsail Head, a gray compact limestone in strong solid beds, 1 to 2 feet thick, showing a vertical thickness of about 100 feet, together with some interstratified shale. The limestone is subjacent to a dark brown, finely laminated shale. Detailed sections are given of the shales and sandstones exposed on Kelly's and Great Bell Islands, Conception Bay; the former has a thickness of 712 feet and the latter of 476 feet. A summary of the rocks referred to the Lower Silurian gives an entire thickness of 3,880 feet.[5] Figures of five sections accompany the text, in which the unconformity between the Lower Silurian rocks and the subjacent intermediate system or Huronian and the Archean is well shown. The subjacent slates and Signal Hill sandstones of Jukes are referred by Dr. Murray to the Cambrian group on account of fossils having been found there, which Mr. Billings described as *Aspidella terra-novica* and Arenicolites.[6]

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[1] Sequence and distribution of the rocks of the great Northern Peninsula. Geol. Surv. Newfoundland, Rep. Prog. for 1864, Montreal, 1866, pp. 10, 44. Revised edition, 1881, pp. 5-47.

[2] Op. cit., p. 10.

[3] Of the sequence and distribution of the formations. Report upon the geological survey of Newfoundland for 1868, St. John's, 1868, p. 68. Revised edition, 1881, pp. 154-167.

[4] Op. cit., p. 154.

[5] Op. cit., pp. 157-160.

[6] Op. cit., p. 144.

In the report for 1869 a description is given of the Lower Paleozoic rocks studied by Mr. Howley as they occur on Trinity Bay and St. Mary's Bay.[1] The variegated slates of Jukes are described as containing Paradoxides and the superjacent argillaceous shales and sandstones carry Cruziana and other fossils. These last represent the rocks of the Bell Islands in Conception Bay. In the report for 1870[2] a summary is given of the then existing knowledge of the Primordial formations in southeast Newfoundland. In descending order the upper formation is a brown and black micaceous shale with the gray micaceous sandstones of Great Bell Isle, Conception Bay. The organic contents are: Two species of Lingula, four species of Palæophycus, *Eophyton linnæanum* of Torrell, another Eophyton and *Cruziana semiplicata* Salter. Thickness, 476 feet. He says that the slates of Little Bell Isle and the beds of shale beneath the water are considered to have a thickness of 1,426 feet, to which the Kelly's Island sandstone and shale are to be added, with a thickness of 720 feet. [As now known this forms the upper division of the Cambrian.] Beneath this he describes the black slates, with *Paradoxides bennetti*, having a thickness of 150 feet. On St. Mary's Bay this division, united with the red, green, and black shales or slates, in which *Paradoxides bennetti*, *Conocephalites gregarius* and other fossils were recognized, has a thickness of 1,045 feet. [This forms the middle division of the Cambrian as now known.] Below this the hard thick beds of gray and reddish limestone of Topsail Head, Brigus South Head, Conception Bay, and the Little Salmonier River of St. Mary's Bay are united with various outcrops of red, green, and blackish argillaceous slates and a series of sandstones below. [These form the lower division of the Cambrian as now known.] The total thickness of the section described is 5,972 feet.[3] Several sections are illustrated to show the relation of the Primordial-Silurian to the subjacent rocks.

In the report for 1872 the Primordial-Silurian rocks are described as they are exposed on Trinity Bay, etc., by Dr. Murray.[4] He states that on paleontological grounds Mr. Billings is disposed to draw a marked distinction between the upper strata of the section of 1870 and the lower members of that section, in consequence of an apparent hiatus or break in organic development between the Paradoxides beds and the fossiliferous strata of Great Bell Island in the Conception Bay section. The lower measures he [Billings] appears to regard as the equivalent of the lower Lingula flags of Great Britain, or the Menevian group of Salter and Hicks; while the upper parts contain forms in some degree typical of the horizon of the Upper Potsdam.[5] This is followed by a

[1] Murray, Alexander. Of the rocks and associated minerals [of Bonavista Bay, etc.]. Report upon the geological survey of Newfoundland for 1869. Revised edition. 1881, pp. 200-203.

[2] Murray, Alexander. Of Primordial, Silurian, and related formations. Geol. Surv. Newfoundland for 1870, St. John's, 1870, pp. 30-43. Revised edition, 1881, pp. 232-241.

[3] Op. cit., pp. 237-239.

[4] Distribution of the formations [of Avalon]. Report upon Geol. Surv. of Newfoundland for 1872. St. John's, 1873, pp. 14-34. Revised edition. London, 1881, pp. 285-297.

[5] Op. cit., p. 291.

list of the species described by Mr. Billings from the Paradoxides zone and the strata of Great Bell Island.

Prof. John Milne traveled extensively along the coast of Newfoundland, and published the results of his geologic studies in association with the "Notes on Geology" by Alexander Murray.[1] The Primordial-Silurian is spoken of as a separate division; then, superjacent to the rocks of this formation, come the Potsdam and Calciferous. There does not appear to be any additional data to that already given in the report on the geology of Newfoundland by Dr. Murray.

When describing some fossils collected by Mr. T. C. Weston, of the Canadian Geological Survey, in 1874, from St. Mary's, Trinity, and Conception Bays, Newfoundland, Prof. J. F. Whiteaves states that the paleontological evidence sustains the view of Sir W. E. Logan that the slates of St. John's, Newfoundland, probably belong to the same horizon as the Acadian or St. John group of St. John, New Brunswick.[2] Of the deposits on the islands of Conception Bay he says: "From Mr. Murray's report already quoted it would appear that the shales of Kelly's Island are not quite so old as those of Manuel's Brook, but that they are older than the Menevian sandstones of Great Bell Island."[3]

Dr. Murray appears to have considered the Potsdam zone as above the Primordial beds of Newfoundland. This is shown in the chapter on the "Geology of Newfoundland," where a summary of the geology is presented as taken from Dr. Murray's work.[4]

Prof. Alpheus Hyatt, in his expedition to Newfoundland, visited the north coast of the Straits of Belle Isle, and collections were made at Anse au Loup and Amour Cove from the "so-called Potsdam sandstones and limestones of the Canadian survey. The observations made at these points indicate a fauna quite distinct from those of any of the limestones or slates of the west coast of Newfoundland. The absence of Cephalopoda and the prevalence of primitive forms of Archæocyathus show the rocks to be probably older than those of the Quebec group at Port au Choix and other localities. The primitive sponges, or Archæocyathi, have here replaced corals completely, and may be described as reef-builders, since numerous hummocks and masses and parts of the strata are formed entirely of their remains. Immediately below these limestones, and conformable with them, lie the red sandstones, several layers of which are perforated with Scolithus burrows."[5]

A brief summary of the Lower Cambrian rocks of Newfoundland, was given by Mr. C. D. Walcott, in a study of the Cambrian faunas of

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[1] On the rocks of Newfoundland. Geol. Mag., new ser., decade II, vol. 4, 1877, pp. 251-262.

[2] On some Primordial fossils from southeastern Newfoundland. Am. Jour. Sci., 3d ser., vol. 16, 1878, p. 225.

[3] Op. cit., p. 226.

[4] Hatton, Joseph, and M. Harvey. Geology of Newfoundland. Newfoundland, the oldest British colony, its history, its present condition, and its prospects in the future. London, 1883, pp. 178-187. American edition, Boston, 1883, pp. 150-157.

[5] Expedition to Newfoundland. Boston Soc. Nat. Hist. Proc., vol. 23, 1886, p. 319. Cruise of the *Arethusa*. Science, vol. 6, 1885, p. 386.

North America[1] when discussing the stratigraphic position of the Olenellus fauna. In it he says[2] that the only locality known where the two faunas occur in the same geographic area is on Conception Bay, Newfoundland; and special stress is placed on the occurrence at Topsail Head of several species of fossils typical of the Olenellus zone at the Straits of Belle Isle. This fauna was referred to the Middle Cambrian,[3] although Dr. Murray states in his section of 1868 that Mr. Billings referred the species to the Potsdam.[4] By this Mr. Billings probably meant his lower Potsdam, which is now (1890) included in the Lower Cambrian.

In an abstract of a paper on the Cambrian faunas of Cape Breton and Newfoundland, published in advance of the paper read before the Royal Society of Canada, Mr. G. F. Matthew[5] classifies the horizons of the Cambrian as follows:

(1) The horizon of *Paradoxides kjerulfi*.
(2) The horizon of the Conocoryphees.
(3) The horizon of *Paradoxides tessini*.
(4) The horizon of *Paradoxides spinosus*.
(5) The horizon of *Paradoxides davidis*.

It is stated[6] that "in this classification of the various Newfoundland horizons in the Paradoxides zone Mr. Matthew has placed that of *Paradoxides kjerulfi* first or oldest, because that is its position in Scandinavia." In the final paper[7] he speaks of the fossils found at Topsail Head, and Brigus on Conception Bay, mentioning *Agraulos strenuus*, Iphidea (allied to *Iphidea bella* Billings), and *Stenotheca paupera* Billings. He says these fossils do not give sufficiently firm indications to make it clear that they are older than some other horizons mentioned hereafter. He then describes the fossils of the Paradoxides zone. A new species, *Solenopleura bombifrons*, is described from the limestone of Topsail Head.[8]

In the summer of 1888 Mr. C. D. Walcott made a careful study of the Cambrian section in Newfoundland, and determined the Olenellus zone to be beneath the Paradoxides zone, and not above it, as arranged by Logan in his scheme of 1864. A detailed section of the Cambrian strata on Conception Bay was published, with lists of the fossils occurring at the different horizons in it.[9]

[1] Second contribution to the studies on the Cambrian faunas of North America. U. S. Geol. Surv., Bull. No. 30, vol. 4, 1886.
[2] Op. cit., p. 49.
[3] Op. cit., p. 29.
[4] Of the sequence and distribution of the formations. Report upon the geological survey of Newfoundland for 1868. Revised edition, 1881, "P. 1" of section, p. 157.
[5] The Cambrian faunas of Cape Breton and Newfoundland (abstract). Can. Record Sci., vol. 2, 1886, pp. 255-258.
[6] Op. cit., p. 258.
[7] On the Cambrian faunas of Cape Breton and Newfoundland. Royal Soc. Canada, Proc. and Trans., vol. 4, section iv, 1887, pp. 147-157.
[8] Op. cit., p. 156.
[9] The stratigraphical succession of the Cambrian faunas of North America. Nature, vol. 38, 1888, p. 551. Stratigraphic position of the Olenellus fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, 1889, pp. 374-392; vol. 38, 1889, pp. 29-42.

NOVA SCOTIA.

The altered or metamorphic slate belt of the Atlantic coast of Nova Scotia is represented on an early geological map by Dr. Abraham Gesner[1] as extending from Cape Canso to Cape Sable. He states that the area is within the primary district and composed principally of granite, gneiss, and mica slate. A general description of the rocks is given in the account of the local geology of the townships in which they occur.

At a meeting of the Geological Society of London on May 10, 1843, Dr. Gesner[2] presented to the society a geological map of Nova Scotia, accompanied by a memoir on the geology. In the text[3] the lowermost of the Silurian rocks devoid of animal remains is referred to the Cambrian. The map was not published with his paper. It appeared in 1845[4] in connection with papers by Mr. Richard Brown, on the geology of Cape Breton, and Mr. J. W. Dawson, on the Lower Carboniferous rocks or gypsiferous formation of Nova Scotia. The strata now provisionally included in the Cambrian group are indicated on the map as micaceous and chloritic slates, clay slate, quartz rock, and graywacke slate. They extend entirely around the central area of granite and syenite, and are separated from the Atlantic coast by a broad belt of color designated as granite. At a later date Gesner described the stratified non-fossiliferous rocks or Cambrian group of Nova Scotia[5] as an extended belt of hornblende slate, chlorite slate, clay slate, graywacke slate, and quartzite, succeeding the granite and its associates, and with them occupying almost the whole of the Atlantic side of the province. No fossil remains have been found in any of these metamorphic masses.

In 1850 Dr. J. W. Dawson described the Atlantic coast series as follows:

> The prevailing stratified rocks in this group are compact and flaggy gray quartzite (often weathering white), mica slate, and clay slate, the latter usually of dark colors, and occasionally passing into flinty slate and quartzite. * * *
>
> The hypogene rocks associated with them are white and flesh-colored granite, which has penetrated the metamorphic rocks in large irregular bands and masses.[6]

As a result of his study of this group of rocks Dr. Dawson concluded that they belonged either to some of the older members of the Silurian system or to a still earlier period. In the first edition of the Acadian Geology Dr. Dawson stated that the rocks are certainly older than the Devonian; and he was inclined to believe that they represented the Potsdam sandstone and Utica and Hudson River shales, in an altered condition.[7] On the accompanying map their geographic distribution

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[1] Remarks on the geology and mineralogy of Nova Scotia. Halifax, N. S., 1836, pp. 272.

[2] A geological map of Nova Scotia, with an accompanying memoir. Geol. Soc. London, Proc., vol. 4, 1843, pp. 186–190.

[3] Op. cit., p. 187.

[4] Geological Map of Nova Scotia. (Accompanying papers by J. W. Dawson and Richard Brown.) Quart. Jour. Geol. Soc., London, vol. 1, 1845, oppo., p. 23.

[5] The industrial resources of Nova Scotia. Halifax, N. S., 1849, pp. 233, 234.

[6] On the metamorphic and metalliferous rocks of eastern Nova Scotia. Quart. Jour. Geol. Soc., London, vol. 6, 1850, p. 348.

[7] Acadian Geology, 1st Edition, Edinburgh, 1855, p. 357.

is shown and in the legend they are noted as "perhaps altered Lower Silurian" strata.

In a supplementary chapter to the first edition the slates and quartzites of the Atlantic coast belt are spoken of, and it is suggested that they may be a continuation of the Primordial zone of Newfoundland, in which Paradoxides have been found.[1] Mr. E. Billings reviews this supplementary chapter and says:[2] "We are strongly inclined to the belief that this supposition will yet turn out to be well founded."

In 1862 the slates of the Nova Scotia metamorphic slate belt were referred to the Taconic System.[3] A more detailed description of the rocks was published by Dr. J. W. Dawson, in 1868, in which they are stated to be formed of granite, gneiss, mica slate, quartz rock or quartzite, and clay slate. The granite appears to be intrusive, and the gneiss is considered a product of a metamorphism or baking of sedimentary rocks. The clay slate or argillaceous slate abounds, and is usually, along the Atlantic coast, of a gray and black color, varying very much in texture and hardness.[4] He states that the series has not afforded fossils, but it appears to be a continuation of the older slate series of Mr. J. B. Jukes in Newfoundland, which has afforded trilobites of the genus Paradoxides. On the map accompanying the volume the geographic distribution of the series is clearly exhibited.

In a general description of the Nova Scotia gold field Mr. J. Campbell[5] publishes a section across the gold-bearing rocks of the Atlantic coast, in which the arrangement and relative position of the different groups of strata are well shown. There is a great thickness of quartzite subjacent to blue and gray slates divided midway by the "black rock." Very few details are given of the section, as the report is mainly devoted to a description of mining and the mode of occurrence of gold.

When reporting upon the Waverly gold district Prof. H. Y. Hind stated that he had found *Palæotrochus minor* and *Palæotrochus major* of Emmons, besides numerous concretionary forms, in the Waverly beds. He considers (*a*) that these fossils, if identical with those from North Carolina, probably establish the age of the gold-bearing rocks of Nova Scotia; (*b*) that they occur near the base of the Lower Silurian System; (*c*) that they belong to the upper part of the Potsdam formation and the lower part of the Calciferous formation, and (*d*) that they are subjacent to the great mass of serpentine and red slates, discovered by Dr. Honeyman in Antigonish, which belong to the Quebec group. The gold series is correlated with that described by Dr. Emmons in North

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[1] Supplementary chapter to the Acadian Geology, Edinburgh, 1860, p. 53.

[2] [Review of] Acadian Geology and a Supplementary Chapter thereto. Canadian Nat., vol. 5, 1860, pp. 450–455.

[3] Marcou, Jules. [The slate of Nova Scotia, metamorphic Taconic rock.] Boston Soc. Nat. Hist., Proc., vol. 9, 1862, p. 47.

[4] Acadian Geology. The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, 2d. ed. London, 1868, pp. 613–615.

[5] Report on the Gold Fields of Nova Scotia. Halifax, 1863, pp. 12.

Carolina.[1] In a paper presented to the Geological Society of London,[2] and subsequently published in the report on the Sherbrooke gold district of Nova Scotia, Prof. Hind describes the gold-bearing rocks of Nova Scotia as follows:

The gold-bearing rocks of Nova Scotia are of Lower Silurian age, and rest either on Huronian strata or, where these have been removed by denudation, on the old Laurentian gneiss. The gold is found chiefly in beds of auriferous quartz of contemporaneous age with the slates and quartzites composing the mass of the series, which in Nova Scotia is 12,000 feet thick, and the auriferous beds are worked, in one district or another, through a vertical space of 6,000 feet.[3]

In a report on the gneissoid series underlying the gold-bearing rocks of Nova Scotia the same writer[4] states that he has provisionally referred the gold-bearing series to the Lower Silurian, but that conclusive evidence derived from fossils has not been obtained from the gold-bearing slates and quartzites. Since the discovery of the forms resembling the Palæotrochus of Emmons, noticed in his report on the Waverly district, he has sent to Mr. Billings slabs containing supposed fossils from the Sherbrooke rocks. Mr. Billings thought that a species of Orthis and an Eospongia were indicated. In describing the gold-bearing rocks under the head of "Lower Silurian" Prof. Hind[5] says:

The known gold-bearing rocks of Nova Scotia consist of quartzites, sandstones, and grits, interstratified with argillaceous slates and thin conformable beds of auriferous quartz. This portion has an ascertained thickness exceeding 9,000 feet. * * * The thickness of the black slates in Nova Scotia exceeds 3, 000 feet, so that the gold-bearing rocks of the province have a known thickness of 12,000 feet.

The essential parts of the description in the last paper are also printed in the American Journal of Science.[6]

In his report on the gold fields of Quebec and Nova Scotia, Dr. A. R. C. Selwyn[7] speaks of the geological position of the Atlantic coast series of stratified gold-bearing slate and quartzite, stating that all former observers are agreed that they probably belong to the Lower Silurian series. His first impression of them was that they represented the groups known in Britain as the Harlech grit or quartzite, and the Lingula-flag series. He discovered in the gray sandy and flaggy pyritous slates at the Oven's Bluffs numerous specimens of the genus Eophyton, and states that Mr. Billings regarded this genus as characteristic of the Primodial Silurian epoch. He then gives an account of the distribution of the genus Eophyton, and in conclusion says: "In

[1] Report on the Waverly Gold District, with geological maps and sections. Halifax, 1869, p. 61.

[2] On two gneissoid series in Nova Scotia and New Brunswick, supposed to be the equivalents of the Huronian (Cambrian) and Laurentian. Quart. Jour. Geol. Soc., London, vol. 26, 1870, pp. 468–479.

[3] Report on the Sherbrooke gold district, together with a paper on the gneisses of Nova Scotia and an abstract of a paper on gold mining in Nova Scotia. Halifax, N. S., 1870, p. 3.

[4] Preliminary report on a gneissoid series underlying the gold-bearing rocks of Nova Scotia, and supposed to be the equivalent of the Laurentian system. Halifax, N. S., 1870, pp. 14.

[5] Op. cit., p. 8.

[6] On the Laurentian and Huronian series in Nova Scotia and New Brunswick. Am. Jour. Sci., 2d ser., vol. 49, 1870, pp. 351–353.

[7] Notes and observations on the gold fields of Quebec and Nova Scotia. Geol. Surv. Canada. Report Prog. for 1870-'71, 1872, pp. 268–270.

general aspect, and in the succession of the beds the whole series in Nova Scotia closely resembles the Cambrian and Lingula-flag series of North Wales."[1]

Dr. J. W. Dawson reviews his studies of the Atlantic coast belt of Nova Scotia in the supplement to the second edition of the Acadian Geology,[2] and places the slates and quartzite in the Cambrian. He states that the evidence of fossils in determining the precise age of these rocks is unfortunately as yet somewhat imperfect, and quotes Prof. Hind as saying that the entire thickness of the series is 12,000 feet; of this the lower or quartzite and slate division comprises about 9,000 feet, and the upper or ferruginous slate division about 3,000 feet.

On the colored geological map of the Dominion of Canada, published in 1882, the Cambrian rocks of Nova Scotia are made to extend from near the northeastern point of the peninsula south to Sable River, where they are interrupted by a mass of granite that extends to Harrington Harbor. From this point around the western slope to Annapolis Basin they occupy a wide strip along the shore. As represented on the map they occupy nearly one-half of the area of Nova Scotia.

In 1888 Sir William Dawson reviewed the rocks referred to the Cambrian group on the Atlantic coast of Canada,[3] stating that the Atlantic coast or gold series of Nova Scotia in their western extension appeared to rest on rocks of Huronian aspect. He also says:

It has unfortunately afforded no well-characterized fossils. The markings called Eophyton and certain radiating bodies (Astropolithon) found in it are, however, similar to those occurring elsewhere in Lower Cambrian rocks. Murray was disposed to regard this formation as corresponding to his Huronian in Newfoundland; but it does not agree with this either in mineral character or in fossils, and is perhaps rather to be regarded as a great development of the lowest member of the Cambrian, an exaggerated equivalent of the Harlech grits and Llanberris slates. In this case, however, it may be expected that it will yet afford true Cambrian fossils.[4]

NEW BRUNSWICK AND CAPE BRETON.

In the report for 1842 on the geology of New Brunswick Dr. Abraham Gesner[5] uses the term "Cambrian system." He says:

This name has been applied to a group of rocks situated beneath the "Silurian" strata, from which it is not always separated by any very distinct line of demarcation, so far as its lithological character is concerned. The few organic remains, however, found in this group are sufficiently characteristic to make it appear that the forms of animal life during the period of the accumulation of its strata were different from those found in the upper Silurian rocks.

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[1] Op. cit., p. 271.

[2] Supplement to the second edition of Acadian Geology, containing additional facts as to the geological structure, fossil remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, London, 1878, pp. 81–83.

[3] On the Eozoic and Palæozoic rocks of the Atlantic coast of Canada, in comparison with those of western Europe and of the interior of America. Quart. Jour. Geol. Soc. London, 1888, vol. 44. pp. 804–807. Canadian Record of Science, vol. 3, 1888, pp. 182, 183, 230, 231.

[4] Op. cit., p. 805.

[5] Report on the geological survey of the Province of New Brunswick, with a topographical account of the public lands and districts explored in 1842. St. John, 1843, p. 72.

The rocks of this group extend from the American boundary line and cross the St. John a little above the Meductic, and proceed in a northeast direction toward Bathurst. * * *

The strata consist chiefly of grauwacke, grauwacke slate, and clay slate. The grauwacke may be compared to a very compact sandstone. There are also beds of conglomerate, containing bowlders and pebbles of almost every variety of rock. The cementing matter is generally calcareous or argillaceous; but it is sometimes silicious, and the beds change imperceptibly into quartz rock. The slates are of different colors; red, blue, and green are often seen. Many of them contain lime, and others will supply roofing slate.

The local details of the distribution of this series are not given, nor is the locality of the city of St. John mentioned. Portions of the rocks mentioned by Dr. Gesner are, however, now included in the Cambrian group.

In his third report Dr. Gesner[1] recognizes two series of rocks, both of which are referred to the Silurian age. The upper group consists of limestones, slates, and sandstones, containing the remains of plants, mollusks, etc. The older group is formed of conglomerates, gray slates, sandstones, talcose slates, and the trap beds of Mispeck and Black Rivers.

On a map prepared by Dr. James Robb,[2] the geographic distribution of the formations described by Dr. Gesner is outlined, and under the "Cambrian system" we find the indicated distribution of the Cambrian rocks to include Carboniferous, Devonian, Lower Silurian, and Cambrian as now known. In the text of the volume accompanying the map Mr. J. F. W. Johnston[3] describes the geographic distribution of the rocks and also their general character. He states that the rocks of the Cambrian are distinguished from those of the Silurian by their greater hardness and by their containing less lime.

In speaking of the rocks referred to the Lower Silurian and Cambrian, by Gesner and Robb, Mr. J. W. Dawson[4] states that for the distribution of these rocks, as indicated on the map, he was indebted principally to the map prepared by Dr. Robb. Of the rocks he says:

I do not think that at present there is any good ground for separating the so-called Cambrian rocks from those last mentioned [Silurian], though it is quite probable that they may belong to an older formation, or that they may be older members of the same formation.

When relating the results of a visit to New Brunswick Prof. W. B. Rogers[5] described, by the aid of a section, the stratigraphic features exhibited at the junction of the older and less ancient groups of strata on the St. John's and Kennebecasis Rivers, a few miles above the city

[1] Third report on the geological survey of the province of New Brunswick. St. John, 1841, pp 5–11.

[2] [Letter on the geological structure of New Brunswick.] Report on the agricultural capabilities of the province of New Brunswick, by J. F. W. Johnston. Fredericton, 1850, pp. 12, 13.

[3] Report on the agricultural capabilities of the province of New Brunswick. Fredericton, 1850, pp. 17, 18.

[4] Acadian Geology, first edition, 1855, pp. 324, 325.

[5] Remarks on the geology of the neighborhood of St. John, New Brunswick. Boston Soc. Nat. Hist., Proc., vol. 7, 1861, p. 176.

of St. John, as observed by Dr. Robb and himself. Referring to the probable ages of the two groups he states that the only fossils discovered consist of vegetable impressions found by Dr. Robb at several localities, and some black scale-like fragments of shells that he found about the city of St. John in loose pieces of siliceous slate. At several points the layers of rock in place are crowded with these remains, the more entire of which presented the form and markings of a Lingula.

Dr. J. W. Dawson described in 1862 the strata about St. John, and published a section[1] that includes the shales and slates of the vicinity of the city; and, in the same section, a series of beds which have since proved to be of Devonian age. He states that the age of the lower members was less certain. They may represent either the Middle and Lower Devonian, or may be in part of Silurian age. "The only determinable fossil, the Lingula of the St. John shales, affords no decisive solution of this question."

In proposing a classification for the pre-Devonian rocks of New Brunswick, Mr. G. F. Matthew[2] states that Gesner's older group is to a great extent younger than his upper series. He reviews the classification of Dr. Dawson[3] dividing the formations into several groups, proposing the name St. John group for Nos. 5 and 6 (in part) of Dawson's section of 1862. He says that the St. John group is formed of several zones of soft, black, dark gray, finely laminated shales, alternating with zones of coarser gray slates, containing numerous thin beds of fine-grained sandstone, the whole having a thickness of about 3,000 feet. The fossils noticed were a Lingula, a Conchifer, Annelids and Coprolites.[4] The Coldbrook group, No. 6 of Dawson, in part, is given a thickness of 3,000 feet or more composed of greenish gray slate, bright red slaty conglomerate and dark red sandy shale, with a reddish conglomerate, grit and hard, gray sandstone. The paper is accompanied by a map showing the geographical distribution; also a section crossing the district in the vicinity of St. John. In a foot-note mention[5] is made of the discovery of numerous trilobites of two or three species, but they were so excessively distorted that the genera could not be made out.

In some observations on the geology of southern New Brunswick, Prof. L. W. Bailey[6] reprinted the table of formations published by Mr. Matthew in 1863. In a table on page 14 he places the St. John group at the base of the Lower Silurian as an equivalent of the Potsdam or Primordial of New York and the Quebec group of Canada. A full description of the St. John group is given,[7] and accompanying it a letter

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[1] On the flora of the Devonian period in northeastern America. Quart. Jour. Geol. Soc. London, vol. 18, 1862, p. 303.

[2] Observations on the geology of St. John County, New Brunswick. Canadian Nat., vol. 8, 1863. p. 243.

[3] Op. cit., p. 242.

[4] Op. cit., p. 244.

[5] Op. cit., p. 247.

[6] Observations on the geology of southern New Brunswick. Fredericton, 1865, p. 8.

[7] Op. cit., pp. 26-31.

from Mr. C. Fred Hartt,[1] in which he states that he has recognized four genera of trilobites from the St. John rocks, viz, Paradoxides, Conocephalites, Agnostus and a new genus (?) allied to Conocephalites. There are also six species of Brachiopods, belonging to the genera Orthisina, Discina, Obolella, and Lingula. Although all of the species are apparently new, the occurrence of Paradoxides and Conocephalites led Mr. Hartt to correlate the entire fauna with the Primordial fauna of Barrande. He states that the lower part of the St. John group, at Coldbrook, has been divided by Mr. Matthew, on lithological grounds, into three bands, viz:

No. 1.—The lower or arenaceous band, with no determinable fossils, and constituting passage beds from the Coldbrook group.

No. 2.—Argillaceous shales, rich in fossils, Paradoxides, Orthisina ?, Conocephalites, Obolella.

No. 3.—Carbonaceous shales, full of fossils, Paradoxides, Conocephalites, Orthisina, Discina, etc., all much distorted.

In the same year Mr. G. F. Matthew described the Azoic rocks of southern New Brunswick.[2] He gave the geographic distribution of the St. John series, and a detailed section of the formation, to which he assigned a total thickness of 4,500 feet. He mentions the identification of the fauna by Prof. Hartt; and refers the St. John group to the Lower Silurian, correlating it with the *Paradoxides harlani* beds of Massachusetts; with the *Paradoxides bennetti* beds of Newfoundland; the Lingula flags of Great Britain; the alum-schists of Scandinavia and "Étage C" of Barrande in Bohemia.[3] He states that the upper portion of the section may be the equivalent of the Calciferous, perhaps the Chazy. The subjacent Coldbrook group is referred to the Huronian, while the terms Cambrian and Huronian are used as synonyms in their application to the Coldbrook formation.[4]

In noticing the discoveries made by Messrs. G. F. Matthew and C. F. Hartt, Dr. J. W. Dawson refers to the correlation made by Prof. Hartt, and proposes to call this series, represented in New Brunswick by the St. John slates, the *Acadian series*.[5] In 1868 he republished all the facts known to him in relation to the St. John group, naming it the Acadian group, and including it under the Lower Silurian.[6] The section given by Mr. Matthew is published, and also descriptions by Mr. C. F. Hartt of all the species discovered by Messrs. Matthew and Hartt in the St. John group.[7]

[1] Preliminary notice of a fauna of the Primordial period in the vicinity of St. John, N. B. Observations on the Geology of southern New Brunswick, 1865, pp. 30, 31.

[2] On the Azoic and Paleozoic rocks of southern New Brunswick. Quar. Jour. Geol. Soc., London, vol. 21, 1865, pp. 422–434, map.

[3] Op. cit., pp. 426, 427.

[4] Op. cit., p. 427.

[5] On recent geological discoveries in the Acadian provinces of British America. Am. Assoc., Proc., vol. 16, 1867, p. 118. Canadian Nat., new series, vol. 3, 1868, pp. 295–297.

[6] Acadian Geology. The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick and Prince Edw. Island, London, 1868, pp. 637–641, 2d ed.

[7] Op. cit., pp. 641–657.

In 1869 Messrs. Matthew and Bailey[1] described in a general manner the rocks referred to the Lower Silurian and stated that this series includes about 150 feet of slates (holding Paradoxides, Conocephalites, Agnostus, and other trilobites, besides several genera of Brachiopods), and an overlying mass, measuring not less than 2,000 feet, of flags and slates containing Lingulæ, worm burrows, etc. Under the caption of "Lower Silurian," the same writers, three years later,[2] include the St. John or Acadian group. A brief historical sketch is given, and a list of fossils that have been described from the formation, with a statement that the apparent thickness of the whole formation, as measured in the city of St. John, is about 4,500 feet. Owing to the disturbed condition of the beds the actual thickness may be much less. If repetitions occur, the aggregate thickness of the series, exclusive of the lower red beds—which have been called Upper Coldbrook—will not much exceed 2,000 feet.[3] This general description is followed by a detailed one, and a copy of Mr. Matthew's section at the city of St. John.[4] The St. John group is then described as found in the Kennebecasis Valley, in northern King's County; in Wickham, Queen's County; in Nerepis Valley, and in Charlotte County.

In the supplement to the second edition of Acadian Geology, Dr. J. W. Dawson[5] introduces the term "Cambrian" and includes under it the Acadian series of St. John and also the great Atlantic coast series of Nova Scotia. Nothing is added in the way of descriptive details to those given in the edition of 1868.

During the survey of the island of Cape Breton, Mr. Hugh Fletcher discovered near Marion Bridge, on the banks of the Mira River, a series of light gray, slaty, fine-grained, feldspathic sandstones, associated with red and green mottled sandstone in which he found numerous specimens of Obolella. He points out the lithologic resemblance of these rocks to the Primordial rocks found by Mr. Alexander Murray in the southeastern part of Newfoundland and to those on the Strait of Belle Isle examined by Mr. Richardson.[6] He also describes a series of purple, red, and green slates, sandstones, and limestones, that he refers to the Lower Silurian.[7] A detailed section of the rocks is given as they occur along St. Andrew Channel. In one of the greenish and blue papery slates he found impressions of an Obolella, with the head and tail of a trilobite, recognized by Mr. Billings as of Primordial or Quebec

[1] Remarks on the age and relations of the metamorphic rocks of New Brunswick and Maine. Am. Assoc., Proc., vol. 18, 1869, pp. 182, 183. Can. Nat., new ser., vol. 4, 1869, pp. 326-328.

[2] Preliminary report on the geology of southern New Brunswick. Geol. Surv. Canada, Rep. of Prog., 1870-'71, 1872, p. 134.

[3] Op. cit., p. 135.

[4] Op. cit., pp. 136, 137.

[5] Supplement to the second edition of Acadian Geology, containing additional facts as to the geological structure, fossil remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, London, 1878, p. 81.

[6] Report of explorations and surveys in Cape Breton, Nova Scotia. Geol. Surv. Can., Rep. Prog. 1875-'76, 1877, p. 393.

[7] Op. cit., p. 388.

group age. In his report for the following year he[1] described a num ber of sections, referring them to the Lower Silurian, and mentioning the occurrence of Lingula, Obolella, and Dictyonema in some of the beds.

In a report on the slate formation in the northern part of Charlotte County, New Brunswick, Mr. G. F. Matthew[2] states that the St. John group occurs in the interval between the Kingston or Upper Silurian rocks and the inclosing Laurentian ridges in King's County. No details are given of the St. John group.

A report on the Primordial-Silurian rocks of New Brunswick by Mr. L. W. Bailey[3] presents a detailed description of the St. John group. A section is given of the strata on Ratcliffe's Mill-stream and Handford Brook and local details of geographic distribution. This is accompanied by a list of the fossils found which were identified by Mr. J. F. Whiteaves.

In a later report on the geology of southern New Brunswick[4] the Cambrian or Primordial Silurian rocks are described as occupying basins or trough-like depressions among the older hills of pre-Cambrian rocks east of the St. John River.

In speaking of the strata carrying the Paradoxides in the vicinity of the city of St. John, Mr. G. F. Matthew[5] states that the strata of the St. John group fill a number of narrow, trough-like basins lying between the Bay of Fundy and the central Carboniferous area of New Brunswick. A carefully measured and detailed section of the St. John outcrop is given with a description of the conditions under which the fossils occur in the same. A thickness of 2,900 feet is assigned to the section.

The same writer argues in a paper on the "Geologic Age of the Acadian Fauna"[6] that on the evidence of the trilobites the St. John group does not quite correspond to the Menevian of Wales, in the restricted application of that term; but, as a whole, they indicate the subjacent Solva group as the equivalent formation to the St. John group. He repeats this correlation a year later,[7] when he says: "Prof. Hartt fixed the age of the St. John group as nearly as was possible in his time

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[1] Report on the geology of part of the counties of Victoria, Cape Breton, and Richmond, Nova Scotia. Geol. Surv. Can., Rep. Prog. for 1876-'77. Montreal, 1878, pp. 429-437.

[2] Report on the slate formations of the northern part of Charlotte County, New Brunswick. Geol. Surv. Canada, Rep. Prog. for 1876-'77. Montreal, 1878, pp. 342, 343.

[3] Report on the pre-Silurian (Huronian) and Cambrian or Primordial Silurian rocks of southern New Brunswick. Geol. Surv. Can., Rep. Prog., 1877-'78, 1879; p. 28DD-34DD.

[4] Bailey, L. W., G. F. Matthew, and R. W. Ells. Report on the geology of southern New Brunswick, embracing the counties of Charlotte, Sunbury, Queens, Kings, St. John, and Albert. Geol. Surv. Can., Rep. Prog., 1878-1879, 1880, pp. 6D-8D.

[5] Illustrations of tha fauna of the St. John group. Royal Soc. Canada, Proc. and Trans., vol. 1, sec. iv, 1883, pp. 8.-88; pp, 271-279.

[6] The Geologic Age of the Acadian fauna. The Primitive Conocoryphean. British Assoc. Rep., 54th meeting, 1884, pp. 742-743. The Geologic Age of the Acadian Fauna. Geol. Mag., new ser., decade 3, vol. 1, 1884, pp. 470-471.

[7] An outline of recent discoveries in the St. John group. New Brunswick Nat. Hist. Soc. Bull. No. 4, 1885, p. 98.

as 'Primordial,' or, as we now call it, Cambrian." He then calls attention to the article in which he correlated the St. John group fauna with the Solva group, stating, "In other words, it is the fauna of the older part of the Lower Cambrian."

In a preliminary study of the Cambrian fauna of North America[1] a review is given of the history of the term "St. John group" by Mr. C. D. Walcott. In this the use of "St. John" was advocated as against "Acadian," and all species described by Mr. C. F. Hartt in the second edition of Dawson's Acadian Geology were illustrated.

When discussing the faunas of the St. John group, Mr. Matthew[2] states that it is highly probable that the group covers nearly the whole of the Cambrian age; and that the fauna of the Upper Cambrian is equivalent to that of the shallow-water deposit of the St. John group near the summit of the series. The fauna discovered by Mr. Fletcher in the Cambrian shales of Mira River, Cape Breton Island, is considered by Mr. Matthew[3] to belong to the Olenus division of the Cambrian fauna. The species recognized by him are *Peltura scarabœoides*, *Sphærophthalmus alatus*, and *Agnostus pisiformis*. In the same paper he mentions the faunas of the Olenus division as found in Newfoundland. (An abstract of this paper appeared in the Canadian Record of Science, vol. 2, 1886, pp. 255–258.)

Incited by the announcement of the discovery of fossils beneath the Paradoxides zone in Sweden and Russia, Mr. Matthew[4] began anew the study of the red rocks beneath the Paradoxides zone. These strata had been spoken of as the upper member of the Coldbrook group[5] and as constituting a series lower than the Primordial rocks at the base of the Silurian. They were subsequently joined to the St. John group[6] as the base of that group. In a later report in 1888, Mr. Matthew[7] says: "It is now found that this red series is unconformable, not only to the St. John group, but also (as had been previously discovered) to the underlying Coldbrook group." In the valley of Long Reach of the St. John River Mr. Matthew estimates that the red series has a thickness of 1,200 feet. He compares it with the red shales described by Dr. Murray in Newfoundland[8] and correlates it with the Caerfai group of Wales and the lower division of the Sparagmite formation of Norway.[9] A detailed description of the section is given[10] with names of the fossils that have been found in the various beds. These include trails and casts of marine

[1] On the Cambrian faunas of North America; preliminary studies. U. S. Geological Survey Bull. No. 10, vol. 2, 1884, p. 289, separately paged, p. 9.

[2] Illustrations of the fauna of the St. John group, No. 4, Can. Rec. Sci., vol. 2, 1887, p. 362. (Abstract.)

[3] On the Cambrian faunas of Cape Breton and Newfoundland. Royal Soc. Canada Proc. and Trans., vol. 4, sec. 4, 1887, p. 147.

[4] On a basal series of Cambrian rocks in Acadia. Can. Rec. Sci., vol. 3, 1888, pp. 21–29.

[5] Observations on the geology of southern New Brunswick. Fredericton, 1865, p. 24.

[6] Bailey, L. W., and G. F. Matthew. Preliminary report on the geology of southern New Brunswick. Geol. Surv. Can., Rep. Prog., 1870–'71, 1872, p. 59.

[7] On a basal series of Cambrian rocks in Acadia. Can. Rec. Sci., vol. 3, 1888, p. 22.

[8] Op. cit., p. 23. [9] Op. cit., p. 25. [10] Op. cit., p. 27.

worms, tracks, and an unrecognized brachiopod. This paper was followed in the same year by an article on the classification of the Cambrian rocks of Acadia in which the classification of the Cambrian system in Acadia and Newfoundland is given as follows:[1]

Series A.—The Basal series or Eteminian.
Series B.—The St. John group or Acadian.
Series C.—The Lower Potsdam or Georgian.
Series D.—The Potsdam sandstone and limestone.

The division of series A was noticed in the preceding paper by Mr. Matthew. In series B he includes the zone of Paradoxides; describes the rocks in detail, and gives lists of the genera of the fossils. Series C, the Lower Potsdam of Billings, he states has not been recognized on the mainland of Acadia, but is found in the Island of Cape Breton, where the fossils are Bathyurus, Orthisina, Orthis, *Hyolithes princeps*. This series is placed provisionally above B.[2] Series D, or the Potsdam series of New York and the Mississippi Valley, is stated to be absent from New Brunswick and, as far as known, from the eastern border of the continent.[3]

A reclassification of the Cambrian rocks of North America was published in 1888 by Mr. C. D. Walcott as follows:[4]

TABLE I.—*Lower Silurian* (*Ordovician*) *system.*

Subdivisions.	Terranes.	Faunas.
Upper Cambrian	Potsdam, Knox, Tonto, Bell Isle, etc	Dicellocephalus or Olenus.
Middle Cambrian	St. John, Avalon, Braintree	Paradoxides.
Lower Cambrian	Georgia, Prospect, Terra Nova	Olenellus.

This is followed by a comparison of typical sections of the Cambrian system in Sweden, Newfoundland, New York, and the Rocky Mountains. The section on Manuel's Brook, Conception Bay, Newfoundland, where the true stratigraphic succession of the Cambrian deposits in America was first discovered, is given in detail.

On learning of the discovery of the Olenellus fauna beneath the Paradoxides zone in Newfoundland, Mr. Matthew published a second paper "On the classification of the Cambrian rocks in Acadia," in which he arranged the Cambrian system as it occurs in Acadia as follows:[5]

	Localities.
D. Upper Cambrian (Potsdam series)	Unknown.
C. Middle and Lower Cambrian—Acadian series	St. John, etc.
B. Lower Cambrian—Georgian series	Cape Breton.
A. Basal Cambrian—Etcheminian series	St. John, etc.

[1] Matthew, G. F. On the classification of the Cambrian rocks of Acadia. Can. Rec. Sci., vol. 3, 1888, p. 72.

[2] Op. cit., pp. 73-74. [3] Op. cit., p. 80.

[4] The stratigraphical succession of the Cambrian faunas in North America. Nature, vol. 38, 1888, p. 551.

[5] On the classification of the Cambrian rocks in Acadia. No. 2. Can. Rec. Sci., vol. 3, 1889, p. 310.

Instituting comparisons between the sections of Sweden and New Brunswick, he discusses the general relations of the Cambrian fauna of North America. The organic remains found in band B are an Agraulos, and at the base of the zone an Ellipsocephalus, of the type associated with *Olenellus* (?) *kjerulfi* in Europe. At the base of band B he found a species of Obolus which he described as *Obolus pulcher*.[1] This comprises the Lower Cambrian fauna or pre-Paradoxides fauna as known to him from New Brunswick up to date.

In another paper on the "Cambrian organisms in Acadia," published in the same year, he notes the discovery in the lower beds of the St. John section, beneath the Paradoxides beds, of several varieties of sponges, a species of Palæochorda and another undescribed species. Undoubted examples of Platysolenites of Pander also occur.[2] Mention is made of the discovery above the Paradoxides zone in the Olenus horizon, of three species of fossils, and above this another stage which he has placed under the title of Peltura beds, corresponding in age to the Cape Breton Upper Cambrian beds.

In September, 1889, Mr. Matthew[3] argues for the uniting of the Olenellus or Lower Cambrian, and the Paradoxides or Menevian zone, as one division of the Cambrian, and the strata above the Paradoxides zone as the upper division, thus returning to the classification of Salter and Hicks, adopted for the Cambrian strata of Wales.

The full text of Mr. Matthew's paper on the Cambrian organisms in Acadia was distributed in June, 1890. It deals almost entirely with the pre-Paradoxides or Basal series of the Cambrian section of New Brunswick, and is accompanied by both tabulated and illustrated sections and sketch maps of Hanford Brook and Caton's Island.[4] It is referred to at length in the description of the Cambrian rocks of New Brunswick in this paper (Chapter. IV).

In a paper read May 28, 1890, Mr. G. F. Matthew gives a detailed description of the geologic structure of the St. John basin in connection with three sections crossing it. Further notice of it will be found in the summary of our present knowledge of the St. John terrane of New Brunswick.[5]

In a list of the geological formations of the Maritime Provinces of Canada, Dr. George M. Dawson tabulates the Cambrian as follows:[6]

2*c*. Upper Cambrian	Miró and St. Andrew series. Cape Breton.
2*b*. Middle Cambrian	Acadian series.
2*a*. Lower Cambrian	Atlantic Coast series. Nova Scotia.

[1] Op. cit., p. 306.

[2] On the Cambrian organisms in Acadia. Can. Rec. Sci., vol. 3, 1889, p. 384.

[3] How is the Cambrian divided? A plea for the classification of Salter and Hicks. Am. Geol., vol. 4, 1889, pp. 139–148.

[4] On Cambrian organisms in Acadia. Trans. Roy. Soc. Can., vol. 7, sec. 4, 1890, pp. 136–143.

[5] Matthew, G. F. Illustrations of the fauna of the St. John group, No. 5. Trans. Roy. Soc. of Canada, vol. 8, sec. 4, 1891, pp. 123–130, pls. II–XVI.

[6] An American Geological Railway Guide. Jame sMcFarlane. 2d ed., 1890, p. 52.

MAINE.

When describing the quartz rock of Bar Harbor, Mount Desert Island, Prof. C. H. Hitchcock[1] suggested a Lower Silurian age for the siliceous slates associated with the coarse sandstone or quartz rock, by comparison with similar rocks on Flint Island, of which he had stated that the correlation was more from fancy than real argument, because it reminded him so much of the Potsdam sandstone in its external appearance.

At a later date he says:[2]

The first rock is a sandstone at Bar Harbor, dipping at an angle of twelve degrees. Ripple marks cover the surface of many layers, and curious cylindrical stems tantalize us by their resemblance to fossils. The formation is probably of Cambrian age.

The strata included under the title of "Cambrian" about Portland, Maine, is described by Prof. Hitchcock[3] as follows:

These rocks crop out in Saco, a dozen miles west. They are clay slates and indurated argillaceous schists, the latter having a northwest strike, while the rocks of the older series run northeasterly. These rocks are in character and position allied to the Cambrian Paradoxides slates of Massachusetts, and exist in immense mass along the coast of Maine west of Saco, and in New Hampshire.

The correlation of these beds is based entirely upon their lithological characters, as no mention is made of any fossils having been found in them.

In his account of the geology about Frenchman's Bay, on the coast of Maine, Dr. W. O. Crosby describes the slate formation. The prevailing rock is a compact and well jointed argillite or clay slate, of black, drab, and purple tints, with distinct stratification. The author concluded that these rocks are the newest rocks on this part of the coast, by their relations in dip and distribution to the present contours of the land; by their uncrystalline character; by their relations to the intrusives; by the fossils which they contain. The latter he describes as smoothly and even gracefully curved semi-cylindrical grooves and ridges about a line in diameter; they are often a foot or two in length, and might sometimes be regarded as annelid trails, but in other cases they are irregularly branched in a way that would be impossible with worm-grooves, but is very suggestive of smooth, slender fucoids.[4] The general conclusion reached was that the Frenchman's Bay series belonged somewhere between the top and bottom of the Cambrian, with the chances in favor of its being near the latter. In other words, his observations tended to corroborate the suggestion made by Prof. Hitchcock twenty years before. He further states:

[1] Reports on the Geology of Maine. Second annual report on the natural history and geology of Maine. Augusta, 1862, pp. 269–271.

[2] Geology of New Hampshire. Concord, 1877, vol. 2, p. 32.

[3] The geology of Portland. Am. Assoc. Proc., vol. 22, pt. 2, 1873, p. 168.

[4] Geology of Frenchman's Bay, Maine. Boston Soc. Nat. Hist., Proc., vol. 21, 1881, pp. 111–116. Geol. of Frenchman's Bay, Maine, just east of Mount Desert Island. Am. Jour. Sci., 3d ser., vol. 23, 1882, p. 64.

The resemblance of these rocks to the Acadian slates of the Boston Basin and St. John is very marked; and I join with Prof. Hitchcock in anticipating the discovery on the Maine coast of characteristic Primordial fossils.[1]

In describing a geologic map of Maine, Prof. Hitchcock says that he is unable to divide the Cambrian and Huronian, owing to a want of knowledge of their distribution.

They are the talcose and mica schists of the reports, called the Quebec group by H. Y. Hind and Sir W. E. Logan; the St. John's group in New Brunswick, and the Merrimack, Rockingham, Kearsage, Andalusite, and Coös groups of the New Hampshire reports. * * * They were called Cambrian in New Brunswick by Gesner, and in our second report it was said that this term might ultimately express their true age. Subsequently Bailey and Matthew referred them to the Lower Devonian but the drift of opinion is towards the earlier view at present.[2]

On the map it is very difficult to make out the distribution, owing to the color of the Laurentian, Silurian, and the Cambrian being apparently identical. The supposed Cambrian rocks of New Hampshire and southeastern Canada follow up the valley of the St. John River from a little distance above the entrance of the Allegosh River, and along the Canadian boundary line nearly to the boundary of New Hampshire. The Canadian extension of these rocks is described more in detail and will be mentioned under the head of the Canadian Extension of the Northern Appalachian District (Chapter IV).

In the latest contribution that we have upon the subject of the geological age of the siliceous slate and associated sandstones or quartz rocks of Mount Desert, Maine, Prof. Shaler says:[3]

We note in the first place that there is a total absence of limestones in all the sections exposed to view. A careful study of the drift materials on the south part of Mount Desert and on the Cranberry Islands where we could hope to find traces of hidden limestones shows that there are no limy beds in the sedimentary deposits of this island. The aggregate thickness of the various Mount Desert sections can not be less than about 6,000 feet and may amount to one-half more than this estimate. It seems as if this fact must exclude the hypothesis that these strata were formed anywhere in the periods above the level of the Cambrian, for nowhere above that level do we have any such sections barren of limy matter.

It may be next noted respecting the schistose series of Mount Desert that those of its east and west margins are of singularly uniform composition. They were doubtless originally shales and thin sandstones of great uniformity of structure. Their texture is not such as at all points to exclude the preservation of fossils; indeed the greater portion of the deposits are well fitted to exhibit organic remains, yet they have afforded no trace of them. Nowhere above the level of the Cambrian series do we find any section of this description. On these grounds, it seems reasonable to place the greater part of the Mount Desert rocks in the lower portion of the Cambrian section, if not yet lower in the geological column.

This coincides with the views of Hitchcock and Crosby, that the strata under consideration are of pre-Silurian and probably of Cambrian age.

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[1] Op. cit., p. 117.

[2] Geological map of Maine (with notes on geology of). In Geology of Northern New England, 1885, p. 2.

[3] The geology of the island of Mount Desert, Maine. Eighth Ann. Rep. U. S. Geol. Survey, pt. 2, 1889, p. 1059.

NEW HAMPSHIRE.

In the final report of the geology and mineralogy of New Hampshire, Dr. C. T. Jackson describes the Cambrian system as understood by him at that time, and states that metamorphic Cambrian rocks occur in New Hampshire, but they contain no fossils. He also says:

The oldest transition, or Cambrian rocks, occur in Maine and Vermont, and dip in opposite directions, indicating an anticlinal axis in New Hampshire.

On the eastern side of this axis we discover the first distinct fossils in the slate strata on the Kennebec River, where the strata dip boldly to the northwestward.

On the western side we have not yet determined the limits of the Cambrian fossils, but indistinct remains of organic substances, whose nature is problematical, occur in the neighborhood of Castleton, and along the western flank of the Green Mountains. They were supposed by Dr. Carr, who first noticed them, to be graptolites, which are supposed to be allied to sea-pens. Graptolites are described by Murchison as belonging to the lower part of the Silurian system. He states, however, that these pen-like serrated fossils have a great vertical range in the older or protozoic rocks, being found from the lower part of the Ludlow formation down to very ancient beds in the Cambrian system.

Should these fossils prove to be graptolites, they would indicate the proximate limits of the Cambrian rocks on the western side of the New Hampshire anticlinal axis, where the strata dip to the southeastward.

It will be observed that the strata become more and more recent as we proceed eastward and westward from this axis, as is proved by order of superposition, lithological characters and fossil contents of the rocks.[1]

Prof. Hitchcock says[2] that the term Cambrian is misapplied by Dr. Jackson, and the ideal section showing the structural geology is incorrect in many of its details. In the final report of the second geological survey of New Hampshire he describes the Rockingham mica-schist as an uncouth mica-schist. The Merrimack group is a micaceous quartzite that has not yet been fully separated from the previous group. It abounds in beds of coarse, indigenous granite, which seem to have been altered in situ from the feldspathic conglomerate. In certain parts of Strafford County the granite beds predominate, forming numerous hills, while the slate occupies the valleys between.[3] Some schists with interbedded clay slates which are referred to the Merrimack group, are supposed to be equivalent to the Paradoxides beds of Massachusetts.

The Connecticut Coös period can easily be divided into three parts: first, the epoch of the deposition of the mountain masses of silica; second, of hornblende and mica schists; third, of limestone.[4]

In the White Mountain region there are several small areas of andalusite slate, supposed to be the equivalent of the Coös group. * * * * The Coös period was terminated by eruptions of syenitic granite. * * * * The Coös quartzite now constitutes a distinct range of mountains.[5]

The Mount Mote conglomerate is formed of an eruption of igneous material cementing together the slaty fragments. This is included in the

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[1] Final report on the geology and mineralogy of the State of New Hampshire, with contributions towards the improvement of agriculture and metallurgy. Concord, 1844, p. 14.

[2] History of the Geological Surveys in New Hampshire. Geology of New Hampshire, vol. 1, 1874, p. 11.

[3] Physical history of New Hampshire. Geology of New Hampshire, Concord, 1874, vol. 1, p. 536.

[4] Op. cit., p. 537. [5] Op. cit., p. 538.

section between the Huronian and the Helderberg period. On the map facing page 536 the formations referred to the mica-schist period are clearly outined. In a subsequent paper Prof. Hitchcock[1] presented a table or scheme representing the stratigraphical column of New Hampshire. The Cambrian includes at the summit the Rockingham schists, and below, in order, the calciferous mica-schist, the Coös group, clay slates, and Mount Mote conglomerate. The description of the various formations is given on page 13 and on the map the geographic distribution is delineated. This paper appears to have been prepared and published prior to the issue of the second volume of the Geology of New Hampshire[2] and it does not refer to the volume. On page 674 of the latter work the formations in New Hampshire are tabulated as follows:

			Feet.
Paleozoic.	Upper Helderberg (Vermont) 200; Lower Helderberg, 500		700
	Calciferous mica schist		4,800
	Coös group.	Staurolite slate	3,000
		Mica schist, often stauroliferous	3,300
		Quartzite	1,000
	Cambrian slates (Connecticut Valley)		3,000
	Total Paleozoic		15,800
Paleozoic?	Kearsarge andalusite group		1,300
	Rockingham mica-schist		6,000
	Merrimack group		4,300
	Ferruginous slates, with steatite (probably repetition of preceding)		
	Total Paleozoic?		11,600

Under the head of Cambrian, in the Geology of Northern New England, Prof. Hitchcock says:[3]

The discussions about the value of the Cambrian series are leading geologists to assign to this place in the column a thick mass of sediment, usually without fossils and largely argillaceous in character. We may for the present place here the following groups: (1) Mica-schists of southern New Hampshire. (2) Merrimack group, including argillo-quartzites in Coös County. (3) Coös group. (4) Clay slates. (5) Mount Mote conglomerates.

In one of his later papers, Prof. Hitchcock,[4] in speaking of the various formations that make up the mica-schist group, says they may be called Silurian, Cambrian, or pre-Cambrian, according as each author is inclined to regard New England as very ancient or on the verge of the Paleozoic. In a table giving the thickness of the formations[5] the Cambrian slate series has a thickness of 4,000 feet; and beneath it

[1] Geological map of New Hampshire and Vermont, with notes on topography and geology. In Geology of Northern New England, 1874, p. 9.

[2] Hitchcock, C. H. Geology of New Hampshire, Concord, 1877, vol. 2.

[3] Geological map of New Hampshire and Vermont, with notes on topography and geology. In Geology of Northern New England, 1874, p. 13.

[4] Geological sections across Vermont and New Hampshire. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, p. 168.

[5] Op. cit., pp. 178, 179.

we find the Crystalline group that was referred to the Cambrian in the Geology of Northern New England in 1874, as follows:

Crystalline group.

	Feet.
Calciferous mica-schist and Coös group	12,000
Kearsarge group	1,300
Rockingham mica-schist	6,000
Merrimack group	4,300

Beneath the Merrimack group the Huronian is placed, with a thickness of 12,000 feet.

In a tabulation of the geological formations of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut, by Prof. Hitchcock,[1] the calciferous mica-schist, staurolite slate and schists, quartzite, andalusite schists, and Rockingham mica-schists are included in the Cambrian. In a foot-note he says that the quartzite, staurolite slate and schist, and the calciferous mica-schists may yet prove to be Silurian. In his classification of the Paleozoic rocks of New England he places under Cambrian the St. John or Braintree slate, Taconic slate, and Roxbury conglomerate.

In a table published in 1890 he includes only the Potsdam, Georgia, Acadian, and the Taconic slate (in part) in the Cambrian. All of the foliated crystalline rocks of New England are classified as pre-Cambrian.[2]

EASTERN MASSACHUSETTS.

The references to the argillite and limestone in which the Cambrian faunas have been found, in the Boston and Narragansett Basins, occur in most of the publications relating to the geology of eastern Massachusetts. In 1818 Messrs. J. F. and S. L. Dana stated that the argillite was the oldest rock known in the region.[3] Its distribution is shown in a general way upon the map accompanying the report. It is stated to be subjacent to the syenite in Milton and Braintree, and to be stratified. In the works of Prof. Amos Eaton[4] the rocks of eastern Massachusetts are shown in sections, but nothing is added to the data given by the Messrs. Dana.

The next description of the geology of Boston and vicinity, by Dr. J. W. Webster,[5] mentions that the light gray clay slate is the only rock found on the Boston Peninsula in situ. He noticed the presence of the slate in Quincy and also at Nahant.

[1] Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. (Geological formations.) Macfarlane's Am. Geol. R. R. Guide, 1879, p. 56.

[2] Idem., second edition, 1890, p. 86.

[3] Outlines of the mineralogy and geology of Boston and its vicinity, with a geological map. Am. Acad. Arts and Sciences, Memoirs, vol. 4, 1818, pp. 129-223.

[4] An Index to the Geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, pp. 52. A Geological and Agricultural Survey of the District Adjoining the Erie Canal, Albany, 1824, pp. 163, plate.

[5] Remarks on the geology of Boston and its vicinity. Boston Jour. Phil. and Arts, vol. 2, 1824, pp. 277-292.

In 1832 Prof. Edward Hitchcock[1] described the argillite in the vicinity of Boston, and stated that the unstratified rocks were of igneous origin and intrusive among the stratified rocks. A general description of the argillite is given in the text with localities, and on the map the geographic distribution, as known to him, is delineated. This includes the Quincy locality. In the final report of the Massachusetts survey Dr. Edward Hitchcock, in speaking of the argillaceous slate of the eastern part of the State, says that owing to its intimate connection with varieties of rock referred to the Graywacke group it ought to be described as one of the members of it, although marked as a distinct deposit on the map. He considered this slate as older than the graywacke, because fragments of the slate occur in one of the varieties of conglomerate of the graywacke.[2] On the same page, in describing the limestone in the southwest part of Attleborough, he says small beds of compact light gray limestone occasion the red sandrock. He did not see much of it in place, but the numerous blocks in the stone walls indicated its existence in that locality. On the map accompanying the report the argillaceous slate is shown in eastern Braintree, the central part of Quincy, and thence extends across Milton and Dorchester to Roxbury. A small outcrop is also indicated on the north side of Nahant. The North Attleborough locality of the Cambrian as now known is covered by the Carboniferous (No. 17 of the legend of the map). The description in the report of 1841 is essentially the same as in the preliminary report of 1833.

In an article on the crystalline limestones of North America Dr. T. S. Hunt[3] suggests that the limestones interstratified with the red slates at Attleborough, as described by Dr. Hitchcock, may correspond to those which with similar slate and sandstone are met with at the base of the Carboniferous formation in Canada and in New Brunswick.

The long silence in relation to the geologic age of the altered rocks of eastern Massachusetts in the vicinity of Braintree was finally broken in 1856 by the announcement of Prof. W. B. Rogers that trilobites of the genus Paradoxides had been discovered at a quarry in a belt of siliceous and argillaceous slate lying on the boundary of Quincy and Braintree, about 10 miles south of Boston. In announcing this discovery he compares the species found with *Paradoxides spinosus* of Barrande. He states:[4]

> The rock in which these fossils occur is a compact, dense, rather fine-grained, silico-argillaceous slate or slaty sandstone, containing little or no carbonate of lime. * * * * * One of the most curious facts relating to the trilobite of the Quincy and Braintree belt is its seeming identity with *Paradoxides harlani*, described by Green in his Monograph of North American Trilobites.

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[1] Report on the geology of Massachusetts, examined under the direction of the government of that State during the years 1830 and 1831. Am. Jour. Sci., vol. 22, 1832, pp. 1-70, with map.

[2] Final report on the geology of Massachusetts, 1841, vol. 2, p. 537, Amherst.

[3] Am. Jour. Sci., 2d ser., vol. 18, 1854, p. 199.

[4] Proofs of the Protozoic age of some of the altered rocks of eastern Massachusetts from fossils recently discovered. Am. Acad. Proc., vol. 3, 1856, p. 317.

He adds further:

The occurrence of well preserved fossils among rocks so highly altered and so contiguous to great igneous masses as are the fossiliferous slates of Quincy may well encourage us to make careful search in other parts of New England where heretofore such an exploration would have been deemed useless.[1]

Prof. Louis Agassiz, in commenting upon the announcement of Prof. Rogers, said that, geologically speaking, its importance could hardly be overestimated. We have now, he remarked, a standard level upon which to build up the formation of the metamorphic rocks.[2] Prof. Rogers also communicated the knowledge of the discovery of the Braintree fossils to Prof. J. D. Dana, in a letter dated August 13, 1856.[3] He states that his attention was called to the locality by Peter Wainwright, Esq., who resided in the vicinity of the quarry.

Dr. Isaac Lea[4] visited the Braintree quarry, and in reporting upon it to the Philadelphia Academy of Natural Sciences stated that he agreed with Prof. Rogers in placing this formation among the more ancient of the Paleozoic periods. "It lies directly on the granite rocks, or rather it is squeezed in, and is embraced by these rocks (on the east and west sides), which are disturbed by an upheaval." He considered the trilobite found there to be undoubtedly the same as described by Prof. Green many years before under the name of *Paradoxides harlani.*

Prof. W. B. Rogers again called attention to the Braintree locality[5] for the purpose of noting the fact that the formation was among the oldest of the Paleozoic series, and situated somewhere about the level of the Primal rocks (Potsdam sandstone and the Protozoic sandstone of Dr. D. D. Owen), containing Dikellocephalus in Wisconsin and Minnesota.

In 1856 Prof. C. T. Jackson[6] described the rock at Braintree as a blue gray, argillaceous slate, containing silicate of lime but no carbonate, and some disseminated iron pyrites. The stratification of the rock, as indicated by its grain and cleavage, dips to the north 50°, and runs east and west. The existence of the genus Paradoxides in the argillaceous slates of Braintree, proves them to belong to the lowest of the fossiliferous Silurian rocks, and he believed them to be the geological equivalents of the argillaceous slates of Sweden, which are in a similar manner disrupted by the intrusion of syenite.

[1] Am. Acad., Proc., vol. 3, 1856, p. 318. [2] Ibid., p. 319.

[3] Discovery of Paleozoic fossils in eastern Massachusetts. Am. Jour. Sci., 2d ser., vol. 22, 1856, pp. 296-298.

[4] [On the trilobite formation at Braintree, Massachusetts.] Phila. Acad. Sci., Proc., vol. 9, 1858, p. 205.

[5] [On trilobites from Braintree and on the geologic relations of the district.] Boston Soc. Nat. Hist., Proc., vol. 6, 1856, pp. 27-29, 40, 41.

[6] [On the Braintree argillite and its trilobites.] Boston Soc. Nat. Hist., Proc., vol. 6, 1856, pp. 42-44.

In arranging the collections of the State cabinet of Massachusetts, Dr. Edward Hitchcock placed the rock near Boston which carries the trilobites in the Silurian and Cambrian.[1]

Prof. W. B. Rogers sent to Mons. J. Barrande[2] a photograph of the Paradoxides found at Braintree. Barrande compared it with *Paradoxides spinosus* and concluded that *Paradoxides harlani* was a synonym of *Paradoxides spinosus.*

In 1861 Prof. Rogers[3] announced the discovery by Mr. Norman Easton of pebbles carrying fossils of the Potsdam fauna in Carboniferous conglomerate north of Fall River, Massachusetts. He thought the forms distinctly recognized in the pebbles were Lingula of two species, resembling *Lingula prima* and *L. antiqua* of Emmons, from the Potsdam sandstone of New York, and that the rocks from which the pebbles were derived were probably closely connected in time with the period of the Braintree Paradoxides beds. The conglomerate in which the pebbles occur is considered to be of Carboniferous age.

Various communications were made to the Boston Society of Natural History respecting the Paradoxides fauna at Braintree, by Messrs. Jules Marcou and C. T. Jackson in 1861 and 1862. From that time until 1869 little attention appears to have been given to the Braintree rocks. In the latter year Prof. N. S. Shaler[4] described the rocks in the vicinity of Boston, and referred to the argillites of Braintree, stating that they were deposited in deep water. In 1870 Dr. T. S. Hunt examined the rocks near Braintree, and stated that the unaltered argillites of Braintree, holding the Primordial fauna, were observed by Prof. Shaler and himself to rest directly upon a hard porphyrite felsite of the ancient series. He says:[5]

> The fact that the Primordial strata of Braintree have suffered no metamorphism is the more significant, since the beds of similar age in New Brunswick and Newfoundland rest unconformably on crystalline strata supposed to belong to the same ancient series that underlies the Braintree beds, and are, like these, unaltered sand and mud rocks.

In 1875 Mr. W. W. Dodge[6] described the rocks at and about Braintree in the Boston Basin with great detail, and accompanied this with a discussion of the correlation of the Paradoxides beds with the various lower Paleozoic rocks of Europe.

In the same year, in some remarks on Massachusetts geology, Dr. T. S. Hunt[7] reaffirms his observation on the relations of the fossiliferous

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[1] [Catalogue of State cabinet and notes on metamorphic rocks] 6th annual report of the Secretary of Massachusetts Board of Agriculture, etc., by Charles L. Flint, Boston, 1859, p. iv.

[2] Trilobiten der Primordial-fauna in Massachusetts. Neues Jahrb. für Mineral., 1860., pp. 429-431.

[3] On fossiliferous pebbles of Potsdam rocks in Carboniferous conglomerate north of Fall River, Massachusetts. Boston Soc. Nat. Hist., Proc., vol. 7, 1861, pp. 389-391.

[4] On the relations of the rocks in the vicinity of Boston. Boston Soc. Nat. Hist., Proc., vol 13, 1869, pp. 172-178.

[5] On the geology of the vicinity of Boston. Boston Soc. Nat. Hist., Proc., vol. 14, 1871, p. 48.

[6] Notes on the geology of eastern Massachusetts. Boston Soc. Nat. Hist., Proc., vol. 17, 1875, pp. 388-419.

[7] [Remarks on Massachusetts geology.] Boston Soc. Nat. Hist., Proc., vol. 17, 1875, pp. 508-510.

rocks of Braintree and St. John, New Brunswick, to the subjacent crystalline Huronian strata.

The following year Prof. W. O. Crosby described the Geological Map of Massachusetts, and said:[1]

> Although the fossils characteristic of the Acadian group have been found at only one locality in Massachusetts, viz, Hayward's quarry, in Braintree, yet most observers agree that the greater portion of the slates in the vicinity of Boston are probably of Primordial age; and I have so represented them on the map.

The strata referred to are then described in a general way.

In 1875 Prof. W. B. Rogers[2] announced the discovery of impressions suggestive of the fossil Lingula mentioned by him from Fall River, in pebbles of the conglomerate, at Newport, Rhode Island. The pebbles consist of a gray siliceous rock or quartzite.

The memoir of Prof. W. O. Crosby on the Geology of eastern Massachusetts, with its accompanying map, appeared in 1880. He says:[3]

> The Paleozoic rocks of eastern Massachusetts occur, as already indicated, only in limited basins or depressions excavated in the ancient crystalline formations. . . .
> The most diligent search, continued for many years, by, in the aggregate, a small army of observers, has failed to bring to light, among the rocks of the Boston Basin, more than one locality affording fossils. This is the celebrated slate quarry of the south shore of Hayward's Creek, in the extreme northeast corner of Braintree.

Prof. Crosby[4] concludes that the Paradoxides bed in Braintree is the established base line for the stratigraphy of the Boston Basin; and that all the rocks in the Boston Basin above the Shawmut group, and including the Paradoxides bed, belong to one and the same essentially conformable series; although (p. 186) there is in the Boston Basin essentially but one conglomerate and one slate, and the former underlies the latter. From this it follows that the slate is of Primordial age, and the conglomerate must be of the same age, or older. The conglomerate is stated to pass gradually into the slate, and a detailed description of these two formations is given as they occur in the Boston Basin. On the map a part of Nahant is colored to indicate the Cambrian slate. In the text he describes white and gray limestones that in texture are very compact and highly crystalline or saccharoidal. These have a thickness collectively of perhaps 20 feet. He assigns to the conglomerate a maximum volume not exceeding 1,000 feet; and considers that the greatest thickness of the slates cannot be much less than that of the conglomerate, though in some cases falling below 500 feet.[5]

Dr. M. E. Wadsworth,[6] in discussing the relation of the Quincy granite to the Primordial argillite of Braintree, states that Dr. Hunt was

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[1] Report on the geological map of Massachusetts, Boston, 1876, p. 40.

[2] On the Newport conglomerate. Boston Soc. Nat. Hist., Proc., vol. 18, 1875, p. 100.

[3] Contributions to the geology of eastern Massachusetts. Boston Soc. Nat. Hist., Occasional papers, No. 3, 1880, p. 181, 183.

[4] Op. cit., pp. 184, 185.

[5] Op. cit., p. 266.

[6] On the relation of the Quincy granite to the Primordial argillite of Braintree, Massachusetts. Boston Soc. Nat. Hist., Proc., vol. 21, pp. 274-277, 1882.

mistaken in regarding the granite as of Huronian age, as was Prof. Shaler in regarding it as a metamorphosed sedimentary rock. He says the argillite is surrounded by intrusive granite of a later age, thus adopting the view advanced by Dr. Hitchcock in 1832. In describing the slates, he says they dip a little west of south at an angle of 55°, nearly as given by Mr. Lea. He thinks that, judging from their writings, Profs. Rogers and Shaler based their conclusions regarding the dip of the argillite upon its structural character. In another paper, published the following year, Dr. Wadsworth discusses the argillite and conglomerate of the Boston Basin,[1] and concludes from studies made by him that there are at least two distinct argillites. One like that underlying the conglomerate on Beacon street, Boston, and resembling in some of its characters the Paradoxides argillite at Braintree. The second is of coarser grain, often more decidedly arenaceous, and generally of a gray, black, or reddish color, and forms the Somerville argillites ("Cambridge slates.") It is stated:[2]

So far as we have any evidence at present the oldest surface rocks in this basin are the argillites and the schists of allied character. Of these we only know the age of a very small area in Braintree and Quincy. * * * Older rocks than the Braintree (Paradoxides) argillites may exist, but of their existence we thus far have no proof.

The discovery of fossils of Lower Cambrian age near North Attleborough, Bristol County, Massachusetts, by Prof. N. S. Shaler,[3] located a second area of Cambrian rocks in eastern Massachusetts. He describes the geographic distribution and the character of the rocks, and in an accompanying paper in connection with Mr. A. F. Foerste gives a description of the fauna. As the description of the strata and the fauna is that which is given in our summary of the present knowledge of the rocks of eastern Massachusetts, it is here omitted.

In a review of the stratigraphic position of the Olenellus fauna by Mr. C. D. Walcott in 1889,[4] it is shown that the Paradoxides fauna of Braintree, Massachusetts, of St. John, New Brunswick, and of southeastern Newfoundland, is superjacent to the Olenellus fauna, and thus above the Olenellus fauna as found at North Attleborough by Prof. Shaler. This is presented more fully in a paper in the Tenth Annual Report of the Director of the U. S. Geological Survey.[5]

In a sketch of the physical history of the Boston Basin, Prof. W. O. Crosby[6] mentions the old and more or less altered or metamorphic slates of the Braintree quarry, and states it to be clearly established that the

[1] The argillite and conglomerate of the Boston Basin. Boston Soc. Nat. Hist., Proc., vol. 22, 1883, pp.130-133.

[2] Op. cit., pp. 132, 133.

[3] On the geology of the Cambrian district of Bristol County, Massachusetts. Bull. Mus. Comp. Zoöl. Harv. College, vol. 16, 1888, pp. 13-26.

[4] Stratigraphic position of the Olenellus fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, 1889, pp. 374-392; vol. 38, 1889, pp. 29-42.

[5] The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rep. U. S. Geological Survey, 1890, pp. 509-763, plates 49-98.

[6] Physical History of the Boston Basin. Lowell free lectures, 1889-1890. Boston, 1889, pp. 22.

granite is eruptive through, and therefore newer than the Primordial slate. The evidence of the trilobites shows that the slates were formed very far back in geological time, and near the base of the recognized geological formations. In a résumé of the geological history of the Boston Basin,[1] a general description of the Primordial slates and quartzites and their physical relations is given.

In mentioning the discovery of fossils in the limestones at Nahant, Mr. A. F. Foerste correlated the Nahant limestone with the red slates of North Weymouth, and concluded that they are stratigraphically beneath the Braintree Paradoxides beds, and that the red slates of Mill Cove at North Weymouth are of Olenellus age and beneath the Paradoxides strata.[2]

In 1889 Mr. A. C. Lane described the geology of Nahant from a mineralogical standpoint,[3] and in the following year Prof. J. H. Sears published a description of the stratified rocks of Essex County, which includes the limestones and associated slates of Nahant. He mentions finding *Hyolithes princeps*, *Hyolithes communis* var. *emmonsi*, *Hyolithes impar*, and *Stenotheca rugosa*.[4] He also discovered an outcrop of the Lower Cambrian limestone in a valley between Prospect Hill and Hunslow's Hill, in Rowley, in which fragments of Hyolithes occur.

PALEONTOLOGY.

NEWFOUNDLAND.

The first announcement of the discovery of the Cambrian fauna in Newfoundland appears to be by Mr. J. W. Salter[5] in the description of *Paradoxides bennettii*. He referred the species to the "Lingula flags or Zone Primordiale."

From collections made by the Canadian Geological Survey Mr. E. Billings described in 1861[6] the fauna from the Cambrian strata on the north side of the Straits of Belle Isle, on the Labrador shore, at L'Anse au Loup, and assigned it to the horizon of the "Lower Potsdam," correlating it with the fauna found in Franklin County, Vermont, which is described in the same paper. The species described are *Palæophycus incipiens*, *Archæocyathus atlanticus*, *Obolus labradoricus*, *Obolella chromatica*, *O. (Kutorgina) cingulata*, *Conocephalites miser*, *Bathyurus senectus*, *B. parvulus*, *Salterella rugosa*, *S. pulchella*, and *S. obtusa*. The new

[1] Op. cit., pp. 19-22.

[2] The Paleontological horizon of the limestone at Nahant, Massachusetts. Boston Soc. Nat. Hist. Proc., vol. 24, 1889, pp. 261-263.

[3] Geology of Nahant. Boston Soc. Nat. Hist. Proc., vol. 24, 1889, pp. 91-95.

[4] The stratified rocks of Essex County. Essex Institute Bull., vol. 22, 1890, p. 32.

[5] On the fossils of the Lingula flags or "Zone Primordiale." Quar. Jour. Geol. Soc., London, vol. 15, 1859, p. 552.

[6] Paleozoic Fossils, vol. 1. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 1860-1865. Montreal, 1865, pp. 426. (Of this volume pp. 1-24 were issued in November, 1861; pp. 25-56 issued January, 1862; pp. 57-168 issued June, 1862; pp. 169-344 issued February, 1865; pp. 395-416 published in Canadian Naturalist, vol. 5, 1860, pp. 301-324.)

genera are Archæocyathus, Obolella, Kutorgina, and Salterella. In reprinting, in 1865, the article published in 1861, Mr. Billings added a new species, *Archæocyathus profundus;* and in the same year described *Acrotreta gemma* from near Portland Creek.

The mode of occurrence of the Cambrian section and fauna on the northwest coast of Newfoundland is given by Sir William Logan in the description of the geological section near Bonne Bay.[1]

From a collection of fossils from Newfoundland sent by Mr. Alexander Murray to Mr. E. Billings, there was described in 1865 *Bathyurus gregarius*=*Solenopleura gregarius* from the Paradoxides horizon of southeast Newfoundland.[2] Subsequently he [3] described the fauna found at Great Bell Island and also "Fossils from the Menevian Group," under which we find *Obolella? miser*, *Straparollina remota*, *Hyolithes excellens*, *Agraulos socialis*, *A. strenuus*, *A. affinis*, *Solenopleura communis*, *Anopolenus venustus*, *Paradoxides tenellus*, *P. decorus*, *Iphidea*, n. gen., *Iphidea bella*, *Stenotheca pauper*, *Scenella*, n. gen., *Scenella reticulata*. Also from the shales and sandstones of Great Bell Island, Conception Bay: *Eophyton linnæanum*, *E. jukesi*, *Arthraria antiquata*, *Lingula murrayi*, *Lingulella (?) affinis*, *L. (?) spissa*, and *Cruziana similis*.

With the exception of *Obolella? miser*, *Solenopleu ra communis*, *Steno theca pauper*, and *Scenella reticulata* the species described in 1872 were republished in the appendix to the report of progress of the Geological Survey of Newfoundland for 1881.

In 1878 Mr. J. F. Whiteaves described[4] a new species of Lingula, *L. billingsiana*, from the shales of Kelley's Island, and republished Murray's geological section on Manuel's Brook, southeast Newfoundland, with a list of fossils collected there as follows: 1. *Agnostus acadicus;* 2. *Agnostus* (sp. undet.); 3. *Microdiscus punctatus;* 4. *M. dawsoni;* 5. *Conocephalites tener;* 6. *C. baileyi;* 7. *C. orestes?;* 8. *Paradoxides* sp. undet.), stating that Nos. 1, 3, 4, 5, 6, and possibly 7, are common to the Primordial slates of St. John, New Brunswick, and to the shales of Manuel's Brook.

In 1887 when reviewing the Cambrian faunas of Cape Breton and Newfoundland Mr. G. F. Matthew[5] described a new species from the Olenellus zone, *Solenopleura bombifrons*, and identified from Manuel's Brook *Paradoxides* sp., *Agnostus gibbus (?)*, *Agraulos socialis*, and *Hyolithes* sp. From Trinity Bay he identified in addition to the species mentioned by Mr. Billings *Eocystites* sp., *Agnostus lævigatus*, *A. punctu-*

[1] Geological Survey of Canada; report of progress from its commencement to 1863. Montreal, 1863. pp. 865-867.

[2] Paleozoic Fossils, vol. 1. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 1860-1865, p. 363.

[3] On some fossils from the Primordial rocks of Newfoundland. Canadian Naturalist, new ser., vol. 6, 1872, pp. 465-479.

[4] On some Primordial fossils from southeastern Newfoundland. Am. Jour. Sci., 3d ser., vol. 16, 1878, p. 226.

[5] On the Cambrian faunas of Cape Breton and Newfoundland. Roy. Soc. Canada Proc. and Trans., vol. 4, sec. 4. 1887, pp. 147-157.

osus, var., Agnosti of three other species, and *Microdiscus punctatus.* From Highland Cove in the same bay, *Paradoxides davidis*, *Centropleura loveni*, *Agnostus punctuosus*, var., *A. brevifrons*, *A. lævigatus*, *A. acadicus*, var. *declivis.*

In connection with the study of the stratigraphy of the Cambrian rocks of Newfoundland, the writer described[1] a number of species from the lower or Olenellus zone, and the middle or Paradoxides zone. From the former there were *Obolella atlantica*, *Coleoloides*, n. gen., *Coleoloides typicalis*, *Hyolithes terranovicus*, *H. similis*, *Helenia*, n. gen., *Helenia bella*, *Microdiscus helena*, *Olenellus* (*M.*) *bröggeri*, *Avalonia*, n. gen., *Avalonia manuelensis*, *Solenopleura harveyi* and *S. howleyi.* From the Paradoxides zone there was described the genus Karlia and the species *K. minor.*[2]

In 1890 Mr. C. D. Walcott[3] described *Agraulos strenuus*, var. *nasutus*, from Manuel's Brook.

NEW BRUNSWICK AND CAPE BRETON.

The first description of the Cambrian fauna as found at St. John, New Brunswick, by Mr. C. Fred. Hartt[4] included the following species: *Eocystites primævus* Billings, *Lingula matthewi*, *Lingula*, n. s., *Obolella transversa*, *Discina acadica*, *Orthis billingsi*, *Orthis*, n. sp., *Conocephalites baileyi*, *C. matthewi*, *C. robbi*, *C. orestes*, *C. elegans*, *C. ouangondianus*, *C. tener*, *C. aurora*, *C. thersites*, *C. gemini-spinosus*, *C. halli*, *C. quadratus*, *C. neglectus*, *C. formosus*, *Conocephalites*, n. sp. (?), *Microdiscus dawsoni*, *Agnostus acadicus*, *Agnostus similis*, *Paradoxides lamellatus.*

It appears that the *Eocystites primævus* was submitted to Mr. Billings, to name the genus and species, in manuscript, and was printed in connection with Mr. Hartt's paper. The *Paradoxides micmac*, figured by Dr. Dawson at the close of Mr. Hartt's paper, was named by the latter in manuscript. The figure is a restoration, and no description accompanies it. In the report of Messrs. Bailey and Matthew[5] it is stated that Mr. E. Billings identified from the St. John group, in the Kennebecasis Valley, fragments of Paradoxides and the pygidium of an Agnostus, three species of Conocephalites, one of Ellipsocephalus, one of Agnostus, what appeared to be a fragment of Salterella, and specimens of Palæophycus of two or three kinds. Among the collections examined by Prof. J. F. Whiteaves for Professor Bailey[6] there is a new

[1] Descriptive notes of new genera and species from the Lower Cambrian or Olenellus zone of North America. U. S. Nat. Mus., Proc., vol. 12, 1889, pp. 33-46.

[2] Descriptions of new genera and species of fossils from the Middle Cambrian. U. S. Nat. Mus. Proc., vol. 11, 1889, pp. 441-446.

[3] The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rept. U. S. Geol. Sur., 1890, p. 654.

[4] Fossils of the Primordial or Acadian group at St. John. Dawson, Acadian Geology, 1868, pp. 641-657.

[5] Preliminary report on the geology of southern New Brunswick. Geol. Surv. Canad., Rep. Prog., 1870-1871, 1872, p. 140.

[6] Report on the pre-Silurian (Huronian) and Cambrian or Primordial Silurian Rocks of Southern New Brunswick. Geol. Surv. Can. Rep. of Prog., 1877-'78, 1879, pp. 30, 31 DD.

species of Agnostus and one of Hyolithes noted in association with other species described by Mr. Hartt.

In the year 1883 the first of Mr. G. F. Matthew's[1] memoirs on the fauna of the St. John group made its appearance. In this is given a brief historical review of the work that had already been done upon the fauna by Prof. Hartt, and a statement that from the collections made from time to time during the progress of the Canadian geological survey in New Brunswick Mr. Billings identified fragments of Ellipsocephalus and Salterella and the remains of two species of Hyolithes. Besides these, there are the supposed plant remains of the genera Palæophycus, Eophyton, etc., of the higher divisions of the St. John group.[2] Mr. Matthew made large collections, which were destroyed by the great fire at St. John in the spring of 1877. His published studies were based upon new material collected subsequently to that date.

In the first memoir we find that he recognized three well defined species of Paradoxides and six varieties, as follows: *Paradoxides lamellatus* Hartt; *P. lamellatus* var. *loricatus* Matthew; *P. acadicus* Matthew; *P. eteminicus* Matthew; *P. eteminicus*, vars. *suricoides, breviatus, quacoensis, malicitus*, and *pontificalis*.

A review by Mr. C. D. Walcott[3] of the typical collections upon which Prof. C. F. Hartt based his species, led to a revision of the genera and species, with the following results:

Lingula matthewi	=	Acrothele matthewi.
Discina acadica	=	Palæacmea (?) acadica.
Theca acadica	=	Hyolithes acadica.
Agnostus similis	=	Agnostus acadicus.
Microdiscus pulchellus	=	Microdiscus punctatus Salter.
Conocephalites matthewi	=	Conocoryphe matthewi.
gemini-spinosus	=	Conocoryphe matthewi.
baileyi	=	Conocoryphe baileyi.
elegans	=	Conocoryphe elegans.
robbi	=	Ptychoparia robbi.
formosus	=	robbi.
ouangondianus	=	ouangondiana.
aurora	=	ouangondiana var. aurora.
quadrata	=	quadrata.
orestes	=	orestes.
thersites	=	orestes var. thersites.
tener	=	tener.
neglectus	=	tener.

The genus Harttia and species, *Harttia matthewi*, is proposed for a small patelloid form of gasteropod. Mr. Matthew was requested to give names to the new species, other than the preceding, and he proposed *Lingula ? dawsoni* (p. 15), *Hyolithes danianus* (p. 20.), *Hyolithes micmac*

[1] Illustrations of the fauna of the St. John group. Royal Soc. Canad., Proc. and Trans., vol. 1, sec. 4, 1883, pp. 87-108. Supplementary section, pp. 271-279.

[2] Op. cit., p. 89.

[3] On the Cambrian faunas of North America; preliminary studies. U. S. Geol. Surv. Bull., No. 10, vol. 2, 1884, pp. 283-354, plates.

(p. 21), *Conocoryphe walcotti* (p. 30). The subgenus Salteria was proposed by the author to include the *Conocephalites baileyi*[1] of Hartt.

All of the species were figured and described, with the exception of *Conocoryphe walcotti*. This included figures of the three species of Paradoxides, *P. lamellatus* Hartt, *P. acadicus* Matthew, and *P. eteminicus* Matthew.

Some of the results of Mr. G. F. Matthew's studies are given in two papers read before the British Association for the Advancement of Science at the Montreal meeting in 1884. In one he refers to the geological age of the Acadian fauna, and correlates it with the fauna of the St. John group and that of the Solva group of Wales. In the second is given a description of the development of *Ctenocephalus matthewi* and other species of the genus Conocoryphe.[2]

In Mr. Matthew's second memoir on the fauna of the St. John group,[3] presented to the Royal Society of Canada in 1884, additional notes are given of the *Paradoxides acadicus* and *P. lamellatus*. He proposes the name *Paradoxides micmac* for a large species, which he thinks is probably the one figured in Acadian Geology.[4] The original species to which Mr. Hartt intended to apply the name is unknown. The *Conocephalites matthewi* of Hartt is referred to the genus Ctenocephalus of Corda. A detailed description is given of the species, and also of the various stages of its growth, as found in the St. John slates. *Conocoryphe baileyi*, *C. elegans*, and *C. walcotti* are described and figured. In the description of the plate[5] the subgeneric name Hartella is placed after Ctenocephalus and Bailiella after Conocoryphe.

In 1885 *Obolella transversa* Hartt was referred by Mr. C. D. Walcott to the new genus Linnarssonia, together with the closely allied Menevian species, *Obolella sagittalis*.[6]

In a paper read before the Natural History Society of New Brunswick in 1885, Mr. G. F. Matthew stated[7] he had found some Pteropods that appeared to have several distinct septa at the base of the tube. He sent them to Prof. Hyatt, who wrote that the aspect of the siphon is due to the compression of the sharper against the flatter side. The form of the sutures favors this impression. "These fossils with their distinct septa are startlingly similar to certain forms of Nautiloidea, but there is no siphon. They, however, confirm Von Jhernig's and my opinion that the Orthoceratites and Pteropods have had a common, but as yet undiscovered, ancestor in ancient times."

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[1] Op. cit., pp. 31, 32.

[2] The geological age of the Acadian fauna. The primitive Conocoryphean. British Association Rep., 54th meeting, 1884, pp. 742–743. The geologic age of Acadian fauna. Geol. Mag., new ser., decade 3, vol. 1, 1884, pp. 470–471.

[3] Illustrations of the fauna of the St. John group, continued; on the Conocoryphea, with further remarks on Paradoxides. Royal Soc. Canada, Trans. and Proc., vol. 2, sec. 4, 1885, pp. 99–124.

[4] Op. cit., p. 101. [5] Op. cit., p. 124.

[6] Paleontologic Notes. Am. Jour. Sci., 3d ser., vol. 29, 1885, p. 115.

[7] An outline of recent discoveries in the St. John group. New Brunswick Nat. Hist. Soc. Bull., No. 4, 1885, p. 102.

The third contribution by Mr. Matthew,[1] presented to the Royal Society of Canada in 1885, treats of the Protozoa, Hydrozoa, Brachiopoda, Pteropoda, Gasteropoda, Phyllopoda, Ostracoda, and some of the Trilobita.

Of the Protozoa, *Archæocyathus ? pavonoides*, *Protospongia ? minor*, *P. ? minor* var. *distans*, the new genus Eocoryne and the species *Eocoryne geminum* are described. Of Hydrozoa *Dendrograpsus ? primordialis* Protograpsus, n. g., with the species *Protograpsus alatus*. But one species of the Echinodermata is mentioned, *Eocystites primævus* of Billings. The new forms of Brachiopoda are: *Lingulella ? inflata*, *L. linguloides*, *Acrotreta baileyi*, *A. ? gulielmi*, *Kutorgina latourensis*, *K. ? pterineoides*, *Orthis quacoensis*. Of species previously described *Lingulella dawsoni*, *Linnarssonia transversa* Hartt, *Linnarssonia misera* Billings, *Acrothele matthewi* Hartt, and *Orthis billingsi* Hartt, are described and illustrated.

Among the Pteropods the new subgenus Camerotheca is proposed, and the species *Hyolithes* (*Camerotheca*) *gracilis*, *H.* (*C.*) *danianus*, and *H.* (*C.*) *micmac* are described and illustrated. The genus Diplotheca includes *Diplotheca hyattiana* and the variety *caudata*; also *Hyolithes acadicus* of Hartt, and its varieties, *sericea*, *obtusa*, and *crassa*.

The Gasteropoda include a notice of the genus Stenotheca and the description of the new species, *Stenotheca hicksiana*, *S. concentrica*, *S. radiata*, *S. nasuta*, and *S. triangularis*. The subgenus Parmophorella is proposed to include the original species, *Discina acadica* Hartt. *Stenotheca acadica* and *Harttia matthewi* Walcott are described and illustrated. To the Phyllopoda (?) the new genus Lepiditta, with the species *L. alata* and *L. curta*, and the new genus Lepidilla, with the species *Lepidilla anomala*, are referred. Mr. Matthew says that these forms are very minute, and belong either to lamellibranchs or Phyllopods. The Ostracod Crustaceans include the new genera Hipponicharion and Beyrichona. One species is referred to the former genus, *H. eos*, and two to the latter, *B. papilio* and *B. tinea*. To the genus Primitia he refers one new species, *P. acadica*.

The Trilobita include the new species of Agnostus, *A. regulus*, *A. partitus*, *A. vir*, *A. vir.* var. *concinus*, *A. tessella*, *A. umbo*, *A. obtusilobus*, and *A. acutilobus*. *Agnostus acadicus* Hartt is described and figured and the variety *declivis* proposed. *Microdiscus pulchella* Hartt is placed as a variety of *M. punctatus* Salter, and a new variety, *precursor*, is proposed to be included under *punctatus*. *M. dawsoni* Hartt is also described and figured. Of the larger forms of the Trilobita, *Agraulos* (?) *articephalus* is proposed, *Solenopleura acadica* of Whiteaves is figured and described for the first time, and *Paradoxides abenacus* is proposed as a new species. A redescription of *Paradoxides micmac* and the proposal of a variety, *suricus* of *P. acadicus* concludes the references to previously described species.

[1] Illustrations of the fauna of the St. John group, continued. No. III. Descriptions of new genera and species (including a description of a new species of Solenopleura by J. F. Whiteaves). Royal Soc. Canada, Trans. vol. 3, sec. 4, 1886, pp. 29-84. (Proc. for 1885.)

In a synopsis of the fauna in Division 1 of the St. John group, Mr. Matthew[1] notes the occurrence of thirty genera, sixty-five species, and twenty-one varieties of fossils. He states that in a higher horizon in the Kennebecasis Bay area he has found the following association of species:[2]

Anopolinus? sp.	Agnostus (cfr. Nathorsti, Brögg).
Parobolina? sp.	A. (cfr. parvifrons, Linrs.)
Anomocare? 2 sp.	A. umbo.
Ptychoparia, 2 sp.	A. acadicus Hartt, var.
Agraulos socialis Bill., var.	Hyolithes, sp.
Microdiscus punctatus Salter, var.?	Linnarssonia transversa Hartt, sp.
Agnostus acutilobus (cfr. gibbus).	

In some preliminary notes on the higher fauna[3] he says that—

The heavy band of black slates which runs through the center of the city of Saint John has yielded the following species, contained in calcareous nodules:

Ctenopyge (cfr.) spectabilis Brögg.	Kutorgina (cfr.) cingulata Bill.
Orthis (cfr.) lenticularis Dal.	Kutorgina?

These indicate a horizon in the upper part of the Lingula flags.

A series of slates are exposed along the north side of the Kennebecasis Basin, whose fossils indicate that they also pertain to the upper part of the Cambrian system:

Conocephalites, a species with broad free cheek and flaring genal spine.	Kutorgina (?), sp.
	Lingulella (cfr.) lepis Salter.
	Lingulella, sp.
Ptychoparia, a small species.	Eophyton linnæanum Torrell, var,
Agnostus (cfr.) pisiformis Ang.	Eophytera, sp.
A. (cfr.) richmondensis Wal.	Arthraria, sp.

In a note to the American Journal of Science Mr. Matthew[4] states that he has found *Olenellus (?) kjerulfi* in the Kennebecasis River Basin in band *c* and *d* of his Division 1; and that the same species occurs in the Cambrian beds of Newfoundland. Upon this reported discovery Mr. S. W. Ford[5] endeavored to show that as the species was found at the base of the St. John Paradoxides beds and at the base of the Swedish Paradoxides beds it was a true Paradoxides, and therefore did not influence the question of the stratigraphical position of the Olenellus fauna in North America.

In an abstract of a paper on the Cambrian faunas of Cape Breton and Newfoundland in the Canadian Record of Science, vol. 2, 1886, pp. 255–258, that preceded the main report in the Royal Society of Canada Transactions,[6] Mr. G. F. Matthew points out that the slates of Mira River, Cape Breton, contain several species of trilobites, which show that these measures are in the upper part of the Olenus zone or Lingula flags of Great Britain. The species observed were *Peltura scarabeoides*

[1] Synopsis of the fauna in Division 1 of the St. John group, with preliminary notes on the higher faunas of the same group. New Brunswick Nat. Hist. Soc., Bull. 5, 1886, pp. 25–31.

[2] Op. cit., p. 29. [3] Op. cit., p. 30.

[4] Note on the occurrence of *Olenellus (?) kjerulfi* in America. Am. Jour. Sci., 3d ser., vol. 31, 1886, p. 472.

[5] Note on the age of the Swedish Paradoxides beds. Am. Jour. Sci., 3d ser., vol. 32, 1886, pp. 473–476.

[6] On the Cambrian faunas of Cape Breton and Newfoundland. Royal Soc. Canada, Proc. and Trans., vol. 4, Sec. 4, 1887, pp. 147–157.

Wahl., *Sphærophthalmus alatus*, and *Agnostus pisiformis*. There was also a small Lingulella similar to that which characterizes the upper flags of the St. John group, and an Orthis similar to *Orthis lenticularis* of Dalman.

In discussing the evidence afforded by the smaller-eyed trilobites of Division 1 of the St. John group, Mr. G. F. Matthew[1] speaks of their bearing on the origin of the Cambrian fauna. He also gives a list of fossils known to him at that date from Division 1 of the St. John series. The total is thirty genera, sixty-five species, and twenty-one varieties, the same as in the paper previously mentioned in the synopsis of the fauna of the St. John group.[2] Mention is made by Mr. Matthew of additional species from the St. John group in 1888.[3] In the measures on the St. John River corresponding to those of Band B in Division 1 of the St. John Basin, a calcareous organism that may be referred to Oldhamia has been found. It resembles *O. antiqua*, but branches less freely. In the same sandstone occurs an elegantly ornamented Lingulella (?) of peculiar form. Mr. Matthew compares it with *Lingula ? favosa* of the Eophyton sandstones of Sweden. In Division 2 of the St. John group were found several genera of seaweeds, among which are two graceful species related to Taonurus or Spirophyton; also fragments of bodies of a small crustacean that is probably a Hymenocaris. In a paper published soon after on the "Classification of the Cambrian Rocks of Acadia," Mr. Matthews states[4] that the Lower Potsdam of Billings, or Georgian of Mr. Walcott, is found in the island of Cape Breton, where the fossils are Bathyurus (sub-genus?), Orthisina, Orthis, and *Hyolithes princeps*. Remarks upon the affinities of the characteristic genera of the Georgian and other portions of the Cambrian fauna occur in this paper.

Mr. Matthew presented Part IV of his illustrations of the fauna of the St. John group to the Royal Society of Canada in 1887.[5] The first species described is the great *Paradoxides regina*, one of the largest trilobites yet discovered in the Cambrian rocks. This is followed by a description of "The smaller trilobites with eyes." An undetermined species is referred to the genus Ellipsocephalus, and *Agraulos? whitfieldianus* is described with its variety *compressa*. The subgenus Strenuella is proposed, with the species *Strenuella ? halliana* as its type. A discussion of the genus Liostracus of Angelin is followed by descriptions of *Liostracus tener* Hartt, *L. ouangondianus* Hartt, and varieties *immarginata*, *aurora*, *gibba*, and *plana*, and a

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[1] Illustrations of the fauna of the St. John group, No. IV. Pt. I: Description of a new species of Paradoxides (*Paradoxides regina*). Part 2: The smaller trilobites with eyes (Ptychoparidæ and Ellipsocephalidæ). Royal Soc. Canada Trans., vol. 5, sec. 4, 1888, pp. 115-166.

[2] Illustrations of the fauna of the St. John Group. Canadian Rec. Sci. vol 2, 1887, p. 361.

[3] On the basal series of Cambrian rocks in Acadia. Canadian Record Science, vol. 3, 1888, pp. 28, 29.

[4] Canadian Rec. Sci., vol. 3, 1888, p. 74.

[5] Illustratations of the fauna of the St. John group, No. IV. Pt. 1. Description of a new species of Paradoxides (Paradoxides regina). Pt. 2. The smaller trilobites with eyes (Ptychoparidæ and Ellipsocephalidæ). Royal Soc. Canada, Trans., vol. 5, sec. 4, 1888, pp. 115-166.

notice of the development of the young of this species. Under Ptychoparia, *Liostracus linnarssoni* Brögger is identified from the St. John series. For the narrow form he proposes the variety *alata*, and this is followed by a description of the development of the young. To the genus Solenopleura of Angelin he refers the *Conocephalites robbi* of Hartt, and gives a description of the development of the young as far as known to him. A more extended description of *Solenopleura acadica* of Whiteaves is given, and the variety *elongata* proposed.

In the second paper by Mr. Matthews on the classification of the Cambrian rocks in Acadia[1] the species *Obolus pulcher* is described from the base of Band B of division 1 of the St. John group. In the middle of the band Mr. Matthews recognized an Agraulos and at the base an Ellipsocephalus. This paper also contains a discussion of the Olenellus fauna as found in Nevada. In a paper read later in 1889, entitled "On the Cambrian Organisms in Acadia,"[2] Mr. Matthew states that he has found in this lower series beneath the Paridoxides zone a species that recalls *Fucoides circinnatus* (p. 384), the Obolus which was described later, and undoubted examples of Platysolenites of Pander. In mentioning the fauna and flora of the Paradoxides beds, he says the basket sponges and the rod-like sponges (?) are common to both this and Series B. In all the fine layers of this band species of Protospongidæ may be found, but no examples of the typical Protospongia of the Paradoxides beds have been observed. A new species of Obolus and three species of Lingulella are mentioned as being described in the paper, and the Algæ are represented by several different types, among which are a Buthotrephis and a microscopic form parasitic on the latter organism. There are also some quite small oval forms, resembling Hydrocystium, which may have been algoid. Among the new species of the Paradoxides beds is a little Platyceras. He says that *Paradoxides pontificalis* is found to be a narrow, and *P. micmac* a broad form of *Paradoxides hicksi* of Wales (p. 385). From stage 2, the Olenus beds, he reports abundant remains of a large Protospongia, including *Protospongia fenestrata* of Salter, and *P.* (?) *major* of Hicks, and another large species. From the fossils which appear to have been placed in the upper part of division 2 are some that have been found in Kennebecasis Basin of the Cambrian rocks. These are Leptoplasti, allied to *L. stenotus* of Angelin, *Agnostus pisiformis*, var. and *Agnostus nathorsti*, var. From division or stage 3, the Peltura beds, he mentions two species, Ctenopyge (cf. *C. flagillifer* and *C. spectabilis*), *Orthis lenticularis*, and a Kutorgina. At the bottom of the division *Lingulella lepis* and another large species, *L. ampla*, var.? are found. These beds are correlated with beds of Cape Breton containing species of Peltura, etc. (p. 386).

In a paper by Mr. Matthew, entitled "How is the Cambrian divided?

[1] Canadian Record Science, vol. 3, 1889, pp. 303–315. [2] Ibid., pp. 383–387.

A plea for the classification of Salter and Hicks,"[1] a comparison of the genera of the different horizons of the Cambrian is made.

In the full paper on the Cambrian organisms of Acadia, published in 1890, Mr. Matthew describes the stratigraphic position of the fauna that he considers beneath the Paradoxides beds, and compares it with the lower Cambrian fauna of Sweden and Russia. The new genera and species described are:[2]

Phycoidella, n. g., p. 144.
Phycoidella stichidifera n. sp., p. 144.
Palæochorda setacea n. sp., p. 145.
Hydrocytium (?) silicula n. sp., p. 146.
Microphycus n. g., p. 146.
Microphycus catenatus n. sp., p. 146.
Monadites n. g., p. 147.
Monadites globulosus n. sp., p. 147.
Monadites pyriformis n. sp., p. 147.
Monadites urceiformis n. sp., p. 147.
Radiolarites n. g., p. 148.
Radiolarites ovalis n. sp., p. 148.
Plocoscyphia (?) perantiqua n. sp., p. 148.
Astrocladia (?) elongata n. sp., p. 148.
Astrocladia (?) elegans n. sp., p. 149.
Astrocladia (?) virguloides n. sp., p. 149.
Dichoplectella n. g., p. 149.
Dichoplectella irregularis n. sp., p. 149.
Hyalostelia minima n. sp., p. 150.
Obolus (?) major n. sp., p. 155.
Lingulella martinensis n. sp., p. 155.
Leperditia ventricosa n. sp., p. 159.
Leperditia steadi n. sp., p. 160.

He also describes and illustrates:

Buthotrephis antiqua Brongn., p. 144.
Platysolenites antiquissimus Eichw., p. 150.
Obolus pulcher Matth., p. 151.
Volborthella tenuis Schmidt, p. 156.
Psammichnites gigas Torrell, p. 157.
Arenicolites lyelli Torrell, var. minor, p. 159.

In a note at the close of the descriptions it is stated that he has learned that a suggestion made by him in reference to *Olenellus kjerulfi* has met with acceptance from a number of naturalists and the generic name Holmia is proposed for *Olenellus kjerulfi*.[3] Mention is made of the relations of the genera Olenellus, Olenoides, and Mesonacis.

In his fifth contribution to the illustrations of the fauna of the St. John group Mr. G. F. Matthew describes the following new genera and species:[4] *Platyceras aperta*, n. sp., p. 132, *Agraulos (?) holocephalus*, n. sp., p. 138, *Medusichnites*, n. gen., p. 143, with five varieties, *Lingu-*

[1] Am. Geologist, vol. 4, 1889, pp. 139-148.
[2] On Cambrian Organisms in Acadia. Royal Soc. Canada, Trans., vol. 7, 1890, sec. 4, pp. 135-162.
[3] Op. cit., p. 160.
[4] Illustrations of the fauna of the St. John group No. V. Roy. Soc. of Canada, Trans., vol. 8, 1891, pp. 130-166, pls. 11-16.

lella starri, n. sp., p. 146, *Lingulella radula*, n. sp., p. 147, *Eoichnites*, n. gen., p. 148, *Ctenichnites*, n. gen., p. 151, *Ctenichnites ingens*, n. sp., p. 151, *Fræna ramosa*, n. sp., p. 159, *Arenicolites brevis*, n. sp., p. 159, *Goniadichnites*, n. gen., p. 160, *Goniadichnites trichiformis*, n. sp., p. 160, *Monocraterion magnificum*, n. sp., p. 161.

In addition to the preceding Mr. Matthew has remarked upon several genera and species that have been previously described from the Cambrian rocks. They include: *Eocoryne geminum* Matt., p. 130, *Lepidilla anomala*, Matt., p. 130, Orthis and Orthisina, p. 131, *Stenotheca* Salter, p. 132, *Stenotheca concentrica*, Matt., p. 133, var. *radiata* Matt., p. 133, *Stenotheca triangularis* Matt., p. 134. In his remarks upon the genus Stenotheca he concludes that the type species is not a molluscan shell, but should be referred to a Phyllopod crustacean. This includes the typical form, but does not include *Discina acadica*, of Hartt, as the latter is a patelloid gasteropod. *Conocoryphe walcotti* Matt., p. 134, *Concoryphe baileyi* Hartt, p. 135, *Paradoxides lamellatus* Hartt, p. 135, *Paradoxides micmac*, var., *pontificalis* Matt., p. 136, *Agraulos* (?) *whitfieldianus* Matt., p. 138, *Agraulos socialis* Bill., p. 138, *Medusites princeps* Torrell, p. 140, *Medusites radiata* Nathorst, p. 141, *Medusites costata*, p. 142, *Eoichnites linnæanus* Torrell, p. 148, *Psammichnites* Torrell, p. 157, *Fræna*, Roualt, p. 158, *Monocraterion* Torrell, p. 160, *Monocraterion tentaculatum*, p. 161, *Histioderma hibernicum*, p. 162.

EASTERN MASSACHUSETTS.

The first description of a fossil from the Cambrian rocks of eastern Massachusetts is that of *Paradoxides harlani*, by Dr. Jacob Green,[1] from specimens sent to him by Dr. Richard Harlan, who supposed they came from Trenton Falls, in the State of New York. It was not until 1856[2] that the true horizon from which the specimens came was discovered. In making the announcement of the discovery Prof. Rogers quoted from Barrande on the distribution of the genus Paradoxides, and stated that he considered the specimens from Braintree, 10 miles south of Boston, to be identical with the *Paradoxides harlani* described by Green in 1834. He says the fossils in the Braintree quarry are in the form of casts, some of them of great size and lying in various levels in the strata, and that as far as he could observe they all belong to one species and agree more closely with Barrande's *Paradoxides spinosus* than with any other form known to him. A fine figure of *Paradoxides harlani* was published by Prof. Rogers,[3] in his final report of the geological survey of Pennsylvania, under the name of *P. spinosus*.

Mons. J. Barrande, in referring to the discovery of Paradoxides in the slates of Braintree,[4] institutes a comparison of the specimens from

[1] Descriptions of some new North American trilobites. Am. Jour. Sci., vol. 25, 1834, p. 336.

[2] Proofs of the Protozoic age of some of the altered rocks of eastern Massachusetts, from fossils recently discovered. Am. Acad. Proc., vol. 3, 1856, pp. 315-318.

[3] The Geology of Pennsylvania, Philadelphia, 1858, vol. 2, p. 816.

[4] Trilobiten der Primordial-fauna in Massachusetts. Neues Jahrb. for 1860, pp. 429-431.

there and *Paradoxides spinosus* from Bohemia, and concludes that *P. harlani* is a synonym for *P. spinosus.*

In 1861 Prof. Jackson[1] exhibited a small trilobite from Braintree of the species *Paradoxides harlani*, stating that it seemed identical with forms from Newfoundland described as *Paradoxides bennetti* from St. Mary's Bay. In a foot-note accompanying a paper on the geology of the vicinity of Boston, by Dr. T. S. Hunt,[2] the writer says:

> Mr. Billings informs me that he regards the *Paradoxides bennettii* (Salter) from Newfoundland as identical with the *Paradoxides harlani* (Green) from Braintree.

A number of collectors obtained specimens of *Paradoxides harlani* from the Braintree beds, but it was not until 1861 that a notice of other species appeared. Mr. Albert Ordway[3] stated at a meeting of the Boston Society of Natural History that he had found a fragment of a trilobite which he referred to the genus Ellipsocephalus. He also reported finding a distinct fucoidal impression which shows three branches, each about 4 inches long, but not sufficiently well marked to afford any evidence as to its nature. Mr. Ordway also published a figure of a head of *Paradoxides harlani* when comparing that species with *Paradoxides spinosus*, Boeck., considered by Barrande identical with *P. harlani.*[4]

In his notes on the geology of eastern Massachusetts Mr. W. W. Dodge[5] reviews the then existing information in relation to the fauna of the Paradoxides zone of Braintree—the Braintree slates—mentioning *Paradoxides harlani* and a few obscure traces of fossils found at that locality. A general description of the Cambrian fauna of Wales is given in this connection.

The second described species from the Paradoxides beds of Braintree is *Arionellus quadrangularis* by Prof. R. P. Whitfield.[6] This is probably the species of Ellipsocephalus referred to by Mr. Ordway.

A review of the fauna of the Braintree argillites by Mr. C. D. Walcott[7] included a mention of the species previously described, and a description of a new Pteropod, *Hyolithes shaleri*, and a new species of trilobite, *Ptychoparia rogersi*. The species described by Prof. Whitfield as *Arionellus quadrangularis* was referred to the genus Agraulos.

Under the title of "Preliminary descriptions of North Attleborough fossils" Messrs. N. S. Shaler and A. F. Foerste[8] made the most important contribution to the Cambrian fauna of Massachusetts since the discovery of *Paradoxides harlani*. They identified the fauna as that

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[1] [On a trilobite from Braintree.] Boston Soc. Nat. Hist., vol. 8, 1861, p. 58.

[2] Boston Soc. Nat. Hist. Proc., vol. 14, 1871, p. 48.

[3] On the occurrence of other fossil forms at Braintree, Mass. Boston Soc. Nat. Hist. Proc., vol. 8, 1861, pp. 5, 6.

[4] Op. cit., p. 3.

[5] Notes on the geology of eastern Massachusetts. Boston Soc. Nat. Hist. Proc., vol. 17, 1875, pp. 405–407.

[6] Notice of some new species of Primordial fossils in the collections of the Museum, and correction of previously described species. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, p. 147.

[7] On the Cambrian Faunas of North America; preliminary studies. U. S. Geol. Surv. Bull. No. 10, vol. 2, 1884, pp. 323–329. Separately paged, pp. 43–49.

[8] Bull. Mus. Comp. Zool., Harv. College, vol. 16, 1888, pp. 27–39.

of the Olenellus zone, as found in the vicinity of Troy, New York. The species described are:

Obolella crassa, var.	H. communis var. emmonsi.
Obolella (?)	H. americanus.
Fordilla troyensis.	H. princeps.
Lamellibranch (?)	H. billingsi.
Scenella reticulata.	Hyolithellus micans.
Stenotheca rugosa, var. paupera.	Salterella curvatus.
S. rugosa var. abrupta.	Aristozoë.
S. curvirostra.	Microdiocus bellimarginatus.
Platyceras primævum.	M. lobatus.
Pleurotomaria (Raphistoma) attleborensis.	Paradoxides walcotti.
	Ptychoparia mucronatus.
Hyolithes quadricostatus.	Ptychoparia attleborensis.

Of these, two genera—Pleurotomaria and Paradoxides—have not heretofore been found in a strongly marked Olenellus zone fauna. A comparison of *Paradoxides walcotti* with specimens of *Olenellus asaphoides* from Troy, New York, of the same size, show them to be generically, if not specifically, identical. This removes Paradoxides from the Olenellus fauna.

Under the view that the Olenellus fauna preceded the Paradoxides fauna Prof. Shaler[1] speaks of *Paradoxides walcotti* as the surviving member of the series, and says the occurrence of the genus indicates close affinities with the Braintree Cambrian horizon. He made careful search for indications of the stratigraphic relations of the North Attleborough and Braintree section but without success. In mentioning the Braintree locality it is stated that a number of distinct remains occur near the Neponset River, and the beds have much the same aspect and are apparently about the same distance from the syenites as those at Braintree.[2]

A notice and description of the fauna found at North Attleborough from the Olenellus horizon, was followed in 1889[3] by the announcement of the discovery of Hyolithes in limestone near East Point, Nahant. Mr. Foerste correlates the limestone and associated shales with those of North Attleborough, and states that the species of Hyolithes appears to be the same as that found at North Attleborough. He proposes the name of *Hyolithes inæquilateralis*. From a study of the type specimens the writer believes it to be identical with *H. communis* var. *emmonsi*.

As now known, the entire Cambrian fauna from eastern Massachusetts includes from the Paradoxides or Middle Cambrian zone four genera and four species, and from the Olenellus or Lower Cambrian zone, twelve genera and nineteen species.

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[1] On the geology of the Cambrian district of Bristol County, Massachusetts. Bull. Mus. Comp. Zool., Harv. College, vol. 16, 1888, p. 21.

[2] Op. cit., p. 23.

[3] Foerste, A. F. The paleontological horizon of the limestone at Nahant, Massachusetts. Boston Soc. Nat. Hist., Proc., vol. 24, 1889, pp. 261-263.

APPALACHIAN PROVINCE.

The Appalachian Province includes the outcrops of Cambrian strata on the line of the Appalachian system of mountains, from the lower St. Lawrence Valley on the north, to Georgia and Alabama on the south.

For the purpose of presenting the historical data the province will be divided as follows:

A. Northern Appalachian district.
B. Southern Appalachian district.

NORTHERN APPALACHIAN DISTRICT.

The northern Appalachian district includes the Hudson River and Lake Champlain area east of the river and lake and an extension northeastward into Canada, as far as the vicinity of Cape Rosier on the St. Lawrence River.

The Hudson River and Lake Champlain area will first be considered. It includes the strata referred to the Cambrian, found on the western slope of the Green Mountains, the foot hills and the more level country stretching westward toward the Hudson River and Lake Champlain.

The earliest reference in the literature to a distinct formation that is now referred to the Cambrian is found in a description of the geology of western Massachusetts and eastern New York. On this account this formation, the "Granular Quartz," will be treated historically as it has been mentioned by authors in Massachusetts, New York, and Vermont, until the year 1861, when its history will be carried forward with that of the "Red Sandrock" and the "Georgia Slates," with which it was then correlated.

GRANULAR QUARTZ.

The first differentiation of a formation referred to the Lower Cambrian in America was made by Prof. Amos Eaton in 1818.[1] Prior to that time Mr. William Maclure, the pioneer of systematic geology in America, published a map with descriptions of the rocks of the Eastern United States, in which all the strata now referred to the Cambrian system in the Appalachian range were included in the Transition series. On his first map[2] the Transition rocks are represented as extending from Hudson, in the valley of the Hudson, south to the vicinity of Poughkeepsie, and thence southwest throughout New York, New Jersey, Pennsylvania, Virginia, eastern Tennessee, northern Georgia, and into Mississippi. On the map accompanying a later work[3] the Transi-

[1] An index to the geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, pp. 52.

[2] Observations on the geology of the United States explanatory of a geological map. Am. Phil. Soc. Trans., vol. 6, 1809, pp. 411-428, map.

[3] Observations of the geology of the United States; with remarks on the probable effects that may be produced by the decomposition of the different classes of rocks on the nature and fertility of soils. With a map and two plates. Am. Phil. Soc. Trans., new ser., vol. 1, 1817, pp. 1-91.

tion rocks are extended north into the valley of Lake Champlain as far as the Canadian border. On the south they terminate in Georgia a short distance south of the Tennessee line.[1]

In his first publication on the rocks between the Catskill Mountains west of the Hudson River and the Atlantic Ocean, Prof. Amos Eaton[2] separated the "Granular Limestone and Quartz" as No. 2 of the section, and an argillaceous and siliceous slate as No. 9, giving the localities at which they occur. Two years later this classification was reviewed[3] and the "Granular Quartz" dropped out of the nomenclature, only to reappear again with a very accurate description of the formation as it occurs in Vermont.[4] It is interesting to note in this publication, that the "Granular Limerock" is mentioned as accompanying the "Transition Granular Quartz" from Whitehall on Lake Champlain, to Barnegat on the Hudson. Up to this time Prof. Eaton appears to have regarded the terms "Granular Quartz" and the "Granular Limerock" as interchangeable. In the classification of 1824,[5] however, the "Granular Quartz" is separated from the "Granular Limerock" and fully described. The "Transition Argillite" and the "Primitive Argillite" are also defined, and some of the localities given are now known as localities of Lower Cambrian slates. The geologic profile accompanying the memoir of 1824 exhibits the differentiation made by Prof. Eaton in the classification of the rocks between the primitive granite and the secondary.

In the geologic nomenclature of to-day the "Granular Quartz" is included in the Lower Cambrian, and the "Granular Limerock" equals the Trenton-Chazy-Calciferous limestone. The "Primitive Argillites" of Williamstown Mountain equal the Upper Hudson or Lorraine shales. The "Transition Argillite" is nearly all Cambrian, with the exception of a small portion near the Hudson River. The Calciferous sandrock is of the same age as the "Transition Argillite." The Graywacke of Peterborough Mountain, and the Metalliferous limerock is of Silurian (Ordovician) age. The "Transition Argillite" is mostly of Lower Cambrian age, and much of the so-called Calciferous sandrock and Graywacke of the section, represented as resting on the upturned edges of the "Argillite," are portions of the same series to which the "Argillite" belongs. Near the Hudson River a profound fault

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[1] In a review of Maclure's memoir by C. S. Rafinesque it is suggested by him that "We must especially collect and describe all the organic remains of our soil, if we ever want to speculate with the smallest degree of probability on the formation, respective age, and history of our strata." (Observations on the geology of the United States of America, by William Maclure; a notice. Am. Monthly Magazine, vol. 3, 1818, pp. 41–44.)

[2] An Index to the Geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818.

[3] Eaton, Amos. An Index to the Geology of the Northern States, 2d ed., 1820, pp. 154–212.

[4] Eaton, Amos. A geological and agricultural survey of Rensselaer County, New York, with a geological profile from Onondaga to Massachusetts, p. 15, plate. Albany, 1822. Memoirs of the board of agriculture of the State of New York, 1823, vol. 2, p. 9.

[5] A geological and agricultural survey of the district adjoining the Erie Canal, 1824, pp. 30, 56–58, plate. Albany.

with a great horizontal thrust has forced the Lower Cambrian over and on to the Silurian (Ordovician) rocks. The misunderstanding of the true relations of these rocks and a dependence upon their lithological characters led Prof. Eaton into an error that has come down to the present day in memoirs relating to the "Taconic System."

Prof. Eaton reviewed his work from time to time until 1832, when his final scheme of classification appeared. It is reprinted in the following tabulation, with the equivalents of his formations as known in the nomenclature of to-day.[1]

	Eaton's Nomenclature (1832).	1891.
III.—Lower Secondary.	3. Corniferous limerock	Upper Helderberg.
	3. Geodiferous limerock	Niagara.
	2. Millstone grit and rubble — Second Graywacke	Oneida, Clinton, Medina.
	1. Second Graywacke slate — Second Graywacke	Utica, Hudson.
II.—Transition.	3. Metalliferous limerock	Trenton.
	3. Calciferous sandrock	Calciferous.
	3. Sparry limerock	Trenton, Chazy.
	2. Millstone grit and gray rubble — First Graywacke	Lower and Middle Cambrian and Silurian.
	2. Graywacke slate — First Graywacke	Hudson.
	1. Argillite: Roof slate, Wacke slate, Clay slate	Considerable Hudson, but includes a great mass of Lower Cambrian in Rensselaer County, N. Y.
I.—Primitive.	3. Granular limerock	Trenton-Chazy limestone, Calciferous. Cambrian limestone.
	2. Granular quartz	Lower Cambrian.
	1. Granite, Mica slate, Hornblende and Talcose rock	Algonkian, pre-Cambrian, and Archean.

The stratigraphic position of the "Granular Quartz" (2 of the Primitive) is correctly represented, and it is now known to contain *Olenellus* sp.? A large portion of the strata referred to the "Argillite" (1, of the Transition) is also known to carry *Olenellus asaphoides* and to belong to the Lower Cambrian terrane. In the text the "Graywacke slate" (2, of the Transition) is described as resting unconformably upon the upturned edges of the "Argillite" (1), and it is so represented in the section. This is essentially the same as the section of 1820 and as in the more detailed section of 1824.

Rev. Chester Dewey studied the geology of the vicinity of Williamstown, Massachusetts, and in 1819[2] published a short sketch of the mineralogy and geology of this region. He followed this in 1820 by a geologic section from the Taconic range in Williamstown to the city of

[1] Geological Text-book for aiding the study of North American Geology; being a systematic arrangement of facts collected by the author and his pupils under the patronage of the Hon. Stephen Van Rensselaer. Second edition, 5 plates. Albany, 1832.

[2] Sketch of the Mineralogy and Geology of the vicinity of Williams' College, Williamstown, Massachusetts. (With a map.) Am. Jour. Sci., vol. 1, 1819, pp. 337–346.

Troy, on the Hudson.[1] In this section the relations of the quartz formation to the mica slates of the Archean are shown, and in a general way the Lower Cambrian slate is described. This is referred to the Transition argillite. In 1824[2] he described the formation more in detail. On the map accompanying this paper the distribution of the various rock masses is more accurately given than in any maps published prior to those of Prof. James D. Dana, when studying the strata referred to the Taconic system. It exhibits an acquaintance with the surface distribution of the rock masses and a clear comprehension of the classification and correlation of rocks on the principle of lithologic characters. The distribution of the Granular Quartz and its relation to the subjacent primitive rocks, or the mica slate of the map, is particularly well worked out.

Dr. E. Emmons, a pupil of Prof. Eaton, adopted the order of succession of the strata as proposed by Eaton, and separated the "Granular Quartz" (2), "Granular Limerock" (3), and "Argillite" (1) to form a distinct series of rocks between the "Granite" (1) and the "Graywacke" (2) of the Transition. To this series of rocks he gave the name "Taconic," as Nos. 3 and 1 are largely developed in the Taconic range of mountains. His central idea was that the rocks were non-fossiliferous and beneath the zone of animal life, and were separated by their mineralogical characters from the subjacent and superjacent rocks.[3]

In accordance with the belief that the "Granular Quartz" belonged to a system of rocks which were beneath the zone of animal life, Dr. Emmons considered it the oldest of the sedimentary rocks, and far beneath the Potsdam sandstone surrounding the Adirondack mountains. He thus differentiated the Potsdam sandstone and the "Granular Quartz" as two distinct formations. The work of Messrs. Dewey and Emmons added little to the knowledge of the true position of the "Granular Quartz" in the geologic series, as they did not discover fossils in it or the associated formations.

Prof. H. D. Rogers, in summing up the results of his study of the marbles and sandstones of the western portion of Berkshire County, Massachusetts, states that he considered the Berkshire limestone and marble to be the equivalent of the (Trenton) limestone series of the New York section; and that the semi-vitrified quartz was equivalent to the sandstone at the base of the same series (the Potsdam sandstone).[4] In the same year, 1841, a discussion of these formations was published in

[1] Geological section from Taconick range, in Williamstown, to the city of Troy, on the Hudson. Am. Jour. Sci., vol. 2, 1820, pp. 246–248.

[2] A sketch of the geology and mineralogy of the western part of Massachusetts, and a small part of the adjoining States. Am. Jour. Sci., vol. 8, 1824, pp. 1–60.

[3] Geology of New York, Part 2, comprising the survey of the second geological (Northern) district, 1842, pages 135–164.

[4] Some observations on the geological structure of Berkshire, Massachusetts, and neighboring parts of New York. Am. Phil. Soc. Proc., vol. 2, 1841, pp. 3, 4. On the physical structure of the Appalachian Chain, as exemplifying the laws which have regulated the elevation of great mountain chains generally. Trans. Am. Assoc. Geol. Nat., 1842, p. 482.

the Geology of Massachusetts,[1] in which the quartzite is described with many details. In the table on page 303, the "Granular Quartz" is placed at the base of the Paleozoic, or Sedimentary series, that is, at the base of the stratified rocks.

Dr. W. W. Mather,[2] in his survey of this region, concluded with Prof. Rogers that the "Granular Quartz" and other rocks referred to the Taconic by Emmons were the same as those of the Champlain division of the New York section, modified by metamorphic agency and the intrusion of Plutonic rocks. This correlates the "Granular Quartz" with the Potsdam sandstone. The "Granular Quartz" and the Potsdam sandstone were referred to the Primal series by Prof. H. D. Rogers[3] along with all the quartzites that were found at the supposed base of the Paleozoic series in the Appalachian region and north through New York and Vermont into Canada, and westward into the Mississippi Valley. This reference to the Primal series is more fully described in the final report of the Geological Survey of Pennsylvania.[4]

Prof. Ebenezer Emmons described the "Granular Quartz" with considerable detail as the basal member of his Taconic system.[5] In the reports of 1844 and 1847 its occurrence in western Massachusetts and western Vermont is noticed, and it is stated that in all probability it occurs as far north as the Canadian border. Its extension into Vermont had been previously noted by Messrs. Eaton and Dewey, and we find in the first annual report of the Vermont survey the statement by Prof. C. B. Adams[6] that a quartz rock constitutes the western base of the Green Mountains from the north part of Addison County to Massachusetts; and it is further said[7] that the quartz rock accompanies the Stockbridge limestone, disappearing with it in the north part of Addison County, and that near Lake Dunmore a bowlder was found in the vicinity of the quartzite beds containing two remarkable species of Polyparia(?). Two years later, in speaking of an excursion into Bennington County Prof. Adams says that the Quartz rock may equal the Potsdam sandstone, but there has evidently been too great a disturbance in this region to admit of certain conclusions.[8]

A full description of this formation is presented under the heading of

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[1] Final report on the geology of Massachusets, vol. 2, 1841, pp. 560-593.

[2] Mather, William. Natural History of New York. Pt. 1, Geology of New York; geology of the first (southeastern) district. Albany, 1843, p. 438.

[3] On American Geology and present condition of geological research in the United States. Am. Jour. Sci., vol. 47, 1844, pp. 151-154.

[4] The geology of Pennsylvania. Philadelphia, 1858, vol. 2, p. 751.

[5] Geology of New York, pt. 2, comprising the survey of the second geological (northern) district. 1842, pp. 135-164. The Taconic System; based on observations in New York, Massachusetts, Vermont, and Rhode Island, pp. i-vii, 67, 6 plates, Albany, 1844. Agriculture of New York, vol. 1, pp. 45-112, plates 21, map. Albany (1846), 1847. American Geology, containing a full statement of the principles of the science, with full illustrations of the characteristic American fossils. 8vo. Albany, 1856, vol. 1, pt. 2, pp. 122.

[6] First Annual Report on the Geology of Vermont. Burlington, 1845, p. 57.

[7] Op. cit., p. 61.

[8] Third Annual Report on the Geology of the State of Vermont. Burlington, 1847, p 13.

"Quartz Rock" in the final report of the Geological Survey of Vermont by Prof. C. H. Hitchcock.[1] Detailed descriptions are given of its character as found in Vermont, where it is said to have a thickness of at least 1,000 feet.[2] On this same page we read that "much of the quartz rock in the valley between Bristol and Starksboro can not be distinguished from members of the red sandrock series." Several species of fossils are mentioned as occurring in it; they are: A species of Lingula, a mollusk, resembling the Modiolopsis, a straight chambered shell (?), a few crinoidal columns, the *Scolithus linearis* (Hall), a few fucoids, and some indeterminable forms which are evidently organic.[3] The exact geological horizon of the quartz rock is not determined.

At this point the review of the literature referring to the "Granular Quartz" will be postponed until it is taken up in connection with the "Red Sandrock" and "Georgia Slates" of Vermont. In 1861 the three formations were practically united in one geologic terrane by the discoveries of Messrs. Billings and Barrande and the correlations of the Geological Survey of Vermont. A review of the references made to the Red Sandrock and the Georgia Slates will next be given, and then the three formations will be considered together as they are described in New York and Vermont.

RED SANDROCK.

When describing the formation terminating the Champlain group of the New York section Dr. E. Emmons correlated the brown or red-brown sandstone of Vermont, on the eastern border of Lake Champlain, as found at Addison, Charlotte, Burlington, and Colchester, with the gray sandstones that terminate the Lorraine shales of Jefferson County, New York.[4] He thus assigned the "Red Sandrock" of the future to the summit of the Lower Silurian.

In presenting the results of his study of a section crossing Vermont from the Green Mountains to Lake Champlain, Prof. C. T. Jackson[5] mentions the occurrence at Burlington Falls of a red sandstone containing numerous beds of buff-colored and blue compact limestone destitute of fossils. He referred it to the Potsdam sandstone of Dr. Emmons. "At Willard's quarry the red sandstone rock alternates with a bright red slate, covered with ripple marks made by the waters, from which the sediment was originally deposited." He further states that a mile from Burlington, on the Winooski River, large beds of compact blue and excellent white limestone are found.

Prof. C. B. Adams describes in the first report of the Geological

[1] Hypozoic and Paleozoic rocks. Report on the Geology of Vermont, descriptive, theoretical, economical, and scenographical, vol. 1, 1861, pp. 342–357.

[2] Op. cit., p. 355.

[3] Op. cit., p. 356.

[4] Geology of New York, pt. 2, comprising the survey of the second geological (northern) district. 1842, pp. 123, 124.

[5] Final Report on the Geology and Mineralogy of the State of New Hampshire, with contributions towards the improvement of agriculture and metallurgy. Concord, 1844, p. 161.

Survey of Vermont the occurrence of roofing slates in southern Vermont[1] which he refers to the Taconic slate of Dr. Emmons, without a further attempt to assign them to a geologic horizon.

In the following year a section is given of Snake Mountain by Prof. Adams[2] in which the Red sandrock is shown resting conformably upon the Hudson River shale. In 1847 he referred to his studies of the Red sandrock[3] and noticed the discovery of fragments of trilobites which Prof. James Hall identified as Conocephalus.[4] He next assigned his Red Sandrock to the Upper Silurian, correlating it with the Medina sandstone.[5] Dr. E. Emmons criticised this view of Adams, and stated that he was in error. He regarded the formation as of Calciferous or of Potsdam age as proved by the fossils, stating that the rocks rest on the Taconic slate.[6] Prof. Adams reasserted his view in 1848,[7] stating that no line of fracture occurred above the Trenton limestone, and that the Snake Mountain section showed that it contained Utica and Hudson River rocks. Later, Dr. Zadock Thompson adopted the view that the Red sandrock was in its natural position on the summit of Snake Mountain.[8] The view that the Red sandrock series was the equivalent or the Medina of the New York section was sustained by Prof. W. B. Rogers[9] and the Medina or Clinton age of the "Red sandrock" was supported by the Geological Survey of Vermont.[10]

Mr. E. Billings, on learning of the discovery of fossils in the "Red sandrock" near Swanton, Vermont, by Dr. G. M. Hall and Rev. J. D. Perry, visited the locality and found a small Theca and a Conocephalites. Upon this paleontological evidence he referred the strata to about the horizon of the Potsdam sandstone, to which position it has since been assigned by most authors who have had occasion to mention it.[11] Mr. Billings also corrected the statement of Prof. Hall, that the trilobites of the Georgia slate were from the Hudson terrane, and referred them to the Primordial or Lower Potsdam. This transferred the Georgia series and the associated "Red sandrock" to the Cambrian.[12]

I have thus far referred only to the "Red sandrock," as it was mentioned more definitely, and assigned to a geological position prior to the argillaceous and arenaceous shales and slates that overlie it. As the "Red sandrock" and these shales or slates will be spoken of together

[1] First Annual Report on the Geology of Vermont. Burlington, 1845, p. 35.
[2] Second Annual Report on the Geology of the State of Vermont. Burlington, 1846, p. 163.
[3] Third Annual Report on the Geology of the State of Vermont. Burlington, 1847, pp. 13–15.
[4] Letter on certain fossils in the Red sandrock of Highgate. Third Annual Report on the Geology of the State of Vermont. Burlington, 1847, p. 31.
[5] On the Taconic System. Am. Jour. Agric. and Sci., vol. 6, 1847, p. 260.
[6] (On the Taconic System.) Am. Jour. Agric. and Sci., vol. 6, 1847, p. 260.
[7] On the Taconic Rocks. Am. Jour. Sci., 2d ser., vol. 5, 1848, pp. 108–110.
[8] Geology of Vermont. Nat. Hist. of Vermont, Burlington, 1853, Appendix, p. 45.
[9] (Notes on the geological structure of western Vermont.) Report on the Geology of Vermont, vol. 1, 1861, pp. 326, 327.
[10] Hitchcock, C. H. Report on the geology of Vermont. Notes on the sections, vol. 2, 1861, p. 650.
[11] On the age of the red sandstone formation of Vermont. Am. Jour. Sci., 2d ser., vol. 32, 1861, p. 232.
[12] On Prof. J. Hall's claim to priority in the determination of the age of the red sandrock series of Vermont. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 370–376.

hereafter, I will now go back and give a short résumé of the history of the latter as mentioned by various authors.

GEORGIA SLATES.

The first notice we find of the slates and shales now referred to the Georgia terrane of Vermont is by Prof. Amos Eaton, in 1818. The argillaceous and siliceous slates and, in isolated masses, a graywacke slate (Nos. 9 and 10 of his figured section) are shown to the east and west of the Hudson River, the slates on the east alone belonging to the Cambrian.[1] These slates were referred to the transition class.[2] In the next edition of his index[3] these beds are referred to the Argillite (7) and the Graywacke (9), these terms being then applied to them as seen in Rensselaer County, New York, and in all of Eaton's subsequent publications. It is the Argillite (1) and the First Graywacke or the Graywacke slate of the First Graywacke of the nomenclature of 1832[4] and his paper of 1839.[5] On Rev. Chester Dewey's Geological Map of 1824[6] the same area in Rensselaer County is included under the term "Grey Wacke" and in part "Transition Argillite."

In defining the limits of the Taconic System in 1844,[7] the northward extension of Prof. Eaton's Argillite and Graywacke of Rensselaer County into Washington County was called the Taconic slates, and it was in this series, a mile north of Bald Mountain, that the first fossils of the Olenellus or Lower Cambrian zone were found by Dr. Asa Fitch. These slates, with their interbedded arenaceous layers, formed the Upper Taconic of Emmons, which he stated could be traced northward to the Canadian border. In the map accompanying Dr. Emmons's memoir on the Taconic System, published in 1844, all of the strata east of the Hudson are colored Taconic slates, or included in the Taconic system. The same strata in the map of 1842, published by the Geological Survey of New York, are included under the Hudson River group.

Dr. Asa Fitch, a practicing physician in Washington County, New York, studied the local geology, and, under the headings of "Taconic

[1] The Greywacke or Grit area of the eastern part of Rensselaer County is now known to be above the metalliferous limestone of Eaton or the Trenton limestone series of the New York State Survey. The recent work of Mr. T. Nelson Dale, of the U. S. Geological Survey, establishes this and proves that I was incorrect in referring this area to the Cambrian on the map accompanying the paper on the Taconic System of Emmons and the use of the name Taconic in geologic nomenclature. (Am. Jour. Sci., 3d ser., vol. 35, 1888, pl. 3.) It is probable that the eastern portion of the Cambrian area, as there mapped, to the north of the Berlin Grit area, in western Bennington and Rutland counties, Vermont, may also prove to be of Lower Silurian (Ordovician) age. (C. D. W., June, 1891.)

[2] An index to the geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, pp. 27-30.

[3] An index to the geology of the Northern States. 2d ed., 12mo, Troy, N. Y., 1820, p. 163.

[4] Geological Text Book, 2d ed., 1832.

[5] Cherty lime-rock or Corniferous lime-rock proposed as the line of reference for State geologists of New York and Pennsylvania. Am. Jour. Sci., vol. 36, 1839, pp. 69, 70.

[6] A sketch of the geology and mineralogy of the western part of Massachusetts and a small part of the adjoining States. Am. Jour. Sci., vol. 8, 1824, pp. 1-60.

[7] Emmons, E. The Taconic System; based on observations in New York, Massachusetts, Vermont and Rhode Island. Albany, 1844, pp. i-vii, 67, 6 plates.

slate" and "Taconic sandstone,"[1] gives a description of the slates and interbedded sandstone with considerable detail. He thinks that they may belong to an older system than the New York rocks, but no evidence is given to support this view. On page 865, Dr. Fitch states that in the summer of 1844 he found at Reynold's Inn the first fossils known from the Taconic slate, and sent them to Dr. Emmons, who named and published illustrations of two species. Dr. Fitch also describes an annelid trail, *Helminthoidichnites tenuis*, from the "Taconic slate" of Granville.[2]

Dr. C. B. Adams, of the Geological Survey of Vermont, called the northward extension of the Upper Taconic slate (of Emmons) of Washington and Rensselaer Counties, the roofing slates of the Taconic system, and included them in his Hudson River group.[3]

The fossils described from a locality of this horizon, near Troy, New York, in the paleontology of New York,[4] were included by Prof. James Hall with those of the Hudson River group and were considered to be of that age. This same view was taken by him of the northward extension of this series in Vermont, when he described the trilobites from the shales of Georgia in 1859. At the close of this article he says:[5]

> In addition to the evidence heretofore possessed regarding the position of the shales containing the trilobites, I have the testimony of Sir W. E. Logan that the shales of this locality are in the upper part of the Hudson River group, or forming a part of the series of strata which he is inclined to rank as a distinct group above the Hudson River proper. It would be quite superfluous for me to add one word in support of the opinion of the most able stratigraphical geologist of the American continent.

Prof. C. H. Hitchcock,[6] in speaking of the trilobite rock of Vermont, from which Prof. Hall's specimens were obtained, stated that he considered them as overlying the equivalent of the Oneida, which was superjacent to the Hudson River Rocks.

The attention of M. Joachim Barrande having been called to the fossils found in the Georgia slate, he studied them with great care, and published an extended review of the literature referring to them, and discussed the paleontologic proof of the age of the rocks.[7] He decided that the fauna was equivalent to his Primordial fauna of central Bohemia, and that it could not be referred to the Second fauna, as had been done by the American observers. Under the impression that Dr. Em-

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[1] A Historical, Topographical, and Agricultural Survey of the County of Washington. Trans. N. Y. State Agric. Soc. for 1849, 1850, pp. 830-857.

[2] Op. cit., p. 868.

[3] First Annual Report on the Geology of the State of Vermont, Burlington, 1845, p. 61. On the Taconic Rocks, Am. Jour. Sci., 2d series, vol. 5, 1848, pp. 108-110.

[4] Paleontology of New York, vol. 1, containing descriptions of the organic remains of the lower division of the New York system, 1847, pp. 252, 256, 257.

[5] Remarks upon the trilobites of the shales of the Hudson River group. Paleontology of New York, vol. 3, supplement to vol. 1, 1859, p. 529.

[6] On the geology of Vermont, chiefly in connection with the Taconic System. Boston Soc. Nat. Hist. Proc., vol. 7, 1861, pp. 426, 427.

[7] Documents anciens et nouveaux sur la faune primordiale et le système taconique en Amérique. Soc. géol. France, Bull., 2e sér., vol. 18, 1861, pp. 203-321.

mons's stratigraphic work was correct, M. Barrande credited him with having correctly located the Primordial fauna in America.

In 1861 Prof. Hall changed the reference of the Georgia trilobites from the Hudson River group to the Quebec group.[1] In a letter written to M. J. Barrande, dated April, 1862, the explanation of this is given. He states that his own conviction was that the Red sandrock and the Granular Quartz of Vermont were of the age of the Potsdam sandstone and that the schists and shales which held the trilobites belong between the Potsdam sandstone and the Trenton limestone. He thus changed his views in relation to the age of the rocks containing Olenellus and other trilobites, and referred them to the lower portion of what is now designated as the Silurian (Ordovician). He says:

> You will understand, then, that if my views touching the relations of these rocks are exact the valley of the Hudson River from the high lands on the south of Lake Champlain, save a small number of inconsiderable exceptions, is occupied by rocks of the Primordial zone, that is, by rocks placed between the Potsdam sandstone and the Trenton group. Thus the Hudson River group in its typical localities belongs to the Primordial period.[2]

In explaining how he came to adopt the view that the trilobites from the Georgia slates of Vermont and those described by Dr. Emmons from the black slates of Washington County belonged to the Hudson River group, together with the strata in which they were contained, he says:

> I wish to claim nothing for myself or for my former views, for we owe the final solution of this question to the Canadian survey. Yet there remain some divergent views in regard to the relation between the shales and the Potsdam sandstone.

He further states that this arose from his seeing the Potsdam sandstone run beneath the slate at Whitehall, New York, and a number of other places; that at no point where the Potsdam sandstone is seen is there any shale or other formation beneath it, excepting the crystalline rocks of the Adirondacks. Speaking of the "Granular Quartz," he says that it presents the same relation as the Potsdam sandstone to the schistose rocks; that he has always referred it without hesitation to the Potsdam sandstone. He held the view that the schistose rocks, with their impure sandstones, brecciated limestones, and calciferous sandrock, are to be placed between the Potsdam sandstone and the Trenton limestone group; that the relation of this group of schists or slates to the Potsdam sandstone seems to be that of an upper formation. In none of the outcrops that he saw in the disturbed region east of the Hudson was there one that could explain the phenomena presented, on the supposition that the sandstone is the upper rock. He then quotes the nomenclature of Eaton to show that it was almost the same as that finally adopted by the Geological Survey of New York, that is, the order of superposition of the formations, the "Granular Quartz" being placed at the base. It is also stated that the graptolites found in the beds

[1] Correction for the thirteenth annual report. 14th Ann. Rep., State Cab. Nat. Hist., 1861, p. 110.
[2] Letter on the Primordial of America. Soc. géol. France, Bull., 2e sér., vol. 19, 1862, p. 732.

formerly referred to the Hudson River are considered to belong to the Primordial fauna.[1]

The geologists of the Vermont survey in their final report included the shales and associated slates and arenaceous beds under the title of Georgia group. In proposing the name Georgia group to designate these rocks, Prof. C. H. Hitchcock said:[2]

> We use the term *Georgia group* to designate this terrain, from the town of Georgia in Franklin County, where it is developed in its full proportions and where the most interesting fossils have been found. It is a name also which does not involve any theory, and may be used by both parties in the controversy respecting its age. * * * The Georgia slate includes what Prof. Emmons has ranked as the black slate, Taconic slate, and roofing slate; and yet not altogether, for we have regarded all the black slate beneath the red sandrock as belonging to the Hudson River group. The characteristic trilobites of the Georgia slate are represented by Emmons in his Taconic System, 1844, as found in the black slate.

The following fossils are cited as characterizing the Georgia slate in Vermont: *Barrandia thompsoni* Hall, *B. vermontana* Hall, *Bathynotus holopyga* Hall, *Graptolithus milesi* Hall, the trail of an annelid, and unknown species of fucoides.[3]

The stratigraphic position of the Georgia series was considered to be above the sandstone which represented the Oneida conglomerate, and the thickness of the slate was thought to be at least 3,000 feet.[4] A discussion of the stratigraphic position of the faunas found in the Georgia slates by Prof. James Hall, Sir William E. Logan, and M. J. Barrande, accompanies the chapter. A fair presentation of the argument for and against the Silurian age of the terrane is given. In a note upon the trilobites of the shales of the Hudson River group, in the same volume, Prof. Hall redescribes the fossils mentioned in his paper of 1859. In the second volume of the Geology of Vermont, on page 799, the "sparry limestones" occurring as thin bands in the roofing slate series in Fairhaven, Vermont, are correlated with the red sandrock or Winooski marble of the northern portion of the State.

In describing the rocks of Waterville, Maine, Prof. C. H. Hitchcock[5] states that the slates are similar in mineralogical structure to the Georgia slates of Vermont, which are equivalent to the Potsdam sandstone.

With the determination (*a*) by Mr. E. Billings that the "Red sandrock" was of primordial age;[6] (*b*) by Mons. Barrande that the fossils from the Georgia slate belonged to the Primordial fauna; (*c*) that the "Granular Quartz" was the basal member of the Paleozoic, and had been correlated with the Potsdam sandstone, which, from its included

[1] Op. cit., p. 732.
[2] Hypozoic and Paleozoic rocks. Report on the geology of Vermont, vol. 1, 1861, p. 358.
[3] Op. cit., p. 367. [4] Op. cit., p. 366.
[5] General report on the geology of Maine. Preliminary Rep. on the Nat. Hist. and Geology of Maine. Augusta, 1861, p. 233.
[6] On the age of the red sandstone formation of Vermont. Am. Jour. Sci., 2d ser., vol. 32, 1861, p. 232.

fossils in the Mississippi Valley, was also referred to the Primordial, the review of the history of these three Cambrian formations as they appear in New York and Vermont is carried forward as that of one terrane.

In speaking of the determination of the age of the slates in Georgia, Vermont, Mr. E. Billings states that Mons. Barrande first determined their age.[1] He further says:

At the time I wrote the note on the Highgate trilobites it was not known that these slates were conformably interstratified with the Red sandrock. This discovery was made afterwards by the Rev. J. B. Perry and Dr. G. M. Hall, of Swanton.

He also mentions the discovery on the Straits of Belle Isle, by Mr. J. Richardson, of the Canadian Geological Survey, of *Scolithus linearis*, *Paradoxides thompsoni*, and *P. vermontana*, and a number of other species of which a list would be given further on. He adds:

The sandstones and limestones of the north shore of the straits [of Belle Isle] appear to be of the age of the Potsdam of Pennsylvania and Tennessee. The form of the Scolithus is identical with that which occurs in these two States, and some portions of the rock is a coarse red sandstone, exactly like the specimens sent to me about a year ago from Tennessee by Prof. Safford.

Mention is made of the discovery by Rev. J. B. Perry and Dr. G. M. Hall of a group of fossils interstratified with the Red sandrock east of Swanton, Vermont. Of the species found, four occur in the limestone which overlies the sandstone with *Scolithus linearis* on the north shore of the Straits of Belle Isle.

Taking all these facts together scarcely anything more is necessary to show that the Red sandrock of Vermont is of the age assigned to it by me from an examination of Conocephalites at Highgate in July last. * * * Barrande's opinion, founded altogether upon the aspect of these trilobites is thus completely verified.[2]

At the close of the paper is a list of the fossils found in Vermont and on the Straits of Belle Isle, all of which are referred to the Potsdam group.[3] In speaking of the claim of Mr. Billings, that he had identified the Primordial fauna in the Red sandrock and determined its geological age, Prof. James Hall[4] states that he had published sections and made statements in relation to the age of these rocks to show that he considered them to be of the age of the Potsdam sandstone of the New York section. In reply Mr. Billings[5] said that the sections spoken of by Prof. Hall do not cross at any point the Red sandrock or Georgia slates, where they are recognized by Prof. Hall as belonging to the Potsdam. On the contrary, they are marked on the section as belonging to the Trenton-Hudson series.

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[1] Further observations on the age of the red sandrock formation (Potsdam group) of Canada and Vermont. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 100-105. (See note and corrections, same vol., pp. 421-422.)

[2] Op. cit., p. 102. [3] Op. cit., p. 104.

[4] On the Potsdam sandstone and Hudson River rocks in Vermont. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 106-108.

[5] On Prof. J. Hall's claim to priority in the determination of the age of the Red sandrock series of Vermont. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 370-376.

When tracing the formations that occur north of the Vermont and Canada boundary to the southward, Sir William E. Logan studied a section in the vicinity of Swanton, Vermont, in which the Georgia slates and the Olenellus fauna occur above the Red sandrock.[1] The latter are red and white dolomites in sandy layers. The measurement of this section gave a thickness of 710 feet, including 190 feet of shale, carrying the fossils which Mr. Billings described. He traced the rocks of the Swanton section north to the vicinity of Saxe's Mill, near the United States and Canadian border, where a measured section of the dolomitic sandstone gave a thickness of 1,410 feet.[2] These sections cross the Red sandrock formation of the older authors. The name Red sandrock is a misnomer, as there is in reality comparatively little sand or arenaceous material, other than arenaceous limestone of a highly dolomitic character, in the entire section.

Prof. Jules Marcou took a very active interest in the discussion of the stratigraphic position of the fauna found in the slates of Georgia, Vermont, and published numerous papers upon the subject from 1860 to 1888. In a paper published in 1861[3] he records some of his own observations, saying that in Vermont the Potsdam sandstone has exactly the same aspect and composition as at Potsdam, in the State of New York. Near Saxe's Mills, a mile east of Highgate Springs, it contains two species of Conocephalites, *C. adamsi* and *C. vulcanus*. He states that the formation is broken up into narrow bands that are numerous and well developed west of Mr. Parker's farm at Georgia, and also on the road between St. Albans and Swanton, Vermont; and that although at first they appear to be interstratified with the Georgia slates, they are not so, but may be compared with the steps of a ladder placed over, or even a little wedged into the Georgia slates and Lingula flags. He says:

> This group has been known for a long time in Vermont by the name of Red Sandrock. * * * Below the Potsdam sandstone lie great masses of slate, four or five thousand feet thick, which for convenience I should divide into three parts.[4]

These are the Lingula flags, Georgia slates, and St. Albans group. The Georgia slates are stated to be characterized by Primordial fossils, notably *Paradoxides* (*Olenellus*) *thompsoni*, *P. vermontana*, *Peltura holopyga*, *Obolella cingulata*, etc.[5]

In noting the discovery of fossils in the Winooski marble, at Swanton, Vermont, Mr. E. Billings[6] states that fossils were discovered by Mr. Solon M. Allis, of Burlington, Vermont, who sent them to him for ex-

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[1] Geological Survey of Canada; report of progress from its commencement to 1863. Montreal, 1863, pp. 281, 282.

[2] Op. cit., p. 282.

[3] The Taconic and Lower Silurian rocks of Vermont and Canada. Boston Soc. Nat. Hist. Proc., vol. 8, 1862, pp. 239-253.

[4] Op. cit., p. 244.

[5] Op. cit., p. 245.

[6] Note on the discovery of fossils in the "Winooski marble," at Swanton, Vermont. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 145, 146. Canadian Nat., new ser., vol. 6, p. 351.

amination. He found a species of Salterella, which he identified as *Salterella pulchella.* He observes that the Winooski marble, both at Swanton and St. Albans, seems to underlie the Georgia slates, and he says:

It is generally of a reddish, mottled color, but sometimes gray or greenish. The limestone at the Straits of Belle Isle, in which *S. pulchella* is found, is also red, gray, and greenish; and is, I have no doubt, of the same age. At this latter locality it overlies a red or brownish sandstone, conformably, which holds *Scolithus linearis.* I consider the Belle Isle sandstone to be the "Quartz rock" of the Green Mountains of Vermont. In that case, the limestone at Belle Isle occupies, stratigraphically, the position of the Stockbridge limestone as represented by Dr. Emmons in his American Geology, part 2, p. 19.[1]

Under the title "Geology of Vermont," Prof. C. H. Hitchcock tabulates the formations of that State.[2] The Potsdam group is made to include the Red Sandrock, part of the Hudson River slate, part of the Georgia slate, most of the quartz rock, and the Potsdam sandstone of West Haven. Speaking of the latter he says, the Potsdam rocks flank the gneiss upon the west side as far north as Middlebury. He further observes that the quartz rock is probably the same as the red sandstone; that both are overlain by the Levis[3] limestone, and resemble each other very much near their supposed union. "I find this view of the identity of those two formations confirmed by the late map of the Canadian survey, published in 1866."

In an article on some points in the Geology of Vermont, Dr. T. S. Hunt states:

It happens, then, from the facts already set forth, that the Potsdam formation, which at its outcrop at the foot of the Adirondacks and Laurentides includes only from 300 to 700 feet of sandstone, is represented a few miles to the eastward by not less than 2,000 feet of dolomites, sandstones, and slates, and moreover that occupying a position between the calciferous and chazy formations, which are contiguous at their eastern outcrop, there becomes intercalated within this short distance a fossiliferous group, several thousand feet in thickness.[4]

The explanation of this is quoted from Logan's opinion, to the effect that the Potsdam sandstone accumulated along the shore, while shales and limestones were accumulating to a greater thickness in the deeper water of the adjacent ocean. In summing up the evidence as to the age of the rocks of western Vermont he says:

All the evidence, paleontological and stratigraphical, as yet brought forward affords no proof of the existence in Vermont of any strata (a small spur of Laurentian excepted) lower than the Potsdam formation, which the present advocates of the Taconic system regard as forming its summit. * * * That strata still older than the Potsdam of New York and Vermont were deposited in some portions of the oceanic area is apparent from the existence in New Brunswick of the St. John's slates holding a Primordial fauna older than the Potsdam, and it is not impossible

[1] Op. cit., p. 351. [2] Am. Assoc. Proc., vol. 16, 1867, p. 120.

[3] Levis group, including the "Eolian limestones," "Hudson River limestones," and the greater portion of the Georgia slate. (Op. cit., p. 120.)

[4] On some points in the geology of Vermont. Am. Jour. Sci., 2d ser., vol. 46, 1868, p. 225.

that their equivalents may underlie the Potsdam formation of Vermont. No such rocks, have, however, as yet been detected in either Vermont or Canada.[1]

That Dr. Hunt also confounded the typical Potsdam sandstone of the Adirondacks, the quartzite of the western base of the Green Mountains, and the Primordial series described by Murray in Newfoundland is shown by his statement that a few hundred feet of typical Potsdam sandstone in New York are represented in Vermont, Quebec, and Newfoundland by thousands of feet of strata lithologically very unlike the type.[2]

In 1867 Prof. C. H. Hitchcock identified the Winooski marble of Vermont as the Red Sandrock, and stated that *Olenellus thompsoni* and *O. vermontana* occurred in the superjacent slaty layers.[3] In the same volume he presents a table of the strata from the Silurian to the Devonian, inclusive, as found in Vermont, and in this connection he says he considers the Taconic to be of Lower Silurian age. This included, as described by Emmons, the Georgia slates.[4]

At the time of the presentation of the two foregoing papers by Prof. Hitchcock a paper on the Red sandrock of Vermont and its relations was read by Mr. J. B. Perry.[5] He concluded that the Red sandrock was equivalent to the Potsdam, and that the sedimentary beds below the Potsdam were not Utica or Lorraine, but belong to the Primordial zone of Barrande. The Potsdam is considered to be the top of the Primordial, not the base of the Silurian. In the table of formations the Red sandrock or Potsdam is placed at the top of the Taconic system, and the Taconic slate with the quartzite limestone or conglomerate at the base. The following year the same author[6] again stated that the Red sandrock was of Potsdam age and not Medina, and he subdivided the slates below into the Swanton and Georgia series, as older than the Utica slate, referring them to the Primordial of Barrande.

In a summary of the Geology of Vermont, by Prof. C. H. Hitchcock,[7] published in connection with the Geology of Northern New England, it is stated, under the head of "Potsdam Group," that it includes (1) black slate, or part of the "Hudson River slate" of the former report of the Vermont Survey. (2) Georgia slate. (3) Red Sandrock and quartz rock at the base of the Green Mountains. (4) Potsdam sandstone, the same as the original beds in New York.

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[1] Op. cit., p. 229.

[2] On the geology of eastern New England. Am. Jour. Sci., 2d ser., vol. 50, 1870, p. 85.

[3] The Winooski marble of Colchester, Vermont. Am. Assoc. Proc., vol. 16, 1867, p. 119.

[4] The Geology of Vermont. Am. Assoc. Proc., vol. 16, 1867, p. 122.

[5] Am. Assoc. Proc., vol. 16, 1867, pp. 128-134.

[6] Queries on the red sandstone of Vermont and its relations. Boston Soc. Nat. Hist., Proc., vol. 11, 1868, pp. 341-353.

[7] The geology of Vermont. In Geology of northern New England, 4to, 1870, p. 2.

The Red sandrock is described as extending from St. Armand, province of Quebec, to Bridport, Vermont.

The brightest red rocks are found along the western border; so that while the alliance of the red rock of Burlington and the quartzite of Bennington seems incongruous, it is otherwise with the reddish rocks of Monkton and the brown quartz of Starksboro' and Bristol.[1]

It is stated that the name Georgia was applied to the group of slates carrying Olenellus. It was then supposed that the slates were entirely distinct from the sandstones, but further investigation has shown an interstratification, with the presence of the characteristic trilobites throughout the beds.

Of the "Granular Quartz" on the western slope of the Green Mountains he says:

No rock can be more distinct from all others than the quartzite from the State line north to Starksboro', consisting chiefly of pure vitreous silica, sometimes hardly showing a sedimentary composition. * * * The group makes a mountain range throughout, some of the peaks exceeding 3,000 feet in height. * * * An abundance of *Scolithus linearis* appears in this formation, and the rock was referred to the Potsdam in 1841 by H. D. Rogers and W. B. Rogers, in opposition to E. Emmons, who subsequently called it "granular quartz," lying at the base of the Taconic system, thousands of feet below the former.[1]

In 1871 Mr. S. W. Ford[2] published an account of a section of rocks at Troy, New York, in which he had found the Olenellus fauna. In 1884, he added[3] a description of a section near Schodack Landing, south of Troy, in Columbia County, New York. By the contained fauna the strata were correlated with those described by Sir William Logan, in Vermont, Canada, and Newfoundland.

Prof. J. D. Dana,[4] from 1872 to 1877 worked out, with considerable detail, the stratigraphic relations of the "Granular Quartz," of Berkshire County, Massachusetts, to the subjacent Archean and the superjacent Silurian limestone, adding many details to the general outlines published by Messrs. Eaton, Dewey, and Emmons. In the description of the quartzite, limestone, and associated rocks of Great Barrington, Berkshire County, Massachusetts,[5] it is stated that the quartzite of Great Barrington alternates with mica schist, and that both of the rocks for the most part overlie the Stockbridge limestone. Of the Green Mountain quartzite, Prof. Dana says:[6] "In the first place there are quartzites of more than one age in New England, west of the Connecticut River." A

[1] Op. cit., p. 3.

[2] Notes on the Primordial rocks in the vicinity of Troy, New York. Am. Jour. Sci., 3d ser., vol. 2, 1871, pp. 32-34. Can., Nat., new ser., vol. 6, 1872, pp. 209-212.

[3] On the age of the glazed and contorted slaty rocks in the vicinity of Schodack Landing, Rensselaer County, New York. Am. Jour. Sci, 3d ser., vol. 28, 1884, pp. 206-208.

[4] Green Mountain geology. On the quartzite. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 179-186, 250-256. An account of the discoveries in Vermont geology of the Rev. Augustus Wing. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 332-347, 405-419; vol. 14, pp. 36-37, 1877.

[5] On the quartz, limestone and associated rocks of the vicinity of Great Barrington, Berkshire County, Mass. Am. Jour. Sci., 3d ser., vol. 4, 1872, p. 362.

[6] Green Mountain geology. On the quartzite. Am. Jour. Sci., 3d ser., vol. 3, 1872. p. 181.

Helderberg quartzite exists at Bernardston, Massachusetts, and another quartzite of different age, about 3 miles west of Plymouth, Vermont, is interstratified with gneiss; and then there is the great quartzite of the Green Mountain range, whose relation to the quartzites interbedded in the gneiss is unascertained. "We can not assume, therefore, that this last is all of one geological age." After examining the quartzite of Canaan, Connecticut, he was led to the conclusion from the facts observed that the quartzite is the inferior rock, and rests unconformably beneath the limestone.[1]

When briefly presenting some conclusions concerning the stratigraphical structure of the Cambrian of western Vermont, Prof. C. H. Hitchcock[2] states that Dr. Emmons believed the rocks were deposited against the western base of the Green Mountains, in order of, first, the Granular Quartz, then the Stockbridge limestone, and lastly the various slates which were capped by the black slates holding Olenellus. The report says further:

Prof. Hitchcock suggested as a better theory of structure, that sediments were formed contemporaneously, both upon the Green Mountains and the Adirondack side of the valley, thus making the granular quartz on the east side of the valley of the same age with the Potsdam sandstone at Whitehall, N. Y., and elsewhere west of Lake Champlain. Next, the Calciferous sandstone, Levis, Chazy, and Trenton limstones, were deposited entirely across the valley and by means of their fossils are now identified adjacent to both the quartz rock and the typical Potsdam sandstone. Thirdly, the limestones are succeeded by slates. This theory of original deposition differs from that of Emmons, in supposing that sedimentation was being effected both on the Green Mountain and Adirondack borders, instead of on the former only.[3]

In summing up the account of the discoveries of Rev. Augustus Wing in Vermont geology, Prof. Dana says:[4]

The Red sandrock on the west of the Eolian limestone—admitted to be Potsdam or Primordial in age—and the Quartzyte on the east which often rises into mountain ridges, are of the same formation, and come nearly or quite together in Monkton, on the northern limits of the limestone area (p. 414).

The quartzyte of the eastern range, with that also of the local belts in the Eolian limestone area, is regarded as Potsdam (or Primordial) in age, because it contains in many places *Scolithi* (worm-burrows) and *Fucoids* like those found in the Potsdam sandstone; because also it adjoins Calciferous limestone beds at the localities just mentioned in North Middlebury and New Haven; and because it joins the Red sandrock in Monkton, and one rock has in many places the character of the other, although not commonly alike in color, and showing differences explainable on the ground of the greater metamorphism of the quartzyte. "In Monkton, the Red sandrock and the Quartzyte meet in a succession of short anticlinals, thus cutting off to the north the great trough or synclinal;" and "the Red sandrock absolutely overlies the beds of Red sandrock in one anticlinal and the quartzyte in another anticlinal, and both hold *Scolithus linearis*."[5]

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[1] Op. cit., p. 185.

[2] Remarks on the stratigraphical structure of the Cambrian and Cambro-Silurian rocks of western Vermont. Boston Soc. Nat. Hist., Proc., vol. 18, 1875, p. 191.

[3] Op. cit., p. 191.

[4] An account of the discoveries in Vermont geology of the Rev. Augustus Wing. Am. Jour. Sci., 3d ser., vol. 13, 1877, p. 414–416; vol. 14, pp. 36–37.

[5] Op. cit. p. 416.

Dr. T. S. Hunt, in 1878,[1] gives an historical review of the rocks referred to the Cambrian and Taconic systems and in this way speaks of the "Upper Taconic" and refers it to the Cambrian, and the "Granular Quartz" to an Archean system. Again, in 1883,-'84,-'86, he went over the same ground,[2] but did not add any original information upon the subject. He adopted the view of Prof. Eaton so well expressed in the section of 1824, and brought down to 1886 the erroneous view of the unconformity between the Calciferous sandrock and the Argillite. To the strata which Dr. Emmons included in the Taconic system, in 1842, he gave the name Taconian, referring them to a pre-Cambrian, Archean, group of rocks.

In a paper upon the colonies in the Taconic rocks of the borders of Lake Champlain,[3] Prof. Jules Marcou gives a résumé of his investigations in northern Vermont up to date. In the vertical section accompanying the geological map, the Potsdam sandstone is placed at the summit of the upper Taconic series, and then in order below, the Swanton schists, Phillipsburg group, Georgia schists, and the St. Albans group. On sections in the text the Potsdam sandstone is represented as unconformably superjacent to the Georgia slates, the Phillipsburg group, and the Swanton schists, and the St. Albans group. A general description is given of the formations as interpreted by Prof. Marcou. As now known the Potsdam sandstone as identified by him, is the Red sandrock of the Vermont geologists, or the arenaceous magnesian limestone of Logan. Its stratigraphical position is at the base of the series described, or at the base of the Lower Cambrian as now understood.

A series of geological sections across Vermont and New Hampshire by Prof. C. H. Hitchcock[4] have the Red Sandrock series marked as Potsdam and the Georgia slate series as Cambrian. The Granular Quartz of the southern portion of Vermont is all marked Potsdam. In the text[5] Prof. Hitchcock says:

> Three bands of sandstone therefore are referred to the Potsdam in the Champlain valley: first, the normal gray sedimentary beds at the foot of the Adirondacks, always known under this name since 1840; second, the quartzite on the flank of the Green Mountains; third, a range of red sandstone and dolomite from the Canada line to Bridport, where it is succeeded by outcrops of a material not distinguishable from the first named band. Partly accompanying the middle band is a series of slates and hard sandstones, passing into roofing slates called the Georgia group in the State report, which carries such fossils as Olenellus and Angelina, and is, therefore, thought to be somewhat older than the typical Potsdam sandstone.

In the same publication Prof. R. P. Whitfield[6] states it to be his

[1] Special report on the trap dikes and azoic rocks of southern Pennsylvania, 2d Geol. Surv. Pa., E., 1878, p. 253.

[2] The Taconic question in geology. Mineral Physiology and Physiography. A second series of chemical and geological essays, with a general introduction. 1886, pp. 517-686.

[3] Sur les colonies dans les roches taconiques des bords du lac Champlain. Soc. géol. France, Bull., 3me sér, vol. 9, 1880, pp. 18-46.

[4] Geological sections across Vermont and New Hampshire. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, pp. 155-179.

[5] Op. cit., p. 160.

[6] Notice of some new species of Primordial fossils in the collections of the Museum, and corrections of previously described species. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, p. 140.

impression that the New York typical Potsdam is about equivalent to the lower portion of the Wisconsin series; and that the Acadian beds of Canada and Vermont, and perhaps the other Atlantic areas, are not appreciably different in age; but the difference in faunæ is more the result of conditions upon which life depended than a difference in time. This generalization of Prof. Whitfield placed the "Granular Quartz," "Red sandrock" or dolomite, Georgia slate and the Potsdam sandstone of New York and the Upper Mississippi Valley in one geologic horizon, the equivalent of the lower beds of the Mississippi Valley section.

In 1888 Prof. N. H. Winchell[1] correlated the "Granular Quartz" of Emmons's Taconic system with the Potsdam sandstone, and mentions its westward extension in the Mississippi Valley. In another paper[2] he says that the stratigraphical relations of the "Granular Quartz" and the Potsdam of New York are the same; that the fossils are cognate with those of the Red Sandrock and with those that have been found in the Potsdam; that the Red sandrock overlies the Georgia unconformably, and that the stratigraphic relations of the Granular Quartz and the Potsdam sandstone to the granite are the same as those of a Primordial quartzite of the northwest to the granite.[3]

In summing up the opinions of the geological position of the quartzite on the eastern border of the limestone, and between the limestone and the Archean, Prof. J. D. Dana[4] says that he pointed out in 1872 that the quartzite formation in southeastern Dutchess County lay between the limestone and the adjoining Archean, and the same also occurs in other localities; that he inferred from the position and apparent conformability that its age was Potsdam or that of the lowest beds of the Lower Silurian of the region; also, that there is a quartzite west of the border of the limestone that overlies the limestone conformably, and is an independent formation and newer than the limestone. In his stratigraphic conclusions at a later date[5] the Cambrian quartzites are supposed to be those immediately adjacent to the Archean gneiss and equivalent to the Potsdam sandstone, while those that occurred at a horizon above the limestone are supposed to belong to the Hudson period.

In a paper on "The Taconic System and its position in stratigraphic geology" Prof. Jules Marcou[6] tabulates the strata referred to the Taconic system in eastern North America. In this, the Saratoga limestone, with Dikellocephalus is the summit of the series, above the Red sandrock of Vermont and the Potsdam sandstone of Keeseville, New York.

[1] A great Primordial Quartzite. Am. Geol., vol. 1, 1888, pp. 173–178.

[2] The crystalline rocks of Minnesota. General report of progress made in the study of their field relations. Statement of problems yet to be solved. Geol. and Nat. Hist., Survey of Minn., 17th Ann. Rep. for 1888, 1889, pp. 5–74.

[3] Op. cit., pp. 49, 50.

[4] On Taconic rocks and stratigraphy, with a geological map of the Taconic region. Am. Jour. Sci., 3d ser., vol. 29, 1885, p. 209.

[5] On Taconic rocks and stratigraphy, with a geological map of the Taconic regions. Part 2. The middle and northern part. Am. Jour. Sci., 3d ser., vol. 33, 1887, pp. 408–409.

[6] Am. Acad., Proc., vol. 20, 1885, p. 224.

In order, below, comes the Swanton slates, and the Phillipsburgh or Point Levis group, subjacent to which are the Georgia slates (or Olenellus zone). The Paradoxides zone, the Upper Cambrian or Eophyton sandstone of Great Bell Island, Newfoundland, and the Aspidella and Arenicolites slates of St. John's, Newfoundland, are assembled under the name "St. Albans group."

In this table, under the upper formations or "Potsdam group," there are brought together the summit of the Cambrian (the Saratoga limestone) and the base of the Cambrian (the Red sandrock of Vermont), as well as the Keeseville sandstone, which is the lower portion of the Upper Cambrian. In the "Swanton slates" (Trenton-Hudson terrane) and in the "Phillipsburg or Point Levis group," we have the Calciferous-Chazy zone. The Eophyton sandstone placed beneath the Georgia slates and the Paradoxides beds is the equivalent of the Saratoga limestone placed at the summit of the series. The Aspidella and Arenicolites slates of St. John, Newfoundland, are of pre-Cambrian age. Thus the lower or "St. Albans group" includes pre-Cambrian, Upper Cambrian, and Paradoxides zone strata.

In an article on the Winooski or Wakefield marble of Vermont, Prof. G. H. Perkins[1] described several sections of the strata containing the quarries worked for marble, one of which has a thickness of 1,410 feet, another 790, and another 710 feet. He found *Salterella pulchella* in the marble beds and considered the series to be of Primordial age.

When describing a section in the Cambrian formation of western Vermont in the town of Georgia, Franklin County, Mr. C. D. Walcott[2] stated that the section consisted of a massive belt of limestone 1,000 feet in thickness subjacent to a series of argillaceous shales, at the base of which the Olenellus fauna occurred. He also stated that this section includes in its vertical range the sections above and below Troy, N. Y., in the Hudson River Valley, and those of Newfoundland and the Straits of Belle Isle. This was followed in the same year[3] by a detailed description of the Georgia section, and another section taken near the Canadian and United States boundary in the township of Highgate. At this latter locality the Red sandrock series has a thickness of 1,170 feet; the Georgia slates a thickness of 1,000 feet. A list of the fossils occurring in the strata is given in the tabulated section. Following the nomenclature proposed by Sir William Logan, the Red sandrock series and the Georgia slates are referred to the Middle Cambrian subjacent to the Potsdam sandstone of the Adirondacks, and above the Paradoxides slates of New Brunswick.[4] In the same year he determined by paleontological evidence that the roofing slates of Granville,

[1] Am. Naturalist, vol. 19, 1885, pp. 128-136.

[2] Classification of the Cambrian System of North America., Am. Jour. Sci., 3d ser., vol. 32, 1886, p. 145.

[3] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey Bull. No. 30, 1886, pp. 13-20.

[4] Op. cit., pp. 63, 64.

Washington County, New York, which includes green and purple slates, were of the same geologic age as the Georgia slate.[1]

The extension of the "Granular Quartz" of the eastern part of New York into Dutchess County was described by Dr. W. W. Mather[2] as it occurred about Stissing Mountain. He refers to it as the "Granular Quartz" and Potsdam sandstone. Within a few years Prof. John C. Smock[3] examined the geological structure of the mountain, stating that the quartzite was unconformably superjacent to the Archean rocks; and that no fossils had been found in it. In the description of the Primordial rocks of the Wappinger Valley, by Prof. W. B. Dwight,[4] mention is made of the quartzite about Stissing Mountain, as well as the discovery by himself and Mr. C. D. Walcott of Middle[5] Cambrian remains in the arenaceous quartzite and limestones on the flanks of the mountain. It is thus correlated with the Olenellus beds of the Georgia series of Vermont.

At the Ann Arbor meeting of the American Association for the Advancement of Science, held in August, 1885, Prof. Dwight[6] announced the discovery of fossiliferous Potsdam strata at Poughkeepsie, New York. He says[7]:

> Lithologically, the rock is here very variable. It is everywhere calcareous, all its varieties effervescing freely with acids. It is also everywhere more or less arenaceous, often conspicuously so; from being compact and massive it changes to a rock fissile into thin slabs or to one splitting into the thinnest leaves, which are covered with loose sand as they decompose.
>
> This rock passes on the one hand into a smooth fine-grained, argillaceous limestone, and then into a very fissile calcareous shale or, on the other hand, into a quartzite, somewhat calcareous.

An account of the localities at which the rock occurs and a list of eleven species of fossils are given. This paper was published more in detail in the number of the American Journal of Science for February, 1886, and was accompanied by a map on which the geographic distribution of the Potsdam and related strata are shown.[8]

Prof. Dwight[9] announced in 1889 the discovery of fossiliferous strata

[1] Walcott, C. D. Cambrian age of the roofing slates of Granville, Washington County, New York. Am. Assoc., Proc., vol. 35, 1887, pp. 220, 221. (Advance sheets published 1886.)

[2] Natural Hist. of New York. Part 1. Geology of New York; Geology of the first (southeastern) district. Albany, 1843, pp. 418, 423, 436, 437.

[3] A geological reconnoissance in the crystalline rock region, Dutchess, Putnam, and Westchester Counties, New York. Thirty-ninth Ann. Rep. State Mus. Nat. Hist., 1886. pp. 166–185.

[4] Primordial rocks of the Wappinger Valley limestones and associated strata. Vassar Brothers Inst., Trans., vol. 4, 1887, pp. 206–214. Discovery of additional fossiliferous Potsdam strata and pre-Potsdam strata of the Olenellus group near Poughkeepsie, N. Y Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 27–32.

[5] Now classed as Lower Cambrian.

[6] Discovery of fossiliferous Potsdam strata at Poughkeepsie, N. Y., Am. Assoc., Proc., vol 34, 1886, pp. 204–209.

[7] Op. cit., p. 205.

[8] Recent explorations in the Wappinger Valley limestone of Dutchess County, N. Y., No. 5. Discovery of fossiliferous Potsdam strata at Poughkeepsie, N. Y. (illustrated by map, Plate VI). Am. Jour. Sci., 3d ser., vol. 31, 1886, pp. 125–133. Primordial rocks of the Wappinger Valley limestones Vassar Brothers' Inst. Trans., vol. 4, 1887, pp. 130–141, Plate 1.

[9] Recent explorations in the Wappinger Valley limestones and other formations of Dutchess County, N. Y. Am. Jour. Sci., 3d ser., vol. 38, 1889, pp. 139–153.

of the Paradoxides zone at Stissing, Dutchess County. In the limestone and calcareous shale immediately overlying the Olenellus limestone, at the south end of Stissing Mountain, he discovered a fauna that is correlated with the Middle Cambrian or Paradoxides fauna, thus establishing the middle member of the Cambrian system in addition to the Lower Cambrian and Upper Cambrian that had been previously found in this region. A plate illustrating the fauna accompanies the paper.

In 1887 Mr. C. D. Walcott[1] published a description of the fauna of the Upper Taconic of Emmons, of Washington County, New York. In this a statement of the stratigraphic position of the fauna was made, based on the correlation with the fauna of the Georgia slates of Vermont. This was followed in 1888 by an account of the discovery of fossils in the Granular Quartz near Bennington, Vermont.[2] The discovery was further described in a paper which followed on the Taconic system of Emmons,[3] where an account is given of the mode of occurrence of the "Granular Quartz" in western Massachusetts and Vermont. The quartzite is referred to the Middle (now Lower) Cambrian zone, of which the Olenellus bearing shales of the Georgia section are the type. A description is given[4] of the slates and shales, and it is stated the formations of the Upper Taconic have a thickness of 14,000 feet. In these the Olenellus fauna occurs more or less abundantly at various horizons. An examination of the sections and the fauna of the "Granular Quartz" and "Taconic" shales and slates, shows that the former is stratigraphically and faunally the equivalent of the upper part of the latter; while the "Granular Quartz" is a sandy deposit of the shore line, and the shales and slates the offshore accumulation of sediments. On the map accompanying this paper the geographic distribution of the "Granular Quartz," the "Red sandrock" of Vermont, and the Georgia slates and their southward extension as the Taconic slates is represented.

In a tabular view of the American Classification and Nomenclature, published in 1888, by Prof. Jules Marcou,[5] the Taconic system is divided into upper, middle, and lower divisions. In the upper division the Potsdam sandstone, Swanton slates, Phillipsburg and Point Levis formations are included. The middle division includes the Georgia formation and the St. John or Paradoxides zone, of New Brunswick, of Braintree, Massachusetts, and of St. Mary's Bay, Newfoundland. In the lower division are the Chuar and Grand Cañon formations of the Grand Cañon, Arizona, the sandstones of Great Bell Island, and the slates of St. John's, Newfoundland. The confusion in this table is not

[1] Fauna of the "Upper Taconic" of Emmons, in Washington County, New York. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 187-199.

[2] Discovery of fossils in the Lower Taconic of Emmons. Am. Assoc., Proc., vol. 36, 1888, pp. 212, 213.

[3] The Taconic System of Emmons and the use of the name Taconic in geologic nomenclature. Am. Jour. Sci., 3d series, vol. 35, 1888, pp. 229-242, 307-327, 394-401.

[4] Op. cit., pp. 241, 242.

[5] American Geological Classification and Nomenclature. Cambridge, 1888, p. 75.

as great as that of the 1885 paper. The Swanton slates, of Hudson age, and the Phillipsburgh and Point Levis formation of Calciferous age, are placed with the Potsdam sandstone; while in the Lower Taconic we find the sandstones of Great Bell Island, which are the geologic equivalent of the Potsdam sandstone.

During the summer of 1888 Mr. C. D. Walcott visited Newfoundland and studied[1] a section on Manuel's Brook, Conception Bay, that extends from the Archean gneiss up to the Olenellus and Paradoxides zones. In this unbroken section it was found that the Olenellus fauna occurred at the base and the Paradoxides fauna above. This necessitated a revision of the classification of the Cambrian. The Lower Cambrian with the Olenellus fauna is at the base; next the Middle Cambrian with the Paradoxides fauna, and lastly the Upper Cambrian or Potsdam zone, at the summit of which the Dikellocephalus fauna occurs. This correlation places the "Red Sandrock" series, the Georgia shale and slate series, the "Granular Quartz," and the "Upper Taconic" of Emmons beneath the Middle Cambrian or Paradoxides zone of the Atlantic coast.

In a paper on the fauna of the Olenellus zone[2] a brief historical review is given of the rocks referred to the Olenellus zone in Vermont and eastern New York, and also an account of the sections and the distribution of the fauna.

In a paper read before the Geological Society of America, December 30, 1890, Dr. J. E. Wolff noted the discovery of fossils of supposed Lower Cambrian age in the limestones of the East Rutland Valley, Vermont. The limestones rest conformably upon the basal quartzite carrying the Olenellus fauna.[3]

Potsdam sandstone.—The Potsdam sandstone of the Adirondack area appears only in a few small outcrops in Vermont and eastern New York. According to Prof. C. H. Hitchcock, there are three different localities in Vermont:[4] near the Lake Champlain shore in West Haven, Orwell, and the east part of Shoreham, in the counties of Addison and Rutland. There were none of these of sufficient importance to be indicated on the map of 1877. The outcrops in eastern New York are practically a continuation of the Vermont exposures. They occur in the vicinity of Whitehall, New York, and south to Fort Ann, Washington County.

In the review of the references made to the "Red Sandrock" series of Vermont, frequent mention has been made of its correlation with the Potsdam sandstone as well as of the correlation of the "Granular Quartz" with the Potsdam sandstone of the Adirondack area. As now known, these two belong to distinct geological horizons, as claimed by

[1] The stratigraphical succession of the Cambrian faunas of North America. Nature, vol. 38, 1888, p. 551.

[2] Walcott, C. D. The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rep. U. S. Geological Survey, 1890, pp. 509-763.

[3] Bull. Geol. Soc. America, vol. 2, 1891, pp. 334-337.

[4] Hypozoic and Paleozoic rocks. Report on the geology of Vermont, vol. 1, 1861, p. 265.

Dr. Emmons in 1842. As the typical Potsdam sandstone in this district is an extension of the sandstone of the Adirondack sub-area within its borders, the review of its literature will be united with that of the typical Potsdam of the Adirondack district.

The occurrence of the Upper Cambrian or Potsdam zone as distinct from the Georgia slate and "Red Sandrock," is spoken of in the description of the section crossing the town of Georgia, Vermont,[1] where mention is made of the discovery of a fauna closely related to that of the Upper Cambrian. This is the same horizon referred to on page 17, par. 14.

In a description of a section crossing the typical Taconic area of eastern New York and western Massachusetts by Mr. C. D. Walcott,[2] the typical Potsdam sandstone is not recognized. It is stated that certain shales designated as Terrane No. 2, may represent the Potsdam terrane, or it may be represented by the lower part of the limestones of Terrane No. 3, or the upper part of the Quartzite of Terrane No. 1.

CANADIAN EXTENSION.

The Canadian extension of the Northern Appalachian District is from the United States boundary northeast to the vicinity of Point Levis, Quebec, on the western side of the extension of the Green Mountain or Sutton Mountain anticlinal, and from Quebec down the south shore of the St. Lawrence River to Cape Rosier, Gaspé. On the eastern side of the anticlinal the supposed Cambrian rocks of New Hampshire, crossing the southeastern portion of the province of Quebec, to the Maine boundary, are also included.

The first notice of the rocks, subsequently referred to the Cambrian in the vicinity of Quebec, was by Dr. J. J. Bigsby.[3] He divided the strata into three series. First, the slaty series, composed of slates and grauwacke, occasionally passing into a brown limestone, and alternating with calcareous conglomerate in beds, some of which are charged with fossils; second, the limestone series; third, gneiss. In the beds of this conglomerate on the south side of the St. Lawrence he noticed the presence of trilobites, encrinites, corallines, and other fossils. He considered them above the supposed equivalent of the Carboniferous limestone of the English geologists.

In his description of the succession of the strata at Montmorenci Falls, Dr. E. Emmons states that the rock forming the falls is a gneiss, and in the figure illustrating the section the Potsdam sandstone is shown resting unconformably upon the gneiss and subjacent to the Trenton limestone, but with a conglomerate between it and the Trenton limestone.[4] He subsequently correlated the sandstones that are extensively

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[1] Walcott, C. D. Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, p. 19.

[2] The Taconic System of Emmons and the use of the name Taconic in Geologic nomenclature. Am. Jour. Sci., 3d ser., vol. 35, 1888, p. 240.

[3] On the geology of Quebec and vicinity. Proc. Geol. Soc., London, vol. 1, 1827, p. 37.

[4] Geology of the Montmorenci. The American Magazine, vol. 1, 1841, p. 148.

used in the construction of buildings, both public and private, and in the fortifications of Quebec, with the gray sandstone terminating the Lorraine section of Jefferson County, New York.[1] These sandstones were subsequently named the Sillery sandstones by Sir W. E. Logan, who at first followed the correlation made by Dr. Emmons, and referred them to the Lorraine shales or Hudson River group.

In the report of progress for 1843, of the Geological Survey of Canada,[2] an account is given in a very general manner of an exploration by Sir W. E. Logan of the rocks on the south shore of the lower St. Lawrence, near Cape Rosier; and they are further described in the report for 1844, as seen from Cape Chat toward Cape Rosier, going down the river. This is followed in the report for 1847–'48[3] by a description of the rocks of the extension of the Green Mountains into Canada, and the strata upon the west which are now supposed to be of Cambrian age. They were then referred to the Hudson River group, with the possible addition of the Shawangunk conglomerate. In their extension it is stated[4] that these recognized rocks of the Hudson River group have a continuous run from Lake Champlain along the south bank of the St. Lawrence to Cape Rosier.

In a report on the rocks on the south side of the St. Lawrence, in the report of progress for 1849–'50,[5] a preliminary description is given of five masses of rock met with. They include the dark gray slates, gray, green, and occasionally red shales, hard sandstones, and a red and green shale that were subsequently largely referred to the Quebec group by Sir Wm. Logan, and now, in part, to the Cambrian by Dr. R. W. Ells. In a report for 1852–'53[6] a description is given of the strata on the north shore of the St. Lawrence between Cap Rouge River and Quebec. At the base there is a succession of hard, sandy layers, with softer shales that extend along the river shore for some distance, and then thick beds of sandstone separated by thinner bands of red and green shales. The red and green shales have a great thickness further down the river. Mr. Logan says that it would be hazardous to pronounce with confidence what it is, from the probably contorted condition of the strata. In regard to the sandstones, however (supposed to represent the Oneida conglomerate), no folds have been detected. They are thought to be about 900 feet in thickness. This is the first preliminary description of the sandstones and shales that were subsequently referred to the Lauzon and Sillery series of the Quebec group.[7]

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[1] Geology of New York, part 2, comprising the survey of the 2d geological (northern) district. 1842, p. 125.

[2] [Account of the general structure of an extended area in North America.] Geological survey Canada, report of progress for 1843. 1845, pp. 6–13 [Documentary Edition.]

[3] Logan, W. E. Geological survey Canada, report for progress 1847–'48. 1849, pp. 2–17 [Documentary Edition.]

[4] Op. cit., p. 17.

[5] Logan, W. E. [Report on rocks on south side of the St. Lawrence.] Geological survey Canada, report of progress for 1849–'50. Toronto, 1850, pp. 32–33.

[6] Logan, W. E. [Exploration on the north side of the St. Lawrence, between Montreal and Cape Tourmente.] Geological survey Canada, report of progress for 1852–'53, 1854, pp. 5–74.

[7] Op. cit., p. 34.

Dr. J. J. Bigsby,[1] in describing the geology of Quebec and its environs, states that the Potsdam sandstone only occurs distinctly, as far as yet known in the neighborhood, at the Falls of Montmorenci; but at Jeune Lorette there are traces of it. He says that—

> The sandstone of Montmorenci has been unhesitatingly declared to represent the Potsdam rock by the New York State geologists, as well as by Sir Charles Lyell and Mr. Logan. With these high authorities I have only to concur. Its geological position is that of the Potsdam sandstone; but its aspect and mineral condition are very different from that of Lake Superior and of the Thousand Islands, near Kingston, Upper Canada.[2]

In describing the geology of the Falls of Montmorenci, he says:

> The sandstone is plentiful on the east bank of the river above the bridge, and is a yard or more thick, as well as on the west bank both above and below the bridge; the plane of contact with the enclosing rock being clean and abrupt. It is white, brownish red or bright green, in well defined layers. Bowlders of the gneiss occur in it.[3]

A section is introduced in which the Potsdam sandstone is represented as beneath the Trenton limestone, and with the latter resting unconformably against the gneiss. It is stated that the Potsdam sandstone at this place has not yet been found to contain organic remains.

Dr. Bigsby described the north shore of the St. Lawrence, from Quebec to Cap Rouge, as consisting of frequent alternations of gritty gray sandstone, and red, brown, and black clay shale. On the south side of the St. Lawrence, near Point Levis, the rocks are stated to be formed of minute alternations of clay-slate, coarse sandstone, calcareous and other conglomerates that were met with on the north side of the river.[4]

In the report of progress for 1852–'53, published in 1854, Sir W. E. Logan[5] describes the red and green shales and green sandstones from Cap Rouge to Quebec, considering them to belong to the Hudson River group of the New York section.

In a description of the Silurian rocks of the environs of Quebec, the same writer[6] states that the only exposure of the Potsdam formation in the vicinity of Quebec is at Lorette, where the sandstone is 7 metres in thickness and without the fossils which characterize the formation in other parts of Canada. The shales and sandstone of the Sillery formation are stated to correspond to the conglomerates of the Oneida formation of the New York geologists. This same view was expressed in the geological essay prepared for the Paris Exposition of 1855 by Messrs. Logan and Hunt.

From the collections of fossils made by the Geological Survey of Canada at Point Levis during the years 1856–'57, Mr. E. Billings, paleon-

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[1] On the geology of Quebec and its environs. Quart. Jour. Geol. Soc., vol. 9, 1853, pp. 82–101.

[2] Op. cit., p. 84. [3] Op. cit., p. 88. [4] Op. cit., pp. 94, 95.

[5] (Exploration on the north side of the St. Lawrence, between Montreal and Cape Tourmente.) Geol. Surv. Canada, report progress for 1852–'53, 1854, pp. 33, 34.

[6] (Sur la formation silurique des environs de Québec.) Soc. géol. France, Bull., 2e sér., vol. 12, 1855, p. 505.

tologist of the survey, decided that the rocks there and those which had been associated with them by Sir William E. Logan belonged at the base of the Lower Silurian and not at the summit, as had hitherto been held. These conclusions were announced by Logan in a letter to Mons. J. Barrande published in 1860.[1] In this letter the whole Quebec group, from the base of the magnesian conglomerate with their accompanying magnesian shales, to the summit of the Sillery sandstone, is stated to have a thickness of perhaps from five to seven thousand feet. It appears to be a great development of strata at about the horizon of the Chazy and Calciferous of the New York section.

He says he is not prepared to state that a typical form of the Potsdam sandstone is present where the shales are in greatest force.

Neither am I prepared to assert its absence, as there are in some places masses of granular quartzite, not far removed from the magnesian rocks of the Quebec group, which require farther investigation; but, from finding wind-mark and ripple-mark on closely succeeding layers of the Potsdam sandstone where it rests immediately upon the Laurentian series, we know that this arenaceous portion of the formation must have been deposited immediately contiguous to the coast of the ancient Silurian sea, where part of it was even exposed at the ebb of tide. Out in deep water the deposit may have been a black, partially calcareous mud, such as would give the shales and limestones which come from beneath the Quebec group.

In Canada no fossils have yet been found in these shales, but the shales resemble those in which *Oleni* have been found in Georgia (Vermont). These shales appear to be interposed between eastward dipping rocks equivalent to the magnesian strata of the Quebec group, and they may be brought up by an overlapping anticlinal or dislocation. We are thus led to believe that these shales and limestones, which may be subordinate to the Potsdam formation, will represent the true Primordial zone in Canada.[2]

In 1863 Sir Wm. E. Logan published his great résumé of the work done by the Geological Survey of Canada from its commencement to 1863.[3] He describes the northward extension of the Georgia series and Red Sandrock of Vermont into Canada, stating that they had been traced but a short distance when they become faulted out and replaced by a later formation.[4]

The Sillery shales and sandstones, as well as the conglomerate beds of Point Levis, Quebec, are described in detail and assigned to about the horizon of the Calciferous-Chazy formations of the New York section. The Levis and Sillery formations are referred to the Quebec group, and the latter series is traced southwestward along the western base of the Sutton Mountain range. The Levis formation is divided into seventeen parts, consisting of alternating calcareous shales, argillaceous shales, limestone conglomerate, and gray sandstone. The upper beds consist of

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[1] Logan, W. E. Remarks on the fauna of the Quebec group of rocks and the Primordial zone of Canada. Canadian Naturalist, vol. 5, 1860, p. 475; vol. 6, 1861, pp. 106–120; Am. Jour. Sci., 2d ser., vol. 31, 1861, pp. 216–220. Remarques sur la faune des roches du groupe de Québec et sur la zone primordiale du Canada, Soc. géol. France, Bull., 2e sér., vol. 18, 1861, pp. 309–314.

[2] Am. Jour. Sci., 2d ser., vol. 31, p. 219.

[3] Geological Survey of Canada. Report of progress from its commencement to 1863. Montreal, 1863, pp. 983.

[4] Op. cit., p. 285.

red and green shales with thin layers of gray sandstone or quartzite in which Lingula and Obolella were found. At the summit of the red and green shales, interstratified sandstones appear and succeed the shales, with a thickness of about 2,000 feet, forming the Sillery division of the Quebec group (p. 232). Subsequently he[1] divided the Quebec group into three parts: Levis or lower; Lauzon or middle; and Sillery or upper. The Lauzon or middle division embraces the red, green, and purple slates of the section above and below Quebec and on the island of Orleans. The only fossils known were *Obolella pretiosa* and fragments of Lingula. The sandstones and accompanying shales of the original Sillery were referred to the Sillery or upper division with the exception of those separated to form the Lauzon. The Levis, or lower division, was distinguished by its yellow, dark and black shales and the presence of numerous graptolites and Calciferous-Chazy fossils.

Up to this time none of the rocks of the Quebec group had been referred to the Cambrian system, or to an equivalent formation, beneath the Calciferous zone of the New York series. Messrs. Billings, Hall, and Barrande spoke of the Primordial character of some of the fossils of the Point Levis conglomerate, but the series as a whole was referred by Mr. Logan to the Calciferous-Chazy zone.

Sir W. E. Logan also described the conglomerate beds of Bic Harbor and Trois Pistoles on the shore of the St. Lawrence River, where bowlders of limestone were found containing fossils of the Olenellus fauna.[2] The shales in which the bowlders occur are supposed at the present time to be of Upper Cambrian age.

The report on the south shore of the St. Lawrence River below Quebec, by Mr. James Richardson, contains the information that another series of rocks came to the surface, differing from those farther to the west. He says:

> These rocks have heretofore been classed with those of the Quebec group, but they appear to underlie them unconformably, and being in some places marked by fossils which Mr. Billings considers to be of Potsdam age, they are now placed in the upper part of the Potsdam group.[3]

They consist at the summit of a light drab quartz rock with intercalated beds of conglomerate holding limestone pebbles in an arenaceous matrix, the whole forming a series 600 feet in thickness. This is superjacent to a series of gray sandstones and interstratified shales with a thickness of 700 feet in which near the base a conglomerate occurs; below this a third division of gray limestones and limestone conglomerate occurs in beds of from 1 to 6 inches thick. A species of Salterella was observed in the limestone, and a species of Archæocyathus in the shales. The third series is assigned a thickness of 700 feet; and the

[1] Logan, W. E., Report of, for 1866. Geol. Survey Canada, report of progress from 1863 to 1866, 1886, p. 4.

[2] Geological Survey of Canada, report of progress from its commencement to 1863. Montreal, 1863, p. 260.

[3] Report on the south shore of the St. Lawrence, below Quebec. Geol. Survey Canada, report progress for 1866, to 1869, 1870, p. 120.

entire section 2,000 feet. A number of species of the Olenellus fauna were found in the pebbles of the conglomerate near St. Denis Station on the Grand Trunk Railway, and also at Bic Harbor.[1]

The reference by Mr. Richardson of the rocks mentioned in the preceding paragraph to the Potsdam zone is objected to by Dr. A. R. C. Selwyn.[2] He says that after examining a considerable portion of these supposed Potsdam rocks, there is in his opinion at present no sufficient evidence, either paleontological, stratigraphical, or mineralogical, for separating this belt from other very large areas of the Quebec group, hitherto assigned, the larger part to the Lauzon, but in some places also to the Levis and Sillery formations. He states that on any map now published it is best to include the whole of the rocks of this great fossiliferous belt in one group, as the data are insufficient to separate the Potsdam zone from the other rocks of the Silurian. The group referred to is No. 1,[3] the Lower Silurian. The second is "the volcanic group, probably Lower Cambrian." Group No. 2 is described as consisting of a great variety of crystalline, subcrystalline, and altered rocks, including red, gray, and greenish siliceous slates and argillites, great masses of diorite, epidotic and serpentinous breccias and agglomerates, etc.[4] Of the age of this group he says:

> If fossils are found I should expect them to indicate a lower horizon than the Levis formation, probably not far removed from that of the St. John group and Atlantic coast series of Nova Scotia, or Lower Cambrian.[5]

This series forms part of the Sillery formation of Mr. Logan.

In speaking of the reference of the Volcanic group to the Cambrian Dr. Selwyn quotes from the paper read before the Royal Society of Canada in May, 1882, as follows:[6]

> The upper portion of this series was designated "the volcanic belt" from the association with it, especially on the southeast side of the main axis, of a great variety of what were considered to be altered eruptive and irruptive rocks, but whether the strata forming this igneous belt are more nearly allied to the Lower Cambrian than to the Upper Huronian is not, fossils being absent, easily determined.

On the map of the Dominion of Canada geologically colored from surveys made by the Geological Corps from 1842 to 1882, under the direction of Dr. Selwyn, there is quite a broad belt of rocks colored Cambrian that extends from Cape Rosier on the Gaspé Peninsula southeasterly along the shores of the St. Lawrence to Point Levis, Quebec. From Point Levis it turns more to the south, extending along the western margin of the Archean anticlinal to Mississquoi Bay, at the foot of Lake Champlain. A narrower strip is represented as extending

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[1] Op. cit., p. 130.

[2] Report of observations on the stratigraphy of the Quebec group and the older crystalline rocks of Canada. Geol. Survey Canada, report of progress, 1877-'78, 1879, p. 4A. Can. Nat., new ser., vol. 9, 1879, pp. 17-31.

[3] Op. cit., p. 3A.

[4] Op. cit., p. 5A.

[5] Op. cit., p. 6A.

[6] Notes on the geology of the southeastern portion of the Province of Quebec. Geol. Survey Canada, report of progress, 1880-'81-'82, 1883, p. 2A.

from the north end of the Archean anticlinal or axis, along the eastern side of the latter to Lake Memphremagog. A smaller area is colored Cambrian in the southeastern part of the Province of Quebec, near the Maine boundary, at the northeastern corner of New Hampshire. In a map of a part of the Province of Quebec published in 1887, the distribution of the Cambrian about the Sutton Mountain anticlinal, or the Archean axis, extending north from the Green Mountains, is given more in detail than in the map of 1882.

In the table of the geological formations, accompanying Macfarlane's American Geological Railway Guide, Dr. T. S. Hunt places the following groups in the Lower Cambrian, in descending order:[1]

Potsdam.
Sillery.
Acadian (Menevian).
Lower Taconic.

This same nomenclature is followed in the list of the geological formations of Canada on page 52.

In a report on the explorations and surveys in the interior of the Gaspé Peninsula, Mr. A. P. Low[2] states that the Cambrian system is represented along the Ste. Anne River and along the east and west flanks of Table-top Mountain, by gray and black shales, limestones, and limestone-conglomerates of the Levis formation. He says:

> These form but a small part of the great area of these rocks, which stretches from Cape Rosier along the south side of the Gulf of St. Lawrence to Quebec and thence through the Eastern Townships into the United States.

In describing the Silurian rocks on a previous page[3] he says the limestones rest in places upon a pinkish or gray sandstone of no great thickness, which is seen on the Ste. Anne and Matane Rivers and on the west side of Lake Matapedia. This sandstone is supposed to be the lowest part of the system.

In his surveys of the eastern portion of the Province of Quebec, Dr. R. W. Ells[4] included in the Cambrian the extension to the northeast of those rocks described as Cambrian by Dr. Selwyn. As described in the reports of the Geological Survey of Canada for 1886, 1887, they consist for the most part of hard quartzite interstratified with mica schists and black slates. Dr. Ells also referred the trappean rocks of Broughton to the Cambrian. All of this series, as described by Dr. Selwyn and Dr. Ells, is unconformably overlapped by the Sillery red slates, conglomerates, and sandstones. It is not improbable that some of the strata referred to the Lower Cambrian may prove to belong to that system of rocks, but in the absence of fossils it is very uncertain whether the strata

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[1] Dominion of Canada. (Geological Formations.) Macfarlane's Am. Geol. R. R. Guide, 1879, p. 51.

[2] Explorations and surveys in the interior of the Gaspé Peninsula, 1883. Geol. Surv. Canada, 1882-'83-1884, p. 14F.

[3] Op. cit., p. 12F.

[4] Second report on the geology of a portion of the Province of Quebec. Geological Survey Canada, new ser., vol. 3, 1889, pp. 1K-120K.

under consideration should be referred to the Cambrian or to some of the pre-Cambrian series of rocks. In a review of Dr. Ells's work by Mr. C. D. Walcott[1] it is suggested that from the occurrence of Lower Cambrian fossils (the Olenellus fauna) in grayish limestone interbedded with purple, green, and black slates, in Washington County, New York, the rocks containing them occupy a similar stratigraphic position to those described by Dr. Ells in the Canadian section. Dr. Ells considered that portions of the strata referred to the Lower Cambrian are very much like those of the gold series of Nova Scotia, while, in part, they resemble the Cambrian of New Brunswick. Stratigraphically they occupy a position between the chloritic and micaceous schists of the Archean and the superjacent Sillery.[2]

The Canadian extension of the rocks referred to the Cambrian System by Prof. C. H. Hitchcock in New Hampshire is represented upon the geological map of Canada, published by Sir William E. Logan in 1864 as the Quebec group, thus being identified with the Quebec group series upon the western side of the Gaspé limestone series. References have been made to them by various authors who have written upon the geology of the townships of eastern Quebec, but not in a manner to distinguish the strata now referred to the Cambrian.

When describing this belt of rocks in 1886, Dr. R. W. Ells[3] states that Prof. Hitchcock has referred a belt composed principally of blackish, wrinkled slates and schistose sandstones, which form a ridge extending northeast from the vicinity of Canaan, between Hall's and Indian streams to the Quebec boundary, to the Lower or Cambrian system. The strata present a well defined anticlinal structure, which is recognized in the adjoining townships of Emberton and Ditton in Quebec, and northeast past the outlet of Lake Megantic and onward to the Maine boundary. The slates are penetrated by quartz veins, which in places have proved more or less auriferous.

> In character and aspect the gold-bearing slates of Ditton and the area to the northeast almost exactly resemble, as already intimated, the rocks of the Nova Scotia gold series.[4]

As far as known no fossils have been found in this series to identify the horizon, in either New Hampshire, Canada, or Maine. This is true also of the second area inclosed on either side of the Stoke Mountains and the Sherbrooke anticlinal. The strata forming the western area west of Sutton Mountain anticlinal have already been mentioned.

The presence of rocks of supposed Cambrian age is indicated on the geological map of Canada, published in 1882, on the eastern side of Hudson's Bay, near the mouth of Big Whale River, and in the vicinity

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[1] A review of Dr. R. W. Ells's second report on the geology of a portion of the Province of Quebec, with additional notes on the "Quebec group." Am. Jour. Sci., 3d ser., vol. 39, 1890, p. 101-115.

[2] Ells, R. W. Second report on the geology of a portion of the Province of Quebec. Geol. Surv. Canada, vol. 3, 1889, p. 87K.

[3] Report on the geology of a portion of the eastern townships of Quebec. Geol. Surv. Canada, 1886, new ser., vol. 2, 1887, pp. 24J, 25J.

[4] Op. cit., p. 25J.

of Richmond Bay. The observations upon which this identification is based were made by Dr. Robert Bell, who explored the east coast of Hudson Bay in 1877. He names the series the Manitounuck group, correlating it with the Nipigon series north of Lake Superior. By combining the sections of slates and sandstones he obtains a thickness of 2,800 feet for the entire section on this part of the coast.[1]

References to the occurrence of rocks of supposed Cambrian age on Lakes Mistassini and Mistassinis are made by Mr. A. P. Low in his report on the Mistassini expedition. The limestones, owing to the absence of any fossil remains, have been referred to the Cambrian horizon on account of their lithologic resemblance to Cambrian rocks of the east side of James Bay.[2]

A map of Lake Mistassini accompanies the report, on which the boundary between the Laurentian and supposed Cambrian formations is traced.

Dr. George M. Dawson tabulates the formations; he refers to the Cambrian in Ontario and Quebec as follows:[3]

3*b*. Sillery and Levis.
3*a*. Calciferous.
2*c*. Upper and Lower Potsdam.
2*b*. Keweenian.
2*a*. Animikie.

SOUTHERN APPALACHIAN DISTRICT.

The Southern Appalachian district includes the outcrops of strata referred to formations of the Cambrian group in northern and central New Jersey, southeastern and southern central Pennsylvania, western Maryland, Virginia, and North Carolina, eastern Tennessee, northwestern Georgia, and northeastern Alabama.

NEW JERSEY.

In a table showing the geologic succession of the lower Secondary or Appalachian rocks as they occur in New Jersey, Prof. Rogers[4] places as No. 1 of the series of formations a compact and very quartzose sandstone, of light bluish gray color, approaching to white. He discovered the formation in only three or four small isolated areas along the western outcrops of the Primary rocks. Prof. Cook refers to this sandstone lying upon the gneiss as the "Potsdam sandstone" as known in New York. It is only a few feet in thickness.[5] In a subsequent report a sketch is given of a section at Franklin Furnace, which shows the sand-

[1] Report on an exploration of the east coast of Hudson's Bay, 1877. Geol. Surv. Canada, Rep. Prog. for 1877-78. 1879, p. 17C.

[2] Report of the Mistassini Expedition, 1884-'85. Geol. and Nat. Hist. Surv. Canada, new ser., vol. 1, 1885, p. 31D.

[3] Macfarlane James: An American Geological Railway Guide. Second ed., 1890, p. 58.

[4] Description of the Geology of the State of New Jersey, being a final report. Philadelphia, 1840, p. 45.

[5] Report of Prof. George H. Cook upon the geological surveyof New Jersey, and its progress during the year 1863. 1864, p. 6, par. 9.

stone resting unconformably on the gneiss and passing conformably beneath the superjacent Magnesian limestone.[1] There are also doubtfully included under the "Potsdam sandstone" several outcrops of quartzite and conglomerate, and the conglomerates and sandstones of the Green Pond Mountain range. On the large geological map of northern New Jersey, published in 1874,[2] the "Potsdam sandstone" includes shales, sandstones, slaty grits, quartz rock, and the Green Pond Mountain conglomerate; this entire series is represented by one color, extending on the trend of the Green Pond Mountain range from the New York boundary southwesterly into the central portion of Morris County.

In the annual report for 1884 the Green Pond Mountain rocks are included with the "Devonian and Silurian rocks."[3] This leaves the so-called "Potsdam sandstone" as the only Cambrian formation within the State. The following year reference is made by Prof. Cook[4] to the contact phenomena with the Paleozoic rocks. In New Jersey one point is at "Owen's Island," in Sussex County, two-thirds of a mile south of the State line, as described by Prof. Rogers in his report of 1836. At this point the sandstone dips 20° northwest, and the Archean 70° to the southwest. Near Franklin Furnace a similar unconformity occurs, and the same conditions appear persistent along the entire northwestern margin of the highlands in New Jersey, though no other actual contact has been observed along this line.

In a paper presented to the Geological Society of America December 31, 1890, Prof. Frank L. Nason stated he had found fossils of Lower Cambrian age in the quartzite resting on the pre-Paleozoic rocks at Hardistonville, Sussex County, New Jersey, and at Franklin Furnace, in the same county. He also discovered fragments of a species of Kutorgina in the superjacent limestone.[5]

DELAWARE.

In the northwestern corner of the State of Delaware there is a triangular area of sandstone referred to the "Potsdam" sandstone by Mr. Fred. D. Chester. He states that it extends into Pennsylvania, and is best exposed beyond the State line.

At Nivin's limestone quarry a mass of quartzite forms what is clearly an anticlinal fold, over which is a corresponding anticlinal of Magnesian limestone.[6]

The extension of this sandstone into Pennsylvania is shown upon the map of Chester County, Pennsylvania, where it occurs in the township of London.

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[1] Geology of New Jersey. Newark, 1868, p. 72.

[2] Cook, Geo. H. Geological Survey of New Jersey. (Map of) northern New Jersey, showing the iron-ore and limestone districts. 1874, in two sheets.

[3] Cook, Geo. H. Geological Survey of New Jersey. Annual report of the State geologist for the year 1884. 1884, p. 29.

[4] Contact phenomena with the Paleozoic rocks. Geological Survey of New Jersey. Annual Report of the State Geol. for 1885. Trenton, 1885, pp. 53-55.

[5] Unpublished.

[6] Preliminary notes on the geology of Delaware—Laurentian, Paleozoic, and Cretaceous areas. Phila. Acad. Sci. Proc., vol. 36, 1884, p. 248.

PENNSYLVANIA.

In the second annual report of the State geologist of Pennsylvania, Prof. H. D. Rogers summarizes in a table the order of stratification, the geographical position, composition, and thickness of the lower Secondary formation in Pennsylvania, east of the Susquehanna River.[1] The description of formation No. I, or the sandstone of the South Mountain, is as follows:

In the ascending order, the first formation which we meet with, reposing on the primary rocks of the South Mountain, * * * is a remarkably compact and rather fine-grained sandstone, usually white or of some light shade of gray. * * * The formation ranges, according to my present belief, from the Delaware, at Easton, more or less interruptedly across the State to the Maryland line, pursuing an undulating, irregular belt, coinciding with the northern and northwestern side of the chain of hills most commonly called in this State the South Mountain, the prolongation of the Highlands of New York and of the Blue Ridge of Maryland and Virginia.[2]

It contains, as far as yet examined in Pennsylvania, very few organic remains, the best defined species discovered in it being a marine plant, indicative of the oceanic position into which the materials of this stratum were originally swept.

I have satisfied myself that this rock is not confined to the Appalachian region of Pennsylvania, but that it possesses a prodigiously extensive range, not only through Maryland and Virginia, but in a contrary direction through New Jersey and New York, and I believe beyond those limits, constituting everywhere the lowermost formation of the widespread Secondary strata which it encircles in a somewhat interrupted belt, following the primary boundary of these rocks from Tennessee to Lake Champlain, and thence northwestward to the northern shores of Lake Huron and Lake Superior.[3]

Prof. Rogers recognized the sandstone at many points in New Jersey and New York, and considered it identical with the formation in northeastern New York, described by Prof. Eaton under the name of Calciferous sandrock,[4] and states that it is probably the same stratum which Dr. Bigsby has mentioned as existing on the north side of Lake Huron.[5] In the table showing the order of stratification, formation No. I is assigned a probable thickness of 1,000 feet.

A description is given in the third report[6] of the geographic distribution of the sandstone as it occurs in the various counties of the southeastern portion of the State.

In Northampton and the eastern corner of Lehigh the sandstone * * * is subordinate in importance to the gneiss and other primary rocks on which it rests.[7]

[1] Second Annual Report on the Geological Exploration of the State of Pennsylvania. Harrisburg, 1838, oppo. p. 19.

[2] Op. cit., p. 21.

[3] Op. cit., pp. 22, 23.

[4] The Potsdam sandstone was not differentiated from the calciferous sandrock by Eaton. He included the sandstone and the superjacent calcareous sandstone, under the common name of calciferous sandrock, as one formation.

[5] Op. cit., p. 23.

[6] Rogers, Henry D. Third Annual Report of the Geological Survey of the State of Pennsylvania. Harrisburg, 1839, pp. 14-16.

[7] Op. cit., p. 15.

In the fourth report[1] formation No. I is spoken of as the extensive slate and sandstone formation constituting "The lowest member of our older Secondary or Appalachian rocks." The slates of the Pigeon Hills are referred to the lowest Secondary formation of the State, and the strata comprise different portions of formation No. I, consisting of dark slate and a light colored sandstone. The stratigraphic succession of the various beds referred to formation No. I of South Mountain, southwest of the Susquehanna, is given in detail. The intercalated limestone bed is considered to belong to the upper part of the division,[2] and there is a bluish slate interstratified in the sandstone. In the report of the following year[3] the geographical range of the rocks of the South Mountains from the Delaware to the Schuylkill is outlined. The white and gray sandstone of formation I is not a continuous stratum in the belt of the South Mountains where they traverse Northampton and Lehigh Counties, but it is very probable it occurs at the base of all the primary ridges, buried under a deep covering of loose diluvium.[4] Mention is made of its various points of outcrop and its occurrence in Berks County, and many details are given of the distribution of the sandstone and the mode of its occurrence in relation to the subjacent primary rocks.

In his grand summary of the geology of Pennsylvania, Prof. H. D. Rogers gives a synoptic description of the Primal series or "Potsdam" sandstone of New York, as follows:[5]

The Primal series, under its fullest and most diversified condition, or that which it wears in the Appalachian chain in Pennsylvania, Virginia, and Tennessee, is a thick fourfold group composed of two slates and two great arenaceous rocks in alternation: (1) The highest or Primal newer slate is a greenish and brownish talco-argillaceous slate, sometimes very soft and shaly. In Pennsylvania it has a thickness of about 700 feet. (2) The next, the Primal white sandstone, is a compact, white and yellowish, fine-grained, vitreous sandstone, often containing specks of kaolin. This rock, which is of easy recognition and of an immense range, has a thickness in some parts of the Blue Ridge of Virginia of at least 300 feet. This is the Potsdam sandstone of New York. (3) The Primal older slate is a brown and greenish gray sandy slate, containing much feldspathic and talcose matter. It has hitherto disclosed no fossils. The thickness of this bed in the Atlantic slope in Pennsylvania is several hundred feet, and in the Blue Ridge of Virginia is not less than 1,200 feet. (4) The Primal conglomerate, the lowest of the yet distinctly recognized formations of the Primal series, is a heterogeneous conglomerate of quartzose, feldspathic, and slaty pebbles, imbedded in a talco-silicious cement. The thickness of this rock in Virginia and Tennessee, north of which it has not been discovered, is at least 150 feet.

In New York and the Northwestern States this series presents a materially different type, the Primal white sandstone being almost the sole representative.

Thickness.—The thickness of the entire series is considerably more than 2,000 feet.

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[1] Rogers, H. D. Fourth Annual Report on the Geological Survey of the State of Pennsylvania. Harrisburg, 1840, pp. 33–35.

[2] Op. cit., p. 41.

[3] Rogers, H. D. Fifth Annual Report on the Geological Exploration of Pennsylvania. Harrisburg, 1841, pp. 16–26.

[4] Op. cit., pp. 26, 27.

[5] The Geology of Pennsylvania. Philadelphia, 1858, vol. 2, pp. 751, 752.

Geographical distribution.—In its geographical distribution this primal series ranges coextensively, or nearly so, with the other formations of the older Paleozoic division to be presently traced; that is to say, it shows two great continuous outcrops, one stretching southwest along the Appalachian chain and the other west from the St. Lawrence, through New York, Canada West, Northern Michigan, Wisconsin, and Minnesota beyond the Mississippi. It is probably likewise brought to the day in the anticlinals of Missouri, Arkansas and Texas, which elevate the gneissic strata on which it rests.

The only fossils found were a peculiar fucoid in the newer Primal slate, annelid borings in the Primal white sandstone, "one or two brachiopodus mollusks, especially lingula. In Wisconsin and other northwestern localities this formation contains several species of trilobites, and abounds in lingulæ, obolus, and an orbicula."[1] Trilobites were also found on Lake Champlain.

Under the heading of "Equivalents" is the following:

These strata seem to be on the horizon of the lower Festiniog group or lingula flags of England, and equivalent to the obolus and lingula sandstone of Sweden and Russia. They represent, too, the primordial zone of Bohemia, and are therefore on the horizon of the very dawn of discovered life.[2]

This summary of Prof. Rogers gives his information respecting the Primal series in Pennsylvania, Virginia, and Tennessee up to the time of publication. Under the heading of "Depositions and disturbances of the Primal period," he discusses the probable conditions under which the sediments were deposited, and sums up the period as one of vast duration; "an enormous age of quiet sedimentation with almost no life in the wide turbid sea."[3] The paleontological record for the Primal series is given a very few words: Three or four fossils known in the white sandstone, and a vaguely defined plant in the subjacent shale in the Appalachian region. But in Wisconsin, the white sandstone imbeds, on a succession of thin floors, some seventeen more species. Two of these are identical with those of the eastern outcrop, so the total number of species known at that date was eighteen. The distribution of the Primal series in Pennsylvania is tabulated in volume I[4] and local details are given in the description of the various counties in which outcrops of the rocks and slates occur.

On an accompanying geological map the geographic distribution of the Primal series is delineated. As a whole it extends with many interruptions diagonally across the southeastern portion of the State, from South Mountain in Adams County to Northampton and Bucks Counties, on the Delaware River.

Two maps of sections also accompany the report of 1858. On the line of section No. 2, the Primal is represented, in Northampton County, at Frey's Run and along Durham Creek to the Delaware River. At Attleborough, in Bucks County, a synclinal of the Primal sandstone is represented as occurring in the midst of the older Primal slate.

[1] Op. cit., p. 751. [2] Op. cit., p. 752. [3] Op. cit., p. 781. [4] Op. cit., pp. 122, 123.

Section No. 3 crosses the Primal slate in Berks County and represents the Primal sandstone dipping southeasterly from the Primal slate forming Mount Pleasant. The Primal sandstone is shown again in Montgomery County at Barren Hill and it is placed in the midst of "Primal mica slate."

Section No. 4, in crossing Lancaster and Chester Counties, passes through the Primal series at Neversink Hill, near Reading, and also at Welsh Mountain, where the Primal sandstone is represented as forming a low anticlinal.

On the line of section No. 5, the Primal sandstone occurs to the west of the Primal slates and gneiss that form Millbough Hill in Berks County. In Lancaster County, on the line of the same section, the sandstones occupy the south end of Welsh Mountain. In Mine ridge the Primal slates and gneiss are represented as much distorted, while the sandstone forms an anticlinal and synclinal axis.

Sections Nos. 7 and 8 cross the South Mountain in Adams and York Counties; and the entire section of the mountain is represented as Primal, as stated in the text. The rocks of Pigeon Hills, to the southeast in section 7, are also referred to the "Primal" and to the "Primal slate, altered and crystalline;" and the same reference is made of the southwestern extension of the slates of the hills where crossed by section 8.

I have been unable to find any account of original researches upon the Primal rocks during the period between the final report of Prof. H. D. Rogers and the renewal of their study by Prof. J. P. Lesley in 1873.

In a paper by the latter, on the iron ore of the South Mountain of Cumberland County, a diagrammatic sketch is given of a cross-section of the county at Carlisle, in which the "Potsdam" sandstone rests on the gneiss for a long distance.[1] On the following page a sketch of a section shows the sandstone, resting on the Azoic slates and gneiss; and beneath is a series of iron ore bearing slates that, in turn, are subjacent to the Calciferous sandstone and Trenton limestone.

In describing the Cornwall iron mines and some related deposits, in Pennsylvania, Dr. T. S. Hunt[2] refers Prof. Rogers's Primal slate of the mines to a portion of the Lower Taconic series of Emmons and beneath the horizon of the Potsdam sandstone of the New York system. This reference carries with it the ores which are found in Pennsylvania along the borders of the Mesozoic and Red Sandstone formations of this portion of the State.

In another paper Dr. Hunt notes the discovery by Prof. Prime of a species of Monocraterion, in the Auroral limestone of Pennsylvania, and says:

[1] The iron ores of the South Mountain along the line of the Harrisburg and Potomac Railway in Cumberland County, Pennsylvania. Am. Phil. Soc. Proc., vol. 13, 1873, p. 4.

[2] The Cornwall iron mine and some related deposits in Pennsylvania. Am. Inst. Mining Eng., Trans., vol. 4, 1876, p. 320.

These same limestones in Pennsylvania, which belong to the Lower Taconic series of Emmons, have also afforded an undescribed species of Lingula.[1]

In reporting on the Paleozoic rocks of Lehigh and Northampton Counties Mr. Fred. Prime, jr., states that the very lowest beds of the Potsdam sandstone are actually pudding-stones, containing pebbles the size of a man's fist and larger, and fragments of red, unaltered orthoclase. The upper beds are composed of a hard, compact quartzite containing greater or less quantities of feldspar nodules. The sandstone often, as elsewhere, contains Scolithus.[2] He gives the geographic distribution of the sandstone as found about the South Mountain in the two counties mentioned. Of the upper Primal slates he says:

Next above the Potsdam sand stone occur hydromica slates, which Rogers has called the Upper Primal slates, but which really form a portion of the No. II limestone, and gradually pass into this. They overlie the Potsdam conformably and are far more persistent in their occurrence.[3]

In the limestone he found specimens of the genus Monocraterion in Lehigh County, specimens of Lingula, and a single specimen of an orthoceratite.[4] In the vicinity of Allentown and Bethlehem the sandstone is about 25 feet thick. The contact between the gneiss and the sandstone is distinctly seen about 2 miles from Allentown, on the Lehigh Valley Railroad track. (Prof. Prime's paper was also printed in the American Journal of Science, under the following title: "On the Discovery of Lower Silurian Fossils in Limestone Associated with Hydromica Slates, and on other points in the Geology of Lehigh and Northampton counties, Eastern Pennsylvania.")[5]

The species of Monocraterion was described and illustrated by Prof. Prime in 1878.[6] It is stated to be from the Siluro-Cambrian limestone.

Prof. Rogers referred nearly all of the strata of the South Mountain, southwest of the Susquehanna River, to the Primal series. He says:

In its geological constitution this tract is without much variety, for it contain scarcely any rocks except those of the Primal series.[7]

He describes the ridges as composed of the Primal white sandstone and the intervening valleys and plateaus of the Primal upper slate. These strata are represented as very much disturbed and extensively metamorphosed. This view is not accepted by Dr. Persifor Frazer, who says that in his report of 1875 (Second Geological Survey of Pennsylvania, CC) it is clearly shown, both in the text and in the graphic illustrations, that the Potsdam or Primal formation of Rogers is wanting over all that country with the exception, perhaps, of scattered patches on the northwestern flank of the South Mountain chain.[8]

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[1] On the history of the crystalline stratified rocks. Am. Assoc., Proc., vol. 25, 1876, p. 208.

[2] On the Paleozoic rocks of Lehigh and Northampton Counties, Pennsylvania. Am. Phil. Soc., Proc., vol. 17, 1878, pp. 248, 249.

[3] Op. cit., p. 249.

[4] Op. cit., p. 251.

[5] Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 261-269.

[6] 2d Geol. Sur., Penn., DD, 1878, pp. 79-80.

[7] The Geology of Pennsylvania. Philadelphia, 1858, vol. 1, p. 203.

[8] Frazer, Persifor, jr. (On the relations of the South Mountain rocks in Pennsylvania.) Am. Inst. Mining Eng., Trans., vol. 7, 1879, p. 336.

In noting the discovery of the Martic anticlinal in Lancaster County, Dr. Frazer calls attention to its exposing fundamental gneiss and granatoid beds in the new railroad cuttings along the left bank of the Susquehanna River and how it sheds off to the north and to the south at least 16,000 feet of Primal (Cambrian?) slates.[1] In a special report upon the geology of Lancaster County the same writer describes the character and mode of occurrence of the "Chikis" quartzite. The actual thickness of the quartzite above water level is not much over 300 feet.[2] Between the limestones and the quartzite there is, he says—

A vast series of hydro-mica schists and decomposed argillaceous slates, which insensibly grow in the deep more and more chloritic until this mineral lends its color as well as its name to the larger part of the whole formation, but generally the chloritic series is divided from these nacrites by a quartzite.[3]

He says further:

A vast series of slates intervene between the lowest rocks of all on the Susquehanna and the formation last described.[4]

As the result of his survey of the southern parts of Montgomery, Bucks, and Philadelphia Counties, Mr. Chas. E. Hall[5] decides that the South Valley Hill hydromica and chlorite slates, which were considered by Prof. Rogers as equivalent to his Primal of the North Valley Hill, are not altered Primal slates, but no other than a series of slates overlying the limestones of No. II or the slates of the Hudson Period. He also gives a description of the Primal quartzite of Rogers, speaking of it as the Potsdam sandstone.[6] He gives his opinion of the age of the sandstone known as the Edge Hill Rock, in Chester County, as follows: "The Itacolumite, or Edge Hill Rock, I consider proven, beyond dispute, to be the equivalent of the Potsdam sandstone."[7]

In a memoir upon the geology of the southeastern portion of Pennsylvania, Dr. Persifor Frazer gives a summary of the general characters and geographical distribution of the Primal quartzite and the subjacent and superjacent schists. The upper division of the Primal of Rogers is referred to No. III or Auroral, and the chloritic schists, subjacent to the quartzite, are referred to the Huronian, the quartzite alone representing the Primal or Potsdam of Rogers.[8] The geographic distribution of the formation in Chester, Lancaster, York, and Adams Counties is represented on the map accompanying the memoir.

Prof. Lesley, in his description of the geology of Chester County, after the surveys of Messrs. Rogers, Frazer, and Hall[9] writes:

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[1] [Note on the Martic anticlinal and on ripple marks on a slab of limestone]. Am. Phil. Soc., Proc., vol. 17, 1878, p. 725.

[2] The geology of Lancaster County. Second Geol. Survey Penn., Rep. Prog. in 1877, CCC. Harrisburg, 1880, p. 7.

[3] Op. cit., p. 5. [4] Op. cit., p. 8.

[5] The geology of Philadelphia County and of the southern parts of Montgomery and Bucks. Second Geol. Survey Pa., C6., 1881, pp. xvii–xviii, 93.

[6] Op. cit., pp. 7, 8. [7] Op. cit., p. xvii.

[8] Mémoire sur la Géologie de la partie sud-est de la Pennsylvanie. Lille, 1882, p. 75.

[9] The geology of Chester County, after the surveys of Rogers, Frazer, and Hall. Second Geol. Sur. Penn., CCCC; 1883, p. viii.

Dr. Frazer divides the Potsdam sandstone formation into an upper and a lower. * * * The upper, or *Kennett rock* division, he identifies with Mr. Hall's Edge Hill rock.

The lower is the Toughkenamon division. Dr. Frazer himself says that the latter, or the lower division, "is composed of weathered particles of a gneiss or syenite loosely compacted and laminated." The second or Kennett rock is the upper division and "it is a thin-bedded rock, lying in plates of fairly parallel sides, composed of fragments of white limpid quartzite, and is generally large-grained."[1]

Prof. Lesley quotes Prof. Rogers's description of the Primal series as it occurs at various localities in the county, together with many of Dr. Frazer's observations; stating that he described three principal and a few very subordinate and doubtful areas of the Primal rock north of the Chester Valley. One important conclusion of Dr. Frazer's is here quoted:

In mentioning thus the "Primal," the quartzite and quartzose sandstone alone are considered here. It will be seen further on that abundant evidence sustains the view that the greater part if not all of the weathered feldspar porphyries, conglomerates, &c., in the townships both north and south of the Chester Valley are really *Lower Potsdam.* The effect of this would be to add a border of these rocks to the area of the (silicious) Potsdam as at present indicated on the map, and thus contract by this much the remaining area of real Azoic or Hypozoic.[2]

The report of Mr. E. V. D'Invilliers upon the geology of the South Mountain belt of Berks County contains an extended description of the "Potsdam" sandstone, or No. 1 of Rogers's classification. The opening paragraph throws a doubt upon the correlation that has been made of this lower sandstone with the Potsdam sandstone of New York:

It would be safer to name this formation the *Reading Sandstone;* but in the descriptions of its outcrops along the Little Lehigh, the Lehigh, and the Delaware Rivers, in vol. I of this report, it has been called *Potsdam Sandstone,* taking for granted that any sand formation underneath the Magnesian limestones of the Great Valley must be the same sand formation which in northern New York underlies the Corniferous [Calciferous?], Chazy, and other limestones of the Mohawk Valley.[3]

The lower sandstone or conglomerate and the lower Primal slates of Rogers were not recognized in Berks County.

The lowest bed of the sandstone, always seen resting on the gneiss, is a coarse conglomerate of angular quartz rock fragments of all sizes in a silicous paste. * * * The term *sub-Potsdam conglomerate* would express its position underneath the *Potsdam quartzite white sandstone proper,* belonging to it by conformity, and separated from the gneiss by nonconformity.[4]

A detailed description of the outcrop of the sandstones and their general character follows. Certain areas of slate exist in places between the sandstone and the Magnesian limestone and are referred to the Primal series. Where the slate is not present the limestone is im-

[1] Geological notes in the several townships of Chester County. Second Geol. Surv. Penn. The geology of Chester County. C4, 1883, p. 307.

[2] The geology of Chester County, after the surveys of Rogers, Frazer, and Hall. Second Geol. Surv. Penn., CCCC; 1883, p. 159.

[3] The geology of the South Mountain Belt of Berks County. Second Geol. Surv. of Penn., D3, 1883, vol. 2, p. 99.

[4] Op. cit., p. 100.

mediately above the Potsdam sandstone. "Its place in the series is next above the Potsdam sandstone formation No. I."[1]

In a lecture upon the geology of Philadelphia, Prof. H. Carvill Lewis describes the Primal slates and Potsdam sandstone as follows:

On top of the gneiss and at the base of that great group of fossiliferous rocks known as the Paleozoic System, is a peculiar formation in the middle strata of which occur the oldest fossils yet found in the vicinity of Philadelphia. The lower part of the formation is the pale sandy slate which forms Edge Hill and Barren Hill, and the northern base of Chestnut Hill. The slates are closely folded and stand often almost perpendicular. * * * A sandstone, which from its great development at Potsdam, N. Y., has been named from that place, overlies the slates and often contains long tubular fossils, known as *Scolithus linearis*, which appear to be the casts of worm-holes. * * * On top of this fossiliferous sandstone is a series of soft, iron-bearing shales, often decomposed into variegated clays, carrying extensive beds of iron ore (limonite).[2]

The "Potsdam" sandstone is described by Prof. Fred. Prime, jr., as it occurs in Lehigh and Northampton Counties. It rarely exceeds 25 feet in thickness, and there are no underlying rocks of any thickness between it and the unconformably subjacent Laurentian rocks. The Primal upper slate of Rogers is classed with the Siluro-Cambrian limestone.[3]

Prof. J. P. Lesley's hand atlas of the sixty-seven counties of Pennsylvania contains a description of the rocks referred to the Potsdam quartzite, No. I, of Rogers, in each of the counties in which they occur; and the geographic distribution is shown upon the maps of the counties. The text presents the best general statement of the distribution of the strata now referred to the Cambrian in Pennsylvania that has yet been published.[4]

Prof. Lesley's résumé was followed in 1886 by an important contribution by Dr. Persifor Frazer entitled "A sketch of the Geology of York County, Pennsylvania." In adopting the classification of the Geological Congress for the system he places under the heading "Cambric" the Hellam quartzite or Potsdam sandstone.[5] The lower series or talcose slates of Rogers are considered in all probability as identical with the Azoic schists; and it is stated that abundant instances occur of the unconformable contact of the quartzite upon the supposed equivalent schists in Chester County. On the geological map accompanying this memoir the details and distribution of the Potsdam formation are delineated. The talcose schist of Rogers, or the upper member of his Primal series, is referred to the "Siluric" as "hydro-mica schists."[6]

Dr. T. Sterry Hunt objects to the interpretation of Prof. Rogers, that

[1] Op. cit., p. 137.

[2] The geology of Philadelphia. Franklin Inst. Jour., 3d ser., vol. 85, 1883, p. 425.

[3] Geology of Lehigh and Northampton Counties. Second Geol. Surv. Penn., D3, vol. 1, 1883, pp. 210, 212.

[4] A geological hand atlas of the sixty-seven counties of Pennsylvania, embodying the results of the Verity field work of the survey, from 1874 to 1884. Second Geol. Surv. Penn., X, 1885, pp. cxii.

[5] General notes. Sketch on the geology of York County, Pennsylvania. Am. Phil. Soc., Proc., vol. 23, 1886, p. 398.

[6] Op. cit., p. 400.

the Primal sandstone, Auroral limestone, and Matinal shales of central Pennsylvania are represented in southeastern Pennsylvania. He criticises the correlation upon the evidence of the presence of *Scolithus linearis*, stating that he has shown it to be very distinct from that found in the Potsdam sandstone. The argument for this is given in his "Azoic Rocks of Pennsylvania."[1] In a later publication Dr. Hunt concludes that—

There is, in fact, up to this time, no evidence that the typical Potsdam sandstone and Calciferous sandrock of northern New York exist in eastern Pennsylvania; but on the contrary there are many reasons for supposing that in this region, as in eastern Canada and along the eastern side of the Champlain and Hudson River Valleys, the period of these two subdivisions of the New York system is represented by the First Graywacke of Eaton, the Upper Taconic of Emmons, which, as will be shown farther on, is now recognized as contemporaneous with the typical Potsdam and Calciferous subdivisions. Rocks supposed to represent this Graywacke series are found in the great valley of Pennsylvania, and these, together with the divisions immediately preceding them—namely, the Primitive quartz rock, the Primitive lime rock, and the transition argillite—which constitute the Lower Taconic of Emmons—are, as we shall endeavor to show, represented by the so-called Primal, Auroral, and Matinal of the southeastern area.[2]

He refers the sandstone, limestone, and shale to his pre-Cambrian Taconian system, correlating the formations with the Granular quartzite, Granular limestone, and Transition argillite of the eastern New York section. This correlation, made long before by Prof. Rogers, is sustained by the latest observations. The "Granular quartz" of Eaton's section is known to be of Lower Cambrian age; the limestone, of the Trenton-Chazy horizon, and the argillite is referred to the Hudson terrane. If the correlation based upon lithologic characters and stratigraphic position by Messrs. Rogers and Hunt be correct, then the quartzite of southeastern Pennsylvania is of Cambrian age, and the limestones, with their superjacent shales and schists, are the equivalents of the Trenton and Hudson terranes.

The statement that the Upper Taconic of Emmons is contemporaneous with the typical Potsdam and Calciferous subdivisions is no longer sustained, as the Upper Taconic of Emmons is mainly the Lower Cambrian of the New York section.

In a discussion on the rocks of Pennsylvania and New York, Mr. T. D. Rand[3] mentions the Cambrian of Chester Valley, near Philadelphia, and, as undetermined, the hydro-mica schist of the South Valley Hill. He states that the Potsdam really exists in between the schist and the limestone, which refers the schist to the Archean. The sandstone is very thin, but it rests upon the Laurentian shore of the ancient ocean, which explains the differences of thickness as compared with the rocks to the northwest.

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[1] Special report on the trap dikes and Azoic rocks of southeastern Pennsylvania. Second Geol. Surv. Pa., E. 1878, pp. 134–139.

[2] The Taconic Question in Geology. Mineral Physiology and Physiography. A second series of chemical and geological essays: 1886, p. 534.

[3] A discussion on the rocks of Pennsylvania and New York. New York Acad. Sci., Trans., vol. 8, 1889, pp. 50, 51.

MARYLAND.

A brief description is given by Prof. P. T. Tyson, in his first report,[1] of the rocks in Maryland referred to the Primal series of Rogers. Two formations are referred to the Primal: (1) a hard sandstone; and (2) a slate, varying in color from gray to brownish and greenish. On the map accompanying the report the geographic distribution of the Primal series is indicated.

VIRGINIA.

One of the earliest attempts to differentiate, by lithologic characters, the formations of the Blue Ridge of Virginia is on the map of a section crossing it east of Winchester.[2] The Transition, or blue limestone, is represented as passing beneath the limestone shale that, in turn, dips beneath a gray schistose rock. This section is of interest only when interpreted by the later sections of Prof. Rogers.

Prof. William B. Rogers describes in the Second Report of the Progress of the Geological Survey of Virginia the Primal series in the central counties of the State, or of the Great Valley, as follows:

(No. 1.) This rock or group of rocks, which is frequently exhibited in extensive exposures along the western side and base of the Blue Ridge, more especially in the middle counties of the valley, is usually a compact, rather fine-grained, white or yellowish gray sandstone. Where resting on the declivity of the ridge it presents a gentle inclination to the northwest—while the subjacent and more ancient strata of the ridge, in almost every instance, dip steeply to the southeast. In Page, Rockingham, Augusta, and Rockbridge counties this rock forms the irregular and broken ranges of hills lying immediately at the foot of the main Blue Ridge, and sometimes attaining an altitude little inferior to that of the principal mountain. A level region, sometimes of considerable breadth, and strewed profusely with the fragments of this rock, in general intervenes between these rugged hills and the first exposures of the valley limestone. * * * Talcose and micaceous matter make their appearance in it. * * * This micaceous and talcose variety is sometimes found in the same hill underlying the more purely silicious rock. The latter, in nearly all the exposures from the Balcony Falls to Thornton's Gap, as well as in various other places, exhibits vague, fucoidal and zoophytic impressions on the surfaces of bedding, together with innumerable markings at right angles to the stratification, penetrating in straight lines to great depths in the rock, and from their frequency and parallelism determining its cleavage in nearly vertical planes. These markings are of a flattened, cylindrical form, from one-eighth to one-tenth of an inch broad, giving the surface of the fractured rock a ribbed appearance, and resembling perforations made in sand which have been subsequently filled up without destroying the distinctness of the original impression. Precisely similar markings are found in great abundance in the white compact sandstone occurring at a higher point in the series, associated with numerous unequivocal impressions of fucoides.

The extent to which these sandstones are developed is comparatively inconsiderable in the southern and northern counties of the valley, and their structure and composition are in many respects materially changed.[3]

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[1] First Report of the State Agricultural Chemist of Maryland. Annapolis, 1860, pp. 34, 35.

[2] Clemson, Thos. G.: Notice of a geological examination of the country between Fredericksburgh and Winchester, in Virginia, including the gold region. Geol. Soc. Penn., Trans., vol. 1, 1835, map, oppo. p. 298.

[3] Second report of the progress of the geological survey of the State of Virginia, for the year 1837. Richmond, 1838, p. 14.

The description of formation No. I in the third annual report is as follows:

The lowest of the Appalachian rocks consist for the most part of a close-grained white or light gray sandstone, in some places containing beds of a rather coarse conglomerate of white silicious pebbles. Near the bottom in many instances a brownish slaty sandstone occurs alternating with the former, while towards the top or approaching the next formation, the sandstone passes into reddish and brownish and olive-colored argillaceous slates.

This formation in Virginia is exclusively confined to the western slope of the Blue Ridge and the narrow belt of rugged hills and mountains extending thence to the commencement of the valley limestone.[1]

In a paper on "The Lower Silurian brown hematite beds of America," Mr. B. S. Lyman states that all these beds seem to lie within the Virginia and Pennsylvania geological formation No. I, wholly below the Calciferous Sandrock of No. II.[2]

On the map accompanying the reprint of the annual reports and other papers on the geology of the Virginias, published in 1884, Prof. Rogers has included under one color, formations I to III or the Primal, Auroral and Matinal series. On the large series of sections, however, the three are differentiated and No. I or the Primal series is shown in sections 1 to 19, and also in 89.

Prof. W. M. Fontaine has added many details to the section of the Primal series described by Prof. Rogers, at Balcony Falls in Rockbridge County. The sketch of the Balcony Falls section[3] is supplemented by that of Rockfish Gap and Harper's Ferry.

For a further notice of the results of Prof. Fontaine's work the reader is referred to the description of the Cambrian rocks of Virginia.

In a note upon the Potsdam or Primal group of Virginia, prepared for Macfarlane's American Geological Railway Guide, Prof. W. B. Rogers puts as equivalent formations No. I of the Pennsylvania and Virginia surveys or Primal of the annual reports and Potsdam group. The latter is used in the nomenclature of the rocks of Virginia and West Virginia. In the note explaining the Potsdam group, he says:

The Potsdam, or Primal group, includes in Virginia, where complete, besides the Potsdam proper, the ferriferous shales next above, and the slates, shaly grits, and conglomerates, below this formation. It is exposed in varying mass and completeness on the western slope and in the west flanking hills of the Blue Ridge throughout much of its length, often, by inversion, dipping to the southeast, in seeming conformity beneath the older rocks of the Blue Ridge, but often, also resting unconformably upon or against them. These older rocks, comprising masses referable probably to Huronian and Laurentian age, include also a group of highly altered beds, corresponding apparently to the copper-bearing or Keweenian series of northern Michigan, and perhaps to the lately described Dimetian rocks of Wales.[4]

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[1] Report of the progress of the geological survey of Virginia, for 1838 (Richmond, 1839), p. 6. A reprint of the annual reports and other papers, on the geology of the Virginias. New York, 1884, pp. 197, 198.

[2] On the Lower Silurian brown hematite beds of America. Am. Assoc., Proc., vol. 16, 1867, p. 114.

[3] On the primordial strata of Virginia. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp, 363–369.

[4] Rogers, W. B. Virginia and West Virginia. [Geological formations.] Macfarlane's Am. Geol. R. R. Guide, 1879, p. 181.

It will be noticed that Prof. Rogers adopts the same reference for the ferriferous or iron-bearing slates and shales that his brother did for the supposed equivalent formation in Pennsylvania.

Prof. J. L. Campbell published two papers in 1879,[1] in which the Primal series of Prof. Rogers is described. These were followed in 1880 by a revised description of the Silurian formation in central Virginia.[2] His observations will be noticed in the section on the Cambrian rocks of Virginia. In another paper he gives a definition of the "*Primordial*" as follows:

> *The Primordial.*—The great bed of ferriferous shales and sandstones skirting the western base of the Blue Ridge from Tennessee to the Potomac; in the upper part of formation No. I of Prof. Rogers's Appalachian series.[3]

The most complete and detailed description of the formations referred to the Primal series of Rogers is that of Prof. W. M. Fontaine, published in 1883.[4] The section is formed of conglomerate at the base, subjacent to shales, upon which the so-called Potsdam quartzite rests. The upper member of the Primal series is the ferriferous shales. The entire thickness of this section is given as 2,380 feet, and the data given by Prof. Fontaine will be used largely in the summing up of our knowledge of the Primal series in Virginia. The reader is referred to that section for further details.

In an article upon the iron ores of the valley of Virginia, Mr. Andrew McCreath divides the "Primal or Potsdam sandstone" (Primal or Potsdam formation) into (1) lower slates, (2) sandstone, (3) upper slate.

> First. In the *lower slates*, or those geologically underneath the Potsdam sandstone occurs a red hemitite ore, sometimes in beds of considerable thickness and of good quality. This is the so-called "specular ore" of the Blue Ridge, and it has been quite extensively developed at numerous points, notably in Botetourt and Bedford Counties. * * * Second. In the *Potsdam sandstone* itself, important beds of iron-ore have been observed. The ore is generally a close-grained, brittle, dark brown hematite, invariably cold-short. In Rockbridge County a bed of it fully ten feet thick is exposed for a considerable distance on the Vesuvius property. * * * Third. The *upper slates*, however, are by far the most important from an economical standpoint, forming, as they do, one of the richest repositories of brown hematite iron ore in Virginia. They intervene between the Potsdam sandstone and the base of the calciferous limestone, and they are found all along the western slope of the Blue Ridge—being geologically coextensive with it. They are generally more or less disintegrated, or decomposed into variegated clays; and while they may not always carry a continuous ore bed, yet, wherever the formation exists, deposits of iron ore of greater or less extent may be confidently looked for.[5]

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[1] Silurian formation in central Virginia. Am. Jour. Sci., 3d ser., vol. 18, 1879, pp. 16-29. Geology of Virginia; Balcony Falls; The Blue Ridge and its geological connections. Some theoretical considerations. Ibid., pp. 435-445.

[2] The Silurian formation in central Virginia (revised). The Virginias, vol. 1, 1880, pp. 41-45, 54-56.

[3] The mineral resources and advantages of the country adjacent to the James river and Kanawha Canal and the Buchanan and Clifton Forge Railway. The Virginias, vol. 1, 1880, p. 3.

[4] Notes on the mineral deposits at certain localities on the western part of the Blue Ridge. The Virginias, vol. 4, 1883, pp. 21, 22, 42-44.

[5] The iron ores of the valley of Virginia. Am. Inst. Mining, Eng., Trans., vol. 12, 1884, pp. 18-20.

In the sheet of sections accompanying "The Virginias" by Prof. William B. Rogers, printed in 1884, section 9 crosses the Primal series of Rockbridge County, about 30 miles north of Balcony Falls. On the eastern slope of the Blue Ridge a small synclinal basin of the Primal series is represented as resting in a hollow in the gneiss; on the western slope, the Primary series is shown as it occurs in numerous sections crossing the Great Valley and the Blue Ridge. The editor of the sections, Mr. Jed. Hotchkiss, states in the note accompanying them that the sections are "exact reproductions, in so far as the geology is concerned, of the sections as Prof. Rogers left them." From this it is evident that Prof. Rogers became aware of the presence of the Primal series on the upper eastern slope of the Blue Ridge in Rockbridge County after the publication of the third annual report in 1839, as he stated then that the Primal rocks were confined to the western side of the ridge.

Messrs. J. L. and H. D. Campbell, while studying the geological relations of the Snowdon slate quarries in Amherst County, on the borders of the counties of Rockbridge and Bedford, discovered the presence of the Balcony Falls series of Cambrian rocks and found that the quartzite passed beneath the slate of the quarries.[1] On the map accompanying the paper (p. 170), an ideal section shows the shales and conglomerates resting on the gneiss beneath the sandstone, which they have referred to the Potsdam owing to its carrying Scolithus borings, and above the latter is the slate belt, in which the quarries are located. Under the title of "Geology of the Blue Ridge near Balcony Falls, Virginia; a modified view," Prof. Campbell corrects the statement made in a former paper, in the American Journal of Science in 1879, that the rocks of the southeast slope are of Archean age. He adds a sentence as follows:

> We may conclude, therefore, that this portion of the Blue Ridge has been formerly spanned by a grand arch, or series of arches, of Cambrian age, upturned perhaps at the time of their upheaval—the broken fragments of which have been carried away, and only the abutments left to tell the story of a great catastrophe.[2]

In a letter on relation of Archean and associated formations in Virginia, Prof. W. M. Fontaine states that he finds in Virginia a valuable guide to the true base of the Potsdam in the conglomerates.

> The lowest conglomerate is not always seen. It is often very coarse, with pebbles sometimes 4 to 5 inches in diameter, and composed of Laurentian or Huronian material, according to the nature of the underlying rock. The matrix is often shaly or slaty.
>
> It is the conglomerates overlying this stratum that afford the best guide, for they may always be seen.
>
> They are simply pebble beds in the slate or shale. The pebbles are from the size of a musket bullet down, and usually of quartz, often pink in color. The pebbles look as if they had been scattered over a muddy bottom, forming a very peculiar conglomerate in which all the material except the pebbles is a fine slate or shale. Sometimes some partially decayed feldspathic matter occurs with the pebbles.

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[1] The Snowdon slate quarries. The Virginias, vol. 5, 1884, pp. 162, 163.

[2] Geology of the Blue Ridge near Balcony Falls, Virginia; a modified view. Am. Jour. Sci., 3d ser., 1884, vol. 28, pp. 222, 223.

These *shaly conglomerates*, as we may call them, might sometimes be *mistaken for certain amygdaloids of the Huronian* when the latter are weathered, but careful examination will always detect the difference. I have never seen any shaly conglomerate in the Huronian.

I am now of the opinion that the conglomerates at the railroad bridge at Harper's Ferry are these lower Potsdam strata, but would require a reexamination of them before I make up my mind positively. I am also inclined to think that Frazer's Mountain Creek conglomerate is the same.[1]

During the year 1885 Prof. H. D. Campbell published a more detailed account of the discovery of the Potsdam group east of the Blue Ridge. A résumé of the section is given as it occurs on the northwestern slope of the Blue Ridge at Balcony Falls for the purpose of comparing the rocks as found upon the southeastern slope. On the eastern slope the strata lie in a basin of Archean rocks forming a synclinal, a section of which practically reduplicates the lower portion of a section of the "Potsdam group" of the western slope. A map and figure of the section accompany the paper.[2] In a second article in connection with his father, the Cambrian-Primordial (No. 1 of Rogers) is described in considerable detail,[3] and mention is made of the discovery of another area referred to the "Potsdam group" on the eastern slope of the Blue Ridge, at Tye River gap, in Nelson County.

Prof. J. J. Stevenson identifies the Cambrian rocks, crossing Montgomery, Pulaski, and Wythe Counties, as the Lower Knox shales and the Potsdam of the Tennessee section. Under the title "Cambrian" he says:

Here are placed the Lower Knox shales and the Potsdam. The former are probably equivalent to the Hydromica schists of Pennsylvánia and the lower part of the Calciferous of New York; the latter is the Potsdam of New York, vastly increased in thickness.

No fossils were observed in the Knox or the Potsdam shale with the exception of *Scolithus linearis*. The geographic distribution of the formations referred to the Cambrian is shown on a map accompanying the paper. Further reference will be made to Prof. Stevenson's paper in describing the Cambrian rocks of Virginia.[4]

In a paper read before the Geological Society of America December 31, 1890, by Messrs. H. R. Geiger and Arthur Keith, it is stated that the shales and quartzite at Harper's Ferry represent the Hudson and Medina series and not the Primal series as stated by Profs. Rogers and Fontaine. They present a number of sections showing the stratigraphic position of the beds. In these the normal succession is limestone, shales, and sandstone. The shales succeed the limestones, and overlap

[1] (Letter on relations of Archean and associated formations in Virginia.) Geol. Chester Co., Pa., 2d Geol. Surv., C4, 1883, p. xv.

[2] The Potsdam group east of the Blue Ridge at Balcony Falls, Virginia. Am. Jour. Sci., 3d ser., vol. 29, 1885, pp. 470–474.

[3] Review of William B. Rogers's Geology of the Virginias. Am. Jour. Sci., 3d ser., vol. 30, 1885, pp. 364–368.

[4] A geological reconnaissance of Bland, Giles, Wythe, and portions of Pulaski and Montgomery Counties of Virginia. Am. Phil. Soc. Proc., vol. 24, 1887, pp. 86–87.

upon the pre-Paleozoic rocks, the quartzite in turn resting upon the shales. This makes the limestones represent the Great Valley limestone of Virginia or the Calciferous-Chazy-Trenton belt; the shales, the Hudson series, and the sandstone, the Medina series of the New York section.[1]

NORTH CAROLINA.

As now known the Cambrian rocks of North Carolina are confined to the extreme western boundary, where the Ocoee conglomerate and Chilhowee sandstone series extend across from Tennessee. This was recognized by Prof. J. M. Safford in his work in Tennessee; and Prof. W. C. Kerr notes the occurrence of thin-bedded, siliceous slates at Paint Rock, on the State line. He says of them:

They are called by Prof. Safford, the geologist of the State of Tennessee, Chilhowee sandstones, and are set down conjecturally by several eminent geologists as Potsdam sandstone. They have never yielded any fossils by which their geological horizon might be determined. A few very thin beds of argillaceous slate are found interpolated here and there between the quartzose strata.

Passing up the deep gorge which the river has excavated, the quartzites are soon found to be interbedded with and are finally replaced by shales and grits, the latter generally fine, but occasionally approaching in appearance a breccia or conglomerate. These are succeeded by heavy beds of argillaceous slates and shales, which in turn give place, at Warm Springs, to a heavy bedded blue and gray limestone. This is followed by a calcareous, compact, fine-grained sandstone, which presently passes into a gray, much jointed quartzite rising in vertical cliffs along the river for 2 miles, and succeeded by a well characterized coarse conglomerate with bluish gray slates and shales, at and below the mouth of Laurel River. A little above this point comes in a very extensive and conspicuous bed of feldspathic quartzite, or petrosilex, which continues for more than a mile, and then graduates through a gneissoid rock into a series of gray, drab, and mottled argillaceous slates and shales. This succession of quartzites, grits, shale, limestone, and conglomerate occupies in direct cross section a space of more than 10 miles. I have elsewhere referred to the identity of this formation with that which is so conspicuous on Valley River, and shall therefore call it the *Cherokee Slates*. They pass in a northeast course up the Laurel Valley and through the Smoky or Unaka Mountains into Tennessee.[2]

In a note on the occurrence of metamorphic Silurian rocks in North Carolina, Prof. F. H. Bradley states that the rocks about Franklin are of Lower Silurian age, and the marbles of Murphy and vicinity are the equivalents of the Knox limestones of Tennessee, which are of Quebec group age.[3] This statement of Prof. Bradley's is noted here, as it is probable that the formations examined by him are equivalent to those exposed on the French Broad, between Warm Springs, North Carolina, and Paint Rock. If so, they may be of Cambrian age. In a paper published the following year, Prof. Bradley refers[4] to the strata in the vicinity of Murphy, in southwestern North Carolina, and takes the view

[1] Bull. Geol. Soc. America, vol. 2, 1891, pp. 155-163.

[2] Report of the State Geologist of North Carolina. Raleigh, 1869, p. 29.

[3] Note on the occurrence of metamorphic Silurian rocks in North Carolina. Am. Jour. Sci., 3d ser., vol. 8, 1874, p. 390.

[4] On the Silurian age of the southern Appalachians. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 286, 382.

already mentioned. There is, however, more or less of uncertainty in relation to the identification of the rocks about Murphy and on the line of the Hiwassee River; so much so that outside of the recognized Chilhowee strata I think it would be very hazardous to state that the Cambrian is represented in southwestern North Carolina. In his description of the stratified rocks, Prof. Kerr states that so far as known the Primordial is represented only in its lowest member, where it crosses the northwest border in a few points along the Smoky Mountain.[1] A description of the section upon the French Broad, from Paint Rock to Warm Springs, is reprinted by him (pp. 138, 139), with the statement that Prof. Safford makes the Paint Rock sandstones to be Chilhowee or Potsdam; the grits and conglomerates below and above Warm Springs to be Ocoee or sub-Potsdam; while the limestone is referred to the Knox Dolomite, which is above the Potsdam.[2] He also gives Prof. Bradley's identification of the rocks that belong to Cherokee County in the southwestern portion of the State.

TENNESSEE.

The classification adopted by Dr. Gerard Troost, in his fourth report as geologist of the State of Tennessee, is as follows:[3]

1. Primordial, or Primitive, or Crystalline.
2. Transition or Fragmentary.
3. Secondary or Sedimentary.
4. Tertiary or Upper Secondary.

In mentioning this classification he says:

I should have confined myself to the two first parts of this division, the Primordial and Transition series, as they constitute the greatest part of the district that I have examined.

This nomenclature is used in the fifth annual report, where he states that the Crystalline Primordial rocks form the highest part of the Appalachian Chain. The line of contact of the Primordial rocks with the Transition or Fragmentary coincides in a general way, but not exactly with the boundary line between Tennessee and North Carolina.

The country lying between the Great Smoky Mountains and the Cumberland Mountains, or East Tennessee, is for the most part composed of strata of grauwacke, sandstone, and limestone alternating with each other, and in which organic remains are rarely found; these strata are highly inclined, approaching in some places towards the vertical, dipping more or less towards southeast and running nearly parallel with the Smoky Mountain ridge; they are covered in several places by horizontal strata of limestone of a dark gray, approaching to a black color, and having a granular structure. It is in some places characterized by *Maclurites*, Le Sueur, *Conotubularia*, nobis, *Isotellus*, Dekay, and several species of *Calamopora*, Goldf.[4]

On the map and sections accompanying the report the Primordial or Crystalline series is colored blue, and the Secondary or Grauwacke

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[1] Report of the geological survey of North Carolina, vol. 1, 1875, p. 115. Raleigh.
[2] Op. cit., p. 140.
[3] Fourth report of the geologist of the State of Tennessee. Nashville, 1838, p. 630.
[4] Fifth geological report on the State of Tennessee. Nashville, 1840, p. 5.

series, composed of grauwacke, slaty grauwacke, sandstone, and limestone, which extend from the Primordial series to where they are lost under the Cumberland Mountains, is colored yellow, thus roughly outlining the relations of the Cambrian and pre-Cambrian rocks of eastern Tennessee.

Before publishing the Sixth Annual Report, Dr. Troost read Murchison's "Siluria," and also the observations of Prof. Sedgwick on the Cambrian rocks of Wales. In discussing the changes of nomenclature made necessary in accepting the views of Messrs. Murchison and Sedgwick, he says:

After having pointed out, in my last report, the line of junction of the Primordial or crystalline rocks in East Tennessee, I mentioned that the country west of the line, which separates Tennessee from the State of North Carolina, is composed of grauwacke, slate, limestone, etc. All this country, according to the views of Murchison and Sedgwick, belongs to a new division, which they call the *Cambrian system.*

This series of strata contains few organic remains; in fact, I have carefully examined, in this respect, the Tennessee strata and have never discovered any in them.[1]

In his attempt to identify the Cambrian and Siluriansy stems in Tennessee, he included rocks in the Cambrian system that, under the original definition of Sedgwick for that system in Wales, is surprisingly correct. In describing the geographic distribution of the Cambrian system, he says:

I consider the termination of the *Cambrian System* towards the west. This system commences, as already observed, about the line which separates the State of Tennessee from North Carolina; and, as mentioned in my preceding reports, is also, with a few exceptions, the line of separation between the transition and primordial strata. It runs sometimes a few miles into North Carolina; sometimes penetrates, for a few miles, into Tennessee, forming the great Unica or Smoky Mountain, Bald Mountain, and Iron Mountains; but the culminating ridge of this mountain chain is mostly composed of the Cambrian rocks, while south of it the crystalline or Primordial rocks are found.

Leaving this ridge in a north, or rather northwest direction, we have a series of slaty rocks, containing here and there chlorite, passing into talcose slate—or into quartzite. This series seems to be equivalent to Sedgwick's *Lower Cambrian* series; some extensive strata, mostly of brown or reddish brown, fine grained limestone occur occasionally in this series; such a stratum is seen about 5 miles west from the Primordial rocks, crossing, near the Warm Springs in Buncombe County, the French Broad River. We have then a series of strata of slates and sandstone, and about 4 or 5 miles west of Newport a limestone stratum appears again, extending through Cocke and Sevier counties, parallel to the above-mentioned high chain. I suppose the Lower *Cambrian system* terminates there.

Upon the Lower Cambrian rocks follows another series. It is composed of roofing slate, glossy aluminous slate, and sandstone. A ridge of fine roofing slate crosses Sevier County. I believe that this series commences with Star's, Tellico, and Chilhowee Mountains in McMinn, Monroe, and Blount counties, ranging parallel with the great Smoky Mountain, extending in a southeastern direction through Sevier County. I have not been able to trace it further to the northeast. This series seems to be equivalent to the Middle Cambrian. * * *

I consider, as stated above, that Bay's Mountain forms the upper part of the *Cambrian system*—or, that it perhaps belongs to the Old Red sandstone—that hence towards

[1]Sixth annual report of the geological survey of Tennessee, by the State geologist. Nashville, 841, p. 4.

the north of that mountain chain another formation commences, which is the *Silurian system* of Murchison, and extends northward as far as the line which separates this State from Virginia—in fact, it continues into that State.[1]

In his description of Sevier County the roofing slate and other slaty rocks and the non-fossiliferous limestones are referred to the Cambrian group.[2]

Dr. Troost identified the Cambrian group in Tennessee with that of Wales entirely upon the lithologic characters and the absence of organic remains; and upon the fact that it was succeeded by a series of limestones from which he obtained and identified Silurian fossils. Although, in the light of our present knowledge, there were many inaccuracies in this correlation it exhibits a comprehensive grasp of the views expressed by Messrs. Murchison and Sedgwick and unusual clearness in the correlation of the groups of rocks in the two countries.

In a sketch of the general geology of the Hiwassee copper region Prof. J. P. Lesley describes the primary region of the Hiwassee and Ocoee Rivers as a southern prolongation of the metamorphic rocks of the Blue Ridge, South Mountain, and Highlands of the Middle and Northern States.

It greatly resembles in every important geological particular the range of the White Hills in New Hampshire. * * * * They are not primary rocks, granites or porphyry, but the Primal and Matinal sandstones, shales, and limestones and conglomerates at the base of the older secondary series, baked, crystallized and upturned in collapsed synclinal and anticlinal axes.

He describes the section on the line of the Ocoee River as formed of slightly metamorphosed conglomerate strata.

In places these rocks are a simple pea conglomerate, quartzose, and interstratified with the hardest homogeneous blue and gray grits and scarcely altered.[3]

The preceding correlation was based upon the view that the strata now referred to the pre-Cambrian Algonkian series were metamorphosed Primal and Matinal rocks, corresponding in age to the unaltered Primal and Matinal rocks to the westward. That they might form a great group of strata beneath the Primal and superjacent to the Primary proper, or Archean, was not at the time entertained by the writer.

In 1856 Prof. J. M. Safford published his first report of "A Geological Reconnaissance of the State of Tennessee," in which he classified the formations as follows:[4]

Formation I.—The mica slate group.
II.—The Ocoee conglomerates and slates.
III.—The Chilhowee sandstones and shales.
IV.—The Magnesian limestone and shale group.

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[1] Op. cit., pp. 5, 6. [2] Op. cit., p. 28.
[3] First annual report of the board of directors of the Hiwassee Mining Company, made May 11, 1853. New York, 1853, p. 16.
[4] A Geological Reconnaissance of Tennessee; first biennial report. Nashville, 1856, pp. 151-154.

Formations III and IV were referred to the Cambrian system, and the formations above IV to the Silurian and Devonian systems, etc.

The term Cambrian was used provisionally to unite the first two fossil-bearing formations. The upper portion of formation No. IV, or the limestone member, was subsequently, in 1869, referred to the Knox dolomite.

This preliminary report was followed in 1869 by the volume on "Geology of Tennessee," in which all the strata now referred to the Cambrian are described in detail.[1] A map illustrating the geographic distribution of the formations in the State, and a transverse section from the North Carolina line west, showing the stratigraphic relations of the formations, accompanies the volume.

In speaking of the age of the metamorphic rocks of eastern Tennessee, which have been referred to by various authors as altered Silurian rocks, Prof. Safford says:

> I have no reason for believing that this group within Tennessee includes the metamorphosed beds of any formation of more recent date than the Ocoee conglomerate and slates. A portion of the beds are certainly referable to the Ocoee group; the remainder, although conformable, may be older, and most likely are. * * * In the northern part of the State, at many points, the passage of the Ocoee beds into gneiss is gradual and apparent. A considerable part, indeed, of our metamorphic rocks can be, I think, thus referred to these beds. The question as to the greater age of other parts is not so easily settled, and must remain open for the present. I know of no sufficient reason for referring any of these rocks to the Huronian or Laurentian series of Canada.[2]

It will thus be seen that the line of demarcation between the pre-Cambrian rocks and the Cambrian rocks has not been closely defined in Tennessee. It is only by comparison with the more clearly defined line found in the sections of the Blue Ridge in Virginia that we are led to consider that the metamorphosed rocks belong to an Algonkian group between the Cambrian and the Archean. The studies which are now in progress under the direction of the Geological Survey clearly demonstrate this, and give as the base of the Cambrian a series of sandstones. Where the sandstones and conglomerates are made up of the material derived from the adjacent Algonkian or Archean rocks they will necessarily have something of the character of those rocks, and it may be difficult in many instances to indicate the actual line of demarcation, especially where the basal beds have been more or less altered and disturbed by the subsequent folding, faulting, and compression that accompanied the Appalachian uplift.

As defined by Safford, Series II, or the Potsdam group of Tennessee, consists of—

1. The Ocoee conglomerate and slates.
2. The Chilhowee sandstone.
3. The Knox group of shales, dolomites, and limestones.

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[1] Geology of Tennessee. Nashville, 1869, pp. 182-226.

[2] Op. cit., pp. 177, 178.

As known to me at the present time the dolomites and limestone are referred to the Lower Silurian, as the equivalent of the Calciferous and Chazy zones of the New York section. This refers the Knox shale to the Upper Cambrian. Prof. Safford states that it is not easy to separate lithologically the *Ocoee sub-group* from the *Chilhowee*, as they often run into each other. The distinction between the latter and the *Knox* is much more apparent.[1]

The Ocoee Conglomerate.—The typical section of the Ocoee conglomerate in the gorge of the Ocoee River, is described by Prof. Safford as follows:

The strata are well displayed. They are, in general, coarse gray conglomerates, talcose, chlorite and clay slates repeatedly interstratified, all having a semi-metamorphic aspect. The slates predominate, and of these, the greenish and light bluish gray, or the chloritic and talcose varieties, are the most abundant. * * * The middle part of the section presents little conglomerate, but in the upper part it abounds. * * * The lower part of the gorge has several bands of conglomerate.[2]

The thickness of the Ocoee formation was not determined. Provisionally it was estimated to be more than 10,000 feet (p. 186). As shown on the map, the main portion of the Ocoee conglomerate occurs south of Nolichucky River. In Johnson County, in the extreme northeastern corner of the State, it occurs as a narrow band next to the metamorphic series. South of the French Broad River, it occupies a wide belt to the Georgia line. Prof. Safford says it is truly a mountain-making formation.

The recent work of the U. S. Geological Survey has shown that the Ocoee conglomerate is of Silurian age, and it is not to be included with the Cambrian.

The description of the Chilhowee sandstone, and Knox shales and sandstone, will be given in the summary of the present knowledge of the Cambrian rocks of Tennessee.

A résumé of the geology is given in a report upon the resources of Tennessee, by Mr. J. B. Killebrew,[3] which was prepared by Prof. Safford. It is a brief restatement of the character of the formations as described in the "Geology of Tennessee," and the geological map accompanying it is based upon that published in 1869.

When discussing the Silurian age of the Southern Appalachians, Prof. F. H. Bradley considered that the Knox group, of Safford, included the Quebec group and the Calciferous; the Chilhowee sandstone represented the typical Potsdam; and the Ocoee the Lower Potsdam or Acadian group. He also thought that the rocks of North Carolina, south and west of the Little Tennessee, together with the metamorphic area of Georgia, north of a line parallel with and 10 miles south of the Chattahoochee (and *probably* that south of this line), and the entire metamorphic area of Alabama, are *Silurian or newer*, with the possible excep-

[1] Op. cit., p. 182. [2] Op. cit., p. 184.
[3] Resources of Tennessee. Nashville, 1874, pp. 26-46.

tion of two or three small patches not over 10 miles in diameter.[1] A description of sections from Athens and Knoxville, Tennessee, to Murphy, North Carolina, accompany the paper.

The descriptive notes and conclusions of Prof. Bradley were followed, in 1883, by the expression of a somewhat similar view of the age of the Southern Appalachians by Mr. J. B. Elliott,[2] in which he concluded with Bradley that the metamorphosed strata east of the unaltered Ocoee and other "Lower Silurian" rocks were formed of metamorphosed strata of the Knox section.

In the table of formations accompanying Macfarlane's American Geological Railway Guide, Prof. J. M. Safford arranges the formations now referred to the Cambrian in the following descending order:

3b. Knox shale.
3a. Knox sandstone.
2b. Chilhowee sandstone.
2a. Ocoee group.

He places as equivalent formations, following Dana's Manual, the Ocoee and the Acadian; the Chilhowee and the Potsdam; the Knox sandstone and the Calciferous; and the Knox shale and the Quebec. This is the classification suggested by Bradley.[3] The Metamorphic group, No. 1, beneath the Ocoee group, is correlated with the Archean.

In an attempt to assign to the proper stratigraphic horizon the rocks referred to the Cambrian group in the United States and Canada, Mr. C. D. Walcott correlated the Knox shale and sandstone with the Potsdam sandstone. The supposed subjacent Chilhowee sandstone and Ocoee conglomerate were referred to a position corresponding to the *horizons* of the Olenellus and Paradoxides faunas.[4] Subsequently, references to the two formations were omitted, pending an investigation of their true stratigraphic position. The discovery, in 1889, of the Olenellus fauna in the shales resting conformably in the Chilhowee series, thus verifying Prof. Safford's section, affirms the correlations of 1883, except that it carries the Middle Cambrian zone above the Chilhowee sandstone and drops the Ocoee, if it proves to be beneath the Chilhowee quartzite, back into the Basal Cambrian.

GEORGIA.

Of the Transition, or older fossiliferous rock formation, Mr. George White said, in 1849, that it has been less explored than any other part of the geology of Georgia.

That part of it which extends from the western base of the primary rocks to the Chattoogatta range of mountains, and which forms the valley of the Oostanaula

[1] On the Silurian age of the Southern Appalachians. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 279, 280.
[2] The age of the Southern Appalachians. Am. Jour. Sci., 3d ser., vol. 25, 1883, pp. 282–298.
[3] Tennessee. (Geological formations.) Macfarlane's Am. Geol. R. R. Guide, 1879, p. 196.
[4] The Cambrian System in the United States and Canada. Washington Phil. Soc., Bull., vol. 6, 1883, p. 100. Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, p. 63.

River, belongs probably to the older series of the New York formations, as those portions which have been examined contain Potsdam sandstones, Calciferous sandrock and limestones of the Trenton group. Very few fossils have been found in it.[1]

This brief description is accompanied by a map, upon which the transition or oldest fossiliferous formations are indicated by one color, in the northwestern corner of the State.

As in the case of North Carolina and Alabama, a long interval elapsed between the first geological survey and the renewal after the conclusion of the civil war. In 1876 Mr. George Little published an account of the geological formations in Georgia, to accompany Janes's Hand-Book of the State. He divides the Lower Silurian into two periods.

The hydromica schists of the copper-bearing series of the Mobile mine and Ducktown, and Ocoee conglomerates and slates along the Ocoee River on the Tennessee line, and on the Etowah River, near Cartersville, are the lowest in position of the rocks in the State, and form a group of (2) Primordial rocks corresponding to what is called the (2*a*) Acadian epoch in Canada. The conglomerate is made up of feldspar and a bluish quartz. The slates are hard and siliceous. This group of rocks is overlaid in the Cohutta Mountains, and on Pine Log Mountain in Bartow County, by a sandstone called the Chilhowee, from a mountain of that name in Tennessee, corresponding to the Potsdam sandstone in New York, * * * and belongs also to the (2) Primordial period and to the (2*b*) Potsdam epoch. This sandstone appears in the north of Haralson and Paulding counties, and in Yonah Mountain, White County, and Tallulah Mountain, Habersham County, being at all these places altered into gneiss by metamorphism.

The next period, called (3) Canadian, embracing the (*a*) *Calciferous* * * * of New York, * * * the (*b*) *Quebec* epoch in Canada, and the (*c*) *Chazy* limestone of New York, is represented by impure sandstones and cherty dolomitic limestones in the northwestern counties; by a sandstone on the western slope of the Cohutta Mountains; and in the metamorphic region to the eastward and southward by calcareous schists, hydromica schists, marble, and itacolumite of the Quebec epoch, and by calcareous schists of the (*a*) Calciferous epoch.[2]

This arrangement follows that of Prof. Safford in Tennessee except that the Knox sandstone and the Knox shales are not included.

In a work on "The Commonwealth of Georgia," prepared under the direction of J. T. Henderson[3] in 1885, there is a general description of the geology of the State. The Acadian or the Ocoee and Chilhowee formations and the Knox shales are all recognized. Reference to this description will be made in the summary of our present knowledge of the Cambrian rocks of Georgia.

In the Tenth Census report a brief résumé of the geology is given with relation to the soils formed from their decomposition. In this Mr. A. R. McCutchen states that the aggregate thickness of the groups, estimating the Primordial at 8,000 feet, and taking the maximum thickness of each of the higher groups, amounts to about 20,000 feet. The Primordial and Calciferous are followed by rocks referred to the Quebec

[1] Statistics of the State of Georgia. Savannah, 1849, p. 22.

[2] Little, George. Geological survey of the State of Georgia. Hand-book of the State of Georgia, with geologic map of State, by T. P. Janes, 1876, p. 37.

[3] Geology (of Georgia). The Commonwealth of Georgia. The country; the people; the productions. Atlanta, 1885, pp. 73-117.

group; first by about 2,400 feet of shales, and then by 5,000 feet of cherty limestones[1]. Combining these estimates we have 8,000 feet of Primordial and 2,400 feet of shales corresponding in position to the Knox shales, which gives a total of 10,400 feet for the Cambrian rocks of Georgia, as estimated. This paper is accompanied by a section crossing Dade, Walker, and Gordon Counties in northwestern Georgia. The stratigraphic relations of the Cambrian rocks are shown as they occur in Gordon County.

A geological section of the Cambrian rocks of northwestern Georgia has recently been published by Mr. C. Willard Hayes of the U. S. Geological Survey. It is referred to in the description of the Cambrian rocks of Georgia.[2]

ALABAMA.

The report of Prof. M. Tuomey for 1858[3] contains a very general description of the formations of the State, and on the accompanying map the Silurian and Devonian formations are included under one color, so that it is impossible to differentiate that portion of the Silurian formation which has subsequently been found to belong to the Cambrian group. In a general north and south section, showing the disposition of the strata, the Silurian and Devonian rocks are represented as unconformably subjacent to the Coal Measures and mountain limestone.

A long interval elapsed between the work of Prof. Tuomey and the organization of the geological survey under Prof. Eugene A. Smith. In the report of progress of the latter, for the year 1875, a general description of the geological formations of Bibb, Shelby, Talladega, and Calhoun Counties is given. In this area there is a large development of metamorphic rocks described by Prof. Smith in the report for 1874.[4] Of this series he says:

> On the southeastern border of the Silurian formation in Alabama, from the Georgia line to the northeast corner of Chilton County, a stratum of crystalline limestone, almost pure carbonate of lime, may be traced by its occasional exposures. * * * Succeeding this limestone and *apparently* overlying it conformably * * * is a series of semi-metamorphic strata between 15,000 and 20,000 feet in thickness, striking northeast and southwest and dipping at high angles (45°) southeast. This series, beginning below, is composed of greenish gray hydro-mica slates (talcoid slates, nacreous argillites, talcose slates), passing upwards into a conglomerate by enclosing lumps of quartz; these slates are succeeded by thick beds of quartzite, alternating with greenish chloritic schists. The quartzite in places is a thin-bedded silicious slate, again a thick-bedded quartzose conglomerate, and still again a laminated quartzose or arenaceous rock, not very coherent, and enclosing small grains of quartz,

[1] Northwest Georgia. (Geologic description.) Tenth Census U. S., vol. 6; Report on Cotton Production in the United States, Part 2, 1884, p. 287.

[2] The overthrust faults of the southern Appalachians. Bull. Geol. Soc. America. Vol. 2, Feb., 1891, p. 143, pl. 3.

[3] Second biennial report on the geology of Alabama. Montgomery, 1858, pp. 168.

[4] Geological survey of Alabama. Report of progress for 1874. Montgomery, Alabama, 1875, pp. 21-25.

This series of quartzites in their several varieties makes up the main body of the Blue Mountains range in Alabama.

These strata are the probable equivalents in Alabama of the Ocoee conglomerates and slates of Prof. Safford, of the Tennessee survey, by him referred to the Silurian age underlying the Potsdam. By Prof. Sterry Hunt the entire system of crystalline schists has been referred to pre-Silurian and pre-Cambrian age. My own observations in the field while inclining me to the latter view, have not been sufficiently extended to enable me to form an independent judgment on this point. * * * Mr. F. H. Bradley refers to the Lower Silurian all the metamorphic rocks of North Carolina as far east as Franklin.[1]

This metamorphic belt is apparently the same as the altered Silurian rocks of Prof. Bradley, as stated by Prof. Smith, and also of the altered rocks forming the northward extension of the Blue Ridge through Tennessee, Virginia, and Maryland into Pennsylvania, where it forms the South Mountain.

In the report for 1875 Prof. Smith states that he has followed the Tennessee subdivisions as found in Prof. Safford's published volume.[2] Under the caption of "Lower Silurian," the Primordial or Cambrian period is divided into (1) Acadian epoch and (2) Potsdam epoch. The Acadian slates and conglomerates of Talladega County are considered to be the exact equivalents of Safford's Ocoee slates and conglomerates.[3] The direct superposition of the sandstone referred to the Potsdam, upon the Acadian slates, is not well shown in Alabama. The formation consists of fine-grained conglomerate, heavy-bedded sandstone, and sandy shale. The most characteristic markings of the rocks of this formation are the sandy rods, caused by the filling in with sand of the burrows of a marine worm, *Scolithis linearis*.[4]

The Knox sandstone and Knox shales are referred to the Canadian period, thus following Prof. Safford's arrangement in Tennessee. The Knox sandstone is considered to rest upon the sandstone referred to the Potsdam, but no contact of the two formations in such a position is known to him. The sandstone is a calcareous sandstone associated with hard calcareous shales.

The Knox shales are very similar to those of Tennessee, and succeed conformably the Knox sandstone. The line between the Knox shale and the Knox dolomite is difficult to draw since the lower part of the dolomite contains beds of blue limestone similar to those in the upper part of the shale. This report contains much detailed information of the strata referred to the Cambrian in Alabama, and will be principally used in the description of the Cambrian rocks of that State.

In a paper on the iron ores of Alabama, with special reference to their geological relations, Prof. Smith states that the Potsdam sandstone frequently contains large amounts of iron, principally as *limonite*. In the Kahatchee hills, in Talladega County, the sandstone is sometimes impregnated with iron in the form of *specular ore* or as *magnetite*.

[1] Op. cit., pp. 21, 22.

[2] Report of progress of the geological survey of Alabama for 1875. Montgomery, 1876, pp. 7, 8.

[3] Op. cit., p. 127.

[4] Op. cit., p. 14.

Small beds of limonite are found in the Knox sandstone and Knox shales.[1] In 1878 the same writer published an outline of the geology of Alabama accompanied by a map of the State, based upon that of Tuomey, published in 1858. Of the age of the metamorphic rocks he says that until further examination he leaves the question of age an open one, except in two instances, in which he believes at least a part of them are metamorphosed Silurian beds.[2]

The classification and general description of the formations is essentially the same as that contained in the reports of 1874–'75.

In a report on the physico-geographical and agricultural features of Alabama, Prof. Smith notes the character of soil produced by the rocks of the different formations, from the Potsdam to the Coal measures.[3] This paper was also printed in a general description of the State of Alabama, in vol. 6, of the Tenth Census.[4]

A brief description of the Cambrian rocks of Alabama is given by Prof. Eugene A. Smith, in a report on the geological structure and description of the valley region adjacent to the Cahaba coal field.[5] A summary of it is given in the description of the Cambrian rocks of Alabama.

References are made to the geology of Alabama, in a general way, by Dr. T. S. Hunt, Prof. Smith, and various mining engineers, but I have not, with the exception of the preceding notice, met with original contributions to the knowledge of the Cambrian rocks, since the publication of Prof. Smith's detailed description.

PALEONTOLOGY.

NORTHERN APPALACHIAN DISTRICT.

The first discovery of fossils in rocks, now referred to the Lower Cambrian, was made by Dr. Asa Fitch.[6] In the summer of 1844 he found trilobites in a black slate in Washington County, New York, which was referred by Dr. E. Emmons to the Taconic slate or Argillite (1 of Eaton). Dr. Fitch sent the fossils to Dr. Emmons, who described from them two species of trilobites under the names of *Atops trilineatus* and *Elliptocephalus asaphoides*.[7] Believing that the rocks in which the trilobites occurred were unconformably beneath the Potsdam sandstone,

[1] The iron ores of Alabama, with special reference to their geological relations. Am. Assoc. Proc., vol. 27, 1878, pp. 247, 248.

[2] Outline of the geology of Alabama. Berney's Hand-Book of Alabama, 1878, p. 140.

[3] (Geological features and divisions of Alabama.) Geol. Survey of Alabama. Report for 1881 and 1882, 1883, pp. 178–181; 192–210.

[4] General description of the State of Alabama. Tenth Census U. S., vol. 6. Report on cotton production in the United States, part 2, 1884, pp. 19–69.

[5] Geological Survey of Alabama. Report on the Cahaba coal field, part II, 1890, pp. 148–150. (Issued January, 1891.)

[6] A Historical, Topographical, and Agricultural Survey of the County of Washington. Trans. N. Y. State Agric. Soc. for 1849, 1850, p. 865.

[7] The Taconic System, based on observations in New York, Massachusetts, Vermont, and Rhode Island, p. 20, 21 Albany, 1844.

Dr. Emmons called them the oldest known fossils in America. In the same work Dr. Emmons described *Fucoides rigida*, *F. flexuosa*, *Gordia marina*, *Diplograptus simplex*, and others of Silurian (Ordovician) age that he referred to the Taconic system.

The second description of fossils was made by Prof. James Hall in the Paleontology of New York, vol. 1, 1847. Under the title "Description of fossils of the Hudson River group," the following species were described as new: *Orbicula cœlata* (p. 290), *Orbicula ? crassa* (p. 290), *Avicula ? desquamata* (p. 292), *Theca ? triangularis* (p. 313), *Metoptoma ? rugosa* (p. 306), *Palæophycus virgatus* (p. 263), and *Agnostus lobatus* (p. 258). A description and figures are given of *Olenus asaphoides*, Emmons, on pages 256, 257, pl. 67, figs. 2a–c. In a later publication[1] he identified Conocephalus and Olenus from the Red Sandrock formation of Highgate, Vermont, but did not assign them to a geologic horizon. In studying a collection sent to him by Rev. Zadock Thompson, Prof. Hall determined and described *Olenus thompsoni*, *O. vermontana*, *Peltura* (*Olenus*) *holopyga*, referring them to the Hudson River group.[2] He supported this reference by the statement that Sir William Logan referred the shales containing the fossils to the upper part of the Hudson River group. In 1860[3] he proposed the genus Barrandia, to include *Olenus thompsoni* and *O. vermontana*. The genus Bathynotus was established to include *Olenus* (*Peltura*) *holopyga*. In 1861[4] the reference of these trilobites was changed from the Hudson River group to the Quebec group; and a little later a strong defense was made of the reference of the fossils of the Georgia slates to the Hudson River and Quebec groups, the authority of Sir William E. Logan for the stratigraphic position of the rocks being cited.[5] Discovering that the proposed generic name, Barrandia, was preoccupied, he substituted the name Olenellus in 1862.[6] This is the first introduction of the name which is now given to the Lower Cambrian fauna.

The last reference of Prof. Hall to the fauna is the proposal of the genus Discinella for what he considered to be a small brachiopod, but which investigation proves to be the operculum of *Hyolithellus micans*.[7]

In notes on the fossils of Washington County, Dr. Asa Fitch[8] de-

[1] Hall, James: Letter on certain fossils of the red sandrock of Highgate. 3d Annual Report on the Geology of the State of Vermont. Burlington, 1847, p. 31.

[2] Remarks upon the trilobites of the shales of the Hudson River group. Paleontology of New York, vol. 3, supplement to vol. 1, 1859, pp. 525–529.

[3] Note upon the trilobites of the shales of the Quebec group in the town of Georgia, Vermont. 13th Annual Report State Cab. Nat. Hist., 1860, pp. 113–119. Report upon the geology of Vermont, vol. 1, 1861, pp. 367–372.

[4] Hall, James; Correction for the 13th Ann. Rep. 14th Ann. Rep. State Cab. Nat. Hist., 1861, p. 110.

[5] Hall, James: Letter on the Primordial of America. Soc. géol. France, Bull., 2e sér vol. 19, 1862, pp. 725–734.

[6] Supplementary note to 13th Ann. Rep. State Cab. Nat. Hist. N. Y. 15th Ann. Rep. State Cab. Nat. Hist. N. Y., 1862, p. 114.

[7] Notes on some new and imperfectly known forms among the brachiopoda, etc. 23d Ann. Rep. N. Y. State Mus. Nat. Hist., 1873, p. 246.

[8] A Historical, Topographical, and Agricultural Survey of the County of Washington. Trans. N. Y. State Agric. Soc. for 1849, 1850.

scribes *Palæophycus rectus* (p. 862), *Buthotrephis* (?) *asteroides* (p. 863), *Helminthoidichnites tenuis* (p. 866), from the slates now referred to the Lower Cambrian. He also mentions *Palæophycus virgatus* Hall, *Buthotrephis* (?) *flexuosus* Emmons (p. 862), and *Gordia marina* of Emmons as *Helminthoidichnites marina* (p. 868).

The fauna of the "Red sandrock" of Vermont was first discovered by Prof. C. B. Adams in 1847,[1] who sent the specimens to Prof. James Hall. The latter identified Conocephalus, but did not refer the fossils to any geological horizon. Prof. Adams in 1848[2] mentions the Conocephalus and also an Atrypa, like *Atrypa hemispherica* (equivalent to *Camerella ? antiquata* Billings).

Mr. E. Billings, as paleontologist to the Geological Survey of Canada, took up the study and correlation of the older paleozoic faunas, and was the first to assign the fossils described by Prof. Hall to a pre-Potsdam horizon and to correlate the strata containing them with the Upper Primal sandstones of Pennsylvania, and the limestones of the Straits of Belle Isle.[3]

In 1861 he described a number of Lower Silurian fossils from the "Potsdam group" of Vermont and assigned the following species to the horizon of *Paradoxides thompsoni* of Hall: *Palæophycus congregatus*, *P. incipiens*, *Obolella* (*Kutorgina*) *cingulata*, *Orthisina festinata*, *Camerella antiquata*, *Conocephalites adamsi*, *C. teucer*, *C. vulcanus*, *C. arenosus*.

A little later he published a note on the "Red sandrock" formation of Vermont,[4] in which he refers the formation to the base of the Lower Silurian somewhere within the horizon of the Potsdam and identifies Conocephalites from the formation. In reprinting in 1865 the article published in 1861[5] he correlates the primordial fauna of the "Red sandrock" of Vermont with that of Newfoundland and Labrador, and refers them to the Potsdam group, stating that there is no paleontological evidence of precise similarity of age, but the general affinities and scope of the fossils and the physical relations of the rocks prove that there can be no great difference.

Under the title "On some new species of fossils from the limestone near Point Levi, opposite Quebec,"[6] Mr. Billings described the fauna collected by the Geological Survey of Canada from the limestone conglomerate. He designated the rocks simply as Limestone Nos. 1, 2, 3, and 4, not recognizing at the time that the bowlders were transported and imbedded in a secondary deposit; and that the fossils in the bowl-

[1] 3d Annual Report on the geology of the State of Vermont. Burlington, 1847, pp. 31.

[2] On the Taconic rocks. Am. Jour. Sci., 2d ser., vol. 5, 1848, p. 109.

[3] Paleozoic fossils, vol. 1. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 1860–1865. Montreal, 1865, pp. 1, 2.

[4] Billings, E.: On the age of the Red sandstone formation of Vermont. Am. Jour. Sci., 2d ser., vol. 32, 1861, p. 232.

[5] Billings, E.: Palezoic Fossils, vol. 1, 1865, p. 371.

[6] On some new species of fossils from the limestone near Point Levi, opposite Quebec. Canadian Nat., vol. 5, 1860, pp. 301–324.

ders were of Upper Cambrian age while those of the limestone matrix, which resembled in character the limestone of the bowlders, was deposited in situ, and carried the Calciferous fauna. As far as I have been able to separate the species by a study of the material from the bowlders and the limestone matrix the following may be referred to the Upper Cambrian or Potsdam fauna: *Camerella calcifera ?*, *Agnostus americanus*, *A. orion*, *A. canadensis*, *Dikelocephalus magnificus*, *D. planifrons*, *D. belli*, *D. oweni*, *D. megalops*, *D. cristatus*, *Arionellus cylindricus*, *A. subclavatus*, *Menocephalus sedgwicki*, *M. globosus*, *Conocephalites zenkeri*, *Asaphus illænoides*.

Mr. T. Devine, of Quebec, having discovered several nearly perfect trilobites in the conglomerate limestone at Point Levi, described two species of them. One as *Olenus ? logani*,[1] the other as *Menocephalus salteri*.[2] In a foot-note accompanying the description of *Olenus ? logani* Mr. Billings states that the species is unquestionably congeneric with those which he had described as *Dikelocephalus belli* and *D. oweni* from the same locality.

To the species described from Point Levi in 1860 Mr. E. Billings added in 1865[3] *Dikelocephalus devinei*, *D. hisingeri*, *D. affinis*, *D. sesostris*, *D. selectus*, and *D. pauper*. He also figured in this connection *Olenus ? logani*, Devine and *Menocephalus salteri*, Devine.

In 1872 Mr. Billings returned to the study of the fossils of the older Paleozoic rocks and described one new genus and several species found in bowlders, of several beds of conglomerate at St. Simon, below Quebec, as follows: The genus Obolella and the species *Obolella gemma* and *O. circe*, *Platyceras primævum*, *Hyolithes americanus*, *H. communis*, *H. princeps*, *H. micans*. On page 240 of the same volume the genus Hyolithellus is proposed for the species *Hyolithes micans;* and on page 351 he notes the discovery of *Salterella pulchella* in the Winooski marble of Vermont.[4]

The Cambrian fauna of northern Vermont was further enlarged in 1884 by Prof. R. P. Whitfield[5] describing *Orthisina orientalis* (p. 144), *Nothozoa vermontana* (p. 144), *Dikelocephalus*, *marcoui* (p. 150), and *Angelina hitchcocki* (p. 148); all of which were referred by him to the horizon of the Potsdam sandstone.

The oldest Phyllopod crustacean, *Protocaris marshi*, was described by Mr. C. D. Walcott[6] in 1884 from the Georgia slates of Vermont,

[1] Description of a new trilobite from the Quebec group. Canadian Nat., vol. 8, 1863, p. 95.

[2] Op. cit., p. 210.

[3] Paleozoic Fossils, vol. 1, 1865, pp. 195–200.

[4] On some new species of Potsdam fossils. Canadian Nat., vol. 6, new ser., 1872, pp. 213–226, 240.
Note on the discovery of fossils in the "Winooski Marble" at Swanton, Vermont. Am. Jour. Sci., 3d ser., vol. 3, 1872, p. 145. Canadian Nat., new ser., vol. 6, 1872, p. 351.

[5] Notice of some new species of Primordial fossils in the collections of the Museum, and correction of previously described species. Am. Mus. Nat. Hist. Bull., vol. 1, 1884, pp. 139–154.

[6] On the Cambrian faunas of North America; preliminary studies. U. S. Geol. Survey, Bull. No. 10, 1884, p. 50.

where it is found in association with *Olenellus thompsoni* and *O. vermontana*. The latter was referred to the new genus Mesonacis in 1885.[1]

Mr. S. W. Ford began, about 1868, a study of the rocks and fossils of the hills east of Troy, New York, from which vicinity the first fossils of the Olenellus fauna, found in New York, were obtained. These were described by Prof. Hall, in 1847, and referred by him to the Hudson River group. Entering into correspondence with Mr. E. Billings, and comparing the fauna he found at Troy with that from below Quebec, referred by Mr. Billings to the Lower Potsdam, he concluded that the strata containing the fauna at Troy should be referred to an equivalent horizon. In his first paper[2] he mentions finding eighteen species, eight of which are referred to described species and ten remained to be described. Mr. Ford published a number of papers from 1871 to 1885,[3] in which he described the rocks, and fossils found in them, that occur near Troy, and also a little south of Schodack landing, in Columbia County, N. Y. The fossils described by him are: *Protocyathus rarum, Archæocyathus rensselæricum, Obolella nitida, Scenella retusa, Hyolithes emmonsi, H. impar, Agnostus nobilis, Leperditia troyensis, Microdiscus meeki, M. speciosus*, and *Solenopleura nana*. One of the most interesting of Mr. Ford's studies is that on the embryonic development of *Olenellus asaphoides*. From the data thus obtained he decided that the Olenellus fauna followed the Paradoxides fauna in time.[4]

[1] Paleozoic notes; new genus of Cambrian trilobites Mesonacis. Am. Jour. Sci., 3d ser., vol. 29, 1885, pp. 328–330.

[2] Ford, S. W.: Notes on the primordial rocks in the vicinity of Troy, New York. Am. Jour. Sci., 3d ser., vol. 2, 1871, pp. 32–34. Canadadian Nat., new ser., vol. 6, 1872, pp. 209–212.

[3] Descriptions of some new species of primordial fossils. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 419–422.

On some new species of fossils from the Primordial or Potsdam group of Rensselaer County, New York. Am. Jour. Sci., 3d ser., vol. 5, 1873, pp. 211–215.

Remarks on the distribution of the fossils in the Lower Potsdam rocks at Troy, New York, with descriptions of a few new species. Am. Jour. Sci., 3d ser., vol. 6, 1873, pp. 134–140.

Note on the discovery of a new locality of primordial fossils in Rensselaer County, New York. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 204–206.

On additional species of fossils from the primordial of Troy and Lansingburg, Rensselaer County, New York. Am. Jour. Sci., 3d ser., vol. 11, 1876, pp. 369–371.

Note on Microdiscus speciosus. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 141, 142.

On some embryonic forms of trilobites from the primordial rocks at Troy, New York. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 265–273.

Two new species of primordial fossils. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 124–127.

Note on *Lingulella cœlata*. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 127–129.

Note on the development of *Olenellus asaphoides*. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 129, 130.

On certain forms of Brachiopoda occurring in the Swedish primordial. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 364–366.

Note on the trilobite *Atops trilineatus* of Emmons. Am. Jour. Sci., 3d ser., vol. 19, 1880, pp. 152, 153.

Remarks on the genus Obolella. Am. Jour. Sci., 3d ser., vol. 21, 1881, pp. 131–134.

On additional embryonic forms of trilobites from the primordial rocks of Troy, New York. Am. Jour. Sci., 3d ser., vol. 22, 1881, pp. 250–259.

Note on the discovery of primordial fossils in the town of Stuyvesant, Columbia County, New York. Am. Jour. Sci., 3d ser., vol. 28, 1884, pp. 35–37.

[4] Embryonic forms of trilobites from the primordial rocks of Troy, New York. Am. Jour. Sci., 3d ser., vol. 22, 1881, pp. 250–259.

In 1886 Prof. William B. Dwight announced the discovery of the fauna of the Potsdam zone in limestone near Poughkeepsie, New York. He gives a list of eleven species as follows:[1]

Lingulepis pinnaformis.
Lingulepis minima.
Lingulepis acuminata (probably).
Obolella (Lingulella) prima.
Obolella sp.
Platyceras sp.
Ptychoparia (Conocephalites) n. sp.
Dikelocephalus sp.
Ptychaspis sp.
Stromatocerium ?
Remains of crinoid columns.

The review of the Olenellus or Lower Cambrian fauna by Mr. C. D. Walcott in 1886[2] resulted in the description of the following species from Vermont: *Climacograptus ? emmonsi* (p. 93), *Orthisina transversa* (p. 121), *Scenella ? varians* (p. 127) and *Microdiscus parkeri* (p. 157). This was followed in 1887[3] by an account of the discovery of a number of new species of fossils from the Upper Taconic slate of Emmons in Washington County, New York. The new species described are as follows:

Lingulella granvillensis.
Linnarssonia taconica.
Orthis salemensis.
Modiolopsis (??) prisca.
Hyolithellus micans, var. rugosa.
Aristozoa rotundata.
Leperditia (I) dermatoides.
Microdiscus connexus.
Olenoides fordi.
Solenopleura (?) tumida.
Ptychoparia (?) fitchi.
P. (?) clavata.

In describing a section of the Cambrian rocks in northern Vermont notice is taken by Mr. Walcott of the occurence in the upper beds of a fauna resembling that of the Upper Cambrian or Potsdam zone.[4]

In a paper announcing the discovery of the fossiliferous strata of the Paradoxides zone at Stissing Mountain, Dutchess County, New York, Prof. W. B. Dwight[5] identified *Hyolithes billingsi ?* (p. 143) and described as new *Leperditia ebenina* (p. 144), *Kutorgina stissingensis* (p. 145), and *Olenoides stissingensis* (p. 147), correlating the fauna with that of the Middle Cambrian of the Rocky Mountain province.

In a review of the Lower Cambrian fauna by Mr. C. D. Walcott, prepared for the Tenth Annual Report of the U. S. Geological Survey, a number of new species and genera are proposed, most of which are described in a preliminary paper published in the Proceedings of the U. S. National Museum.[6] These are *Archæocyathus dwighti* (p. 34), *Plan-*

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[1] Recent explorations in the Wappinger Valley limestone of Dutchess County, New York. No. 5; Discovery of fossiliferous Potsdam strata at Poughkeepsie, New York. Am. Jour. Sci., 3d ser., vol. 31, 1886, p. 131.

[2] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886.

[3] Fauna of the "Upper Taconic" of Emmons, in Washington County, New York. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 187–199.

[4] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, pp. 17, 19.

[5] Recent explorations in the Wappinger limestones and other formations of Dutchess County, New York. Am. Jour. Sci-, 3d ser., vol. 38, 1889, pp. 139–153.

[6] Descriptive notes of new genera and species of the Lower Cambriam or Olenellus zone of North America. U. S. Nat. Mus. Proc., vol. 12, 1889, pp. 33–46.

olites annularius (p. 34), *Agnostus desideratus* (p. 39), and *Zacanthoides eatoni* (p. 45), from Washington County, and *Camerella minor* (p. 36), from Dutchess County, New York; *Kutorgina cingulata*, var. *swantonensis* (p. 36) from northern Vermont.

In 1890 the following new species were described:[1] *Trachyum vetustum*, Dawson, from Metis, Canada; *Phyllograptus cambrensis*, from Georgia, Vermont; *Stenotheca* (?) *rugosa* var. *acuta-costa*, *erecta*, and *levis*, *Platyceras dawsoni*, from St. Simon, Quebec; *Olenoides ellsi*, from below Quebec, Canada; *O. desiderata*, from Highgate Springs, Vermont; *Conocoryphe reticulata*, from Washington County, New York; *Ptychoparia metisensis* and *Agraulos redpathi*, from below Quebec.

SOUTHERN APPALACHIAN DISTRICT.

NEW JERSEY, ETC.

The Cambrian fauna of New Jersey, Delaware, Pennsylvania, Maryland, and Virginia is thus far restricted to the presence of the Annelid boring *Scolithus linearis*. It is extremely probable that trilobites and other fossils will be found in the Granular Quartzite series, or the basal quartzite and the immediately superjacent shales and limestones.

TENNESSEE.

The Cambrian fauna of Tennessee consists of *Scolithus linearis* tubes found in the Chilhowee sandstone; while in the shales just above the sandstone occur numerous Annelid trails, a species of Hyolithes like *H. americanus*, an Ostracod crustacean, *Isoxys chilhoweana*, and a species of Olenellus closely allied to *Olenellus thompsoni* and *O. asaphoides* in that portion of the head preserved.[2]

From the upper part of the Knox shale Prof. J. M. Safford[3] has named, without description or illustration, several species, as follows:

Crepicephalus similis, Safford.
roanensis, Safford.
tennesseensis, Safford.
Lonchocephalus fecundus, Safford.
Agnostus arcanus, Safford.
Lingula prima? Conrad.

Quite a large fauna occurs at this horizon in the collections of the Geological Survey which has not yet been studied with care. As far as examined it appears to be of the type of the Upper Cambrian of the Mississippi Valley.

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[1] Walcott, C. D.: The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rep. U. S. Geol. Surv., 1890, pp. 598-655.

[2] Ibid., p. 626.

[3] Geology of Tennessee. Nashville, 1869, p. 212.

GEORGIA.

A trilobite was sent to the great exhibition in London in 1851 said to be found somewhere in Georgia. Mr. J. W. Salter[1] describes the species as *Conocephalus antiquatus*, comparing it with *C. striatus* of the Primordial rocks of Bohemia. The exact locality from which this species came was not known until collections were made in northwestern Georgia by the U. S. Geological Survey in 1885. It was then found to be associated with a fauna much like that of the Middle Cambrian fauna of the Rocky Mountains. The specimens occur in and upon siliceous concretions imbedded in the Coosa Valley shales of Floyd County and to the southwest in Alabama.

A second species was described by Mr. C. D. Walcott in 1889 as *Olenoides curticei*. It occurs on and in siliceous concretions found in the shales of the Coosa Valley.[2]

ROCKY MOUNTAIN PROVINCE.

The area of Cambrian rocks in this province includes the Cambrian outcrops of northern and western Utah, Nevada, eastern Idaho, and the Gallatin River district of Montana. The Canadian extension is considered separately.

UTAH AND NEVADA.

During the progress of the geological survey of the fortieth parallel, under the charge of Mr. Clarence King, Prof. F. B. Meek described two species of trilobites from Antelope Spring, Nevada, *Pardoxides* (?) *nevadensis* and *Conocoryphe* (*Conocephalites*) *kingi*, referring them to the Primordial zone.[3]

In the following year Prof. J. D. Whitney exhibited before the California Academy of Sciences some fossils that had been collected by Mr. J. E. Clayton near Eureka, Nevada. He referred them to the age of the Potsdam sandstone, identifying *Agraulos oweni*, M. and H., or a species closely resembling it; *Lingulepis prima*, *Obolella*, *Conocoryphe*, *Paradoxides*, etc.[4] A note on the occurrence of the Primordial fauna in Nevada was also sent to the American Journal of Science by Prof. Whitney. In this he mentions the occurrence of certain Primordial species, and the persistence with which these constantly recurring trilobites and brachiopods are found at various localities. In Bohemia they occur in argillaceous shales; throughout the United States, from New York to the Rocky Mountains, in the Potsdam sandstone, or in shales or slates; in Texas, and now in Nevada, in limestones.[5]

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[1] On the fossils of the Lingula-flags or "Zone Primordiale." Quart. Jour. Geol. Soc., London, vol. 15, 1859, p. 554.

[2] Descriptions of new genera and species of fossils from the Middle Cambrian. U. S. National Museum Proc., vol. 11, 1889, p. 443.

[3] Descriptions of fossils collected by the United States Geological Survey, under the charge of Clarence King, esq. Phila. Acad. Sci., Proc., vol. 22, 1870, pp. 62-64.

[4] [On some fossils from Eureka, Nevada.] California Acad. Sci., Proc., vol. 4, 1871, p. 200.

[5] Note on the occurrence of the "Primordial Fauna" in Nevada. Am. Jour. Sci., 3d ser., vol, 3, 1872, p. 85.

In the Sixth Annual Report of the U. S. Geological Survey of the Territories, Prof. F. H. Bradley states that his section along the Wasatch range of Utah is not complete. The bedded quartzites, referred to the Potsdam from the character of the overlying strata, rest unconformably upon the "Metamorphic." No fossils were found in the quartzite or in the superjacent gray and calcareous shales. The limestone above the shales is referred to the Niagara.[1]

During the progress of the survey west of the one hundredth meridian Mr. G. K. Gilbert visited the Antelope Spring locality, discovered by Mr. J. E. Clayton, and mentioned by Prof. Whitney when calling attention to the Primordial fossils found there. The fauna occurs in a blue gray, calcareous shale, some 200 feet in thickness. In addition to the species described by Mr. Meek, he collected *Bathyurellus (Asaphiscus) wheeleri*, Agnostus, and Discina. Beneath the blue gray shales is a massive gray limestone, 900 feet in thickness, superjacent to a vitreous sandstone.[2] From our present knowledge of the Cambrian rocks in Nevada, the gray limestone, blue gray shales, and an upper gray limestone some 200 feet in thickness all belong to the Cambrian.

The section of the Oquirrh range at Ophir City, Utah, was found by Mr. Gilbert to have, near its base, 100 feet of light gray limestone containing Conocoryphe and Dikelocephalus. Subjacent to this a massive limestone with coralline mottling extends downward some 300 feet to an argillaceous shale, in which Mr. J. E. Clayton found *Olenus gilberti*.[3] At the south end of the Timpahute range of eastern Nevada Mr. Gilbert also discovered a succession of shales and sandstones, in which he found Conocoryphe in the lower portion, and above, a band of purple ripple-marked vitreous sandstone, with bands of siliceous shale.[4] The descriptions of *Olenus (Olenellus) gilberti* and *O. (O.) howelli* of Meek are printed on pages 182 and 183 of Mr. Gilbert's report.

In the same volume Mr. E. E. Howell states that at Pioche, Nevada, the massive quartzite forming the base of the section is subjacent to about 400 feet of arenaceous and calcareous shales of a reddish yellow color, containing in the more calcareous portions several types of Primordial fossils in great abundance.[5] From the material found by Mr. Howell, Mr. Meek described two species of trilobites, *Olenellus howelli* and *O. gilberti*.

On the map accompanying the Wheeler survey reports, published in 1874, the Cambrian rocks are included under the same color with those of the Silurian.

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[1] Report of Frank H. Bradley, geologist of the Snake River division. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, p. 194.

[2] Report on the geology of portions of Nevada, Utah, California, and Arizona, examined in the years 1871 and 1872. Report on Geog. and Geol. Expl. and Survey west of the 100th meridian, in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 167.

[3] Op. cit., pp. 166, 167.

[4] Op. cit., p. 169.

[5] Report on the geology of portions of Utah, Nevada, Arizona, and New Mexico examined in the years of 1872 and 1873. Rept. Geog. and Geol. Expl. Sur. west of the 100th mer., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 258.

A reconnaissance of the northwestern portion of the Wasatch Mountains in Utah was made by Prof. F. H. Bradley in 1872. He found that the crest and eastern slopes are composed of quartzite and limestone. The former, a white and ferruginous quartzite, 1,500 feet in thickness, was referred to the Potsdam, and a band of superjacent gray calcareous shale, 1,000 to 1,200 feet thick, to the Lower Silurian. The section as arranged by Prof. Bradley is as follows:[1]

3. Blue and gray magnesian limestones, partly pebbly, 1,900 to 2,000 feet..................................	Upper ? and Lower Silurian.
4. Gray calcareous shales, 1,000 to 1,200 feet	
5. White and ferruginous quartzite, base pebbly, 1,500 feet	Potsdam.

Under the title of "Paleozoic subdivisions of the fortieth parallel" Mr. Clarence King describes the strata referred to the Cambrian system. This includes 12,000 feet of quartzites and argillites in the Big Cottonwood Cañon section of Utah, superjacent to which is a shaly zone some 75 feet in thickness, carrying well defined Primordial fossils. He says:

> Comparing the quartzites and argillites with those of the Cambrian section in Wales, the likeness is too great to pass unnoticed, and in view of the enormous developments of these low-lying rocks, as compared with the Silurian lying above the Primordial horizon, I have determined to draw a line at the upper limit of the Primordial period to include the uppermost members of the Potsdam epoch and to consider the whole underlying conformable series as Cambrian down to the point of their nonconformity with the Archean. In the extreme east of our work, in the region of the Rocky Mountains, the Cambrian formation is of variable thickness and nowhere reaches an exposure of over 100 feet. In middle Nevada the uppermost zone of the Cambrian, equivalent to the calcareous and argillaceous shales of the Wahsatch, is an immense body of dark limestones at least 3,000 feet in thickness carrying Primordial fossils throughout; the downward continuation of the series being there entirely hidden by the overlying Quaternary desert.[2]

This general definition of the Cambrian is accompanied by a list of the fossils described by Messrs. Hall and Whitfield.

The Cambrian section of Big Cottonwood Cañon referred to by Mr. King is described by Mr. S. F. Emmons with more detail.[3] On the west side of Box Elder Peak, near the little village of Call's Fort, in a body of dark blue argillaceous slates in the lower portion of the Ute limestone body, Mr. Emmons states that the following fossils of the Quebec group were found: *Dikelocephalus wasatchensis*, *D. gothicus*, *Crepicephalus* (*Loganellus*) *quadrans*, and *Lingulepis ella*.[4] In the section on Muddy Cañon, within 25 feet of the base of the series, occurs a body of calcareous shales, interstratified with narrow beds of a dark,

[1] Explorations of 1872; United States Geological Survey of the Territories, under Dr. F. V. Hayden; Snake River division. Am. Jour. Sci., 3d ser., vol. 6, 1873, p. 194.

[2] King, Clarence: Paleozoic subdivisions on the 40th parallel. Am. Jour. Sci., 3d ser., vol. 11, 1876, p. 476.

[3] Hague, Arnold, and S. F. Emmons; Descriptive Geology. U. S. Geol. Expl. of the Fortieth Par.; vol. 2, 1877, pp. 366, 367.

[4] Op. cit., p. 405.

fine-grained limestone, which contains abundant organic remains. Two species were recognized, *Dikelocephalus quadriceps* and *Conocephalites subcoronatus*.[1] The reference of the fossils at Call's Fort and Muddy Cañon to the Quebec group was on the authority of the paleontologists. More recent studies of this fauna, by Mr. Walcott, in connection with the section at Big Cottonwood Cañon prove that the fauna mentioned at these localities is a portion of the Middle Cambrian fauna, and that the Upper Cambrian strata are absent in the section by non-deposition.

In the Weber Cañon region of the Wasatch Mountains, 800 to 1,000 feet beneath limestones referred to the Devonian, there were obtained from a shaly limestone three forms of trilobites, which Mr. Emmons thought probably indicated the horizon of the Potsdam group. One was identified as *Ogygia parabola* and another as Crepicephalus allied to *C. diadematus*.[2]

In the Oquirrh Mountains, at Ophir City, Utah, the section discloses a thickness of about 400 feet of compact reddish white Cambrian quartzite, above which are about 100 feet of greenish yellow clay slate, in which numerous trilobites and primordial fossils occur.[3]

In the Schell Creek Mountains of Nevada there are limestones in which primordial fossils have been found overlying heavy bodies of quartzite. Among the organic remains of this range two species have been identified: *Crepicephalus (Loganellus) anytus* and *Lingulepis mœra*.[4]

At the northern end of Pogonip Ridge, of the White Pine Mountains of central Nevada, Mr. Arnold Hague mentions the presence of obscure outcrops of mica slates and black arenaceous and argillaceous slates and shales, in turn overlaid by an undetermined thickness of a compact, vitreous, steel-gray quartzite, closely resembling the Cambrian quartzites of other Nevada localities. Above this quartzite, and forming the lower beds along the greater part of the ridge, occurs the Pogonip limestone, which extends to the top of Pogonip Mountain, with a thickness of from 3,000 to 4,000 feet of strata. They dip with an angle of 24° to 30° eastward. The lower beds are a fine-grained, somewhat siliceous, black limestone, varying considerably in compactness and bedding, and frequently passing into calcareous shales. Higher up in the series, they develop more of a dark blue color, banded with layers of fine arenaceous limestones and occasional cherty bands a few inches in thickness.[5] From the lower beds of the limestone series he collected thirteen species of Upper Cambrian fossils.

Mr. Hague states that in Eureka mining district, northwest of White Pine, the section of Prospect Mountain has the same lithologic habit as that at White Pine, and carries throughout the greater part of the forma-

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[1] Op. cit., p. 410.
[2] Op. cit., p. 377.
[3] Op. cit., p. 444.
[4] Op. cit., p. 486.
[5] Hague, Arnold, and S. F. Emmons: Descriptive Geology. U. S. Geol. Expl. of the 40th Par.; Clarence King, vol. 2, 1877, pp. 542, 543.

tion Primordial fossils, showing beyond doubt that the two series of beds are the same and equivalent to the Potsdam sandstone of Wisconsin. This statement is followed by a list of fifteen species, all of which belong to the Upper Cambrian fauna.[1]

The collections made by the officers of the Fortieth Parallel Survey were studied and reported upon by Messrs. Hall and Whitfield. Of the fauna referred to the Potsdam period they say: "Although there is not a single species common to the two regions, yet there is such a close generic resemblance as to leave no doubt whatever of the positive identity of the formations." They mention the resemblance between the fauna referred to the Potsdam zone in Texas and the Upper Mississippi Valley, Wisconsin, Minnesota, etc.[2] In speaking of the trilobites from the base of Ute Peak, Wasatch range, Utah, they state that the fauna is referred to the Quebec group on the evidence of the Brachiopodus and Molluscan fauna.[3] There must have been some confusion in relation to the occurrence of trilobites and the Molluscan fauna, as the trilobites belong to the Lower Cambrian zone, and have nothing in common with the fauna which they refer to the Quebec group.

In the comprehensive review of the geology of the fortieth parallel, Mr. Clarence King describes the Cambrian and Silurian rocks largely from the data published in the volume of Messrs. Hague and Emmons[4] and in the recapitulation of the Paleozoic he gives a condensed description of the Cambrian as known to him in Utah and Nevada. The base of the Cambrian is never seen. This is explained by the fact that the Cambrian sediments accumulated in the deep valleys between the Archean ridges, and that the lower beds have not subsequently been brought up to the surface. Under the term Cambrian he includes all of the rocks of the lowermost Paleozoic exposures up to and including the whole of the Primordial, thus following approximately the eastern nomenclature. In describing the rocks referred to the Cambrian he says:

> Thus far, among the reported occurrences of the rocks of this horizon in the Cordilleras, the locality at the mouth of Big Cottonwood Cañon must remain as the finest example and the stratigraphical type. The lowest member—the Cottonwood slates, a group about 800 feet thick, which here rest upon highly metamorphic Archean schists—has thus far yielded no organic forms. Though searched by us with considable care, it presented no indications of life. The rocks are dark blue, dark purple, dark olive-green, and blackish argillites, all highly siliceous, and as a group sharply defined from the light-colored quartzitic schists which conformably overlie them. This second group, by far the greatest of the whole Cambrian series, is a continuous zone of schists which have a prevailing quartzitic character, though varied with considerable amount of argillaceous matter. It would seem to be the product of a fine-grained arkose formation, simply compressed into dense schists. From 8,000 to 9,000 feet thick, it has a general uniformity of lithological condition from bottom to top,

[1] Op. cit., pp. 547, 548.

[2] Hall, James, and R. P. Whitfield: Paleontology (of the 40th Parallel). General remarks. U. S. Geol. Survey of the 40th Parallel, vol. 4, 1877, pp. 199, 200.

[3] Op. cit., p. 200.

[4] Systematic Geology: U. S. Geol. Exploration of the 40th Parallel, Clarence King, geologist in charge, vol. 1, 1878, pp. 154–189.

except that in the region of Twin Peaks are some phlogopite schists and siliceous zones carrying considerable muscovite. The phlogopite members recur in the Egan Cañon region. The prevailing colors of this member are gray, greenish gray, drab, and pale brown; never dark colors. Conformably overlying it are 2,500 to 3,000 feet of cream-color and salmon- color and white quartzites and quartzo-feldsites. Occasional sheets of conglomerate are seen in the quartzites not far below the summit of the Cambrian.[1]

The details of the Cottonwood Cañon section to this point have not been quoted, as these rocks are beneath the line provisionally drawn between the Cambrian and pre-Cambrian rocks. This will be noticed under the description of the Cambrian rocks of the Rocky Mountain province. Above the quartzite series there is a thin series of green siliceous argillites which are usually not more than 75 or 80 feet thick, in which fossils of a Primordial type have been found. A description is given of the Cambrian as recognized in central Nevada, and a comparison made between it and the Cambrian of the Mississippi Valley and the Wasatch section. A complete list of the fossils of the Utah and Nevada Cambrian is given on page 231, and on page 233 a list of those from the Quebec group, eight of which are from the Middle Cambrian zone, and will be mentioned under the description of the Cambrian fauna of the Rocky Mountain province. The geographic distribution of the Cambrian rocks and their mode of occurrence, as shown in cross-section, is represented on the sheets of the atlas accompanying the report.

In 1882 Mr. Arnold Hague published a preliminary report on the geology of the Eureka district,[2] which was followed in 1883 by the abstract of a report on the geology of the district.[3] In this latter report a detailed description is given of the Cambrian rocks of the Prospect Mountain section. It is accompanied by a map of the district and a plate of sections showing the relation of the Cambrian rocks to the superjacent formations.

The fauna of the Cambrian rocks of the Eureka district was described and illustrated by Mr. C. D. Walcott in 1884. A short description of the range of the species is given, also a tabulation of the Paleozoic section of Central Nevada, showing the vertical range of genera.[4] This was republished in 1886 with greater detail,[5] accompanied by an original description of the Big Cottonwood Cañon section (pp. 38, 39), and a section in the Highland range, 125 miles south of the Eureka section (pp. 33–35), with notes upon the section at Pioche and Ophir City.

[1] Op. cit., pp. 229, 230.

[2] Report [on work in Eureka district]. 2d annual report U. S. Geol. Survey, 1880–'81. pp. 21–35, 1882.

[3] Hague, Arnold: Abstract of report on geology of the Eureka district, Nevada. U. S. Geol. Surv., 3d annual report, 1881, 1882, pp. 237–290, 1883.

[4] Paleontology of the Eureka district. U. S. Geol. Survey, Monograph vol. 8, 1884.

[5] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Surv., Bull. No. 30, 1886, pp. 30–33.

IDAHO.

In a letter to Prof J. D. Dana, dated Fort Hall, Idaho, July 7, 1872, Prof. F. H. Bradley wrote to announce the discovery of the Quebec group. In a limestone he found many trilobites, some gasteropods and brachiopods, and beneath the limestone a compact ferruginous quartzite, which from its position he considered as representing the Potsdam sandstone.[1] Near Malade City he discovered a series of limestones containing Conocoryphe, Bathyurus, Dikelocephalus, Agnostus, etc. He states in a later report that—

> The first examination of these Malade rocks was made at a point where the section terminated below in a very quartzitic sandstone, which occupied the relative position of the Potsdam, and was accordingly referred with doubt to that group in a letter extract which was published in the August number of the American Journal of Science. Later examinations have shown that this was really a part of the true Quebec, whose base is not here exposed.[2]

The fossils collected by Prof. Bradley were studied by Mr. F. B. Meek, who identified the genera Agnostus, Conocoryphe, etc., along with several genera of the Lower Silurian fauna, and gave Prof. Bradley the paleontologic data for his correlation.[3]

It is to be borne in mind that at the time of the work referred to, the Quebec group was made to cover the horizons of the Potsdam, Calciferous, and Chazy of the New York section. Again, throughout the writings of Messrs. Hayden, Bradley, and Meek there are found many references to the Quebec group, of strata that belong to different formations. This confusion arose primarily from the misinterpretation of the mode of occurrence of the Upper Cambrian and Lower Silurian faunas at Point Levis, Canada, the typical locality of the Quebec group.

The Cambrian rocks north of Malade City were studied by Dr. A. C. Peale in 1877, in the Portneuf and Bannock ranges. He also visited the Bear River range. Several carefully measured sections are published with a summary of the rocks referred to the Silurian that will be referred to in the description of the rocks of Idaho.[4]

The northern end of the Portneuf range, in the vicinity of Mount Putnam, came within the Teton district of Prof. Orestes St. John. The central portion of the mountain is formed of ancient quartzite, alternating with slaty micaceous shale, which alternates with limestones above; and on the northern terminus of Mount Putnam there is an exhibition of the full series of the Paleozoic formations as developed in this region.[5]

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[1] On the discovery of the Quebec formation in Idaho. Am. Jour. Sci., 3d ser., vol. 4, 1872, p. 133.

[2] Bradley, Frank H.: Report of Frank H. Bradley, geologist of the Snake River division. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, p. 201.

[3] Preliminary paleontological report, * * * with remarks on the ages of the rocks, etc. U. S. Geol. Surv. of the Territories, embracing portions of Montana, Idaho, Wyoming, and Utah. 6th Ann. Rep., 1873, pp. 431, 432.

[4] Report on the geology of the Green River district. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, pp. 567-572, 599, 613-616.

[5] Report of the geological field work of the Teton division. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, pp. 477-484.

On the map accompanying the twelfth annual report of the Hayden survey, issued in 1883, the geographic distribution of the strata referred to the Silurian (which includes the Cambrian and the quartzite referred to the Potsdam and a portion of the limestones referred to the Quebec) is delineated as it occurs in southeastern Idaho. This is based on the work of Messrs. Bradley, Endlich, St. John, and Peale, of the Hayden survey.

MONTANA.

During the field season of 1872 Dr. F. V. Hayden made a geologic reconnaissance of certain portions of Montana and noted the presence of limestone on the Gallatin River, above Gallatin City, that contained numerous fossils. The thickness of the entire series of strata referred to the Lower Silurian is estimated at 1,600 feet. The massive limestones referred to the Potsdam group are about 400 feet thick and pass gradually down into 50 feet of thinly laminated, cherty limestones or calcareous mud layers, with abundant organic remains. These are separated by a purplish sandstone that rests upon variegated shaly clays, yellow, green, etc., then hard, dull purplish brown quartzose sandstones, which in turn are underlaid by alternating sandstones and clays, the whole having a thickness of over 1,000 feet.[1]

The fossils collected were studied by Mr. F. B. Meek, who identified the genera Lingulepis, Conocoryphe, Bathyurus, Acrotreta, Hyolithes, and Agnostus from the beds of the east side of the Gallatin River.[2]

Strata of "Primordial age" were discovered by Messrs. Dana and Grinnell upon the southwestern slope of Little Belt Mountains and the south extremity of the Belt range of mountains; these are referred to with certainty, owing to the finding of Primordial fossils.[3]

In 1884 Dr. F. V. Hayden revisited the Gallatin River locality, in company with Dr. A. C. Peale.[4] The section near the mouth of the East Gallatin River was studied in detail by Dr. Peale and two lithologically well defined groups determined.

In the report of the following year the East Gallatin group is spoken of as probably Middle Cambrian.[5]

In his administrative report to the Director of the U. S. Geological Survey for the field season of 1889, Dr. A. C. Peale tabulates the Gallatin River Paleozoic section, and includes under the Cambrian the Gallatin limestone, 835 feet in thickness, and the Gallatin sandstone, 415 feet. Beneath the Gallatin limestones are 5,000 feet of conglomer-

[1] Report of F. V. Hayden, U. S. Geol. Sur. of the Terr., 6th Ann. Rep., 1873. p. 72.

[2] Preliminary paleontological report, . . . with remarks on the ages of the rocks, etc. U. S. Geol. Sur. of the Territories, embracing portions of Montana, Idaho, Wyoming, and Utah; 6th Ann. Rep., 1873, pp., 431, 432.

[3] Geological report. Report of a geological reconnoissance from Carroll, Montana Terrritory, on the Upper Missouri, to the Yellowstone Park and return, made in the summer of 1875, by Wm. Ludlow; 1876, p. 22.

[4] Administrative Report Montana Division. U. S. Geol. Survey, 6th Ann. Rep., 1884-'85, 1885, pp. 49-51.

[5] Ibid., U. S. Geol. Survey, 7th Ann. Rep. for 1885-'86, 1888, p. 86.

itic micaceous sandstones, with bands of siliceous limestones and indurated clay shales, which he refers to the Algonkian.[1]

CANADIAN EXTENSION.

The discovery of rocks of Cambrian age in the western portion of British Columbia is of recent date. During the summer of 1883 Dr. G. M. Dawson and Mr. R. G. McConnell investigated the Paleozoic rocks on the line of the Canadian Pacific Railroad and discovered at the Crow Nest Pass a great thickness of limestone of Devonian age, beneath which is a great series of slaty and quartzite rocks. No fossils were found in the beds, but some were found in detached fragments, which are referred to the Cambrian.[2] In the report published in 1886 Dr. G. M. Dawson says that of the rocks referred to throughout his report as Cambrian no complete general section can be offered. Along the line of the Columbia Valley the basal beds were not observed. The component beds of the great Cambrian series are, in the main, quartzites and quartzitic shales, passing into argillites, occasionally including limestones or more or less calcareous or dolomitic materials and conglomerates.[3]

Near Waterton Lake a section was measured 3,000 feet in thickness; another at South Kootanie Pass had a mininum (estimated) thickness of the outcropping Cambrian beds of 11,000 feet, and it included neither the summit nor the base of the series. Other sections were measured, but none were found in which the whole volume of the formation could be ascertained.[4]

Dr. Dawson compares these sections with that of the Wasatch Mountains of Utah; and more recent discoveries have shown that they are quite similar in character. If the view of separating the pre-Olenellus beds from the Cambrian is accepted, most of the South Kootanie Pass rocks will be referred to the Algonkian, corresponding in this respect to the Algonkian (?) of the Big Cottonwood section of the Wasatch Mountains, Utah.

Dr. Dawson further states that Mr. H. H. Winwood announced the discovery of Cambrian fossils in the Kicking Horse Pass in a letter to the Geological Magazine in 1885.[5] From among the specimens obtained at that time Mr. C. D. Walcott recognized *Olenellus howelli* and *Olenoides levis*, trilobites characteristic of the Prospect Mountain group of Nevada.[6] Numerous other references occur in Dr. Dawson's report in connection with the description of the local details of the

[1] Administrative Report, Montana Division. U. S. Geol. Surv., 10th Ann. Rep., 1890, p. 131.

[2] Dawson, Geo. M.: Recent geological observations on the Canadian Northwest Territory. Science, vol. 3, 1884. p. 648.

[3] Preliminary report on the physical and geological feature of that portion of the Rocky Mountains between lat. 49° and 51° 30′. Geol. Survey Canada, new ser., vol. 1, 1886, p. 157B.

[4] Op. cit., p. 158B.

[5] Geological age of the Rocky Mountains. Geol. Mag., new ser., dec. 3, vol. 2, 1885, p. 240.

[6] Preliminary report on the physical and geological features of that portion of the Rocky Mountains between latitudes 49° and 51° 30′. Geol. Surv. Canada, new ser., vol. 1, 1886, p. 140B.

geology. One of these refers to the finding of a specimen of *Ptychoparia oweni* M. and H. on the Cascade River in débris brought down from the mountain, indicating the presence of the Cambrian in the Cascade Mountains.[1]

An admirable map accompanies Dr. Dawson's report, and includes the region between latitude 49° and 50° 30′. The geographic distribution of the Cambrian quartzite series and its relations to the superjacent Carboniferous and Devonian rocks is delineated, and their stratigraphic position is shown in an accompanying diagrammatic section.

When exploring the Yukon district in 1887 Dr. Dawson[2] discovered that the country north of Dease Lake had a granitic nucleus with Paleozoic rocks on its flanks, ranging from the Cambrian to the Carboniferous. No details are given.

The detailed exploration of the Paleozoic rocks west of the great Archean area, near the border of British Columbia and Alberta, was undertaken by Mr. R. G. McConnell, and his results are presented in the annual report of the Canadian Survey for 1886. The Castle Mountain group, a great limestone formation, has a known minimum thickness of 7,700 feet. The lower portion is of Cambrian age, and the upper part forms the base of the Lower Silurian (Ordovician). Beneath the Castle Mountain group the Bow River series forms a great thickness of dark colored argillites, associated with some sandstones, quartzites, and conglomerates. The portion exposed has an estimated thickness of 10,000 feet, and in the upper part of it occur the fossils menby Dr. Dawson, *Olenellus gilberti*, etc.[3] The occurrence of fossils of Cambrian age in the lower portion of the Castle Mountain group is noted on page 28D of the report.

The fauna from the slates or shales at the base of the Castle Mountain group, in the Mount Stephen section, was described by Dr. C. Rominger in 1887,[4] and reviewed by Mr. C. D. Walcott in the following year.[5]

In noticing the two papers just mentioned Mr. R. G. McConnell gives a résumé of the section at Mount Stephen. He states that no fossils have been detected in the lower part of the Bow River series, but specimens of *Olenellus gilberti* were found by Dr. Dawson in 1884 about 2,000 feet below the top of the formation. The next fossiliferous zone occurs near the junction of Bow River and Castle Mountain groups, where Paradoxides was found; and a third zone, between 3,000 and 4,000 feet higher up, carries the fauna described by Dr. Rominger.[6]

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[1] Op. cit., p. 143B.

[2] Notes on exploration in Yukon District. Science, vol. 10, 1887, p. 165.

[3] Report on the Geological Structure of a portion of the Rocky Mountains, with a section. Geol. Surv. Canada, Ann. Report, new ser., vol. 2, 1887, pp. 24–30 D.

[4] Description of Primordial fossils from Mount Stephens, Northwest Territory of Canada. Phila. Acad. Sci. Proc., 1888, pp. 12–19, Pl. I.

[5] Cambrian fossils from Mount Stephens, Am. Jour. Sci., 3d ser., vol. 36, 1888, pp. 161–166.

[6] Notes on the geology of Mount Stephen, British Columbia. American Geologist, vol. 3, 1889, pp. 23–25.

In a "Note on the geology of the Selkirk Range," of British Columbia, Dr. George M. Dawson states that the Olenellus fauna has been found 3,000 feet down in the Bow River series.[1] He refers the Nisconlith, and the lower 15,000 feet of the Selkirk series, of the Selkirk section, to the Cambrian, and correlates them with the Bow River and lower portion of the Castle Mountain series of the western side of the Rocky Mountains. (The details of these series are given in chapter IV, of this paper.)

PALEONTOLOGY.

The first description of Cambrian fossils from the Rocky Mountain province is that by Mr. F. B. Meek, in 1868, who described from the material discovered by Mr. Clayton at Silver Peak, Nevada, *Ethmophyllum whitneyi* and *E. gracile*.[2] Shortly after he changed the reference of these species to Archæocyathus, making *A. whitneyi* and *A. gracile*.[3] In 1870 he added *Paradoxides? nevadensis* and *Conocoryphe* (*Conocephalites*) *kingi*, from Antelope Spring, Nevada. From the known position of the genus Conocephalites the two species were referred by him to the Primordial zone.[4]

In 1872 Prof. J. D. Whitney calls attention to the occurrence of the Primordial fauna near Eureka, Nevada, at a locality discovered by Mr. J. E. Clayton. He identified a species closely related to *Agraulos oweni* of Meek and Hayden, and fragments of the genera Conocoryphe, Paradoxides, Lingulepis, and Obolella.[5] A notice of this discovery was also published in the proceedings of the California Academy of Sciences in the same year. (Vol. 4, p. 200.)

From the Upper Cambrian rocks of southeastern Idaho and southern Montana, Mr. F. B. Meek described in 1873 *Iphidea?? sculptilis* (p. 479), *Agnostus bidens* (p. 463), *Conocoryphe* (*Conocephalites*) *gallatinensis* (p. 485), *Bathyurus ? haydeni* (p. 482), *B. serratus* (p. 480), *Bathyurellus* (*Asaphiscus*) *bradleyi* (p. 484), *Bathyuriscus wheeleri* (p. 485, foot-note). It is stated on page 465 that *Bathyuriscus* (*Dikelocephalus ?*) *truncatus* is described in the report. It does not, however, appear in the text. He also identified the species *Acrotreta subconica* Kutorga (*A. attenuata* proposed if it proved to be a distinct species, p. 463), *Hyolithes gregaria* M. & H., *Camerella calcifera* Billings, and *Agnostus josepha*, Hall. Numerous generic references are made from the fragments in the collection, and in the lists from various localities species of the Calciferous zone of the Lower Silurian (Ordovician) occur, especially in the list of the collection from Malade City.[6]

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[1] Bull. Geol. Soc. America, vol. 2, 1891, p. 171.

[2] Preliminary notice of a remarkable new genus of Corals, probably typical of a new family, * * * from the Silurian rocks of Nevada Territory. Am. Jour. Sci., 2d ser., vol. 45, 1868, pp. 62–64.

[3] Note on Ethmophyllum and Archæocyathus. Am. Jour. Sci., 2d ser., vol. 46, 1868, p. 144.

[4] Meek, F. B.: Descriptions of fossils collected by the U. S. Geological Survey, under the charge of Clarence King, esq. Phil, Acad. Sci. Proc., vol. 22, 1870, pp. 62–64.

[5] Note on the occurrence of the "Primordial Fauna" in Nevada. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 84, 85.

[6] Preliminary paleontological report, * * * with remarks on the ages of the rocks, etc. U. S. Geol. Surv. of the Terr., embracing portions of Montana, Idaho, Wyoming, and Utah; 6th Annual Report, 1873, pp. 463–487.

From the collections made by the geologists of the Wheeler survey west of the one hundredth meridian, Dr. C. A. White describes, in a preliminary report, *Cruziana linnarssoni*, *C. rustica*, *Acrotreta ? subsidua*, *Trematis pannulus*, and *Agnostus interstricta*. He also identified *Hyolithes primordialis* Hall ?; and published the manuscript description by Mr. Meek of *Olenellus gilberti* and *O. howelli*.[1] From the strata referred to the age of the Quebec group he describes *Acrotreta pyxidicula* (p. 9) and *Dikelocephalus flagricaudus* (p. 12). The former species was subsequently identified by Mr. C. D. Walcott as *Acrotreta gemma* of the Upper Cambrian, and the latter species is referred to the Middle Cambrian fauna as *Zacanthoides flagricaudus*. The manuscript descriptions of *Olenellus gilberti* and *O. howelli* by Mr. Meek were also printed in 1875 under the names of *Olenus* (*Olenellus*) *gilberti* and *O.* (*O.*) *howelli* in the report of Mr. G. K. Gilbert.[2]

The species described by Dr. White in his preliminary report of 1874 were redescribed and illustrated by him in 1875. In addition to the species mentioned in the preliminary report he describes and illustrates *Concoryphe* (*Ptychoparia*) *kingi* Meek (p. 40) and *Asaphiscus wheeleri* Meek (p. 43.)[3]

The two species described by Mr. Meek from Antelope Spring, Utah, in 1870, were redescribed and illustrated by him in 1877, under the names of *Conocoryphe* (*Ptychoparia*) *kingi* and *Paradoxides ? nevadensis*. In the description of the latter species he gave reasons for believing that the generic reference was incorrect, and that the species belonged to an undescribed genus. For this genus, if the species proved not to be Paradoxides, he proposed the genus Olenoides.[4]

The description of the collections of the Fortieth Parallel Survey by Messrs. Hall and Whitfield added a large number of new forms to the Middle Cambrian fauna.[5]

The new species described are:

Obolella discoidea, p. 205.
Lingulepis mæra, p. 206.
  ? minuta, p. 206.
Kutorgina minutissima, p. 207.
Leptæna melita, p. 208.
Crepicephalus (Loganellus) haguei, p. 210.
  (Loganellus) nitidus, p. 212.
  (Loganellus) granulosus, p. 214.
  (Loganellus) maculosus, p. 215.

[1] Preliminary report upon invertebrate fossils collected by the expeditions of 1871, 1872, and 1873, with descriptions of new species, pp. 27. Geog. and Geol. Sur. west of 100th Mer., Lieut. Wheeler in charge, Washington, 1874, pp. 4–12.

[2] Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872 Report on Geog. and Geol. Expl. and Sur. west of 100th Mer., vol. 3, Geology, 1875, pp. 182, 183.

[3] Report upon the invertebrate fossils collected in portions of Nevada, Utah, Colorado, New Mexico, and Arizona by parties of the expeditions of 1871–'74. Wheeler's Expl. and Sur. west of the 100th Mer., vol. 4, pt. 1, 1875.

[4] U. S. Geol. Expl. of the 40th Parallel, vol. 4, pt. 1, 1877, pp. 20–25.

[5] Ibid., vol. 4, 1877, pt. 2, pp. 205–246.

Crepicephalus (Loganellus) unisulcatus, p. 216.
(Loganellus) simulator, p. 218.
(Loganellus) anytus, p. 219.
(Bathyurus) ? angulatus, p. 220.
Conocephalites (Pterocephalus) laticeps, p. 221.
Ptychaspis pustulosa, p. 223.
Chariocephalus tumifrons, p. 224.
Dikelocephalus bilobatus, p. 226.
multicinctus, p. 226.
flabellifer, p, 227.
Agnostus communis, p. 228.
neon, p. 229.
prolongus, p. 230.
tumidosus, p. 231.
Lingulepsis ella, p. 232.
Conocephalites subcoronatus, p. 237.
Crepicephalus ? (Loganellus) quadrans, p. 238.
Dikelocephalus quadriceps, p. 240.
wasatchensis, p. 241.
? gothicus, p. 242.
Ogygia producta, p. 244.
parabola, p. 245.

Of these species those from *Lingulepsis ella* to *Ogygia parabola*, inclusive, are referred to the Quebec group, and the others to the Potsdam. The descriptions are accompanied by fine illustrations of all the species mentioned.

In 1880 Dr. C. A. White referred his *Acrotreta ? subsidua*, described in 1874, to the genus Acrothele of Angelin.[1]

The study of a collection made by the U. S. Geological Survey from the Eureka district, Nevada, gave Mr. C. D. Walcott material for the description of a number of new species from the Cambrian. They include the following:[2]

Acrothele ? dichotoma, p. 14.
Scenella ? conula, p. 15.
Kutorgina whitfieldi, p. 18.
prospectensis, p. 19.
Orthis eurekensis, p. 22.
Stenotheca elongata, p. 23.
Agnostus richmondensis, p. 24.
seclusus, p. 25.
Olenellus iddingsi, p. 28.
Dikelocephalus nasutus, p. 40.
richmondensis, p. 41.
? angustifrons, p. 42.
iole, p. 43.
marica, p. 44.
? expansus, p. 45.
Ptychoparia (?) prospectensis, p. 46.
(?) linnarssoni, p. 47.

[1] Note on Acrothele. U. S. Nat. Mus. Proc., vol. 3, 1880, p. 47.
[2] Paleontology of the Eureka district. U. S. Geol. Surv., Monograph, vol. 8, 1884, pp. 11-64.

Ptychoparia (?) (Solenopleura) (?) breviceps, p. 49.
(?) pernasutus, p. 49.
(Euloma ?) dissimilis p. 51.
occidentalis, p 51.
similis, p. 52.
similis, var. robustus, p. 53.
(Euloma ?) affinis, p. 54.
læviceps, p. 54.
(Pterocephalus) occidens, p. 58.
Anomocare ? parvum, p. 59.
Agraulos ? globosus, p. 61.
Arethusina americana, p. 62.
Ogygia ? spinosa, p. 63.
(?) problematica, p. 63.

The following genera and species are mentioned and illustrated:

Protospongia fenestrata, p. 11.
Lingulepis mæra, p. 12.
? minuta, p. 13.
Lingula ? manticula, p. 13.
Obolella discoidea, H. & W., p. 14.
Acrotreta gemma, Billings, p. 17.
Under this species are also included *Acrotreta subconica* and *A. attenuata*, Meek, 1873, and *Acrotreta pyxidicula*, White, 1874.
Kutorgina sculptilis, Meek, p. 20.
The synonymy of this species includes *Iphidea (??) sculptilis*, 1873, and *Kutorgina minutissima*, H. & W., 1877.
Leptæna melita, H. & W., p. 22.
Hyolithes primordialis, Hall, p. 23.
Agnostus bidens, Meek, p. 26.
communis, H. & W., p. 27.
neon, H. & W., p. 27.
prolongus, H. & W., p. 28.
Olenellus gilberti, Meek, p. 29.
howelli, Meek, p. 30.
Dikelocephalus bilobatus, H. & W., p. 40.
osceola, Hall, p. 40.
? quadriceps, H. & W., p. 45.
Ptychoparia oweni, M. & H., p. 55.
Under this species are placed as synonyms *Conocoryphe (Ptychoparia) gallatinensis*, Meek, 1873, *Crepicephalus (Loganellus) centralis*, Whitfield, 1877.
anytus, H. & W., p. 56.
granulosus, P. haguei and P. nitidus, H. & W., p. 57.
Under the latter species *Crepicephalus (Loganellus) simulator*, H. & W., 1877, is placed as a synonym.
unisulcatus, H. & W., p. 38.
(Pterocephalus) laticeps, H. & W., p. 59.
Ptychaspis minuta, Whitfield (?) p. 60.
Chariocephalus (?) tumifrons, H. & W., p. 61.

Notes on the genus Acrotreta of Kutorga are given on page 16; and observations on *Olenellus howelli* on pages 32–39.

In 1886 Mr. C. D. Walcott reviewed the species which he then considered to belong to the Olenellus, or Middle Cambrian fauna.[1]

The following new species were described from Utah and Nevada:

Eocystites ?? longidactylus, p. 94.
Orthis ? highlandensis, p. 119.
Hyolithes billingsi, p. 134.
Leperditia ? argenta, p. 146.
Olenoides typicalis, p. 183.
  levis, p. 187.
Ptychoparia housensis, p. 201.
  piochensis, p. 201.
Crepicephalus liliana, p. 207.
  augusta, p. 208.
Orytcocephalus, new genus, p. 210.
Orytcocephalus primus, p. 210.
Bathyuriscus howelli, p. 216.

The genus Ethmophyllum, described by Mr. Meek in 1868, and the species placed under it referred in the same year to Archæocyathus, is redefined as the genus Ethmophyllum, with *Ethmophyllum whitneyi* as the type (p. 81.) *Ethmophyllum gracile* Meek is placed as a synonym of the latter species. Descriptions and illustrations of the following species also appear in this work:

Protospongia fenestrata, Salter, p. 90.
Lingulella ella, H. & W. p. 97.
Acrotreta gemma, Billings, p. 98.
Kutorgina pannula, White, p. 105.
  prospectensis, Walcott, p. 106.
Acrothele subsidua, White, p. 108.
Scenella ? conula, Walcott, p. 127.
Stenotheca ? elongata, Walcott, p. 129.
Agnostus interstrictus, White, p. 149.
Olenellus iddingsi, Walcott, p. 170.
  gilberti, Meek, p. 170.
Olenoides nevadensis, Meek, p. 181.
  spinosus, Walcott, p. 184.
  ? flagricaudus, White, p. 185.
  quadriceps, H. & W., p. 187.
  wasatchensis, H. & W., p. 189.
Ptychoparia kingi, Meek (sp.), p. 193.
  quadrans, H. & W., p. 199.
  ? prospectensis, Walcott, p. 202.
  subcoronata, H. & W., p. 205.
Anomocare ? parvum, Walcott, p. 209.
Bathyuriscus productus, H. & W., p. 217.
Asaphiscus wheeleri, Meek, p. 220.

A discussion of several of the genera is also presented.

In a paper on the stratigraphic position of the Olenellus fauna Mr. C. D. Walcott reviewed the stratigraphic position of the fauna described in Bulletin 30 of the U. S. Geological Survey, and referred the

[1] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886.

following species, formerly assigned to the Lower Cambrian fauna, to the Middle Cambrian zone, considering the Olenellus zone to include only the Lower Cambrian fauna.[1] The species are:

Protospongia fenestrata, Salter.
Eocystites ? ? longidactylus, Walcott.
Leperditia argenta, Walcott.
Agnostus interstrictus, White.
Olenoides nevadensis, Meek (sp.).
  quadriceps, Hall & Whitfield (sp.).
  wasatchensis, H. & W. (sp.).
  spinosus, Walcott.
  typicalis, Walcott.
Ptychoparia housensis, Walcott.
  kingi, Meek (sp.).
  piochensis, Walcott.
  ? prospectensis, Walcott.
  quadrans, H. & W. (sp.).
  subcoronata, H. & W. (sp.).
Bathyuriscus howelli, Walcott.
  productus, H. & W. (sp.).
Asaphiscus wheeleri, Meek.

Ptychaspis piochensis occurs 100 feet above the Olenellus zone proper, in the Highland range section, but as it also occurs 1,137 feet higher up in the same section, it is now referred to the Middle Cambrian fauna and not to the Olenellus fauna.[2]

The presence of Cambrian fossils at Kicking Horse Pass of the Rocky Mountain division of the Canadian Pacific Railway was announced by Mr. H. H. Winwood in 1885.[3] Indirect reference was also made to this by Dr. G. M. Dawson in 1884.[4] The specimens obtained at that time were examined by Mr. C. D. Walcott, who recognized *Olenellus howelli* and *Olenoides levis*, trilobites characteristic of the Prospect Mountain group of Nevada.[5]

During the survey by Mr. R. G. McConnell of the section along the line of the Canadian Pacific Railway there was discovered at Mount Stephen a zone of fossiliferous slate 2,000 feet above the base of the Castle Mountain limestone. From the collections obtained Dr. C. Rominger described the new genus Embolimus and five new species of trilobites, viz: *Ogygia klotzi*, *O. serrata*, *Embolimus spinosa*, *E. rotundata*, and *Conocephalites cordilleræ*. He also identified *Menocephalus salteri ?*, Billings, *Bathyurus ?*, *Agnostus* ("compare *A. interger* Barr"), and the genera Orthis, Obolella, Kutorgina, Leptæna ?, Metoptoma, and Hyolithes.[6]

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[1] Stratigraphic succession of the Olenellus fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, pp. 374–392; vol. 38, 1889, pp. 29–42.

[2] Op. cit., p. 387.

[3] Geological age of the Rocky Mountains. Geol. Magazine, new ser., dec. 3, vol. 2, 1885, p. 240.

[4] Recent geological observations on the Canadian Northwest Territory. Science, vol. 3, 1884, p. 648.

[5] Preliminary report on the physical and geological features of that portion of the Rocky Mountains between latitudes 49° and 51° 30′. Geol. Surv. Canada, new ser., vol. 1, 1886, p. 140B.

[6] Description of Primordial fossils from Mount Stephen, Northwest Territory of Canada. Philadelphia Acad. Sci., Proc., 1887, pp. 12–19.

A review of Dr. Rominger's work on the Mount Stephen fossils by Mr. C. D. Walcott resulted in his determining that *Embolimus spinosa*, Rom. = *Zacanthoides spinosus*, Walcott; *Embolimus rotundata*, Rom. = *Bathyuriscus howelli*, Walcott; *Ogygia serrata* = *Olenoides nevadensis*, Meek; and that *Conocephalites cordilleræ*, Rom. = *Ptychoparia cordilleræ*, Rom. (sp.), and *Ogygia ? ? klotzi*, Rom., are new to the previously known Cambrian fauna. The genus Zacanthoides is proposed to include *Olenoides typicalis*, *O. spinosus*, *O. levis*, and *O. flagricaudus*, described in 1886. There were also identified from the material studied by Dr. Rominger *Agnostus interstrictus*, *Acrotreta gemma*, *Kutorgina prospectensis*, and *Hyolithellus micans*.[1] Subsequently from the collection studied by Dr. Rominger there were described by Mr. Walcott, *Lingulella macconelli* *Crania ? columbiana*, *Acrotreta gemma* var. *depressa*, *Orthisina alberta*, *Platyceras romingeri*, *Karlia stephenensis*, *Bathyuriscus* (*Kootenia*) *dawsoni*, and the genus Ogygopsis was proposed to include the *Ogygia klotzi* of Rominger. *Linnarssonia sagittalis* was also identified.[2]

In 1890 Mr. C. D. Walcott[3] described three new species from the Highland range section of Central Nevada, referring them to the Upper Cambrian. These species are *Hyolithes attenuatus*, *H. curvatus*, and *H.* (?) *corrugatus*.

INTERIOR CONTINENTAL PROVINCE.

This province includes the Upper Mississippi area, the eastern border or Adirondack subprovince, the western border or Rocky Mountain subprovince, and the Llano County area of central Texas and the Grand Cañon of Arizona as a minor southwestern subprovince.

UPPER MISSISSIPPI AREA.

For convenience of reference the review of the literature pertaining to Wisconsin, Minnesota, and Iowa is assembled for each State. The Ozark area of southeastern Missouri is considered separately, and the Lake Superior sandstones and the controversy in relation to them is noticed under a distinct heading, after the description of the recognized Upper Cambrian rocks of Wisconsin, Iowa, and Minnesota, and their extension into Canada. This division also includes the references to the Cambrian rocks of Michigan.

WISCONSIN.

In 1843, in notes on the geology of the Western States, Dr. D. D. Owen called attention to the presence of a sandstone on the Mississippi River, at Prairie du Chien, visible beneath the Lower Magnesian lime-

[1] Cambrian fossils from Mount Stephens. Am. Jour. Sci., 3d ser., vol. 36, 1888, p. 165.

[2] Descriptions of new genera and species of fossils from the Middle Cambrian. U. S. National Museum, Proc., vol. 11, 1889, pp. 441-446.

[3] Description of new forms of Upper Cambrian fossils. U. S. Nat. Mus. Proc., vol. 13, 1890, pp. 267-279.

stone of the Wisconsin River.[1] Five years later, in the report of a geological reconnaissance of the Chippewa land district of Wisconsin, he describes with considerable detail Formation 1, or the lower sandstone of the Upper Mississippi. The formation, as a whole, is subdivided into five parts. The lowest part rests upon crystalline and metamorphic rocks, in the eastern part of the Chippewa land district, as a coarse sandstone overlaid by a still coarser quartzose sandstone.[2] At the Falls of the St. Croix the schistose, silico-calcareous layers of the second division are highly fossiliferous. In the third division the prevailing genera are Lingula and Orbicula[3] and it is designated as the "Lingula sandstone." In speaking of the beds of sandstone beneath the fossiliferous layers at Mountain Island it is stated that in all probability this is the western equivalent of the Lingula beds of the New York Potsdam sandstone.[4]

A notice of the discovery of the fauna in the lower sandstone of Wisconsin was communicated by Dr. Owen in 1848 to the Geological Society of France through a letter to M. de Verneuil.[5]

In a letter descriptive of the geology of southeastern Wisconsin addressed to Mr. J. W. Foster, Mr. I. A. Lapham states that—

The *Inferior*, or *Potsdam sandstone*, is found at Janesville and above, occupying the bed of the river. The grains are rounded, smooth, and without apparent cement; the rock easily crumbles upon exposure; color white or red. The white variety might be used for the manufacture of glass. The discovery, in 1849, of that singular and characteristic fossil described by Mr. Hall as *Scolithus linearis* (New York Pal., vol. 1, p. 2) in this rock, in Sauk County, may be considered as settling the question of the identity of this rock with the Potsdam sandstone of the New York reports. It occupies much of the counties Marquette and Columbia, enters Dane County, and is seen in the banks of Rock River from Lake Koshkonong to Janesville.

* * * II. *Calciferous rock of Eaton.*—Resting immediately upon the sandstone, at Janesville, is a limestone with grains of the same sand intermixed, giving it the form and appearance of an oolite limestone; the amount of sand diminishing as you rise from the surface of the sandstone. It accords exactly with the description given of a portion of the calciferous sandstone of New York, and contains the same fucoid (*Palæophycus tubularis*), as well as other characteristic fossils. Its character and relative position also clearly show that it is the same rock that, farther west and north, is called the *Lower Magnesian limestone*, by Drs. Owen and Locke.[6]

In the same report, Mr. Charles Whittlesey describes the sandstone as it occurs near Wolf River, etc., stating it to be a sandstone easily crushed between the fingers, which has been so extensively denuded that it is only here and there that a trace of its former existence is

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[1] On the geology of the Western States. Am. Jour. Sci., vol. 45, 1843, p. 164.

[2] Owen, David Dale: Report of a geological reconnaissance of the Chippewa land district of Wisconsin, and incidentally of a portion of * * * Iowa and of the Minnesota territory. Letter of the Secretary of the Treasury communicating a report of a geological reconnaissance of the Chippewa land district of Wisconsin, etc., by D. D. Owen, Thirtieth Congress, first session, Senate Ex. Doc. No. 57, 1848, p. 13.

[3] Op. cit., p. 14.

[4] Op. cit., p. 15.

[5] Letter on geology of Wisconsin Territory. Bull. Soc. géol. France, 2e sér., vol. 5, 1848, pp. 294-296.

[6] Lapham, I. A.: "On the geology of the southeastern portion of the State of Wisconsin, being the part not surveyed by United States geologists." Rept. on the geology of the Lake Superior land district, by Foster and Whitney, part 2, 1851, p. 169.

left.[1] On the Upper Menomonee River the sandstone has a thickness of 150 feet, and the entire thickness is estimated at 200 feet.[2]

In giving an account of his investigations in connection with the geological survey under the direction of Messrs. Foster and Whitney, Prof. J. Hall states:

I have also satisfied myself that the sandstones of the Upper Mississippi are of the same age as the Potsdam sandstones, and that the Lower Magnesian limestone of the Western geologists is identical with the calciferous sandstone of New York, the next member of the series above the Potsdam sandstone. The thin bed of sandstone succeeding this rock can not be identified as the Potsdam sandstone by itself, but must be regarded as a repetition of the arenaceous deposits below, which likewise alternate with the calciferous sandstone near its base.[3]

He thus corroborates the view of Dr. D. D. Owen that the lower sandstone of Wisconsin is the equivalent of the New York Potsdam.

In 1851 M. E. Desor called attention to the presence at St. Croix of a fossiliferous sandstone 800 feet beneath that described by Professor Hall, in which he found fossils.[4]

In a paper on the paleontology of the lowest sandstone of the northwest Dr. D. D. Owen states that he observed multitudes of Lingulas and Orbiculas disseminated in strata abutting against the southwest side of the trap range that crosses the St. Croix River at the falls. This was in 1847. During the remainder of this season and in that of 1848 he found finer-grained and more laminated soft sandstones, with subordinated silico-calcareous layers, charged with Obolus, like those which characterize the lowest sandstones of Russia. This was in a section on the Mississippi, between the Falls of St. Anthony and the mouth of the Wisconsin River. From the results of these observations he finally developed beneath the Lower Magnesian limestone at least six different trilobite beds, separated by from 10 to 150 feet of intervening strata.[5]

In the final report on the geology of the Upper Mississippi Valley, the same writer describes the lower sandstone as composed of light-colored quartzose sandstone that forms the greater part of the formation, with intercalations of magnesian limestone, especially toward its upper part, where it graduates into Formation No. 2, and at certain localities argillaceous, and other beds of a mixed character form a considerable portion of its lower mass.[6] In a table of the elementary stratification of the lowest Protozoic sandstones he places the Lake Superior ferrugi-

[1] Remarks upon the section from the falls of Wolf River, through Navarino to Lake Michigan. Rept. on the geology of the Lake Superior land district, by Foster and Whitney, part 2, 1851, p. 174.

[2] Whittlesey, Charles: The dip, bearing, and thickness of the Silurian groups. Rept. on the geology of the Lake Superior land district, by Foster and Whitney, part 2, 1851, p. 183.

[3] (Geological investigations on Drummond's Island and the north shores of Lakes Huron and Michigan, etc.) Am. Acad. Proc., vol. 2, 1851, p. 254.

[4] [Potsdam sandstone on the river St. Croix.] Boston Soc. Nat. Hist. Proc., vol. 3, 1851, p. 202.

[5] On the paleontology of the lowest sandstones of the Northwest. Am. Assoc. Proc., vol. 5, 1851, pp. 169–172.

[6] Geol. Surv. of Wisconsin, Iowa, and Minnesota, and incidentally of a portion of Nebraska Territory, Philadelphia, 1852, p. 48.

nous and argillaceous sandstones, shales, and conglomerates at the base, assigning it a thickness of 5,000 feet. Above this occur coarse grits and sandstones of the Chippewa, Black and Wisconsin Rivers.[1] The placing of the lower sandstone of Lake Superior in this position is theoretical. Above the coarse sandstone the formation is divided into six trilobite beds, as follows:[2]

Table of the elementary stratification of the lowest Protozoic sandstones.—Formation 1.

			Feet.
f.	Sixth Trilobite bed...	Quartzose, light-colored sandstones of various degrees of induration, with intercalations of beds of magnesian limestone, with glistening crystalline facets, and calcareo-siliceous oolite, produced by rounded grains of quartz, encased in calcareous cement, containing Euomphalas and imperfect Trilobites. Locally with a band of green earth	50 to 85
f.		Mammillary and botryoidal layer of white sandstone; sometimes banded with yellow ..... 5 to 6 inches.	
e.	....	Thick beds of soft, yellowish and brown sandstone, sometimes with botryoidal, hard, projecting concretions passing downward into fine-grained soft sandstones approaching tripoli	40 to 50
d.	Fifth Trilobite bed...	Ash-colored and yellowish argillo-calcareous and magnesio-calcareous beds, containing *Dikelocephalus minnesotensis.*	
d.	Fifth Trilobite bed...	Stillwater Trilobite bed	8 to 10
d.		Green, red, and yellowish sandstones with thin, schistose, dolomitic intercalations	40
d.		Upper, brown dolomitic layers containing Orthis, Lingulas, and columns of Crinoidea as at La Grange Mountain	4
d.	Fourth Trilobite bed..	Alternations of yellow, laminated sandstones, with green particles disseminated	5
d.	Fourth Trilobite bed..	Marine Mill Trilobite grit	5
d.		Fucoidal layers, and thin-bedded green and yellow sandstones, at their base often a band of about 6 inches of green earth used by the Indians as a pigment	30 to 40
d.		Green and red sandstones, charged with silicate of iron	5
d.		Loose, green sand, and soft green sandstone	15
d.	Third Trilobite bed...	Micaceous sandstone, containing *Dikelocephalus meniskaensis*, *D. granulosa*, etc	3
d.	Third Trilobite bed...	Alternations of green and ferruginous sandstones	20
d.	Third Trilobite bed...	Micaceous sandstones containing *D. meniskaensis*, etc	2
d.		Thin layers of green sand, alternating with green earth, impregnated with silicate of iron	30 to 40
d.		Lower, brown siliceo-calcareous and dolomitic bands of Mountain Island, and elsewhere	4
d.		Soft, thin-bedded sandstones, with scales of mica disseminated	10 to 15
c.	....	Coarse lingula grit, green, yellow, sometimes almost white	100 to 130

[1] Op. cit., p. 53.

[2] Op. cit., pp. 52, 53.

Table of the elementary stratification of the Lowest Protozoic sandstones, etc.—Continued.

			Feet.
b.	Second Trilobite bed..	Fine grit. Place of the Menomonie Trilobite grit (?). White and yellow sandstone, and Obolus layers of Black River	15
	First Trilobite bed....	Ferruginous Trilobite grits. Schistose sandstone, containing fork-tailed Trilobite beds and Obolus layers	1 to 8
		Magnesio-calcareous rock, with Obolus and fork-tailed Trilobite	3
		Highly fossiliferous schistose, siliceo-calcareous layers, interlaminated with argillaceous, marly beds, charged with sulphate of iron; the former full of Lingulas and Orbiculas (Falls of St. Croix)	50
a.		Sandstone, with oblique lines of deposition, alternating with pebbly sandstones and coarse grits of the Chippewa and Black and Wisconsin Rivers near the falls	50 to 100
		Place of the Lake Superior ferruginous and argillaceous sandstones, shales, and conglomerates	5,000

The geographic distribution of the formation is shown on the map accompanying the report.

The local details of the sections in Wisconsin are reported upon by Prof. B. F. Shumard. Much of the information here given was used by Dr. Owen in giving the summary of the divisions referred to Formation No. 1, or the lower sandstone.[1]

The sandstones of the south shore of Lake Superior are described by Mr. J. C. Norwood, and a section given of them as seen at the mouth of Cranberry River. He also describes the sandstones of the St. Croix River.[2]

In his annual report of the geological survey of the State of Wisconsin Prof. J. G. Percival describes the lower sandstone with considerable detail, but without special addition to the information given by Dr. Owen. He separates, however, the quartz rock of the Baraboo and of Portland from the Lower sandstone.[3]

The volume of the geological survey of Wisconsin, by Prof. James Hall, contains a general account of the Potsdam sandstone. The opening paragraph describes it as follows:

> The lowest rock of the series is the Potsdam sandstone, which is known in the northwest as the Lower sandstone, in contràdistinction to the Upper or St. Peter's sandstone, which lies above the Lower Magnesian limestone. This is equivalent to the Potsdam sandstone in New York, and holds in all respects the same geological position: it is the lowest fossiliferous rock observed in the geological surveys of New York, where it received its name.
>
> This rock has been traced, with slight interruptions, westward from Lake Cham-

[1] Geol. Report of local, detailed observations in the valleys of the Minnesota, Mississippi, and Wisconsin Rivers. Report of a geological survey of Wisconsin, Iowa, and Minnesota; and incidentally of a portion of Nebraska Territory. Philadelphia, 1852, pp. 475–531.

[2] Geol. Report of a survey of portions of Wisconsin, and Minnesota. Rep. Geol. Surv. of Wisconsin, Iowa, and Minnesota; and incidentally of a portion of Nebraska Territory. Philadelphia, 1852, pp. 275–277.

[3] **Annual Report of the Geological Survey of the State of Wisconsin. Madison, 1856, pp. 92–101.**

plain through Canada to the outlet of Lake Superior and along the south shore of that lake.[1]

This is followed by a general account of the formation and of the organic remains found in it.[2]

In the same volume Prof. J. D. Whitney prints a brief résumé of the Potsdam or lower sandstone.[3]

In a paper entitled "Preliminary notice of the fauna of the Potsdam sandstone," Prof. James Hall states that in 1850 he had the opportunity of tracing the formations from Drummond's Island and St. Mary's River to the head of Green Bay and thence across the country to the Mississippi River.[4] He comes to this conclusion:

The position of the sandstone on the St. Mary's admitted of no doubt, and its relative position to the lower limestone had before that time been well determined, and the same was likewise ascertained by the several exploring parties along different lines between Lake Superior and Green Bay.

Throughout Wisconsin there is no difficulty in recognizing the following sequence:

Trenton limestone;
Black River or Buff limestone;
Birdseye limestone;
St. Peter's sandstone;
Lower Magnesian limestone, or calciferous sandstone;
Potsdam sandstone.

The St. Peter's sandstone holds the place of the Chazy limestone of the more eastern localities, and, with this exception, we have the same sequence that we find in New York, many of the fossils being common to the limestone of New York and Wisconsin.

Dr. Owen, in his published report, has adopted this view of the sequence, and the explorations of subsequent years have confirmed the opinions then entertained; and I believe at this time every geologist will admit the identity of the Potsdam sandstone of New York and the Lower sandstone of the Upper Mississippi Valley.

In speaking of this sandstone I shall, therefore, without hesitation, refer to it as the Potsdam sandstone.[5]

A list of fossils described in the memoir is given to illustrate their stratigraphic position.[6] In this list the fauna is divided into that of the lower beds, middle beds, and upper beds, the latter characterized especially by the presence of the genus Dikelocephalus. In a supplementary note on the Potsdam sandstone that accompanies the memoir he gives a résumé of the evidence upon which the lower sandstone of the Upper Mississippi Valley has been placed in parallelism with the sandstone of New York, known as the Potsdam sandstone, as follows:[7]

In comparing the older rocks of New York and of the East generally with those of the West, it should not be forgotten that there is a long interval on the line of the

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[1] Physical geography and general geology. Geol. Surv. Wisconsin, Report, vol. 1, 1862, p. 14.
[2] Op. cit., pp. 20-23.
[3] Stratigraphical geology. Geol. Surv. Wisconsin, Rep., vol. 1, 1862, pp. 140-144.
[4] Preliminary notice of the fauna of the Potsdam sandstone, with remarks on the previously known species of fossils and descriptions of some new ones from the sandstone of the Upper Mississippi Valley. 16th Ann. Rep. Regents Univ. N. Y., State Cab. Nat. Hist., 1863, pp. 119, 120.
[5] Op. cit., p. 120.
[6] Op. cit., p. 209.
[7] Op. cit., pp. 211-212.

northern outcrop of these ancient strata, between the St. Lawrence and the western limit of Michigan on the Menomonee River, where we can expect little aid from paleontology. The fossiliferous beds of these ancient formations in Wisconsin lie to the west of what appears to have been a great promontory at the time of their deposition, stretching southward from the region of Lake Superior far into the ancient sea. The disconnection caused by this promontory between the East and the West would of itself prepare us to expect a fauna differing in a great degree from beds of corresponding age on the opposite sides.

It has been shown, by the investigations of the Canadian Survey, that not only the Potsdam sandstone, but all the fossiliferous beds below the Birdseye and Black River limestones are absent from Kingston on Lake Ontario to Lacloche on Lake Huron. From Lacloche to Lake Superior there is a sandstone coming in below the Birdseye limestone, which, from its position, may be considered of the age of the Chazy[1] formation and equivalent to the St. Peters sandstone of Wisconsin and Minnesota; and it is this sandstone, doubtless, which has been taken for the Potsdam sandstone in some localities along that line.

The succeeding Birdseye and Black River formation, from Lacloche to Lake Superior, has become a buff-colored magnesian limestone, or weathering externally to this color, but still holding the characteristic fossils.

In New York a sandstone (the Potsdam) lies immediately beneath a magnesian limestone (the "Calciferous sandrock"): this deposit is succeeded by a calcareous formation (the Chazy), including a sandstone and surmounted by the Birdseye, Black River, and Trenton limestones.

In Wisconsin, Iowa, and Minnesota, we have undoubted Trenton limestone, and below it a buff-colored magnesian limestone containing so many of the characteristic fossils of the Birdseye and Black River limestones as to leave no doubt of the parallelism of these beds with those of New York. Below this magnesian limestone we have the St. Peters sandstone, corresponding, as already shown, with the Chazy formation; and beneath this a magnesian limestone, which, in its position and lithological character, corresponds in all respects with the "*Calciferous sandrock*" of New York.

It is from all these facts that the lower sandstone of the Upper Mississippi Valley has been placed in parallelism with the sandstone of New York known as the "Potsdam."

Notwithstanding, however, that this sequence is precisely like that observed in New York, it may not yet be regarded as proved that the sandstone, from which I have described these fossils, is in all respects the equivalent of the Potsdam sandstone of New York, Vermont, and Canada. It may represent more, or it may represent less than that formation. The *lower* accessible beds of the Mississippi Valley may represent the Potsdam of 150 or 200 feet in thickness in the typical localities in New York, while the middle and upper beds of the West may be of epochs not represented in that part of the series studied in New York; and in some other places, as in the regions just mentioned, the same epochs may be represented by a shaly or semicalcareous deposition, or may be included in the commencement of the Calciferous epoch. It should not therefore be regarded as decided that the Potsdam sandstone, as developed in New York, occupies the entire interval from the base of the oldest sedimentary formation of the Paleozoic era to the Calciferous sandstone. From what we know of the primordial fauna in other localities, we are prepared to find beds above or below, or both above and below, the epoch represented (so far as now known) by the Potsdam sandstone of New York, and which may still be of the same period.

[1] The "Chazy formation" of the Canadian Geological Survey, in its eastern localities, includes a sandstone which comes in below the greater part of the limestone, leaving from 10 to 20 feet of shale and limestone beneath (Geology of Canada, 1863, p. 123). It is apparently this sandstone of the Chazy formation, having in Canada a thickness of 50 feet, which has become augmented in its western extension, while the calcareous part of the formation has partially or entirely disappeared.

He then enters upon the discussion of the relative age of the sandstones of Wisconsin and those of Lake Superior, and concludes that while the older beds of the latter area are apparently below the fossiliferous beds of the Upper Mississippi Valley, the newer sandstone of the St. Mary's River, which is apparently of the age of the St. Peter sandstone, or the Chazy formation, will be found overlying the fossiliferous sandstone, either with or without the intervention of the Lower Magnesian limestone.[1]

On a geological map of Wisconsin published in 1855 Mr. I. A. Lapham delineates the distribution of a sandstone occurring beneath the Lower Magnesian limestone. Under the same color he includes the sandstone on the south shore of Lake Superior, both on the north and southeastern side of the trap rocks of Keweenaw Point. The distribution of the fossiliferous sandstone south and southeast and east of the northern area of the primitive rocks is also laid down.[2] In a new geological map of Wisconsin, published in 1869, only the sandstones of the northwestern portion of the State are colored as Potsdam sandstone. In the vicinity of the shores of Lake Superior the Michigan area on the map of 1855 is left uncolored.

A paper on the age of the quartzites, schists, and conglomerates of Sauk County, Wisconsin, by Prof. R. D. Irving, proves conclusively that the quartzites are of pre-Potsdam age, and that the latter are deposited unconformably upon the flanks of the hill formed by the quartzites.[3] The evidence given by Prof. Irving negatives the conclusion arrived at by Dr. Alexander Winchell in his description of the fossils of Sauk County, where he states that Ptychaspis and Dikelocephalus occur at the base of the Potsdam, and that the quartzites in question are the lower beds of the Potsdam formation.[4] In the region of south-central Wisconsin, especially in Dane and Columbia Counties, Prof. Irving obtained a thickness of 800 feet for the lower or Potsdam sandstone, and for the superjacent Mendota limestone 30 feet, above which occurs the Madison sandstone, with a thickness of 35 feet. He refers only the lower or Potsdam sandstone to the Primordial.[5]

The sketch on the geology of northern Wisconsin by Mr. E. T. Sweet gives a general description of the Potsdam sandstone, and attention is called to the fact that all the strata at the falls of St. Croix belong to this sandstone formation and that none of them are of igneous origin, as suggested by Dr. Owen.[6]

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[1] Op. cit., p. 220.

[2] Lapham, I. A.: Geological Map of Wisconsin. Milwaukee, 1855. Also a map for 1869.

[3] On the age of the quartzites, schists, and conglomerates of Sauk County, Wisconsin. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 95–99. Wisc. Acad. Sci. Trans., vol. 1, 1872, pp. 129–137.

[4] Notice of a small collection of fossils from the Potsdam sandstone of Wisconsin and the Lake Superior sandstone of Michigan. Am. Jour. Sci., 2d ser., vol. 37, 1864, pp. 226–232.

[5] Note on some new points in the elementary stratification of the Primordial and Canadian rocks of south-central Wisconsin. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 441, 443.

[6] Notes on the geology of northern Wisconsin. Wisc. Acad. Sci. Trans., vol. 3, 1876, p. 51.

A note on the age of the Crystalline rocks of Wisconsin by Prof. Irving states that the exact junction between the Potsdam and the Huronian formations is often to be seen, the almost loose sand of the Potsdam, with numerous fossils, together with fragments derived from the older rocks, lying upon and wedged in between the tilted edges of Huronian quartzite, schist, or other rock. Exactly similar unconformability is to be seen at the Dalles of the St. Croix River between the Potsdam and copper-bearing series; the horizontal beds of the former, filled with shells of Lingulella, lying directly upon the columar, melaphyre (?) of the latter series, the exact junction of the two series being exposed.[1]

The description of the geology of eastern Wisconsin by Prof. T. C. Chamberlin contains a detailed account of the "Potsdam sandstone." He says:

That it is the exact equivalent of the Potsdam sandstone of New York, as would seem to be implied by the name, is not absolutely certain, but as the term has been used to designate this formation in previous reports upon the geology of the State, and as the weight of evidence and authority favors this view, the name Potsdam sandstone will be used without further qualification in this report.[2]

The sandstone varies greatly in thickness, ranging from zero to about 1,000 feet. A detailed account of the formation is given with a list of the fossils found in the sandstone. The Madison sandstone and Mendota limestone are included as subdivisions of the terrane.

Reference to the description of the Lower or "Potsdam" sandstone series of central Wisconsin by Prof. R. D. Irving,[3] will be made under the description of the Potsdam terrane in Wisconsin.

A general description of the mode of occurrence and character of the Potsdam sandstone in the lead regions of northwestern Wisconsin was published by Mr. Moses Strong in 1877.[4]

Upon the basis of work in St. Croix, Dunn, and adjacent counties, Mr. L. C. Wooster subdivided the "Potsdam" as follows:[5]

The numbers indicate the distances below the Lower Magnesian limestone.

(*a*) Upper calcareous band: This varies greatly in thickness, and is the probable northwestern equivalent of the Mendota limestone near Madison; 75 to 85 feet.

(*b*) Lower calcareous band: The limestone characters and the thickness are more uniformly persistent than in *a;* 145 to 195 feet.

(*c*) Hudson trilobite beds: Quite rich in trilobites and brachiopods, including one new species of the former, with several undetermined ones; 150 to 200 feet.

(*d*) Glauconite layers: These comprise those layers which are very rich in glauconite. Crinoid stems were found in these at Hudson; 160 to 210 feet.

In *b*, *c*, and *d*, the lesser distance from the Lower Magnesian is true for western St. Croix County, while the greater is nearer true for points east.

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[1] Note on the age of the Crystalline rocks of Wisconsin. Am. Jour. Sci., 3d ser., vol. 13, 1877, p. 308.

[2] (Geology of eastern Wisconsin.) Geol. Wisc., Surv. of 1873–'77, vol. 2, 1877, p. 257.

[3] (Geology of central Wisconsin.) Geol. Wisc., Surv. of 1873–'77, vol. 2, 1877, pp. 525–607.

[4] Geol. Wisc. Surv. of, 1873–'77, vol. 2, 1877, pp. 668–688.

[5] Work in St. Croix, Dunn, and adjacent counties. Geol. Surv. Wisconsin, Ann. Rep. for 1877, 1878 pp. 36, 37.

(*e*) Eau Claire trilobite beds: These hold at least seven species of trilobites, of which three are new, and a few brachiopods. These beds mark the lower limit of calcareous matter in the formation; 450 feet.

(*f*) Eau Claire grit: These layers mark the upper limit of the coarse sandstones, almost conglomerates; 680 feet.

The mode of occurrence and character of the "Potsdam" sandstone in the upper St. Croix district is described in great detail by Mr. Moses Strong.[1] In this he shows the unconformity between the "Potsdam" and the subjacent strata referred to the Keweenawan (Keweenaw) series, and describes the various sections of the sandstone exposed. The knowledge of the local details of the distribution and character of the "Potsdam" sandstone of the Mississippi region north of the Wisconsin River was increased by him in 1882 by the publication of many sections and descriptive details that will be used in a summary of our knowledge of the Cambrian rocks of that region.[2]

The "Potsdam" terrane of the lower St. Croix district was described by Mr. L. C. Wooster in the same volume with the report of Mr. Strong. This report also contains considerable data that will be referred to in the description of the Cambrian rocks of the region.[3]

The geographic distribution of the "Potsdam" sandstone and its relation to the subjacent pre-Cambrian rocks and the superjacent magnesian limestone is shown with great accuracy upon the general geological map of Wisconsin, published in 1881, and in the two sections at the bottom of the sheet.

A note by A. A. Young on the crystallized sands of the "Potsdam" sandstone of Wisconsin describes the manner in which the original grains of the sandstone are surrounded by crystalline envelopes of quartz.[4]

The summary of the geology of Wisconsin by Prof. T. C. Chamberlin contains a description of the rocks of the "Potsdam" period. These include the "Potsdam" epoch, the Lower Magnesian epoch, and the St. Peters epoch, in part. A general description of the formations, accompanied by an account of the life of each epoch, is followed by some general observations upon the Cambrian age, to which the formations are referred.[5]

The occurrence of a conglomerate formed of bowlders from the trap of the copper-bearing series in a matrix of sandstone that contains fragments of Linguloid shells, apparently *Lingulepis pinnaformis*, is noted by Mr. L. C. Wooster at a locality on the St. Croix River. From the mode of occurrence of the conglomerate he concludes that it must have

[1] Geology of the upper St. Croix district. Geology of Wisconsin, survey of 1873-1879, 1880, vol. 3, pp. 390-428.

[2] [Geology of the Mississippi region north of the Wisconsin River.] Geol. Wisconsin, survey of 1873-'79, vol. 4, 1882, pp. 38-91.

[3] [Geology of the lower St. Croix district.] Geol. Wisconsin, survey of 1873-'79, vol. 4, 1882, pp. 109-130.

[4] Further observations on the crystallized sands of the Potsdam sandstone of Wisconsin. Am. Jour. Sci., 3d ser., vol. 24, 1882, pp. 47-49.

[5] General Geology. Geol. Wisconsin, survey of 1873-'79, vol. 1, 1883, pp. 119-200.

accumulated along a cliff of the copper-bearing rocks and that the age of the conglomerate must be late "Potsdam."[1]

In an extended paper on the classification of early Cambrian and pre-Cambrian formations Prof. R. D. Irving illustrates the unconformity between the "Potsdam" sandstone and the subjacent Huronian and Keweenawan rocks. He also discusses the similar stratigraphic relations of the Cambrian and pre-Cambrian rocks of the Grand Cañon Region.[2]

MINNESOTA.

The presence of the lower sandstone along the Mississippi River below the Falls of St. Anthony to the Iowa line was proved by the survey of Dr. D. D. Owen in Wisconsin, Iowa, and Minnesota. Alternating exposures of the strata occur along the river and some of the tributaries flowing into it from the west.[3] On the accompanying map there is also a narrow area colored Potsdam along the valley of the Minnesota or St. Peter's River.

Little additional information in regard to Minnesota was published until Prof. N. H. Winchell, in the first annual report of the geological survey of Minnesota, discussed, under the title of "Potsdam Sandstone," the Sioux quartzite of northwestern Minnesota, and "The St. Croix Sandstone," the fossiliferous sandstone of the southeastern portion of the State, referred to the Potsdam by Dr. Owen.[4] Of the term "Potsdam," he says:

> This term is strictly applicable only to the sandstones of New York State, to which the name was first given, and to the equivalents of those strata in their extension through the West. It has been abundantly proved that the red sandstones of Lake Superior, however disturbed and changed locally, or however much increased in thickness by the agency of volcanic outbursts, are the exact equivalents of the New York *Potsdam*. They occupy the first position over the metamorphic slates of the *Huronian* rocks on which they lie unconformably, and from which they differ in being but slightly and only locally metamorphosed. They retain usually their evidently sedimentary characters, and have not well preserved fossil remains.[5]

He states further that in Wisconsin the upper sandstones are found to lie unconformably upon the red sandstones where they have been tilted by volcanic agency, thus referring the quartzite of Sauk County to the Potsdam, and the superjacent fossiliferous, Upper Cambrian sandstones that have been correlated by authors with the Potsdam of New York, to his St. Croix sandstone. The red sandstone or Sioux quartzite is said to be both older than and unconformable with the

[1] Transition from the copper-bearing series to the Potsdam. Am. Jour. Sci., 3d ser., vol. 27, 1884, pp. 463–465.

[2] On the classification of the early Cambrian and pre-Cambrian formations. U. S. Geol. Surv., 7th Ann Rep. for 1885–'86, 1888, pp. 365–454.

[3] Geol. Surv. of Wis., Iowa, and Minn., and incidentally of a portion of Nebraska Territory, Philadelphia, 1852, pp. 48, 49.

[4] General sketch of the geology of Minnesota. Geol. and Nat. Hist. Survey Minnesota, 1st Ann. Rep. for 1872–'73, 1st ed., pp. 68–80.

[5] Op. cit., p. 68.

light-colored sandstones that occupy a conspicuous place in the bluffs of the Upper Mississippi, below the Lower Magnesian limestone. Of the *Sioux quartzite* he says that—

Its features here are easily identifiable with those of the Potsdam at the rapids in the St. Mary's River, at Sault Ste. Marie, Michigan. In their passage to the west, the over-lying, light-colored sandstones seem to become more largely developed. They acquire a thickness, including the intercalated beds of shale, of about 600 feet in their exposures along the Mississippi River.[1]

Of the fossils collected from the horizontal beds at the Falls of the St. Croix it is said they:

Were described as coming from the *Potsdam sandstone*, and were supposed to belong to a horizon much lower than that of the *Lingula Beds* of the *Potsdam* of New York. The name has been still further removed from its original use by the Iowa geologists, *in its application only to these upper beds*, and in giving the name *Sioux quartzite* to the western representative of the original *Potsdam*. Dr. Owen, although he recognized many points of difference between the Lake Superior and New York *Potsdam*, and these light-colored sandstones of the St. Croix and Upper Mississippi, seems not to have noted the important fact that the former are everywhere subject to distortions and fractures by volcanic forces, while the latter are never known to be disturbed by such causes. It is true that he embraces both the red and the light-colored sandstones in the designation of "Potsdam," and argues at length to prove the great age of the red. (Geological Survey of Wisconsin, Iowa and Minnesota, p. 187.)

It is in accord with geological precedent, therefore, to separate these two sandstone formations under different names, retaining the name of *Potsdam* for the older, and giving provisionally the name of the St. Croix River, on which they are best exposed, to the latter.

The following reasons may be assigned:

(1) The *Potsdam* beds were laid down before the close of the volcanic disturbance so evident in the rocks of the early Silurian and pre-Silurian ages; the *St. Croix* beds were deposited and still lie in horizontal layers, unconformably not only over the *Laurentian* and latest trappean rocks of the northwest, but also on the upturned beds of the Potsdam.[2]

(2) This reason has little bearing and will not be quoted.

(3) The lithological characters of the *Potsdam* beds are uniformly different from those of the *St. Croix* beds. The former are hard and often vitreous, usually of a brick-red color. Their bedding is very distinct, and often separated into slaty layers by partings of red shale. They are strongly marked by the so-called fucoidal impressions. They are frequently ripple-marked and sun-cracked. The latter are white or buff-colored, often friable, and constitute a heavy bedded or massive sandstone, of handsomely rounded quartzose grains.

(4) This notes differences in chemical composition.

(6) [3]The *Potsdam sandstone* has a thickness of at least 400 feet; (Note—D. Owen makes the thickness of the Potsdam (red sandstones of Lake Superior) over 5,000 feet. See Owen's report on Wisconsin, Iowa, and Minnesota, p. 193); the *St. Croix* sandstone also has a thickness of over 500 feet. It is more in keeping with the canons of geological nomenclature to give separate titles to formations so well defined and so largely developed.

(7) This gives the evidence of paleontologic differences. He states that the fossils of the Potsdam sandstone of New York are *Lingula*

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[1] Op. cit., p. 69. [2] Op. cit., pp. 69, 70. [3] 5th does not occur in the original.

antiqua (Con.) and *Lingula prima* (Con.), a Discina (or Orbicula), and uncertain impressions supposed to be of a Pleurotomaria and of crinoidal remains. A species of Theca has also been described from Keeseville. In comparison to this he cites a large number of species described by Owen and Hall from Wisconsin.[1]

(8) In this it is shown that the number of species of the Lake Superior district and from the New York district, in the sandstone referred by him to the Potsdam sandstone, are the same, namely three.

Notwithstanding these considerations, it has not been thought best to attempt the delineation of the areas of these sandstones separately on the preliminary geological map accompanying this report.[2]

A detailed description of the lithological characters of the St. Croix and Potsdam sandstone is also given.[3]

The preceding observations by Prof. Winchell have been quoted in detail as they are the foundation for the theoretical views subsequently advanced by him correlating the Potsdam sandstone of New York with various other sandstones of pre-Silurian age.

On the map accompanying the report (opposite p. 45) the Sioux quartzite area of northwestern Minnesota is colored the same as the St. Croix sandstone of the southeastern portion of the State. In the legend the color is placed under the heading of Potsdam and St. Croix.

In the fourth annual report Prof. Winchell describes the St. Croix sandstone as it occurs in Fillmore County and illustrates the geographic distribution on an accompanying map.[4] In some notes on a deep well drilled at Minneapolis, Minnesota, the same writer states that Nos. 11, 12, and 13 represent the St. Croix sandstone with a total thickness of 217 feet. Beneath this there is a red marl and red sandstone which he refers to the same horizon as the catlinite beds of the Sioux quartzite series. Of No. 14 it is said: "No. 14 may represent the Lingula flags or the upper portion of the Potsdam, so called." No. 15 is correlated as undoubtedly the upper portion of the great series of marls and sands which characterize this horizon in Minnesota. "It is the same formation as the rock that embraces the well known 'pipestone' or catlinite of Minnesota."[5]

The Sioux quartzite is referred by Prof. Winchell to the Potsdam sandstone in a description of the geology of rocks in Pipestone County in the sixth annual report. It includes the famous pipestone quarry near the center of Pipestone County.[6]

A more extended account of the strata referred to the "Potsdam" sandstone is published by Prof. Winchell in the tenth annual report

[1] Op. cit., p. 71. [2] Op. cit., p. 73. [3] Op. cit., pp. 75-80.

[4] Report on the geology of Fillmore County. Geol. and Nat. Hist. Surv., Minnesota; 4th Ann. Rep. for 1875, 1876, pp. 31-32.

[5] Notes on the deep well drilled at East Minneapolis, Minnesota, in 1874-'75. Minn. Acad. Sci., Bull., vol. 1, 1876, pp. 188-189.

[6] The geology of Rock and Pipestone Counties. Geol. and Nat. Hist. Survey, Minnesota, 6th Ann. Rep., for 1877, 1878, p. 97.

of the survey. In this he affirms that the horizontal fossiliferous beds referred to the Potsdam by Dr. Owen, Prof. Hall, and other authors is above the true Potsdam of New York, and that the latter is represented by the rocks of the copper-bearing series in the west; also, that no fossils representing the Primordial fauna have yet been discovered in the west nor have any been found in the western representative of the Potsdam; and finally, that the second fauna of Barrande is found in the Quebec group of Canada and in the St. Croix sandstone of the west, lying in each case above the Potsdam sandstone.[1]

An article by Dr. J. H. Kloos, translated by Prof. Winchell, describes the rocks of the Falls of St. Anthony and the St. Croix River, and gives a description and a diagrammatic section of the river bank at Taylor's Falls, illustrating an unconformity between the Potsdam sandstone and the subjacent copper-bearing rocks.[2]

In an account of the geology of a deep well drilled at Minneapolis Prof. Winchell states that the drill passed through sandstone in the lower portion of the well as indicated in the following section:[3]

	Feet.
1. Drift	10
2. Trenton limestone	24
3. Light, crumbling sandstone (St. Peter?)	125
4. Brown-red pipestone clay	2
5. Potsdam sand	42
6. Red quartzite, Potsdam	102
7. Light-colored Potsdam sand and shales	722
8. Red Potsdam sandstone and shales at least	347
	1,374

Particular attention is called to the brown-red pipestone clay of the section, which is the equivalent of No. 12 of that section on page 212. No. 6 of the section quoted is compared to a layer of red quartzite, seen at New Ulm, Minnesota, and at Baraboo, Wisconsin. Commenting upon this he says:

> Thus we find an interbedded red quartzite in the Potsdam formation similar to those seen in the same formation in the Black Hills and in several other places in the Rocky Mountain region.[4]

Attention is called to this statement as it is a correlation of a quartzite of the Upper Cambrian rocks of the Black Hills with a bed of quartzite in the Sioux quartzite series of Minnesota and the Baraboo quartzite series of Wisconsin.

In a tabulation of the strata beneath the lower fossiliferous sand-

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[1] The Potsdam Sandstone. Geol. and Nat. Hist. Survey Minnesota, 10th Ann. Rep. for 1881, 1882, p. 136.

[2] Geological notes on Minnesota. (Translated by N. H. Winchell.) Geol. and Nat. Hist. Survey Minnesota, 10th Ann. Rep. for 1881, 1882, pp. 186-200.

[3] The geology of the deep well drilled by C. C. Whelpley at Minneapolis, at the "C" Washburn Mill. Geol. and Nat. Hist. Survey Minnesota, 10th Ann. Rep. for 1881, 1882, p. 217.

[4] Op. cit., p. 214.

stone or St. Croix sandstone, Prof. N. H. Winchell defines the Potsdam formation as follows:[1]

Potsdam formation.—Tilted red sandstones, shales and conglomerates, changed by igneous gabbros and dolerites locally to red quartzites, felsites, quartz-porphyries and to red granite. The Keweenian and Huronian in part, in Wisconsin.

He places the Taconic group second and defines it as follows:

Taconic group.—Horizontal black slates and gray quartzites, with interbedded limestones and diorites (the Animikie group), changed to tilted slates, quartzites, iron ores, and silicious marble. The Gunflint beds, the Mesabi iron rocks, the Ogishke Muncie conglomerate (?), the Thomson slates and quartzites, the Vermilion iron rocks; the Huronian in part, in Wisconsin and Michigan.

A description of the Sioux quartzite as it occurs at New Ulm is given by Prof. Winchell in the second annual report.[2] In the first volume of the final report of the Minnesota survey he describes the St. Croix sandstone as it occurs in Houston, Winona, and Fillmore Counties.[3] The entire thickness of the formation in Winona varies from 488 to 558 feet.[4] Under the title of Potsdam quartzite a description is given in this volume by Messrs. Winchell and Upham of the pre-Cambrian quartzite of northwestern Minnesota.[5]

From the Sioux quartzite series at Pipestone, Minnesota, Prof. Winchell described, in 1885, *Lingula calumet* and *Paradoxides barberi*, referring them to the equivalent of the Potsdam sandstone of New York.[6]

In a note on the revision of the stratigraphy of the Cambrian in Minnesota, Prof. Winchell includes under the St. Croix terrane, Jordan sandstone, St. Lawrence limestone, shales, and Dresbach sandrock.[7] It is interesting to note that after the upper member of the St. Croix, the Jordan sandstone, we find "Potsdam" (?); also after the Dresbach sandstone at the base and (Potsdam) after formations placed as pre-St. Croix.

The geological age of the Sioux quartzite of the pipestone quarries in Dakota and Minnesota is discussed by Prof. R. D. Irving,[8] who concludes that their tilted position, great thickness, and lithological contrast with the Potsdam sandstone "make it evident that they are not merely a downward continuation of that formation, but, on the contrary, form a great unconformably underlying series."

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[1] Notes on the age of the rocks of the Mesabi and Vermilion iron districts. Geol. and Nat. Hist., Survey Minnesota, 11th Ann. Rep. for 1883, 1884, p. 170.

[2] The geology of the Minnesota Valley. Geol. and Nat. Hist. Surv., Minn. 2d Ann. Rep. for 1873, 1874, p. 157.

[3] The Geology of Minnesota. Vol. 1, of the Final Report, 1884, pp. 223–227, 257–259.

[4] Op. cit., p. 258.

[5] Op. cit. pp. 422–424, 499–503.

[6] Fossils from the red quartzite at Pipestone. Geol. and Nat. Hist. Surv. Minnesota, 13th Ann. Rep. for 1884, 1885, pp. 65–72.

[7] Revision of the stratigraphy of the Cambrian in Minnesota. Geol. and Nat. Hist. Survey Minnesota, 14th Ann. Rep. for 1885, 1886, p. 337

[8] Preliminary paper on an Investigation of the Archean formations of the Northwestern States. U. S. Geol. Surv. 5th Ann. Rep., 1883–84, 1885, pp. 201, 202.

Mr. Warren Upham in notes on the geology of Minnehaha County, Dakota,[1] refers to the rocks in various portions of Minnehaha County as "*Typical Potsdam quartzite*," but he mentions no reasons for concluding it to be of this age. No fossils were found in it.

In the second volume of the Geology of Minnesota Prof. N. H. Winchell states that the St. Croix formation in Wabasha County is about 250 or 300 feet in thickness; and it is not known to vary particularly in its stratigraphic composition from that of Winona County.[2] In the account of the geology of Goodhue County he describes the formation and accompanies it with a list of the fossils found in the St. Croix formation in the Upper Mississippi Valley.[3]

In the same volume Mr. Warren Upham describes the St. Croix sandstone as it occurs in Chisago County, in the valley of the St. Croix River.[4] He also describes the formation as it occurs in Pine County, along the upper portion of the St. Croix River.[5]

In an article on the age of the St. Croix sandstone, Prof. N. H. Winchell discusses its relations to the typical Potsdam of New York and concludes it is a distinct formation.[6] In an account of a deep well drilled at Stillwater, Minnesota, it is stated by Mr. A. D. Meads that—

> The well starts at about 740 feet above the sea, and after passing through 701 feet of drift, white friable sandstone, and green shales belonging to the St. Croix and so-called Potsdam of the Northwest, enters a series of dark red and brown shales and brown feldspathic sandstones which exhibited a thickness of more than 1,500 feet. These gradually assume characters of a volcanic detrital tuff—"amygdaloidal," calcitic, kaolinic, still brown, slightly siliceous—and finally at the depth of about 3,300 feet unmistakable beds of trap rock were encountered, alternating with sandstone beds. At this depth some grains of native copper were seen in the drillings.[7]

Prof. N. H. Winchell has recently published his latest conclusions on the Taconic rocks of Minnesota. On the evidence of the tracks described by Mr. G. F. Matthew[8] he considers the Taconic (Lower Cambrian) age of the "Animike" formation to be sufficiently established, and thinks the name Taconic should be substituted for Animike.[9] The Pewabic quartzite is referred to the base of the "Animike," although he says: "it was at first supposed to be the equivalent of the Potsdam (Paradoxides horizon) which apparently overlies the "Animike."[10]

A correction is made in relation to the reference of the stratigraphic position of the Granular quartz as follows:[11]

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[1] Notes on the geology of Minnehaha County, Dakota. Geol. and Nat. Hist. Survey, Minnesota, 13th Ann. Rep. for 1884, 1885, pp. 88–97.

[2] The Geology of Minnesota. Vol. 2 of Final Report, 1888, p. 13.

[3] Op. cit., pp. 31–36.

[4] The Geology of Minnesota. Vol. 2, Final Report, 1888, pp. 407, 409.

[5] Op. cit., pp. 637–642.

[6] Geol. and Nat. Hist. Surv. of Minn., 17th Ann. Rep. for 1888, 1889, pp. 56–64.

[7] The Stillwater Deep Well. American Geologist, vol. 3, 1889, p. 342.

[8] Am. Jour. Sci., 3d ser., vol. 39, 1890, p. 145.

[9] The iron ores of Minnesota. Geol. and Nat. Hist. Surv. Minnesota. Bull. No. 6, 1891, p. 113.

[10] Op. cit., p. 125.

[11] Op. cit. Foot note on pp. 417, 418.

The writer wishes to correct the view published by him in the American Geologist a few years ago ("A Great Primordial Quartzyte," vol. 1, p. 178), that the granular quartz probably overlies the black slate of the Taconic system, and is equivalent of the Red sandrock of Vermont. The Red sandrock appears to be a part and near the top of the "Georgia series" and above the Winooski marble, but the "granular quartz" lies below the Winooski marble. The typical Potsdam is probably the "granular quartz." But the Red sandrock, and also some light-colored, loose sandstones still higher have very largely been regarded its equivalent.

IOWA.

On the map accompanying Dr. D. D. Owen's report of the geological survey of Wisconsin, Iowa, and Minnesota a small area is colored as the Potsdam sandstone of New York, in the northeastern corner of the State.[1]

As State geologist of Iowa, Prof. J. Hall stated that the Potsdam sandstone attains its greatest exposures in Minnesota and Wisconsin north of the limits of Iowa, and about the regions of Lake Fepin. The excavation of the Upper Iowa River, however, has removed the calciferous sandstone; so that at the junction of that river with the Mississippi there is exposed a broad belt of the lower rock. A general description of the sandstone is given with the statement that some slightly calcareous bands contain fragments of trilobites. In numerous localities shells of Lingula are found, though by no means so abundantly as in the same rocks in Minnesota. These fossiliferous bands appear in the vicinity of Lansing.[2] In the same volume there is a general account of the Potsdam or inferior sandstone by Prof. J. D. Whitney.[3]

In a general description of the geology of Iowa Dr. C. A. White describes the Sioux quartzite as occurring in the extreme northwestern corner of the State. In the table of classification he places it as Huronian (?) and beneath the Potsdam sandstone.[4] This is the quartzite referred to the Potsdam in Minnesota by Prof. N. H. Winchell. In describing the Potsdam sandstone Dr. White states that it reaches a known thickness in Iowa of 300 feet, and it is exposed only in a small portion of the northeastern corner of the State.[5]

In the account of a deep well at Emmetsburg, Iowa, Prof. N. H. Winchell refers to a white sandstone found beneath the blue shales of St. Croix, assigning it a thickness of 107 feet. The rock beneath this, which Mr. Swan, who kept a record of the well, called granite, is referred to the Potsdam quartzite.[6]

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[1] Geol. Surv. of Wisc., Iowa, and Minn.; and, incidentally, of a portion of Nebraska Territory, Philadelphia, 1852.

[2] Geology of Iowa, vol. 1, 1858, pp. 47-48.

[3] Ibid., pp. 328-331.

[4] General geology. Azoic, Lower Silurian, Upper Silurian, and Devonian systems. Geol. Surv. Iowa, Rep., vol. 1, 1870, p. 168.

[5] Op. cit., p. 172.

[6] Section of a deep well at Emmetsburg, Iowa. Minn. Acad. Sci. Bull., vol. 1, 1880, pp. 387, 388.

In describing a deep well at Washington, in southeastern Iowa, Prof. S. Calvin states that a gray sandstone 1,230 feet from the surface probably represents the upper part of the Potsdam series.[1]

LAKE SUPERIOR SANDSTONE.

In an account of a journey along the south shore of Lake Superior, Dr. J. J. Bigsby describes a red and white sandstone, for the most part horizontal, that predominates along the shore, resting in places on granite.[2] He also mentions the red sandstone of Point Keewawoonan and the sandrock described to him by Mr. Thomson.[3]

The description of the geology of Lake Superior, by Capt. H. W. Bayfield, mentions a horizontally stratified sandstone that he traced from one extremity of the lake to the other, on both the north and south shores, and on many of the islands in the lake. A description of the mode of occurrence of the sandstone on the south shore of the lake is given, with several diagrams illustrating the unconformity between the granite and the sandstone.[4] He considers it quite probable that the formation extended to the west and southwest as far as the foot of the Rocky Mountains, and that it might possibly be the same as the sandstone at the Falls of Niagara, etc., but concluded it required much more elaborate investigation than has yet been bestowed to render it certain that the sandstone of Lake Superior and that of the extensive tracts of country mentioned are the same formation. He then gives reasons for terming the sandstone of Lake Superior the Old Red. These are its position immediately on the granite, its structure, and component parts.[5] No fossils were observed. The student will find in this paper of Capt. Bayfield's a very fair description of the sandstones as they occur about Lake Superior, and it is worth reading in connection with the controversy in relation to their age.

As State geologist of Michigan Dr. Douglass Houghton reported upon the strata of the northern peninsula. In the second annual report he says that "the *Old Red sandstone*" has been very much shattered by the protrusion of trap rock through it.[6] In his third report a more extended account is given of the Lake Superior sandstone on the Ste. Marie River. The sandstone passes conformably beneath the superjacent limestone.[7] Of the bulk of the formation he says:

> The Lake Superior sandstone in its easterly prolongation does not attain a very great thickness, but in proceeding westerly this thickness is vastly increased, attaining on the south shore of Lake Superior to several hundred feet.

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[1] Notes on the formations passed through in boring the deep well at Washington, Iowa. American Geologist, vol. 1, 1888, p. 30.

[2] Notes on the geography and geology of Lake Superior. Quart. Jour. Lit., Sci. and Arts (of the Royal Inst. of Gt. Brit.) vol. 18, 1825, p. 33.

[3] Op. cit., p. 260.

[4] Outlines of the geology of Lake Superior. Quebec Lit. and Hist. Soc. Trans., vol. 1, 1829, p. 17, figs. 2 and 3, on plate.

[5] Op. cit., p. 19.

[6] (Peninsula District.) Second annual report State geologist of Michigan, Detroit, 1839, p. 14.

[7] Third annual report State geologist of Michigan. House Reps. Document, No. 8, 1840, p. 14.

So far as my examinations during the past year have extended the rock is destitute of fossils, and in fact after a careful examination (several years ago) along its whole line of outcrop, on the southerly shore of Lake Superior, I have never been able to detect in the rocks a single contained fossil.[1]

The fourth report describes the "lower or red sandstone and shales" as follows:

The red sandstone, with its accompanying red and gray shales, occupies a much larger extent of the country bordering upon Lake Superior than any other single rock or group of rocks. It rests upon the primary and metamorphic rocks immediately west from Chocolate River; upon the conglomerate and mixed rocks from near Eagle River, of Keweenaw Point, west to the head of Lake Superior; upon the primary trap, metamorphic and conglomerate rocks of the north shore of the lake, and upon the conglomerate rock of Isle Royale. It is this rock which forms the basis of the level plateaus or valleys occupying the spaces between the several ranges of hills south from Lake Superior, and west from Chocolate River. In these last situations this rock is frequently seen undisturbed to surround the bases of isolated knobs of granite, though when near to or in contact with knobs or [of] trap there are invariable evidences of very great disturbance.[2]

A second bed of sandstone is described as the "upper or gray sandstone." "Upon the shore of Lake Superior, and extending from Point Iroquois to Grand Island, a sandstone occurs, differing widely in its appearance from that before described. This sandstone rests *unconformably* upon the red sandstone, the former dipping gently to the south or southeast, while the latter dips very considerably to the north or northwest."[3]

A sandy limerock rests conformably and immediately upon the upper or gray sandstone. The tabulation of the rocks of the Upper Peninsula is as follows:[4]

9. Tertiary clays and sands.
8. Upper limerock group (embracing as members the Drummond Island and Mackinaw limestones).
7. Lower lime rock and shales.
6. Sandy or intermediate limestone.

		Thickness.
5. Upper or gray sandstone, mean	feet..	700
4. Lower or red sand rock and shales, extreme	do...	6,500
3. Mixed conglomerate and sand rock, extreme	do...	4,200
2. Conglomerate rock, extreme	do...	5,260

1. Metamorphic, trap, and primary rocks.

A detailed account of the red sandrock and shales is given on pages 37 to 41. This is followed by a description of the upper or gray sand rock, of which he says:

The only remaining rock which separates the red sandrock from the limestone lying to the south is a gray or brownish sandrock that is almost wholly composed of grains of quartz, usually feebly cemented with calcareous matter. The composition of this rock differs from that of the lower sand rock in being more exclusively quartz, while in epoch of deposition the rock under consideration should not be confounded with that of the red sandstone. It has already been stated that the red sandrock of

[1] Op. cit., p. 15.
[2] Fourth Ann. Rep. State geologist of Michigan, 1841, pp. 18, 19.
[3] Op. cit., p. 19.
[4] Op. cit., p. 22.

the south coast dips regularly northerly, while the upper or gray sandstone dips equally regularly south or southeasterly, in which respect the last-mentioned rock conforms to the limestones resting upon it, while it rests itself upon the uptilted edge of the red sandrock below.[1]

The upper sandrock, like the lower, abounds in clearly defined ripple marks, and its line of cleavage is very irregular, frequently being opposed to the line of stratification over very considerable districts of country. Two indistinct species of fucoides were all the fossils noticed in connection with it.

I was unable to obtain any observations upon the thickness of the upper sand rock which were satisfactory, but from the imperfect observations which were obtained I was led to conclude that the average thickness as far westerly as the Pictured Rocks does not vary far from 700 feet. The upper sandrock, like the rocks before mentioned, wedges out as far as we proceed in an easterly direction.[2]

When presenting to the Boston Society of Natural History an account of his visit to Lake Superior Prof. H. D. Rogers states that he discovered in the neighborhood of Chocolate and Carp Rivers the following conditions of stratification:

First, a group of rocks, the equivalents, undoubtedly, of the Primal sandstone and Primal slate of Profs. W. B. Rogers and H. D. Rogers, denominated, in the nomenclature of the New York survey, the Potsdam sandstone, and these rocks, highly inclined, and traversed by parallel east and west axes. Secondly, upon the uptilted edges of this earliest Paleozoic formation rests, in an unconformable position and with a very gentle northern dip, the conglomerates and shales of the red sandstone series. Specimens of the conglomerate were displayed, in which the pebbles were all from the older rocks. Mr. Rogers thought this fact of unconformable superposition an almost conclusive proof of a post-Paleozoic date; and he proceeded to argue, from various points of analogy between the red sandstone itself, its trappean dikes, and their mineral associations, with similar components of the Mesozoic or new red sandstone of the Atlantic States, that the formation in question is of equivalent age and origin with this last-named interesting group of rocks.[3]

In his reconnaissance of the Chippewa land district of Wisconsin, Dr. D. D. Owen examined a portion of the shores of Lake Superior. He noted the red sandstone, its mode of occurrence, and character. He states that various views have been advanced by different writers regarding the age of the red sandstone, marls, and conglomerates of Lake Superior. Some authors have referred them to the date of the oldest sandstones of the New York system; others believe them to be contemporaneous with the New Red sandstone of Great Britain and the *bunter Sandstein* of Germany. He further states:

Judging, however, from lithological and mineralogical character, there certainly is strong presumptive evidence that they were deposited subsequently to the Carboniferous era.

He calls attention to the strong resemblance between them and the formations above the Coal Measures, not only of the State, but of some parts of Europe.

Ranging through Connecticut, New Jersey, Maryland, and Virginia there are red sandstone and marly beds that are almost a counterpart of some portion of the Lake Superior formations, as well in aspect as in composition; like them, too, they are

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[1] Op. cit., pp. 41, 42.

[2] Op. cit., pp. 42, 43.

[3] On the mineralogy and geology of the south shore of Lake Superior. Boston Soc. Nat. Hist. Proc. vol. 2, 1846, p. 125.

traversed by ranges of intrusive trap, with accompanying veins of copper. * * * To draw up in detail a comparison between these formations and those of the Northwest would, at this early stage of the survey of Wisconsin, be premature.[1]

In 1849 Prof. C. T. Jackson argued that the red sandstone and conglomerate rocks of Keweenaw Point existed there anterior to the elevation of the trap rocks, and that the eastern sandstone and the red sandstone were the same in geologic age. After reviewing the mode of occurrence and the relation of the sandstone to other rocks, especially a limestone from which a fragment of *Pentamerus oblongus* was obtained, indicating the upper member of the Niagara, New York series, he concluded that the sandstone of Keweenaw Point was not of the Potsdam series, but that it was most probably the New Red, or that system of sandstones which is regarded as such in New England.[2]

In their report of 1849 Messrs. Foster and Whitney color the accompanying map of Keweenaw Point so as to indicate that they consider the sandstone and conglomerate superior to the trap series, forming the base of the Silurian system. The same coloring and nomenclature are used on the map of the district between Mackinaw Bay and Chocolate River, and that between Portage Lake and Montreal River and Isle Royale.[3]

In the same volume, following the report by Foster and Whitney, is a general description of the region between Keweenaw Point and Montreal River. The writer says the age of the sandstone of Lake Superior could not be determined by any evidence he had been able to collect. It is entirely destitute of fossils, and lies directly upon granitic rocks.[4] Whether it is written by Mr. Foster or Prof. Whitney is not stated.

Mr. J. W. Foster states that he is disposed to regard the sandstone of Lake Superior as resting at the base of all the fossiliferous rocks.[5] He evidently considered the horizontally bedded sandstone at Keweenaw Point the same as the disturbed sandstone on the opposite side. Full descriptive details of the sandstones at Keweenaw Point are also given by Mr. W. A. Burt.[6] In the same report Mr. Bela Hubbard states that the Red sandrock is the equivalent of the Potsdam red sandrock of the New York reports, and that on the map the geographic distribution skirts the trap range on both sides, but having by far its broadest extension on the south side.

[1] Report of a geological reconnaissance of the Chippewa land district of Wisconsin; and incidentally of a part of Iowa and of the Minnesota Territory, 30th Congress, 1st sess., Senate Ex. Doc. No. 57, 1848, pp. 57-58.

[2] Report on the geological and mineralogical survey of the mineral lands of the United States in the State of Michigan, Ex. Doc. No. 5, House of Reps., 31st Congress, 1st sess., part 3, 1849, pp. 398, 399, 452.

[3] Synopsis of the explorations of the geological corps in the Lake Superior land district in the northern peninsula of Michigan, Ex. Doc. No. 5, House of Reps., 31st Congress, 1st sess., part 3, 1849, pp. 605-625.

[4] Op. cit., p. 655.

[5] Notes on the geology and topography of portions of the country adjacent to Lakes Superior and Michigan, in the Chippewa land district, Ex. Doc. No. 5, 31st Congress, 1st sess., part 3, 1849, p. 781.

[6] Topography and geology of the survey of a district of township lines south of Lake Superior, 1845, H. R. Ex. Doc. No. 5, part 3, 1849, pp. 815-839.

It here lies in nearly horizontal strata, though at the coast a slight dip inland is observable, becoming more apparent as it approaches the basin of Portage Lake. In its approach to the trap, however, it is found more or less tilted from its original horizontal position, and is also very much altered by its contact with that igneous rock. The evidences both of the deposition of this extensive rock formation in calm and shallow waters and of the subsequent change induced in it by the trap rocks when in a fused or heated state are very important.[1]

In their report upon the copper region of Lake Superior, Messrs. Foster and Whitney tabulate the stratified sedimentary rocks as follows:[2]

I. *Conglomerate.*—Not strictly a sedimentary rock, but a volcanic tuff.

II. *Inferior sandstone.*—Potsdam sandstone.

III. *Compact or Lower Magnesian limestone.*—Calciferous sandstone, Chazy limestone, Bird's-eye and Black River limestone.

This table is followed by a detailed description of the conglomerate, sandstone and superjacent limestone. No attempt is made to differentiate the horizontally bedded Red sandstone, of Keweenaw Point, from the banded sandstone that occurs on the western part of the Point.

Of the transition of the sandstone to the magnesian limestone they say:

The sandstone, as we ascend from the lower strata to the higher, is found to be less colored by the oxides of iron, and to take into its composition particles of lime until finally it passes into well characterized, compact, magnesian limestone. * * * We apply the term magnesian to this belt to define its lithological characters, although the associated organic remains would seem to indicate the presence of several of the lower Silurian groups, which can not be recognized by lithological differences.[3]

A notice of the work by Foster and Whitney in the copper district was published in the American Journal of Science, 2d series, volume 12, 1851, pp. 222–239.

In a letter describing the Silurian terrane of Lake Superior, Messrs. Foster and Whitney reaffirm their opinion that the standstones of Lake Superior are of the age of the Potsdam of the New York series, and that the section exhibits the Azoic system at the base, upon which rests the conglomerate, formed of igneous rocks, and then in turn the Potsdam sandstone, the Calciferous sandstone, the Trenton limestone, etc.[4]

In commenting upon this statement of Messrs. Foster and Whitney, that the Lake Superior sandstones are of the same age as the Potsdam sandrock of New York, Prof. Jules Marcou disputes their correlation and considers the formation as equivalent to the New Red sandstone, as was stated by Prof. Jackson.[5]

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[1] General observations upon the geology and topography of the district south of Lake Superior, subdivided in 1845 under Houghton, House of Reps., Ex. Doc. No. 5, part 3, 1849, p. 840.

[2] Report on the geology and topography of a portion of the Lake Superior land district in the State of Michigan. Washington, 1850. Stratified and sedimentary rocks. Vol. 1, 1850, p. 99.

[3] Op. cit., p. 117.

[4] (Aperçu de l'ensemble des Terrains Siluriens du lac Supérieur.) Bull. Soc. géol. France, 2e sér., vol. 8, 1850, p. 91.

[5] Response à lettre de MM. Foster et Whitney sur le lac Supérieur. Bull. Soc. géol. France, 2e sér., vol. 8, 1850, pp. 101–105.

In their report on the geology of the Lake Superior land district, Messrs. Foster and Whitney describe, under the heading of "Potsdam sandstone,"[1] a sandstone on the north shore, occurring in insulated patches on the isthmus between Thunder and Black Bays. This sandstone attains, according to Logan, a thickness of at least 200 feet.[2] On the south shore the sandstones of the northwestern side of Keweenaw Point are considered to be of the same age as those on the south side of the point, extending along the lake shore from Keweenaw Bay to St. Mary's River. The sandstone extending southward, subparallel to the bay, is also cor related with the sandstone mentioned; and all of these are correlated with the Potsdam sandstone of the New York series. They quote from the manuscript of Prof. James Hall in relation to the westward extension of the sandstone in Wisconsin, in the Upper Mississippi Valley.[3]

In some observations on the age of the sandstones of the United States Prof. C. T. Jackson concludes that the Lake Superior sandstone is of Upper Silurian age.[4]

Messrs. Foster and Whitney returned to the discussion of the age of the sandstone of Lake Superior in 1851 and conclude there can no longer be any doubt that this sandstone lies below the lowest fossiliferous members of the Silurian in the position of the Potsdam sandstone of New York.[5] They describe with considerable detail the mode of occurrence of the horizontally bedded sandstone at the southeastern end of the lake along the Sault Ste. Marie, with its extension westward along the coast to Keweenaw Bay. They show it to be one continuous formation around the great central granitic and azoic nucleus; that it is a granular, quartzose material, mostly friable, and containing little iron; that the thickness of the whole formation did not exceed 100 feet at Sault Ste. Marie, and that at the Pictured Rocks it was probably more than 300 or 350 feet, gradually increasing from the east toward the west.[6] They then describe a sandstone on the western side of the Keweenaw Point and Isle Royale which is now referred to the Algonkian. This is the best résumé of the information relating to the Lake Superior sandstone published up to its date.

In his tabulation of the lowest Protozoic sandstones Dr. D. D. Owen places the Lake Superior ferruginous and argillaceous sandstones, shales, and conglomerates at the base of the section, assigning it a thickness of 5,000 feet.[7] On the accompanying map the Lake Superior

[1] Lower Silurian System. Potsdam and Calciferous Sandstones. Rept. on Geol. of Lake Superior Land Distr., Pt. 2, 1851, pp. 113-134.

[2] Op. cit., p. 115.

[3] Op. cit., pp. 133, 134.

[4] [Some observations on the age of the sandstones of the United States.] Bost. Soc. Nat. Hist. Proc., vol. 3, 1851, pp. 335, 336.

[5] On the age of the sandstone of Lake Superior, with a description of the phenomena of igneous rocks. Am. Assoc. Proc., vol. 5, 1851, p. 25.

[6] Op. cit., p. 29.

[7] Geol. Surv. of Wis., Iowa, and Minn., and, incidentally, of a portion of Nebraska Territory. Philadelphia, 1852, p. 53.

sandstone west of the Montreal River is colored the same as the sandstones of the central portion of Wisconsin referred to the Potsdam. In the legend the Lake Superior sandstone is included with the lower sandstones of Wisconsin and Minnesota as the equivalent of the Potsdam sandstone of New York.

Mr. J. C. Norwood calls attention to the resemblance of the sandstone on the south shore of Lake Superior, west of Montreal River, to the sandstones of the Chippewa, St. Croix, and Kettle Rivers. A section is given that occurs above the mouth of Cranberry River.[1]

In some remarks connected with the geology of the north shore of Lake Superior Prof. J. D. Whitney states that from Sault Ste. Marie, following the south shore in its whole extent, and along the north side as far east as the northeastern extremity of Neepigon Bay, we find exposed on the lake shore only shales, sandstones, and conglomerates, the equivalent of the Potsdam sandstone and the accompanying trappean rocks.[2]

In speaking of the red sandstone of Lake Superior Mr. H. R. Schoolcraft states that in his expedition of 1820 he recognized a sandstone at the Sault of St. Mary's. He says:

> That this is the Old Red sandstone may be inferred simply from the fact that, although deposited originally in horizontal beds, its position has been disturbed in many localities.[3]

In his report as State geologist of Michigan Dr. A. Winchell describes the sandstone at the Falls of the St. Mary's River, where it has a measured thickness of at least 18 feet. On some of the surfaces he observed obscure traces of Algæ. On some specimens from the Montreal River not less than three species of fossil plants have been discovered. He favors the view that the sandstones of the south shore of Lake Superior are of the age of the Potsdam.[4]

When commenting upon the fact that Prof. Jules Marcou had referred the red sandstone of Lake Superior to the Trias Prof. J. S. Newberry states:

> No American geologist will need to be informed that the sandstones of Lake Superior are of the age of the Potsdam of New York and lie at the base of the Silurian series. It is true that there is considerable lithological resemblance between the Potsdam sandstones of Lake Superior and those overlying the Carboniferous series in New Mexico; but that fact serves simply to show how fallacious are the inferences derived alone from lithological characters.[5]

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[1] Description of the geology of middle and western Minn., including the country adjacent to the northwest and part of the southwest shore of Lake Superior. Rep. Geol. Surv. of Wis., Iowa, and Minn., and, incidentally, of a portion of Nebraska Territory. Philadelphia, 1852, p. 269.

[2] Remarks on some points connected with the geology of the north shore of Lake Superior. Am. Assoc. Proc., vol. 9, 1855, p. 205.

[3] Observations on the geology and mineralogy of the region embracing the sources of the Mississippi River and the Great Lake basins during the expedition of 1820. Schoolcraft's Mississippi River. Phila., 1855, pp. 316, 317.

[4] Geology, general sketch. Geol. Surv. Michigan, 1st Biennial Rep. of Prog. Lansing, 1861, pp. 49–51.

[5] Geological report. Report upon the Colorado River of the West, expl. in 1857–'58 by Lieut. J. C. Ives. Part III, 1861, p. 75.

Of the sandstone at the base of the fossiliferous series Dr. T. S. Hunt says:

Along the northern rim of the great Paleozoic basin of North America the Potsdam sandstone of the New York geologists is unquestionably the lowest rock from below Quebec to the Island of Montreal, and thence passing up the valley of Lake Champlain and sweeping round the Adirondack Mountains until it reenters Canada and soon disappears to the north of Lake Ontario, where the Birdseye and Black River limestones repose directly upon the Laurentian rocks, and furthermore overlie the great Lake Superior group of slates and sandstones, which, reposing on the unconformable Huronian system, constitute the upper copper-bearing rocks of this region. This Lake Superior group, as Sir William Logan remarks, may then include the Potsdam, Calciferous, and Chazy, and thus be equivalent in part to the Quebec group, hereafter to be described.[1]

The section on the Montreal River, including 11,850 feet of strata, according to Mr. Charles Whittlesey, is referred by him to the Potsdam sandstone, with a statement that this is not the entire thickness of the Potsdam at the mouth of the Montreal.[2] He states that some foreign geologists have essayed to place this formation nearly at the summit of the geological system, not only without evidence but against the most conclusive proof. He correlates the sandstone at the Falls of the St. Croix, with its abundance of fossils, with the sandstone of the section mentioned, and states that it has been traced stratigraphically beneath the Trenton and Calciferous strata of the New York survey, on the St. Mary's River, at the Pictured Rocks, on the Escanawba, the Menominee, Oconto, Wolf, Wisconsin, and St. Croix Rivers.[3]

The view that the sandstones and superjacent rocks of the south shore of Lake Superior were deposited within the lake's basin when the lake stood at a higher level has been held only, as far as known to me, by Mr. Thomas Macfarlane. In a report on the geological formations of Lake Superior he says:

On the other hand, the Upper rocks and St. Mary sandstones are never found far inland, but occur close to the shore in comparatively low-lying land and rocks. They seem to have had, as the theater of their eruption and deposition, the bottom of the lake, at a time when its surface was at a higher level than it is at present, although not so high as the general surface of the surrounding Laurentian and Huronian hills.[4]

In a paper on the position of the sandstone of the southern slope of a portion of Keweenaw Point, Lake Superior, Prof. Alexander Agassiz states that the sandstone of the southern side of the mineral range in the vicinity of Torch Lake is plainly of a different age, lying, as it does, unconformably upon the former (i. e., the trap). This view agrees with that held by the geologists who refer the sandstone of the southern portion of Keweenaw Point to the Potsdam, and that of the northern coast to a pre-Potsdam formation.[5]

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[1] On some points in American geology. Am. Jour. Sci., 3d ser., vol. 31, 1861, p. 397.

[2] The Penokie Mineral Range, Wisconsin. Bost. Soc. Nat. Hist. Proc., vol. 9, 1863, p. 238.

[3] Op. cit., p. 239.

[4] On the geological formation of Lake Superior. Canad. Naturalist, new ser., vol. 3, 1867, p. 178.

[5] On the position of the sandstone of the southern slope of a portion of Keweenaw Point, Lake Superior. Boston Soc. Nat. Hist., Proc., vol. 11, 1868, p. 245.

In an article on the age of the copper-bearing rocks of Lake Superior, Messrs. Brooks and Pumpelly refer the sandstones of the south shore to the Silurian, and state that they were deposited unconformably upon the subjacent copper-bearing rocks.[1]

In his report upon the Paleozoic rocks of Michigan, Dr. C. Rominger concludes that the Lake Superior sandstone is the equivalent of the Potsdam sandstone. He states that there is no record of any instance in which recognizable fossils were found in situ in the Lake Superior sandstone.[2] The reference of the sandstones of the western side of Keweenaw Point is based upon their lithologic resemblance to those east of the trap range along the center of the point.

In a paper on some points in the geology of northern Wisconsin Prof. R. D. Irving drew the conclusions that—

(1) The Copper-Bearing and Huronian series were once spread out horizontally one over the other and owe their present highly tilted position to one and the same disturbance. (2) That subsequently, after a long period of erosion, the horizontal Silurian sandstones were laid down over and against the upturned edges of the Copper-Bearing series, filling also the synclinal, in Ashland County, which lies between the northward and southward dipping sandstones. (3) That hence the Copper-Bearing series is more clearly allied to the Archean than to the Silurian rocks.[3]

He describes the series of horizontal sandstones and shales that form the basement rock of the Apostle Islands and the north coast line of Ashland, Bayfield, and Douglas Counties. These he considers in every way to be the equivalent, or, which is more probable, the downward continuation of light-colored Primordial sandstone of the Mississippi Valley. They reappear farther south, on the headwaters of the St. Croix, from whence they can be traced uninterruptedly until they disappear beneath the light-colored sandstones of the Mississippi Valley.[4] This paper of Prof. Irving's was reprinted in the American Journal of Science, under the title "On the age of the copper-bearing rocks of Lake Superior," etc.[5]

It is stated by Mr. E. T. Sweet that the term "Lake Superior sandstone" "is generally employed to designate the reddish aluminous sandstones which nearly everywhere border the south shore of Lake Superior. They also form the basement rock of the Apostle Islands. They have never been found in a tilted condition."[6] He considers that Dr. Rominger, of the Michigan Geological Survey, has definitely settled that these sandstones are the downward continuation of the light-colored sandstones of the Mississippi Valley;[7] and concludes that the western sandstone of Irving, or that of the Apostle Islands and vicin-

[1] On the age of the copper-bearing rocks of Lake Superior. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 431-432.

[2] Paleozoic rocks. Geol. Surv. Michigan, Upper Peninsula, 1869-1873, vol. 1, pt. 3, 1873, p. 80.

[3] On some points in the geology of northern Wisconsin. Wisconsin Acad. Sci. Trans., vol. 2, 1874, p. 117.

[4] Op. cit., pp. 114, 115.

[5] Am. Jour. Sci., 3d ser., vol. 8, 1874, pp. 46-56.

[6] Notes on the geology of northern Wisconsin. Wis. Acad. Sci. Trans., vol, 3, 1876, p. 48.

[7] Op. cit., p. 49.

ity, is of the same age as the eastern sandstone, along the shore of Lake Superior, east of Keweenaw Point.

A description of the Lake Superior sandstone is given by Dr. Irving in his account of the geological structure of northern Wisconsin that is very full and complete, and it will be referred to again in the summary of our present knowledge of that formation.[1] In the account of the geology of the eastern Lake Superior district in the same volume Dr. Irving described the Lake Superior or Potsdam sandstone of the Apostle Islands and adjoining shore.[2] An account of the sandstone as it occurs in the western Lake Superior district is given by Mr. E. T. Sweet in 1880.[3]

Dr. M. E. Wadsworth notes that the sandstone at Marquette rests upon the Azoic schists. That south of the Carp River, in the locality figured by Messrs. Foster and Whitney, the sandstone strata are seen to abut against and overlie the vertical edges of the quartzite.[4]

A general account of the Potsdam sandstone series is given by Dr. R. D. Irving in his article on the mineral resources of Wisconsin. Of the Lake Superior sandstone he says:

> The horizontal sandstone of the south shore of Lake Superior belongs unquestionably to this formation, though it is a matter of doubt whether the two sandstones do or ever did connect. The Lake Superior rock differs from its more southern equivalent in its red color.[5]

The sandstones at the eastern end of Lake Superior, on the St. Mary's River, were referred to the Chazy formation by Sir W. E. Logan. Dr. T. S. Hunt calls this view a speculation, which was shown to be untenable by the establishment of the Potsdam age of the sandstones overlying the quartzites of Wisconsin and in northern Michigan, where Rominger finds the upper sandstone to be overlaid by Calciferous-Chazy beds.[6]

The Eastern sandstone, or that between the Keweenaw Ridge and eastward along the south shore of Lake Superior, is well described by Dr. R. D. Irving in his account of the copper-bearing rocks of Lake Superior.[7] This is followed by a description of the western sandstone, or that occurring on the south shore of the lake, west of Keweenaw Point. An abstract of this report also appeared in the third annual report of the U. S. Geological Survey, 1883, pp. 89–188.

In an article on the age of the rocks of the northern shore of Lake Superior Dr. A. R. C. Selwyn states that he considers the trap and sandstone to be of Lower Cambrian age. He calls them all Lower Cambrian, which includes Potsdam and Primordial Silurian. He holds

[1] Geological structure of northern Wisconsin. Geol. Wisc. Surv. of 1873–'79, vol. 3, 1880, pp. 1-25.
[2] Op. cit., pp. 207-210.
[3] Lake Superior Sandstone. Geol. Wisc. Surv. of 1873–1879, vol. 3, 1880, pp. 350–352.
[4] Notes on the geology of the iron and copper districts of Lake Superior. Camb. Mus. Comp. Zoöl. Bull., vol. 7, 1880, p. 60.
[5] The mineral resources of Wisconsin. Am. Inst. Mining Eng. Trans., vol. 8, 1880, p. 489.
[6] The Geology of Lake Superior. Science, vol. 1, 1883, p. 219.
[7] U. S. Geol. Survey, Monograph, vol. 5, 1883, pp. 351–365.

that there is at present no evidence whatever on the north shore of Lake Superior of their holding any other place in the geological series.[1]

This view of Dr. Selwyn's was concurred in by Prof. J. D. Whitney, who stated it to be the opinion held by Messrs. Foster and Whitney thirty years previously.[2]

Dr. Irving took exception to the statement made by Dr. Selwyn that there is no evidence whatever of the rocks holding any other place in the geological series than that including the Potsdam and Primordial Silurian, and stated:

(1) That the copper-bearing rocks underlie unconformably, and with an immense unconformity, a series of sandstones holding Cambrian fossils. * * * (2) That the copper-bearing strata also underlie unconformably the "eastern sandstone" of the south shore of the eastern half of Lake Superior. * * * (3) That the time-gap between the copper-bearing series and the Huronian was too long to allow of our classing them together.[3]

The view of Messrs. Selwyn and Whitney was also opposed by Dr. T. S. Hunt, who referred the basal sandstone to a pre-Cambrian group.[4]

In a note on Dr. Selwyn's paper, Prof. N. H. Winchell concurs with him in the sweeping affirmation that there is at present no evidence whatever of their (i. e., the copper-bearing rocks) holding any other place in the geological series than that of the Potsdam or Primordial Silurian. "I would also add that there is incontestible evidence that they *can hold no other*."[5]

In opposition to the view of Prof. Winchell, Prof. Chamberlin stated the evidence upon which the pre-Cambrian age of the copper-bearing series of Lake Superior is based. It is (1) the general stratigraphical relation indicated. This he considers to be the weakest of all. (2) Differences in thickness; (3) differences in constitution; (4) unconformity; (5) the inherent inconsistency of the view; (6) the dynamic simplicity of the view; (7) the discovery of a like series in the Grand Cañon of the Colorado.[6]

Shortly after Prof. Chamberlin's paper, Dr. M. E. Wadsworth published an article on the relations of the Keweenawan series to the Eastern sandstones. His observations differ from those of Dr. Irving and he claims that the Keweenawan series has no existence distinct from or older than the sandstone of Potsdam age. In speaking of his observations he says, "These observations also prove at the birthplace of the Keweenawan series, that formation and the Eastern sandstone were one and the same."[7]

The paper of Dr. Wadsworth was followed shortly after by one of Messrs. Whitney and Wadsworth on the "Azoic system and its pro-

[1] Age of the rocks on the northern shore of Lake Superior. Science, vol. 1, 1883, pp. 11, 221.
[2] Geology of Lake Superior. Science, vol. 1, 1883, p. 39.
[3] The copper-bearing rocks of Lake Superior. Science, vol. 1, 1883, pp. 140, 141, 359, 360, 422.
[4] The Geology of Lake Superior. Science, vol. 1, 1883, pp. 218, 219.
[5] The Lake Superior Rocks. Science, vol. 1, 1883, p. 334.
[6] The copper-bearing series of Lake Superior. Science, vol. 1, 1883, pp. 453-455.
[7] On the relation of the "Keweenawan series" to the Eastern sandstone in the vicinity of Torch Lake, Michigan. Boston Soc. Nat. Hist. Proc., vol. 23, 1884, p. 174.

posed subdivisions." This contains a critical review of the published papers upon the age of the copper-bearing rocks of Michigan, Wisconsin, and Canada.[1]

In their observations on the junction between the Eastern sandstone and the Keweenaw series Messrs. Irving and Chamberlin published a map of Keweenaw Point, showing the distribution of the Eastern sandstone to be confined to the southeastern side of the point, the northern and northwestern sides being formed of the Keweenaw series.[2] They discuss the views held by Messrs. Jackson, Foster and Whitney, Agassiz, Rominger, and Credner upon the stratigraphic position in the geologic series of the Eastern sandstone and the sandstones of the Keweenawan series; and give also a detailed account of the contact between the sandstone and the Keweenaw rocks.

MISSOURI.

The first notice we have of a sandstone about the Ozark Mountains of southeastern Missouri is by Dr. Edwin James in 1822, who called attention to an inclined sandstone, like that of the Alleghany Mountains, between which and the granite there intervened a stratum of clay slate highly inclined and resembling the primitive clay slate of New England.[3]

This was followed twenty-nine years later by a sketch of the geology of the State of Missouri, in which Mr. H. King describes what he calls the second magnesian limestone. Beneath this is a sandstone which he was inclined to correlate with the Potsdam sandstone of New York. The presence, however, of Lituites, Euomphalus, Pleurotomaria, Natica? was opposed to this view, but the stratigraphic and lithologic evidence sustains the correlation. In order to explain the presence of the fossils he suggests that "this may be an independent formation not represented in New York or elsewhere, and yet nearly contemporary with the first evidences of organic existence there and to be associated with them in the same geological epoch."[4]

The work of the first Missouri survey proved the presence of four magnesian limestones with a belt of sandstone between the third and the fourth, the fourth limestone forming the base of the series. Prof. G. C. Swallow describes the third sandstone, above the fourth magnesian limestone, as a white saccharoidal sandstone, made up of slightly cohering transparent globular and angular particles of silex. It is assigned a thickness of 30 feet, and owing to its position below the third magnesian limestone is considered at least as old as the Calciferous sandrock, and there is great probability that it may prove to be beneath

[1] The Azoic system and its proposed subdivisions. Harvard Mus. Comp. Zool. Bull., vol. 7, 1884, pp. 482–498.

[2] Observations on the junction between the Eastern sandstone and the Keweenaw series on Keweenaw Point, Lake Superior. U. S. Geol. Surv. Bull., No. 23, 1885, pl. i.

[3] Geological sketches of the Mississippi Valley. Phil. Acad. Sci., Jour., vol. 2, 1822, p. 329.

[4] Some remarks on the geology of the State of Missouri. Am. Assoc. Proc., vol. 5, 1851, pp. 190, 191.

the Potsdam sandstone.[1] In a foot-note on page 129 it is said that since the report was written Mr. Meek discovered a trilobite in the third magnesian limestone, which he and Dr. B. F. Shumard considered identical with one from the Potsdam sandstone of the Northwest. In the tabulation of the strata as determined in Missouri both the third sandstone, and the fourth magnesian limestone are included under Calciferous sandrock.[2]

When speaking of the geological map and the section of the rocks of Missouri, prepared prior to 1861, Prof. G. C. Swallow states that the Potsdam sandstone rests unconformably upon the Azoic stratified slates of Missouri.[3]

The presence of the third sandstone and the fourth magnesian limestone is noted by Mr. F. B. Meek in Morgan and Miller Counties. In Miller County the two formations have a thickness of 33 feet and in Morgan County the third sandstone varies from 15 to 30 feet. The fourth magnesian limestone is assigned a thickness of 150 feet.[4]

On the map of Madison County, prepared by Messrs. C. J. Norwood and G. C. Broadhead, the geographic distribution of the rocks referred to the Cambrian and pre-Cambrian is delineated.[5]

Below the third magnesian limestone in Madison, St. Francois, and Iron Counties, Prof. G. C. Broadhead found siliceous or gritstone beds with intercalated magnesian limestones and subjacent to these are marble beds, beneath which occur sandstones, conglomerates, and shales. These are numbered one, two, and three, respectively. In No. 3, beneath the third magnesian limestone, *Lingulella lamborni*, Meek occurs. On the St. Francois River, in Madison County, the lower unaltered sandstones rest directly on the granite.[6]

At a deep well at the St. Louis County Insane Asylum the following section is referred to as beneath the third magnesian limestone:

11. 98 feet of third sandstone.
12. 384 feet of fourth magnesian limestone.
13. 54 feet of Potsdam sandstone.
14. 245·4 feet, mostly granite, although a portion of the upper part may be sandstone.
15. 40 feet of granite.[7]

A more detailed account of the strata beneath the third magnesian limestone is given on pages 352–357. The fossiliferous bed is separated as a "Lingula grit." In this there were observed *Lingulella lamborni*,

[1] Geology of Missouri. Silurian System. Geol. Surv. [Missouri; 1st and 2d ann. repts, part 1, 1855, pp. 128, 129.

[2] Op. cit., pls. between pp. 60 and 61.

[3] Remarks on the Geological Map and Section of the rocks of Missouri. Am. Nat., vol. 5, 1871, p. 541.

[4] Reports on the geological survey of the State of Missouri, 1855–1871, 1873, pp. 127, 149.

[5] Atlas accompanying Geological Survey of Missouri, Report, including field work of 1873–1874, vol. 1. Jefferson City, 1874.

[6] Op. cit., p. 31.

[7] Op. cit., p., 32.

Orthoceras, a gasteropod, and a form resembling a cross-section of a coral of the genus Zaphrentis.

In a description of the southeast Missouri lead district Prof. Broadhead gives a résumé of the geology, and suggests that if the *Lingula* (*Lingulella*) *lamborni* and Scolithus should be found in the Calciferous group he would prefer to assign all the rocks from the lower sandstone to No. 1, inclusive, as Calciferous.[1] The marble of southeastern Missouri was referred in 1882 by Prof. Broadhead to the older series or Potsdam, and the upper series to the Upper Silurian, with the statement that Potsdam quarries are found in Madison, Iron, and Reynolds counties. The marble beds will be spoken of in the summary of the Cambrian rocks of Missouri.[2]

In a paper upon "The Geological History of the Ozark Uplift" Prof. G. C. Broadhead describes, in 1889,[3] in a general way rocks referred to the Potsdam and the Calciferous formations. Of these he says:

The evidence is that the sandstones and magnesian limestones (Potsdam and Calciferous) were deposited in Archean valleys of erosion, for they generally repose nearly horizontally, or with slight inclination, upon the Archean.[4]

EASTERN BORDER OR ADIRONDACK SUB-PROVINCE.

This includes the area about the Adirondack Mountains of New York and the adjoining portions of Canada to the north.

In a report of the geological structure of the county of Saratoga, Mr. J. H. Steele states that a conglomerated mass of rock is found in the town of Greenfield not far from its south line, on the southeast side of the Kayadarosseras Mountains, resting upon the primitive rocks. He says:

It consists of rounded pebbles of quartz, from the size of a small shot to that of a man's head, united into one common mass by a kind of coarse ferruginous sand. It extends along the mountains to no great distance, but fragments of it lay scattered in all directions, and, indeed, are found along the whole extent of the south line of the town of Greenfield, and in various other places.[5]

Under the heading of "Coarse Siliceous sandstone" a description is given of an extended horizontal stratum along the west part of the north line of the town of Saratoga Springs, and some way into the town of Greenfield:

It is a coarse, hard rock, resembling common quartz in its fracture, but it is more loose and granular in its structure. It is of a white color, and when heated and thrown into water, crumbles into a fine white sand. * * * I have been somewhat at a loss to know where to place this formation, but from several circumstances I am confident it should be placed among the oldest of the transition class.[6]

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[1] The Southeastern Missouri lead district. Am. Inst. Mining, Eng., Trans., vol. 5, 1877, p. 102.

[2] Marble of southeast Missouri. Kansas City Review, vol. 5, 1882, pp. 524-526.

[3] Am. Geologist, vol. 3, 1889, pp. 6-13.

[4] Op. cit., p. 8.

[5] A report of the geological structure of the county of Saratoga. Memoirs of the Board of Agriculture of the State of New York, vol. 2, 1823, p. 53.

[6] Op. cit., p. 54.

A description is also given of a Calcareous sandstone as it occurs on the west side of the Kayadarosseras Mountains.[1] The sandstone referred to by Mr. Steele, and also the lower portion of the Calcareous sandstone, are now known to be of Upper Cambrian age.

Various references are made by Prof. Amos Eaton to the Calciferous sandrock (or Transition sandrock) as examined by him in the valley of the Mohawk. He also says: "Perhaps the Transition sandstone of the Green Mountain series may not be connected with that of the Macomb Mountain series."[2] Most of Prof. Eaton's references to this formation are very indefinite, and he included it with the Calciferous sandrock, as exposed at Little Falls in the valley of the Mohawk. That he was aware of its stratigraphic position is shown by the comparisons made between the Transition sandstone of the Green Mountains and that of the Macomb Mountains, the latter now being known as the Adirondacks.

The attention of Mr. J. H. Steele was called to the oolitic formation about 2 miles from the village of Saratoga Springs. He described the occurrence of great quantities of calcareous concretions of a most singular structure; they are mostly hemispherical, but many of them are globular and vary in size from half an inch to that of 2 feet in diameter; they are obviously composed of a series of successive layers, nearly parallel and perfectly concentric, etc.[3] This is the first notice of a fossil that was subsequently described by Prof. James Hall as *Cryptozoon proliferum*.[4] It occurs in layers in which the Upper Cambrian or Dikelocephalus fauna is found a few miles west of Saratoga Springs.

In the first annual report of the geological survey of New York Dr. Emmons mentions a sandstone resting on the primitive rocks both on the Lake Champlain side of the Adirondack Mountains, at Whitehall, and on the western side, in the vicinity of Theresa, on the Indian River.[5] In this preliminary paper the Calciferous sandrock of Prof. Eaton and the subjacent sandstone are not clearly differentiated. In the second report, however, he separated the sandstone as the "sandstone of Potsdam."[6] His description of the rock is as follows:

I shall not enter upon its geological relations any further than to state that in Potsdam and other towns in which it appears it uniformly rests on the primary strata; and in no part of the county is there any rock which interposes itself between it and the Primary, so that it appears here as the oldest representative of the transition series. The identification of this rock with the sandstones along the southern border of Lake Ontario will be a matter of some difficulty. It is geologically below

[1] Op. cit., p. 56.

[2] A geological and agricultural survey of the district adjoining the Erie Canal, 1824, p. 78.

[3] A description of the oolitic formation lately discovered in the county of Saratoga and State of New York. Am. Jour. Sci., vol. 9, 1825, p. 17.

[4] Cryptozoon, n. g., Cryptozoon proliferum, n. sp. Description of Pl. VI, 36th Ann. Rep. N. Y. State Mus. Nat. Hist., 1884.

[5] First annual report of the second geological district of New York. First annual report of the geological survey of New York. Albany, 1837, pp. 106, 107.

[6] Report of the geologist of the second geological district of New York. Second annual report of the geological survey of New York. Albany, 1838, p. 214.

the transition limestone and never in the northern district alternates with it, but always holds the relation of an inferior rock.[1]

This rock is a true sandstone, of red, yellowish red, gray, and grayish white colors. It is made up of grains of sand and held together without a cement. Intermixed with the siliceous grains are finer particles of a yellowish feldspar, which do not essentially change the character of the sandstone, but they show the probable source from which materials forming it were originally derived, viz, some of the varieties of granite. Unlike, however, most of the sandstones, it is destitute of scales of mica. The coloring matter of the rock is evidently oxide of iron, but unequally diffused through it, giving it intensity or deepness of color in proportion to its quantity. In some places it is almost wanting, which makes it, when pulverized, a good material for glass. The grains and particles in its composition are generally angular, but where it takes the character of a conglomerate, as it does in the inferior layers, they are frequently rounded. The thicker strata exhibit an obscurely striped appearance, owing to prevalence of certain colors in the different layers.[2]

In the description of the sandstone on the Lake Champlain side in Essex County it is said:

This I consider the same formation I have described under the name of the "Potsdam sandstone." Its position is evidently beneath the Transition limestone and Calciferous sandrock. It is very deficient in organic relics, though not entirely destitute of them. It is unnecessary to repeat what has already been said of this rock; it is purely quartzose or siliceous in its composition and finely stratified. It dips to the northeast at Port Kent, at an angle varying from 5° to 10°. The places where it occurs along Lake Champlain are indicated on the map of a part of this county, to which I refer the reader. This rock at Keeseville has been rent in the most remarkable manner; several fissures, the principal one of which extends nearly a mile, and through which the Au Sable flows, have been opened by some convulsion in nature to the depth in some places of 100 feet, and from 5 to 20 feet wide. Near the bottom of the fissure at the High Bridge, as it is called, I discovered numerous specimens of a small bivalve mollusca, a Lingula. I found also, on examination, that the same fossil occurred through an extent of seventy feet at least, and so far as I could discover it was the only fossil inclosed in the rock. It is extremely thin and delicate, yet the shell is perfectly preserved, and is probably one of the oldest inhabitants of the globe, as the rock in which they occur is the oldest of the transition series.[3]

In the second annual report of the paleontological department of the New York survey Prof. T. A. Conrad tabulated the formations to show the order of superposition and some characteristic fossils in the transition strata. On the primary occurs No. 1, formed of variegated sandstones (Potsdam sandstone of Emmons), and the olive sandstones and slates, characterized by *Fucoides serra*. These are classified under the Cambrian system of Prof. Sedgwick.

The base of the Lower Silurian is a gray calcareous sandstone, characterized by *Lingula acuminata*. This part of his table is as follows:[4]

LOWER SILURIAN STRATA.

Gray calcareous sandstone	*Lingula acuminata*

[1] Op. cit., p. 214.
[2] Op. cit., p. 215.
[3] Op. cit., p. 230.
[4] Second annual report of the paleontological department of the survey. Third annual report of the geological survey of New York. Albany, 1839, p. 63.

CAMBRIAN SYSTEM (SEDGWICK).

1. { Olive sandstone and slate .... *Fucoides serra* (Brong.)
{ Variegated sandstone (Potsdam sandstone of Emmons) .... *Dictuolites radians*

A description of the geographic distribution of the Potsdam sandstone in Clinton County is given by Dr. Emmons in the third annual report of the New York State survey. He also describes its stratigraphic character and appearance, and states that at Flat Rock the sandstone is more or less a conglomerate and coarser than at Potsdam or Keeseville.[1]

A description of the Potsdam sandstone as it occurs on the western side of the Adirondacks, in Jefferson County, is given by Dr. Emmons in his fourth annual report, as follows:[2]

Lying unconformably upon the primary is the Potsdam sandstone. It is therefore next in the series. It is a firmer rock, more crystalline, and less porous than the same rock in St. Lawrence, and especially that belonging to Potsdam.

The only fossil found in it was a small linguloid shell called *Lingula ovata.*[3]

The presence of the Potsdam sandstone in Lewis County is noted by Mr. Lardner Vanuxem, who states that the sandstone appears in the northeastern part of the county in low ridges, with all the characteristics given by Prof. Emmons, in whose district it is an extensive rock.[4]

The Potsdam sandstone as it occurs in Washington County, upon the eastern side of the mountains, is described by Dr. W. W. Mather as

a hard, siliceous sandstone, white, red, gray, yellowish, and frequently striped. It is well developed at Whitehall, where it has a thickness of 150 to 200 feet. It extends up the valley of Wood Creek in a southerly direction by Comstock's Landing, 1 mile east of Fort Ann, and so on farther south, diminishing in thickness and becoming interlaminated with finer-grained strata of grits, slates, and shales. Some of the strata of this rock are covered with the most beautifully characterized ripple-marks, as perfect as if just formed on the sand of a sea beach, while the rock is of the most indurated kind of sandstone.[5]

The only fossils noticed were fucoidal impressions.

The geographic distribution of the Potsdam sandstone about the Adirondacks is shown on the map of 1844 that accompanies the final report of the State geologists of New York. On a geological map of the Middle and Western States by Prof. James Hall[6] the main geographic distribution is indicated and a small area on the southern side of the Wisconsin River in Wisconsin is the same tint as the Potsdam area of New York.

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[1] Third annual report of the second geological district. Third annual report of the geological survey of New York, 1839, pp. 231, 232.

[2] Fourth annual report of the survey of the second geological district of New York. Fourth annual report of the geological survey of New York. Albany, 1840, p. 322.

[3] Op. cit., p. 323.

[4] Fourth annual report of the geological survey of the 3d district. Fourth Report of the Geological Survey of New York. Albany, 1840, pp. 363, 368.

[5] Fifth annual report on the geological survey of the 1st geological district. Fifth Annual Report of the Geological Survey of New York, 1841, p. 102.

[6] Geological map of the Middle and Western States. Geol. of New York. Report on the Fourth Geol. district, Albany, 1843.

In a tabulation of the Lower Silurian strata of the State of New York, published in 1842, Prof. T. A. Conrad states that the Cambrian system has proved to be the Lower Silurian, and he places the Potsdam sandstone at the base of the latter system, beneath the Calciferous sandstone.[1]

The final report of the geology of the second geological district contains a summary by Dr. Emmons of the characters of the Potsdam sandstone as found in the counties of Warren, Essex, Clinton, Franklin, St. Lawrence, and Jefferson, and also gives details of the formation as found in each county.[2] A description of the formation in detail and also a general descriptive summary of the formation is given by Mr. Lardner Vanuxem as it occurs in his district,[3] and Dr. W. W. Mather describes it as it occurs in Washington County and in Saratoga County.[4] Prof. James Hall describes it concisely in an account of the rocks of New York State. In its geographic distribution the rock is known in Canada, on Lake Superior, and, from its position, it is probably the same that appears on the Mississippi River mentioned by Dr. Owen in the report on the lead region of the northwest.[5] He also identifies it with No. 1 of the Pennsylvania survey, or a sandstone extending through New Jersey, Pennsylvania, and Virginia.[6]

In the account of his travels in North America Sir Charles Lyell describes the Potsdam sandstone as he saw it at Au Sable Chasm, near Keeseville, Essex County, New York. He speaks of it as a siliceous sandstone:

> In many places, this most ancient of the fossiliferous rocks of New York (the Potsdam sandstone) is divided into laminæ by the remains of innumerable shells of the genus *Lingula*. They are in such profusion as to form black seams like mica, for which they were at first mistaken. With the Lingula occurs another placunoid shell allied to, if not identical, according to Prof. E. Forbes, with a fossil which occurs in company with a small Lingula in the lowest beds of the English Silurian series at Builth, in Brecknockshire.[7]

A general account of the Potsdam sandstone is given by Dr. E. Emmons in the Agriculture of New York. It is an excellent summary of the general characters of the formation.[8]

The Potsdam sandstone of Lewis County is described by Mr. F. B. Hough in a general manner. He states that it thins out to an unimportant stratum as compared with the formation in St. Lawrence County; also that the superjacent Calciferous sandrock is represented by only a

[1] Observations on the Silurian and Devonian systems of the United States, with descriptions of new organic remains. Phila. Acad. Sci. Jour., vol. 8, 1842, pp. 229, 230.

[2] Geology of New York, part 2, second geological (northern) district, pp. 102-105, 177-179, etc.

[3] Geology of New York, part 3, third geological (central) district, Albany 1842, pp. 28, 29.

[4] Geology of New York; geology of the first (southeastern) district. Albany, 1843, p. 418.

[5] Geology of New York; geology of the fourth (western) geological district. Albany, 1843, p. 27.

[6] Op. cit., p. 28.

[7] Travels in North America. New York, 1845, vol. 2, pp. 131, 132.

[8] Agriculture of New York, vol. 1, 1846, pp. 117, 118.

thin layer of the fucoidal sandstone.[1] In 1850 he called attention to cylindrical masses from 3 inches to 15 and 20 feet in diameter that occur in the Potsdam sandstone near Somerville, St. Lawrence County.[2]

The description and accompanying figure recall the *Cryptozoon proliferum* described by Prof. Hall from the Potsdam formation of Saratoga County. A year later attention was again called by Mr. Hough to the cylindrical masses.[3] They are described as vertical cylinders from 2 inches to 20 feet and upward in diameter, and show a concentric structure. Numerous smaller bodies, not larger than an orange, of a spheroidal structure are also met with in the vicinity. No traces of organic life were observed in the matrix. It is evident that these bodies are unlike the Saratoga Cryptozoon.

A more extended definition of the Potsdam sandstone was given by Dr. E. Emmons in 1856. He then included with it the lower sandstone of the upper Mississippi Valley, and No. 1 of the Pennsylvania survey.[4]

An excellent summary of the existing knowledge of the Potsdam sandstone was given by Dr. J. J. Bigsby in 1858 in a paper on the Paleozoic Basin of the State of New York. A description is given of the mineral characters, mode of transition, stratigraphic position, mode of occurrence, thickness, and paleontologic character.[5]

In a tabulation of the succession of sedimentary rocks Prof. Richard Owen states that the Potsdam sandstone of New York geologists is considered by some English writers as belonging to a separate system, the Cambrian.[6]

The presence of the peculiar cylindrical masses in the Potsdam sandstone mentioned by Mr. Hough is also noticed by Mr. T. G. B. Lloyd in Jefferson County,[7] but without any attempt to explain their origin or nature.

In a note on the geology of Port Henry, New York, Dr. T. S. Hunt states that the Potsdam sandstone and the basal member of the overlying Paleozoic series is well seen in a railway cut near Port Henry. The lower beds are massive and compact, dark bluish or iron gray, with lighter bands and thin, blackish, shaly layers. The only fossils observed were *Scolithus linearis* and *S. canadensis* of the Potsdam of the Ottawa Basin.[8]

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[1] Observations on the geology of Lewis County, New York. Am. Jour. Sci. and Agric., vol. 5, 1847, p. 273.

[2] Catalogue of mineralogical and geological specimens received from F. B. Hough, 3d Annual Rep. of Regts. Univ. State Cab. Nat. Hist, 1850, pp. 32, 33.

[3] On the cylindrical structure observed in Potsdam sandstone. Am. Assoc. Proc., vol. 4, 1851, pp. 352–354.

[4] American Geology, containing a full statement of the principles of the science, with full illustrations of the characteristic American fossils. Albany, 1856, vol. 1, pt. 2, pp. 128–132.

[5] On the Paleozoic Basin of the State of New York. Part I. A synoptical view of the mineralogical and fossil characters of the Paleozoic strata of the State of New York. Quart. Jour. Geol. Soc., London, vol. 14, 1858, pp. 338, 339.

[6] Preliminary observations; general report and description by counties. (Lower and Upper Silurian). Geological reconnaissance of Indiana, made in 1859–'60. Indianapolis, 1862, p. 14.

[7] Geological notes from the State of New York. Quart. Jour. Geol. Soc., London, vol. 32, 1876, pp. 78, 79.

[8] The geology of Port Henry, New York. Canadian Nat., new ser., vol. 10, 1883, p. 421.

A short notice of the discovery of a massive limestone superjacent to the typical Potsdam sandstone containing species of the Potsdam fauna equivalent to the fauna of the upper horizon of the lower sandstone of the Mississippi Valley was made by Mr. C. D. Walcott in 1884. The limestone was originally referred to the Calciferous formation.[1]

Mention is made of the contact between the Potsdam sandstone and the subjacent pre-Cambrian rocks in the vicinity of Fort Ann, Washington County, New York, by Mr. C. E. Hall.[2]

A section of the Potsdam sandstone with the superjacent limestone, carrying the Upper Cambrian fauna was published by Mr. C. D. Walcott in 1886 accompanied by a list of the fossils found and a comparison of them with the Wisconsin fauna referred to the Potsdam by Prof. James Hall.[3]

In the fifth annual report of the State geologist of New York, in some field notes on the geology of the Mohawk Valley, with a map, Messrs. C. E. Beecher and C. E. Hall describe a section that occurs in a cut on the West Shore Railroad at "Little Nose, Randall, Montgomery County, New York."[4] In the woodcut illustrating the section, a breccia that occurs unconformably beneath the Calciferous sandrock is stated to contain Potsdam sandstone, crystalline limestone, quartzite, etc. The evidence upon which the fragments of sandstone were identified as of Potsdam age is not given.

In a paper on a great Primordial quartzite Prof. N. H. Winchell republishes a description of the Potsdam sandstone by Dr. Emmons and correlates the formation with the "granular quartz" of the western slope of the Green Mountains and the pre-Cambrian quartzites of Wisconsin and Minnesota.[5]

In a paper read before the Geological Society of America, at Washington, D. C., December 31, 1890, Messrs. N. S. Shaler and H. S. Williams described the presence of a thin bed of shale beneath the Calciferous sandrock and just above a thin bed of sandstone that rests unconformably upon the subjacent pre-Paleozoic rocks. The locality is a quarry at Little Falls. In the shale numerous specimens of *Lingulepis acuminata* were found.[6]

CANADIAN EXTENSION.

In a report of progress of the geological survey of Canada for 1845-'46 Sir W. E. Logan notes the presence of a sandstone in the Ottawa district, but is doubtful whether it represents the Potsdam sandstone, as

[1] Potsdam fauna at Saratoga, New York. Science, vol. 3, 1884, pp. 136, 137.

[2] Laurentian Magnetic iron ore deposits from northern New York, accompanied by a geological map of Essex County. Report of the State geologist for the year 1884. Albany, 1885, p. 32.

[3] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, pp. 21, 22.

[4] Fifth Ann. Rept. State Geologist of N. Y., for 1885. Albany, 1886, p. 10.

[5] A Great Primordial Quartzite. Am. Geol., vol. 1, 1888, pp. 173-178.

[6] Unpublished.

it may be in the lower beds of the Calciferous.[1] In a later report he noted the presence of the Potsdam sandstone on the north shore of the St. Lawrence at Murray's Bay, 90 miles below Montreal, describing it as a formation consisting of white, translucent, slaty quartz-rock having an exposed thickness of 45 feet and conformably subjacent to the Calciferous sandrock.[2]

A brief summary of the lithologic and paleontologic characters of the Potsdam sandstones in Canada was read by Dr. T. S. Hunt before the American Association for the Advancement of Science in 1851.[3]

In an extended paper on the foot-prints occurring in the Potsdam sandstone of Canada, Sir W. E. Logan describes the Potsdam sandstone as it occurs in Canada in the St. Lawrence Valley. He states that—

> The sandstone in Beauharnois County and the neighboring part of the State of New York is from 300 to 700 feet thick. In the lower part it contains many beds of conglomerate, with quartz pebbles, and it has some red layers; but towards the top it becomes a fine-grained, hard, white sandstone, and at the summit it is interstratified with calcareous layers, forming a passage to the rock which overlies it.[4]

The description of the extention of the Potsdam sandstone between the River of the North and Beauharnois was continued by Sir W. E. Logan in the report for 1851–'52.[5] In the same volume Dr. Alexander Murray describes the sandstone along the shores of the St. Lawrence in the vicinity of Brockville, and also in the outcrops exposed between the rivers Ottawa and St. Lawrence.[6]

This was followed in 1854 by the account of Dr. Murray's exploration between Kingston and Lake Simcoe. In this region the Potsdam is not largely developed, the greatest thickness of it observed in any one place being certainly not over 40 or 50 feet, while west of Knowlton Lake, in Loughborough, it appears gradually to decrease in thickness, and eventually to die out altogether.[7]

In the summary of the work of the Geological Survey of Canada from its commencement to 1863, there is given a very complete description of the stratigraphic, lithologic, and paleontologic characters of the Potsdam sandstone as known in Canada.[8] Since that time very little has been published upon the formation.

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[1] Report on sequence and distribution of the formations (on the Ottawa). Geol. Surv. Canada: Report of progress for 1845–'46, Montreal, 1847, p. 51.

[2] Report on Bay St. Paul and Murray Bay. Geol. Surv. Canada: Report of progress for 1848–'49. Toronto, 1850, pp. 10, 11.

[3] Remarks on the lithological and paleontological characters of the Potsdam sandstone. Am. Assoc. Proc., vol. 6, 1852, pp. 271-273.

[4] On the foot-prints accurring in the Potsdam sandstone of Canada. Quart. Jour. Geol. Soc., Lond., vol. 8, 1852, p. 200.

[5] Report [on country between Rivière du Nord and Beauharnois] Geol. Surv. Canada, 1851–'52. 1852. pp. 8–14.

[6] Report [of country lying between rivers Ottawa and St. Lawrence] Geol. Survey of Canada for 1851–'52, 1852, pp. 64–67.

[7] [Exploration between Kingston and Lake Simcoe.] Geol. Surv. Canada: Report of progress for 1852–'53, 1854, p. 109.

[8] Geological Survey of Canada: Report of progress from its commencement to 1863. Montreal, 1863, pp. 87–109.

WESTERN BORDER OR ROCKY MOUNTAIN SUBPROVINCE.

This subprovince includes central Colorado, central and northern Wyoming, South Dakota and southern central Montana.

COLORADO.

The probable presence of the equivalent of the Potsdam sandstone of the Mississippi Valley in the Colorado range was noticed by Dr. F. V. Hayden in 1874. He says:

The lowest beds of sedimentary rocks are rather coarse sandstones, and conglomerate made up of water-worn quartz pebbles, with very irregular laminæ of deposition, the whole reminding one of the Potsdam group. * * * There is considerable variety in the aggregate of beds here, which may be regarded as Silurian, and we may conclude that the Potsdam group is quite well represented, and that it is possible that some of the higher divisions occur. These rocks require a still more careful study, yet it is an interesting fact to know of their existence in this locality. In the lower sandstones I found a species of Lingula, the present season, probably a Potsdam form.[1]

These observations were made along William's Cañon, 2 or 3 miles above Colorado Springs. Of the probable presence of the "Potsdam" in the South Park, on the north slope of Mount Lincoln, and on all of the surrounding high mountains he does not appear to have any doubt. He says:

Before going further I will state what I believe to be the age of all the limestones and quartzites which seem to cover the highest mountains, and in which most of the valuable mines are found. I think there is no doubt that they belong to the Potsdam group, though I was unable to discover any fossils. Dr. Peale found a few obscure forms which indicated that the group is of the same age as those next to the granites in Utah, which we now know are of that age.[2]

While studying the geology from Denver to Colorado Springs, Dr. A. C. Peale examined and measured a number of sections passing from various horizons in the superjacent rocks to the Archean. In one, extending from Glen Eyrie eastward to Camp Creek, there are 40 feet of coarse sandstone of a grayish white, dark green, gray and brick red color. This series rests upon the granite; is beneath limestones referred to the Quebec group, and is considered to represent the Potsdam group.[3]

On Trout Creek, in Bergen Park, 93 feet of sandstone is referred to the Potsdam.[4] In a reddish sandstone superjacent to the "Potsdam" a number of fossils were found that were referred to the Quebec group. As now known this fauna is of Lower Silurian (Ordovician) age, corresponding to the Calciferous zone of the New York section. Another section was measured on one of the eastern tributaries of Trout Creek,

[1] Report of F. V. Hayden, U. S. Geologist. U. S. Geol. Surv. of the Terr., 7th Ann. Rep., 1874, p. 35.

[2] Op. cit., p. 41.

[3] Report of A. C. Peale, M. D., geologist of the South Park Division. U. S. Geol. Surv. of the Terr., 7th Ann. Rep., 1874, p. 202.

[4] Op. cit., p. 208.

in which 67 feet of sandstone occur resting upon the granite. Of these sections Dr. Peale says:

A comparison of the sections given above shows that the Potsdam group is represented by sandstones having a thickness of from 60 to 80 feet, while the beds that represent the Quebec group are a little over 100 feet thick.[1]

References to the sandstone supposed to be Potsdam are also found on pages 226, 236, 242, and 255.

During the field season of 1874 Dr. A. C. Peale found on Eagle River a series of beds resting on the gneiss and schist. From their position and lithologic relations to corresponding beds seen in the Colorado Range in 1873 the lower layers are referred to the Potsdam group. It is represented by a bed of white quartzite.[2]

A reference to the probable occurrence of the Potsdam horizon upon the eastern side of the Colorado Range is made by Mr. Arnold Hague, in his general description of the geology of the range. From the fact that a sandstone occurs in the Black Hills, and contains fossils of a Primordial type, he thinks the sandstone occupying a similar stratigraphic position in the Colorado Range will be found to contain the same fauna.[3]

On the geological map of Colorado, published by Dr. Hayden in 1877, the quartzite and the limestone referred to the Potsdam series are included with the Silurian, and their geographic distribution is merged with the latter on the map.

In his synopsis of the geological formations found in Colorado Dr. F. M. Endlich tabulates the localities and formation of the "Potsdam group."[4]

When describing the Paleozoic rocks of the Mosquito Range in central Colorado, Mr. S. F. Emmons states that the Cambrian is represented by quartzites passing gradually upward into calcareous shales, with limestones of probably Silurian age above, the aggregate thickness of the two being about 400 feet.[5] In the tabulation of the Mosquito section the Cambrian white quartzite is given a thickness of from 150 to 200 feet before passing into calcareous and argillaceous shales above.[6] The only fossil remains found in this series occur in a bed of greenish chloritic slates on the east flank of Quandary Peak, about a mile above the Monte Cristo mine. They belong to the genus Dikelocephalus and resemble closely *Dikelocephalus minnesotensis* of the Potsdam formation. From analogy with other sections Mr. Emmons thinks it safe to assume that the fossiliferous shales occur above the main body of quartzite and near the base of the transition series.[7]

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[1] Op. cit., p. 209.

[2] Report on Middle Division. (Stratigraphy-Paleozoic formations). U. S. Geol. and Geog. Survey of the Terr., Ann. Rep. for 1874, 1876, pp. 110, 111.

[3] Hague, Arnold, and S. F. Emmons. Descriptive geology U. S. Geol. Expl. of the Fortieth Par.; Clarence King, vol. 2, 1877, p. 29.

[4] Report of F. M. Endlich, geologist of the White River Division. U. S. Geol. Surv. of the Terr., 10th Ann. Rep., 1878, p. 130.

[5] Geology and mining industry of Leadville, Colorado. Mon. U. S. Geol. Survey, vol. 12, 1886, p. 55.

[6] Op. cit., p. 57.

[7] Op. cit., p. 60.

WYOMING.

As geologist to Capt. Reynold's expedition to the headwaters of the Missouri and Yellowstone Rivers, Dr. F. V. Hayden identified, in 1861, the fossiliferous "Potsdam" sandstone of the Black Hills, and considered a sandstone holding the same relative position and exhibiting the same lithologic characters on the slopes of the Big Horn Range as the same formation. It is further stated that "a few thin layers of fine calcareous sandstone were observed filled with fossils characteristic of this period."[1]

From the Big Horn Range he crossed to the Laramie Range. At the head of the La Bonté Creek he noticed a bed resting discordantly upon Azoic slates 50 to 100 feet in thickness, holding the same position and possessing the same lithologic characters it reveals at other localities.

> I could discover no fossils in it at this point, but I am confident that this bed represents the Potsdam sandstone. This rock (the Potsdam) is more or less changed by heat from beneath, but I was able to trace it continuously from the source of the Chugwater Creek to the source of Cache la Poudre, a distance of over 100 miles. It was also seen along the eastern slope of the Wind River Mountains, but did not contain any organic remains.[2]

A more extended account of the character of the Primordial sandstone of the Rocky Mountains was published by Dr. Hayden in 1862.[3] It is accompanied by a description of the species of fossils found in the Black Hills and the Big Horn Mountains and further reference to it will be found in the account of the Cambrian rocks of Wyoming.

All of the essential part of Dr. Hayden's article of 1861 was reprinted in an article on the Geology and Natural History of the Upper Missouri, which appeared in 1863.[4] This essay is, as stated by the author, the substance of a geological report made by him to Capt. Raynolds on the exploration of the Yellowstone and Missouri Rivers. The latter report was issued in 1869, accompanied by a large map, dated 1859-'60, upon which the geographic distribution of the formations identified by Dr. Hayden are delineated. Within the present area of Wyoming a narrow belt of the "Potsdam" sandstone is represented as entirely surrounding the Big Horn Mountains, and as forming a continuous band with that along the eastern side of the Wind River Range and an interrupted belt on the western side of the latter range. The two mountains now known as the Wyoming Mountains also had a narrow band of "Potsdam" sandstone about them. To the north this band is represented as continuing westward across the Big Horn River, then north on the western side of the Yellowstone Lake region as far north as Beaver River, where it is interrupted. Several mountains directly north

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[1] Sketch of the geology of the country about the headwaters of the Missouri and Yellowstone Rivers Am. Jour. Sci., 2d ser., vol. 31, 1861, p. 234.

[2] Op. cit., p. 234.

[3] The Primordial Sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci. 2d ser., vol. 33, 1862, pp. 68-79. Canadian Jour., new ser., vol. 7, 1862, pp. 149-151.

[4] On the Geology and Natural History of the Upper Missouri. Am. Philos. Soc. Trans., vol. 12, new ser., 1863, pp. 1-218.

of the Yellowstone Lake region are represented as surrounded by the same formation.[1]

At the South Pass of the Wind River Mountains Dr. Hayden found the granites occupying a very restricted area and extending from them a large thickness of "Potsdam" sandstone containing *Obolella nana* and a Lingula.[2]

Prof. F. H. Bradley in 1873 identified the "Quebec group" by the presence of Conocoryphe and Dikelocephalus in limestones upon the flanks of the Teton range of mountains. At one of the outcrops of these limestones "they are immediately underlaid by about 300 feet of partly compact, partly shaly, glauconitic sandstones, which are evidently equivalent to the so-called Knox sandstones of Safford, which form in Tennessee, the lower part of the Quebec group. No fossils were seen in these beds. They are apparently unequally distributed, since no corresponding beds appear along the cañon of West Teton Creek. Beneath them, and often present when they are absent, we generally find from 50 to 75 feet of a very compact ferruginous quartzite which must represent the Potsdam, though this also, is sometimes wanting."[3] In a diagram of a section extending from Henry's Fork through the Teton Mountains the so-called Quebec group and Potsdam quartzite are represented on each side of the range, the quartzite resting directly on the granite.[4]

The preliminary paleontological report of Mr. F. B. Meek refers the beds containing fragments of Conocoryphe and Dikelocephalus, found on the west base of Big Horn Mountains by the Hayden survey in 1872, to the Potsdam or Primordial zone.[5]

In speaking of the Paleozoic rocks of the Laramie Hills, Mr. Arnold Hague states that all paleontologic evidence obtained from these beds would tend to show that they belong to the Coal Measure limestone.[6]

The strata along the eastern slope of the Wind River Mountains referred to the Potsdam by Dr. Hayden were studied by Prof. T. B. Comstock while geologist of Capt. W. A. Jones's expedition to northwestern Wyoming. He found the sandstone closely resembled that described by Prof. J. D. Whitney in Wisconsin. The local peculiarities of this sandstone and its associated rocks as described in the Mississippi Valley and New York are strikingly repeated in the Rocky Mountain region. The greatest thickness of the sandstone in the region of the

[1] Geological report of the Exploration of the Yellowstone and Missouri Rivers. Under the direction of Capt. W. F. Raynolds, 1859-'60, Washington, 1869, p. 144, map.

[2] Report of F. V. Hayden (on the geological survey of Wyoming.) U. S. Geol. Surv. of the Terr., 4th Ann. Rep., 1871, p. 33.

[3] Report of Frank H. Bradley, geologist of the Snake River division. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, p. 216.

[4] Op. cit., p. 218.

[5] Preliminary paleontological report . . . with remarks on the ages of the rocks, etc. U. S. Geol. Survey of the Territories, embracing portions of Montana, Idaho, Wyoming, and Utah; 6th Ann. Rep. 1873, p. 431.

[6] Descriptive geology, U. S. Geol. Expl. of the Fortieth Par.; Clarence King, vol. 2, p. 76. Washington, 1877.

Wind River Mountains is about 200 feet. All the beds bear evidence of deposition in shallow seas or upon beaches or sand flats.[1]

Under the head of Quebec group, Prof. Comstock describes some calciferous layers and dolomitic limestones that are conformably superjacent to the sandstone. In them he found a species of Theca?, a trilobite of the genus Dikelocephalus and *Orthis tritonia*? Fragments of other fossils too imperfectly preserved for identification were found.[2]

If the identifications by Prof. Comstock of the species found in the limestone are correct, that portion of the limestone containing them must be referred to the Upper Cambrian zone. On the map accompanying the report the "Potsdam" formation is represented along the entire eastern margin of the Wind River Mountains and along the western central portion of the range. A narrow belt of it surrounds Creek Mountain in the northeast of the Snake Indian Reservation, and the Wyoming Mountains to the northwest of the Wind River Range.

The southern portion of the Sweetwater district in the Wind River Range was visited by Dr. F. M. Endlich in 1877. He found a Lingula, probably *Lingula prima*, and estimated the thickness of the entire series as varying between 180 and 320 feet.[3] He refers to the Calciferous group a thin series of sharply bedded strata composed of blue limestones and blue and yellow dolomite and locally of oolitic dolomite, altogether having a thickness of about 250 feet.[4] These strata are correlated with those containing Dikelocephalus, etc., discovered by Prof. Comstock in 1874.

The Teton Mountain district was studied by Prof. Orestes St. John in 1877, and in his report he refers to the work of Prof. Bradley in 1872. Very little is added to the information given by Prof. Bradley of the lower quartzite series, but an important advance is made in the classification of the rocks of the district by the division of Prof. Bradley's Quebec group into the Upper and Lower Quebec limestone. The Lower Quebec limestone, carrying Conocoryphe and Dikelocephalus, is described in detail and separated from the upper limestone carrying Raphistoma, etc.[5]

The line of separation of these two limestones is the line between the Cambrian and Silurian (Ordovician) Systems, and reference will be made to it under the description of the Cambrian rocks of Wyoming.

Prof. St. John also studied the Buffalo Fork Mountain, east of the Teton Range, and found there the same succession of beds as in the Teton section. Numerous fossils were collected from the limestone overlying the quartzite.[6]

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[1] Geological report. Report upon the reconnaissance of northwestern Wyoming, made in the summer of 1873, by William A. Jones. 1874, pp. 107, 108.

[2] Op. cit., p. 110.

[3] Report on the geology of the Sweetwater district. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, p. 71.

[4] Op. cit., p. 72.

[5] Report of the geological field-work of the Teton Division. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, pp. 481-483.

[6] Op. cit., p. 469.

In his report on the geology of the Wind River district, made in 1883, Prof. St. John describes the geology of the Gros Ventre Range, accompanying it with two plates of sections across the range at various points.[1] On the map accompanying the volume the geographic distribution of the strata referred to the Silurian is delineated. He also describes the out-crops of the strata on the northwestern and northeastern sides of the Wind River Range, that he refers to the Silurian.[2] Reference to Prof. St. John's sections will be made in describing the Cambrian rocks of the Wind River and Gros Ventre Ranges.

On the map accompanying the twelfth annual report of the Hayden survey, issued in 1883, the geographic distribution of the strata referred to the Silurian in the Sweetwater Range, the Wind River Range, the Gros Ventre Range, and the Teton Range is shown. The Silurian includes the quartzite referred to the Potsdam, the Cambrian limestone referred to the Lower Quebec by Prof. St. John, and the Calciferous referred by him to the Upper Quebec. This map was compiled from the work of Messrs. Peale, St. John, and Endlich. There is also a special map showing the district reported on by Prof. St. John in 1883.

DAKOTA.

The presence of evenly bedded sandstones about the Black Hills was noted as early as 1822 by Dr. Edwin James, who represented them upon a diagrammatic section, extending from the Alleghany to the Rocky Mountains. He undoubtedly confused the sandstones of the Trias with those of the Cambrian; but it is one of the earliest recorded illustrations of the mode of occurrence of the sandstone in this region. That he did not penetrate to the interior portion of the hills is evident, as his section represents the sandstone extending in level horizontal layers entirely across the area occupied by them.[3]

In 1856 Mr. H. Engelmann published a description of the rocks of the Black Hills. The strata next to the granitic nucleus are described as "more or less altered sandstones and limestones, dipping in various directions and degrees. Most of the sandstones are fine grained, light yellowish red, and do look much like metamorphic, but some show the transition into a siliceous rock."[4] Not far from camp 56 he found a friable sandstone made up of coarse square grains of granite, apparently deposited after the formation of the igneous rocks. Near camp 58 the sandstone is light yellowish red and fine grained. There is also a gray variety, above which is a layer of a dark red sandstone, coarse grained, soft, and highly micaceous.[5] This is the sandstone in which Dr. Hayden subsequently found the Upper Cambrian fauna.

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[1] Report on the geology of the Wind River district. U. S. Geol. Surv. of the Terr., 12th Annual Report, 1883, p. 208.

[2] Op. cit., pp. 251-253.

[3] Geological sketches of the Mississippi Valley. Phil. Acad. Sci., Jour., vol. 2, pt. 2, 1822, pp. 326-329.

[4] Report of a geological exploration from Fort Leavenworth to Bryan's Pass, made in connection with the survey for a road from Fort Riley to Bridger's Pass, under Bryan. Rept. Sec. of War, Appendix H, 1856, p. 508.

[5] Op. cit., p. 510.

In notes explaining the second edition of a geological map of Nebraska and Kansas in 1858 Dr. F. V. Hayden[1] states that the existence of the Potsdam sandstone on the eastern slope of the Rocky Mountains was discovered during Lieut. G. K. Warren's expedition to the Black Hills in the summer of 1857.

In March, 1858, Messrs. Meek and Hayden presented a paper to the Academy of Natural Sciences, Philadelphia, containing "some remarks on the geology of the Black Hills and portions of the surrounding country." In this a section of the formations is given, in which the "Potsdam" sandstone is given a thickness of 30 to 50 feet and is said to contain Lingula, Obolus ?, and fragments of trilobites.[2] The sandstone is described as of a reddish and grayish color, composed of angular grains of quartz, cemented by siliceous and sometimes small portions of calcareous matter. The fossils then identified were *Lingula antiqua* Hall, great numbers of a small shell similar to *L. prima* Conrad and fragments of trilobites.[3] The information contained in this first paper by Messrs. Meek and Hayden was also published in the American Journal of Science,[4] the Canadian Naturalist (vol. 3, 1858, pp. 182–193), the report of the Chief of Engineers to the Secretary of War, 1858,[5] the American Journal of Science (vol. 25, 2d ser., p. 439, 1858), the Proceedings of Philadelphia Academy of Science (vol. 10, p. 139, 1859), and in a reprint of the Preliminary Report of the Exploration of Nebraska and Dakota, issued in 1875, which is the official account of Lieut. G. K. Warren's exploration transmitted to the Chief of Engineers.

In a paper on the Primordial sandstone of the Rocky Mountains and Northwestern Territories of the United States Dr. Hayden describes the sandstone he referred to the Potsdam in the Black Hills in considerable detail, as follows:[6]

> 3. Variegated sandstone, of gray and ferruginous red color, composed chiefly of grains of quartz and particles of mica, cemented with calcareous matter. Some portions of the bed are very hard, compact, siliceous; others a coarse friable grit, others a conglomerate. Fossils: *Lingula prima*, *L. antiqua*, *Obolella nana*, and fragments of a trilobite, *Arionellus? oweni*. . . 50 to 80 f.
>
> 4. Stratified azoic rocks standing in a vertical position for the most part.

The "Potsdam" sandstone is again described by Dr. Hayden in 1863,[7] and in the following year he published, in connection with Mr.

[1] Explorations under the War Department; explanations of a second edition of a geological map of Nebraska and Kansas, based upon information obtained in an expedition to the Black Hills under command of Lieut. G. K. Warren. Am. Jour. Sci., 2d ser., vol. 26, 1858, pp. 276–278.

[2] [Some remarks on the geology of the Black Hills and portions of the surrounding country.] Phil. Acad. Sci., Proc., vol. 10, 1859, p. 44.

[3] Op. cit., p. 49.

[4] Explorations under the War Department; explanations of a second edition of a geological map of Nebraska and Kansas, based upon information obtained in an expedition to the Black Hills under command of Lieut. G. K. Warren, Top. Engr., U. S. A. Am. Jour. Sci., 2d ser., vol. 26, 1858, p. 276.

[5] Catalogue of the collections in geology and natural history obtained by the expedition under command of Lieut. G. K. Warren. Appendix to Rept. Sec. of War in Rept. of Topog. Eng. for 1858. (Reprint edition of 1875, pp. 59–125. Map.)

[6] The Primordial sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci., 2d ser., vol. 33, 1862, p. 70.

[7] On the geology and natural history of the Upper Missouri. Am. Phil. Soc. Trans., vol. 12, new ser., 1863, pp. 36–38.

Meek, the description of the fossils he found in the Black Hills during the expedition of 1858. They are *Lingulepis pinnaformis*, *L. prima*, *Obolella nana*, and *Agraulos* sp.[1]

A general description of the sandstone of the Black Hills is given by Prof. N. H. Winchell in his report to Capt. William Ludlow, and the geographic distribution of the outcrop in the southern portion of the Black Hills is shown on the accompanying map.[2] In the same report Prof. R. P. Whitfield[3] describes *Obolus pectenoides*, a new species of brachiopod, and also figures *Lingulepis pinnaformis*.

The report of Mr. Henry Newton on the geology of the Black Hills contains a detailed description and full discussion of the strata referred to the Potsdam sandstone. This will be again referred to in the summary of our knowledge of the Cambrian rocks of the Black Hills.[4] From the paleontologic portion of the report we learn that the entire fauna of the Black Hills below the Carboniferous is Primordial, and Prof. R. P. Whitfield states it closely resembles that from Wisconsin, and although the species are nearly all distinct the generic facies is the same throughout.[5]

In 1888 Prof. F. R. Carpenter published a series of notes on the geology of the Black Hills, in which he criticised some of Newton's views, and also advanced some theoretical considerations of interest in relation to the original deposition of the sediments forming the Potsdam group.[6]

SOUTHWESTERN SUBPROVINCE.

This includes the areas of Texas and Arizona.

TEXAS.

The presence of Silurian rocks in Texas, subsequently referred to the Primordial, was announced by Dr. F. Roemer in 1849.[7] In the same work he describes from the lower portion of the section *Lingula acutangula* (p. 420) and *Pterocephalia sancti-sabæ* (p. 421).

On the map accompanying this volume the entire Paleozoic series is included under one color, on the northern side of the granitic band, northwest of Austin.

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[1] Paleontology of the Upper Missouri; a report upon collections made principally by the expedition under command of Lieut. G. K. Warren in 1855-'56. Invertebrates. Smithsonian Contributions No. 172, 1864, pp. 2-10.

[2] Geological report of a reconnaissance of the Black Hills of Dakota, made in the summer of 1874 by Captain William Ludlow. Report of the Chief of Engineers, Appendix PP, 1876, p. 1170.

[3] Description of new fossils. Report of Geological Reconnaissance of Black Hills. Appendix PP of Report of Chief of Engineers, 1876, pp. 1202, 1203.

[4] Geology. Section IV. The Silurian. The Potsdam sandstone. U. S. Geog. and Geol. Surv. of the Rocky Mountain region, J. W. Powell in charge; report on the Black Hills of Dakota. 1880, pp. 80-107.

[5] Paleontology of the Black Hills of Dakota. Report on the geology and resources of the Black Hills of Dakota. 1880, pp. 329, 330.

[6] Notes on the geology of the Black Hills. Preliminary Rept. Dakota School Mines on the Black Hills of Dakota, 1888, pp. 11-52.

[7] Texas. Mit besonderer Rücksicht auf deutsche Auswanderung und die physichen Verhältnisse des Landes nach eigener Beobachtung geschildert. Bonn, 1849.

A more extended account of the geology and the paleontology was published by him in 1852, in which he notes the occurrence of Silurian rocks in Llano County, on the San Saba River (p. 7); and describes and illustrates *Lingula acutangula* (p. 90), *Pterocephalia sancti sabæ* (p. 92), and the genus Pterocephalia. Attention is called by notes and figures to two undescribed species of trilobites.[1]

In a letter addressed to the Secretary of the St. Louis Academy of Sciences in 1859 Dr. B. F. Shumard states that he had discovered in Burnet County, Texas, an extensive development of Lower Silurian rocks, equivalent to the Potsdam sandstone and the Calciferous sand-rock of the New York system. The Potsdam sandstone is filled with trilobites belonging to the old genus Arionellus, with Obolus and Lingula, and a small Orthis, and it rests directly upon the granite. Above the Potsdam we have beds which appear to represent the third magnesian limestome and second magnesian limestone of the Missouri survey.[2] Two years later Dr. Shumard published a more detailed account of the Primordial zone of Texas, accompanied by a number of sections measured in Burnet County, and a description of new species of fossils from limestones referred to the Primordial. Under the heading of "Potsdam sandstone" three sections are given; one, 5 miles northwest of the town of Burnet, has a thickness of 275 feet. In this fossils were abundant in the upper portion, just beneath the Cretaceous limestone, as well as in the lower beds. The base was not seen. This section is made up almost entirely of limestones, as are the other two sections mentioned.[3]

Dr. Shumard states that the Potsdam sandstone is also finely displayed in the southern part of San Saba County and around the margins of the granite districts of Llano. "The fauna of this division of the Primordial zone of Texas is very analogous to that of the Potsdam sandstone of Iowa, Wisconsin, and Minnesota." The genera identified are: "Dikelocephalus, Bathyurus, Arionellus, Conocephalites, Agnostus, Lingula, Discina, Orthis, Camerella, Obolus, and Capulus, all of which genera have been discovered in the Primordial sandstones of the northwest except Agnostus and Camerella."[4] In the latter part of the paper six new species were described, and a species of Camarella and one of Capulus mentioned. In a letter to M. Barrande, dated September, 1860, Dr. Shumard describes in a general way the Primordial rocks of Texas as seen along the Colorado River in Burnet County.[5]

Attention was called in 1874 to the presence of a sandstone in Organ Mountains, close to the city of El Paso, in southwestern Texas, by Mr.

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[1] Die Kreidebildungen von Texas und ihre organischen Einschlusse. Bonn, 1852, pp. 92, 93.

[2] Letter touching the late discovery of Lower Silurian rocks, equivalent to the Potsdam sandstone and Calciferous sandrock of the New York system, in Burnet County, Texas. Trans. Acad. Sci. St. Louis, vol. 1, 1859, pp. 672, 673.

[3] The Primordial zone of Texas, with descriptions of new fossils. Am. Jour. Sci., 2d ser., vol. 32, 1861, pp. 216, 217.

[4] Op. cit., pp. 217, 218.

[5] Letter on the Primordial of Texas. Soc. géol. France, Bull., 2e sér., vol. 18, 1861, pp. 218, 219.

W. P. Jenney. He states that the quartzite rests upon a coarse feldspathic granite, and passes upward into sandstone, filled with *Scolithus linearis*, which he identified as the Potsdam sandstone. The superjacent formation is a crystalline limestone identified as calciferous. It contains several species of fossils resembling Archæocyathus, and rarely a gasteropod, like Pleurotomaria.[1] In commenting upon the statements of Mr. Jenney, Prof. J. S. Newberry says:

> Now it appears there are found in the Rio Grande Valley the crystalline base-rocks overlaid in succession by the Potsdam and Primordial, the Trenton, Hudson, Upper Silurian (?), and Carboniferous, just as they occur in the Northern and Eastern States. * * * It would seem as though the Organ Mountains had formed one border, and the New York and Canadian highlands the other, of the great Paleozoic invasions of the sea.[2]

A section of the strata referred in 1874 to the Potsdam by Mr. S. B. Buckley, at Packsaddle Mountain, in Llano County, gave a thickness of 385 feet of alternating limestone and sandstone, beneath which occurs a massive bed of reddish brown sandstone 326 feet in thickness. Numerous genera of Primordial fossils were found, characteristic of this horizon.[3] Other references are made to the occurrence of the Potsdam sandstone at various localities in this county. In the report for the following year Mr. Buckley refers to the occurrence of sandstones of the Potsdam period in Mason and Menard Counties. He also calls attention to the probable presence of rocks of Silurian age at the base of the Organ Mountains at Fort Bliss, near the town of El Paso.[4]

A preliminary report of a reconnaissance of a portion of the Paleozoic area of central Texas was made by Mr. C. D. Walcott in 1884. A measured section of the strata referred to the Cambrian on the west side of Honey Creek Valley gives 245 feet of sandstone and 625 feet of limestone, all marked by the presence of an abundant Upper Cambrian (Potsdam) fauna. The upper beds of the limestone become compact, hard, and have a little included cherty matter. The Cambrian fauna terminates here, as far as observed, and it is not until over 1,000 feet of limestone are passed through that recognized fossils again occur. The fauna is then of the type of the Calciferous group.[5] The text is accompanied by a diagrammatic section of Packsaddle Mountain, that illustrates the unconformity between the Llano group and the strata referred to the Potsdam or Upper Cambrian. This gave a total thickness of 605 feet for the formation, with a massive sandstone 205 feet in thickness at the base.[6]

The latest addition to our knowledge of the Cambrian rocks of Texas

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[1] [Recent explorations in the Geology of Texas.] New York Lyceum Nat. Hist. Proc., vol. 2, 1874, p. 69.

[2] Remarks on geology of Western Texas. New York Lyceum Nat. Hist.. Proc. vol. 2, 1874, p. 70.

[3] First annual report of the geological and agricultural survey of Texas. Houston, 1874, p. 73.

[4] Second annual report of the geological and agricultural survey of Texas. Houston, 1876, p. 10.

[5] Notes on Paleozoic rocks of Central Texas. Am. Jour. Sci., 3d ser., vol. 28, 1884, p. 433.

[6] Op. cit., p. 432.

is by Prof. T. B. Comstock.[1] He divides the rocks referred to the Cambrian into the Hickory series (Lower Cambrian?), the Riley series (Middle Cambrian?), and the Katemcy (Potsdam) series (Upper Cambrian?). The supposition that the Lower Cambrian and Middle Cambrian are represented is based upon the presence of certain beds beneath the fossiliferous Upper Cambrian. He considers that the Hickory beds have altogether a thickness of 200 to 250 feet. The maximum thickness of the Riley series is probably 300 to 400 feet. The upper or Katemcy series is divided into, Division A, or the Potsdam sandstone, thickness 90 to 140 feet; Division B, the Potsdam flags, probable thickness 50 feet; Division C, the Potsdam limestone, 200 feet.

ARIZONA.

As geologist of Lieut. J. C. Ives's expedition to the Colorado River of the West, Prof. J. S. Newberry was the first one to recognize the presence of a sandstone resting upon the Archean granite in the "Big Cañon" of the Colorado. A diagrammatic cross-section of the cañon represents the "Potsdam" sandstone unconformably superjacent to the granite and conformably subjacent to strata doubtfully identified as Silurian.[2] In the text it is said "the Potsdam (?) sandstone which is largely developed in the Great Cañon is a coarse siliceous rock that must have been derived from the erosion of land at no great distance."[3]

A section at Diamond Creek, as described by the same author, includes a conglomerate 3 feet in thickness resting on the granite, above which occurs 820 feet of sandstone. Of the upper beds of the sandstone, No. 10 of the section, Prof. Newberry says:

> The foliated sandstones of No. 10 have an indescribable look of antiquity. They are usually fine grained and hard, the lighter ones drab or gray, speckled with dark red. The shales above and below these sandstones are very soft red or green mudstones, containing great numbers of cylindrical bodies, which resemble the casts of worm holes.
>
> Nos. 12 and 13 are coarse siliceous rocks, having the same appearance of extreme age as No. 10, but much coarser and more massive. The lithological characters of these strata are strikingly like those of much of the Potsdam sandstone of the exposures I have examined of that rock on Lake Superior and in Canada. * * * In the absence of fossils, whatever conclusions may be arrived at in regard to the age of these sandstones must be in some degree conjectural and liable to modification by the discovery of new facts; yet the evidence is in a good degree satisfactory that they are the equivalent of the Potsdam sandstone of the New York geologists. The indications of this identity are found in their great relative antiquity and in their lithological characters.[4]

Attention is called to the resemblance of these sandstones to those of the Black Hills which occupy the same relative stratigraphic posi-

[1] A preliminary report on the geology of the central mineral region of Texas. 1st Ann. Rep. Geol. Surv. of Texas for 1889, 1890, pp. 285-289.

[2] Geological report. Report upon the Colorado River of the West, expl. in 1857-'58 by Lieut. J. C. Ives. Part III, 1861, p. 42.

[3] Op. cit., p. 47.

[4] Op. cit., p. 56

tion, and which contain the Potsdam fauna, as identified by Dr. Hayden.[1]

When describing the section of the Grand Cañon of the Colorado where it passes through the Kaibab plateau, Maj. J. W. Powell states that the summit of the section was formed by Carboniferous limestone. This extends from the edge of the plateau down 3,500 feet, and beneath it occurs 1,000 feet of conformable rocks of undetermined age. These in turn extend down to the unconformity between them and the subjacent 10,000 feet of strata that were subsequently referred to the Grand Cañon group. At the close of the same paragraph, in speaking of the latter series of rocks, he says:

The beds themselves are not conformable to the overlying Carboniferous rocks; that is, the Carboniferous rocks are spread over their upturned edges.[2]

It thus appears that all of the strata down to the unconformity were referred to the Carboniferous. This includes the series of sandstones referred to the Potsdam by Dr. Newberry.

As the result of his studies of the lower strata of the Colorado Cañon region at Diamond Creek and at the mouth of the cañon, Mr. G. K. Gilbert in 1874 designated the series of sandstones referred to the Potsdam by Newberry, as the Tonto group, and considered it to belong to the Primordial division of the Silurian.[3] The data for this conclusion were published in the following year.[4]

The section at the mouth of the Colorado has 80 feet of vitreous sandstone resting unconformably upon the granite, and 605 feet of shales alternating with limestones between the sandstone and a superjacent massive limestone.[5] At the mouth of the Kanab Creek 100 feet of green arenaceous and micaceous shales occur between the superjacent massive gray limestone and the level of the river.[6] From the stratigraphic position of the Tonto sandstone and shales and the presence of a species of the genus Cruziana he was led to conclude that the Tonto group is certainly Lower Silurian in age, and probably Primordial.[7]

The section of the Tonto series at the mouth of the Grand Cañon was measured more in detail by Mr. A. R. Marvine in the same year. He traced[8] the formation to the south and southeast along the margin of

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[1] Op. cit., p. 57.

[2] Exploration of the Colorado River of the West and its tributaries, explored in 1869, 1870, 1871, and 1872. Washington, 1875, p. 212.

[3] On the age of the Tonto sandstone. (Abstract.) Washington Phil. Soc. Bull., vol. 1, 1874, p. 109.

[4] Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872. Report on Geog. and Geol. Expl. and Survey west of the 100th merid., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, pp. 184–186. Report on the geology of portions of New Mexico and Arizona, examined in 1873. Ibid., vol. 3, 1875, pp. 521, 522.

[5] Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872. Report on Geog. and Geol. Expl. and Survey west of the 100th merid., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 163.

[6] Op. cit., p. 162.

[7] Op. cit., pp. 185, 186.

[8] Report on the geology of route from St. George, Utah, to Gila River, Arizona, examined in 1871. Rept. on Geog. and Geol. Expl. and Surv. west of 100th merid., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 199.

the plateau that extends southward from the Grand Cañon. The geographic distribution of the formation is indicated on the atlas sheets published by the Wheeler survey in 1874.

When describing the sedimentary groups of the Plateau province Maj. Powell accepted the name Tonto group, proposed by Mr. Gilbert, but did not agree with him in considering the strata to be of Silurian age. From geological considerations he was inclined to consider the Tonto group as forming the base of the Carboniferous series. This opinion was strengthened by the fact that he found in the Grand Cañon 10,000 feet of sandstone, shales, and limestones underlying the Tonto series unconformably, and hence separated from them by long periods of erosion, and at the base of the latter series he reported finding Silurian fossils.[1]

The fossils mentioned by Maj. Powell were studied by Dr. C. A. White, who identified the genera Lingulella and Obolella and referred them to the Lower Silurian.[2]

The supposed Primordial age of the Tonto series was accepted by Capt. C. A. Dutton in his account of the physical geology of the Grand Cañon district.[3]

The section at the mouth of the Kanab Cañon was studied by Mr. C. D. Walcott in 1880. He found that 450 feet of a mottled limestone and 100 feet of arenaceous and micaceous shales at the base of the section were of Primordial age, as indicated by the presence of the genera Lingulepis, Conocephalites, and Bathyurus in the upper portion, and in addition to these *Hyolithes primordialis*, Lingulepis, and Crepicephalus in the lower beds.[4] Further evidence of the Cambrian age of the Tonto group was published by Mr. Walcott in 1883. Fossils representing the genera Cruziana, Lingulepis, Iphidea, Conocephalites, Crepicephalus, and Dikelocephalus were found in the upper 700 feet of the sandstones, shales, and limestones that form the upper part of the group in the cañon valleys entering on the left side of the Kaibab plateau.[5]

PALEONTOLOGY.

UPPER MISSISSIPPI AREA.

The first reference that we find to the fossils of the Cambrian fauna of the Upper Mississippi Valley is by Dr. D. D. Owen in his report of 1848 on a geological reconnaissance of the Chippewa land district of

[1] Report on the geology of the eastern portion of the Uinta Mountains and a region of country adjacent thereto. Washington, 1876, p. 56.

[2] Invertebrate paleontology of the Plateau province, together with notice of a few species from localities beyond its limits in Colorado. Rept. on the geology of the eastern portion of the Uinta Mountains, by J. W. Powell, Washington, 1876, p. 79.

[3] The physical geology of the Grand Cañon district. U. S. Geol. Surv., 2d Ann. Rep. 1880-'81. 1882, p. 114.

[4] The Permian and other Paleozoic groups of the Kanab Valley, Arizona. Am. Jour. Sci., 3d ser., vol. 20, 1880, p. 225.

[5] Precarboniferous strata in the Grand Cañon of the Colorado, Arizona. Am. Jour. Sci., 3d ser., vol. 26, 1883, p. 439.

Wisconsin.[1] The fossils discovered were referred to the genera Asaphus, Agnostus, Trinucleus, and Triarthrus, but on Pl. 7, accompanying the report, there is figured, but not named, the head and pygidium of *Dikelocephalus minnesotensis*, and a species of Ptychoparia as now known.

In a later paper in 1851 on the paleontology of the lowest sandstones of the Northwest he gives the name "Dikello-Cephalon" to a large genus of trilobites obtained in the lower sandstone formation.[2] He also notes the discovery of Lingulas and Orbiculas by himself in 1847 at the Falls of St. Croix, and the discovery of fossils on the Mississippi River between the Falls of St. Anthony and the Wisconsin River, the presence of trilobites in the sandstone 10 miles below Mountain Island, etc.

One of the first species described from the "Potsdam" sandstone of Wisconsin is *Graptolithus hallianus* Prout, 1851, from the middle portion of the formation at Osceola Mills, near the falls of St. Croix River.[3]

The occurrence of the Potsdam fauna in the sandstone of northeastern Wisconsin is noted by Prof. James Hall in his report to Messrs. Foster and Whitney.[4] He describes and illustrates *Lingula prima* Conrad (p. 204), *Lingula antiqua* Hall (p. 204), and an undetermined species of Dikelocephalus (p. 205).

We note that *Lingula prima* was subsequently described by Hall as *Obolella polita*, and that *Lingula antiqua* equals *Lingulepis acuminata* of Conrad and the *Lingulepis pinnaformis* of Owen.

From the material collected from the lower sandstones of Wisconsin (the Potsdam sandstone of New York) Dr. Owen described, in 1852, the following genera and species:[5]

Dikelocephalus (n. gen.), p. 573.
    minnesotensis, p. 574.
    pepinensis, p. 574.
    miniscaensis, p. 574.
    iowensis, p. 575.
    granulosus, p. 575.
Lonchocephalus (n. gen.), p. 575.
    chippewaensis, p. 576.
    hamulus, p. 576.
Crepicephalus (n. gen.), p. 576.
Menocephalus (n. gen.), p. 577.

In the description of Pl. 1 the species *Menocephalus minnesotensis* is named and figured (Fig. 11); also *Crepicephalus ? wisconsensis* (Fig. 13), and on Pl. 1*a*, *Crepicephalus* (?) *miniscaensis* is named and illustrated (Fig. 14). On Pl. 1*b*, the species *Lingula pinnaformis* is proposed and illustrated (Figs. 4, 6, 8); *Lingula ampla* is figured and named

[1] Report of a geological reconnaissance of the Chippewa land district of Wisconsin; and incidentally, of a part of Iowa and of the Minnesota Territory. Letter of the Secretary of the Treasury communicating a report of a geological reconnaissance of the Chippewa land district of Wisconsin (etc), by D. D. Owen. Thirtieth Congress, 1st Sess., Senate Ex. Doc. No. 57, 1848, pp. 13-15.

[2] Am. Assoc. Proc., vol. 5, 1851, p. 171.

[3] Description of a new Graptolite found in the Lower Silurian rocks near the falls of the St. Croix River. Am. Jour. Sci., 2d ser., vol. 11, 1851, p. 189.

[4] Description of new or rare species of fossils from the Paleozoic series. Rept. on the geology of the Lake Superior land district, by Foster and Whitney, pt. 2, 1851, pp. 203-231.

[5] Geol. Surv. of Wisc., Iowa, and Minn., and, incidentally, of a portion of Nebraska Territory. Philadelphia, 1852.

(Figs. 5, 12), together with figures of *Lingula antiqua* and *L. prima*, and a number of others placed under Obolus and Orbicula.

Mr. Edward Daniels stated in 1859 that upon a small island in Black River he had found perfect impressions of crustaceans consisting of double rows of parallel tracks, precisely like those in Montreal.[1] (Protichnites of Logan.—C. D. W.)

In the report of the superintendent of the geological survey of Wisconsin, Prof. Hall describes, from the Potsdam sandstone:[2]

Lingula polita, p. 24.
Lingula aurora, p. 24.
Theca primordialis, p. 48.
Serpulites murchisonia, p. 48.

In the geological volume he illustrates:[3]

Graptolithus (Dendrograptus) hallianus, p. 21.
Lingula polita, p. 21.
pinnaformis, p. 21.
antiqua, p. 21.
aurora, p. 21.
Theca primordialis, p. 21.
Serpulites murchisonii, p. 21.
Dikelocephalus minnesotensis, p. 22.
D. pepinensis, p. 22.

In a letter to Principal J. W. Dawson, Prof. Hall describes a new crustacean from the Potsdam sandstone under the generic name of Aglaspis, stating it to be the same form mentioned in a communication to the Albany Institute.[4]

In 1862 Prof. C. H. Hitchcock published a list of the fossils of the Potsdam group in North America, including in it all the species known to him described from the Potsdam sandstone and also from the strata now referred to the Cambrian of other parts of North America. The list includes one hundred and thirty-four species.[5]

In 1862 Prof. B. F. Shumard describes from the Potsdam sandstone of Wisconsin and Missouri the following species:[6]

Dikelocephalus latifrons, p. 101.
Arionellus bipunctatus, p. 101.
Conocephalites minor, p. 105.

He also noticed under the name of *Conocephalites iowensis*, the *Dikelocephalus* (?) *iowensis* of Owen (p. 102), and *Crepicephalus* (?) *wisconsensis*, under the name of *Conocephalites wisconsensis* (p. 103). The *Lonchocephalus chippewaensis* Owen and *L. hamulus* are both referred to the genus Conocephalites (p. 104). A species of Agnostus was referred to *Agnostus orion* (?) of Billings (p. 105).

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[1] Notes on geology of Wisconsin and adjacent States. Boston Soc. Nat. Hist. Proc., vol. 6, 1859, p. 310.

[2] Report of the superintendent of the geological survey (of Wisconsin), exhibiting the progress of the work. January 1, 1861. Madison, 1861, pp. 52.

[3] Physical geography and general geology. Geol. Surv. Wisconsin, Report, vol. 1, 1862, pp. 1-72.

[4] On a new crustacean from the Potsdam sandstone. Canadian Naturalist, vol. 7, 1862, p. 445.

[5] Fossils of the Potsdam group in North America. Portland Soc. Nat. Hist. Proc., vol. 1, 1862, pp. 87-90.

[6] Notice of some new and imperfectly known fossils from the Primordial zone (Potsdam sandstone and Calciferous Sand-group of Wisconsin and Missouri. St. Louis Acad. Sci. Trans., vol. 2, 1862, pp. 101-105.

In the same year Prof. James Hall read before the Albany Institute a preliminary notice of the fauna of the Potsdam sandstone, with remarks upon the previously known species and descriptions of some new ones from the sandstone of the Upper Mississippi Valley. This was first published in the Sixteenth Report of the State Cabinet of Natural History in 1863, and in 1867 in the Transactions of the Albany Institute. The new genera and species described are as follows:[1]

Lingula winona, p. 126.
mosia, p. 126.
aurora var., p. 127.
Discina (?) inutilis, p. 130.
Orthis pepina, p. 134.
Platyceras primordialis, p. 136.
Euomphalus (?) vaticinus, p. 136.
Dikelocephalus minnesotensis var. limbatus, p. 141.
Dikelocephalus minnesotensis var., p. 141.
Dikelocephalus spininger, p. 143.
misa, p. 144.
osceola, p. 146.
Conocephalites eos, p. 151.
perseus, p. 153.
shumardi, p. 154.
nasutus, p. 155.
oweni, p. 155.
eryon, p. 157.
anatinus, p. 158.
patersoni, p. 159.
? binodosus, p. 160.
winona, p. 161.
diadematus, p. 167.
Ptychaspis sp.?, p. 174.
Chariocephalus whitfieldi, p. 175.
Illænurus quadratus, p. 176.
Triarthrella auroralis, p. 177.
Agnostus josepha, p. 178.
parilis, p. 179.
disparilis, p. 179.
Aglaspis barrandi, p. 181.
Pemphigaspis bullata, p. 221.
Amphion ? matutina, p. 222.
Conocephalites ? (Arionellus ?) dorsalis, p. 222.
Conocephalites optatus, p. 222.

Of species previously described he redescribed and illustrated:

Graptolithus hallianus, Prout., as Dendrograptus hallianus, p. 124.
Lingula ampla, Owen, p. 125.
aurora, Hall, p. 126.
pinnaformis, Owen, as Lingulepis pinnaformis, p. 129.
Obolus apollinus Owen, as Obolella ? polita, p. 133.
Lingula ? polita Hall, as Obolella ? polita, p. 133.
Theca primordialis Hall, p. 135.*
Serpulites murchisoni, Hall, p. 136.*[2]
Dikelocephalus minnesotensis, Owen, p. 138.
pepinensis, Owen, p. 142.
Conocephalites minor, Shumard, p. 149.
minutus, Bradley, p. 150.
Dikelocephalus iowensis, Owen, as Conocephalites iowensis, p. 162.
Crepicephalus ? wisconsensis, Owen, as Conocephalites winconsensis, p. 164.
Lonchocephalus hamulus, Owen, as Conocephalites hamulus, p. 166.
Arionellus bipunctatus, Shumard, p. 169.
Dikelocephalus miniscaensis, Owen, as Ptychaspis miniscaensis, p. 171.
granulosus, Owen, as Ptychaspis granulosa, p. 173.

Agnostus orion (?) Billings, noted by Shumard, is described as *Agnostus josepha* (p. 178). The genus Dikelocephalus is redefined (p. 137),

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[1] Preliminary notice of the fauna of the Potsdam sandstone, with remarks on the previously known species of fossils and descriptions of some new ones from the sandstone of the Upper Mississippi Valley. 16th Ann. Rep. Regents Univ. State Cab. Nat. Hist., 1863, pp. 119-220. Albany Inst. Trans., vol. 5. 1867, pp. 93-195.

[2] Pages 135, 136 each have an asterisk (*) placed after them to indicate interpolated pages.

and the genus Obolella of Billings is described with special reference to the species *Obolella polita* (pp. 131-134).

The new genera described are:

Lingulepis, p. 129.
Ptychaspis, p. 170.
Chariocephalus, p. 175.
Illænurus, p. 176.
Triarthrella (subgenus), p. 177.
Aglaspis, p. 181.
Pemphigaspis, p. 221.

The genus Conaspis is proposed in the event of a new generic group being formed of *Conocephalites perseus*, *C. shumardi*, *C. nasutus*, *C. oweni*, *C. eryon*, *C. anatinus*, and *C. patersoni* (p. 152).

Prof. Hall states that he was unable to recognize the six successive trilobite beds of the sandstone as indicated by Dr. Owen, but he nevertheless refers the species described to three different epochs of the Potsdam period, as follows:

In the lower beds of the formation I have found Conocephalites proper, together with Lingula, Lingulepis, Obolella? and Theca. In the middle stage, neither the limits of the beds, nor the range of species or genera, have been so well determined; but, grouping together all that I have found between the well-defined upper beds and the lower fossilferous beds known, we have Conocephalites, Dikelocephalus, Arionellus, Ptychaspis, Chariocephalus, Illænurus and Agnostus, in the trilobitic fauna, together with Orthis and Platyceras.

The Graptolitidæ apparently begin their existence somewhere in this central epoch, but their precise relations to the other beds have not been determined.

In the higher beds of the formation, and clearly separated from the great central mass, we have the genera Dikelocephalus, Triarthrella, and Aglaspis, together with Lingula, Serpulites, and Euomphalus.

We observe, therefore, that the earliest trilobites are referable to the genus Conocephalites; and the genus Dikelocephalus does not appear in the first stages of the formation, nor below the beds which I have referred to the second or middle stage of the period. There this genus appears in three species, smaller and less conspicuous than those in the higher beds. It is only in the later stages of the sandstone that the typical species of this genus of Dr. Owen appear, and those from the lower beds, thus referred by him, belong apparently to other genera.[1]

From a small collection of fossils from the Potsdam sandstone of Sauk County, Wisconsin, Dr. Alexander Winchell describes in 1864 four new species and mentions the presence of some others that have been described.[2] The new species are:

Orthis barabuensis, p. 228.
Straparollus (Ophileta) primordialis, p. 228.
Pleurotomaria ? advena, p. 228.
Ptychaspis barabuensis, p. 230.

He mentions the occurrence of *Scolithus linearis* (p. 227) and *Dikelocephalus minnesotensis* and *Dikelocephalus pepinensis* (p. 229). From the Lake Superior sandstone he describes *Palæophycus articulatus* (p. 231) and *P. informis* (p. 232). The two latter species are doubtfully re-

[1] Op. cit., p. 183.
[2] Notice of a small collection of fossils from the Potsdam Sandstone of Wisconsin and Lake Superior Sandstone of Michigan. Am. Jour. Sci., 2d ser., vol. 37, 1864, pp. 226-232.

ferred to the Cambrian fauna. In this paper, Dr. Winchell points out, or, rather, he claims, that Dikelocephalus and Ptychaspis occur at the recognized base of the Potsdam sandstone.[1]

The preliminary notice of the fauna of the Potsdam sandstone of the upper Mississippi Valley read before the Albany Institute in 1862, by Prof. J. Hall, was published with illustrations in 1863, as has been noticed. The original paper appeared in 1867 in the transactions of the Albany Institute. The descriptions are the same as those of the paper of 1863, with the exception of the omission of those of *Theca primordialis* and *Serpulites murchisoni*.

From the material collected by the Wisconsin Geological Survey Prof. R. P. Whitfield described in 1878 under the title of Potsdam sandstone species:[2]

Palæophycus plumosus, p. 50.
Triplesia primordialis, p. 51.
Palæacmæa irvingi, p. 51.
Bellerophon antiquatus, p. 52.
Conocephalites calymenoides, p. 52.
Crepicephalus onustus, p. 53.
Ptychaspis striatus, p. 55.
minuta, p. 55.
Agraulos (Bathyurus ?) woosteri, p. 56.
Arionellus (Agraulos) convexus, p. 57.
Ellipsocephalus curta, p. 58.

Dikelocephalus granulosus, Owen, is redefined under *Ptychaspis granulosa*, but not the *Ptychaspis granulosa* of Hall (p. 54). *Ptychaspis granulosa*, Hall, is redescribed as *P. striata* (p. 55).

In 1879 Prof. T. C. Chamberlin referred to some tracks found on the Potsdam sandstone by Rev. A. A. Young, of New Lisbon, Wisconsin. He named *Climactichnites youngi* and *C. fosteri*. The material was subsequently studied by Mr. J. E. Todd, who published an illustration and description of the species. These tracks or trails are congeneric with *Climactichnites wilsoni*, described by Logan in 1863, from Perth, Canada.[3]

In 1882 in his final report on the paleontology of Wisconsin, Prof. R. P. Whitfield described from the Potsdam sandstone the following new species:[4]

Holopea sweeti, p. 174.
Conocephalites ? quadratus, p. 180.
(Ptychaspis ?) explanatus, p. 181.
Dikelocephalus lodensis, p. 188.
Aglaspis eatoni, p. 192.
Arenicolites woodi, p. 177.

He also describes and illustrates:

Paleophycus plumosus Whitf., p. 169.
Lingulepis pinnaformis, Owen, p. 169.
Orthis pepina, Hall, p. 170.
barabuensis, Winchell, as Leptæna barabuensis, p. 171.
Triplesia primordialis Whitf., p. 172.

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[1] Op. cit., p. 226.

[2] Preliminary descriptions of new species of fossils from the lower geological formations of Wisconsin. Geol. Surv. of Wisconsin, Ann. Rep. for 1877, 1878, pp. 50-58.

[3] A description of some fossil tracks from the Potsdam sandstone. Wisconsin Acad. Sci., Trans., vol. 5, 1882, pp. 276-281.

[4] Paleontology (of Wisconsin). Geology of Wisconsin, vol. 4, 1882, pp. 169-193.

Palæacmæa irvingi, p. 173.
Straparollus (Ophileta) primordialis, Winchell, as Ophileta (Raphistoma) primordialis, p. 173.
Theca primordialis, Hall, as Hyolithes primordialis, p. 175.
Bellerophon antiquatus, Whitf., p. 176.
Conocephalites calymenoides, Whitf., p. 179.
Crepicephalus onustus, Whitf., p. 182.
Conocephalites gibbsi, Whitf., as Crepicephalus? gibbsi, p. 184.
Dikelocephalus granulosus, Owen, as Ptychaspis granulosa, p. 185.
Ptychaspis granulosa, Hall, as P. striata, p. 186.
 minuta, Whitf., p. 186.
Dikelocephalus minnesotensis Owen, p. 187.
Agraulos (Bathyurus?) woosteri, Whitf., p. 189.
Arionellus (Agraulos) convexus, Whitf., as Arionellus convexus, Whitf., p. 190.
Ellipsocephalus curtus, Whitf., p. 191.

In the preliminary remarks on the fauna he says:

It is a matter of considerable interest that, in different localities of the Potsdam formation, the forms of trilobites found are generally specifically distinct; and notwithstanding the large number of species already described from this formation, both in this State and other parts of the country, other new forms, readily detected by those familiar with the several details of structure peculiar to these animals, are met with at almost every new locality examined. This change in species between different localities is usually accompanied also by some slight difference in the material or composition of the rock, which not only shows that the species were of short duration in time, or that they were restricted to limited geographical areas, but that a change in the conditions of life and circumstances under which the animals existed, and with which they had to contend, was constantly taking place. How much these circumstances or conditions had to do with the production of forms, or modification of types among them, it would be difficult to determine; but one thing is certain, that where the same character of rock and apparent conditions of deposition prevail over a limited geographical area, or are repeated within a slight vertical range, we are pretty sure to find the same, or closely allied forms represented, showing that under like conditions similar forms prevail.[1]

In 1883, when describing the life of the Potsdam epoch, in the General Geology of Wisconsin, Prof. T. C. Chamberlin illustrates the following species:[2]

Palæophycus plumosus, p. 125, Fig. 11.
Bellerophon antiquatus, Whitfield, p. 126, Fig. 12, a, b.
Ophileta primordialis, Winchell, p. 126, Fig. 12, c, d.
Holopea sweeti, Whitfield, p. 126, Fig. 12, e.
Palæacmæa irvingi, Whitfield, p. 126, Fig. 12, f.
Platyceras primordialis, Hall, p. 126, Fig. 12, g.
Serpulites murchisoni, Hall, p. 126, Fig. 12, h.
Theca primordialis, Hall, p. 126, Fig. 12, i.
Dendrograptus hallianus, Prout, p. 126, Fig. 12, j.
Lingula antiqua, Conrad, p. 127, Fig. 13, b.
Lingulella stoneana, Whitfield, p. 127, Fig. 13, a.
 aurora, Hall, p. 127, Fig. 13, c.
 ampla, Hall, p. 127, Fig. 13, d.
 mosia, Hall, p. 127, Fig. 13, e.

[1] Op. cit., pp. 163. 164.
[2] General Geology. Historical Geology. Paleozoic Era. Geol. Wis. Survey of 1873–1879, vol. 1, 1883.

Lingulepis pinnaformis, Owen, p. 127, Fig. 13, f, g.
Obolella polita, Hall, p. 127, Fig. 13, h.
Orthis pepina, Hall, p. 127, Fig. 13, i, j, k, l.
Triplesia primordialis, Whitfield, p. 127, Fig. 13, m.
Leptæna barabuensis, Winchell, p. 127, Fig. 13, n, o.
Arenicolites woodi, Whitfield, p. 128, Fig. 14, a, b.
Dikelocephalus sp. ?, p. 129, Fig. 15.
    lodensis, Whitfield, p. 130, Fig. 16, a, b.
    pepinensis, Hall, p. 130, Fig. 16, c, d, e, f.
Aglaspis eatoni, Whitfield, p. 130, Fig. 16, g.
Chariocephalus whitfieldi, Hall, p. 130, Fig. 16, h.
Arionellus convexus, Whitfield, p. 130, Fig. 16, i.
Ptychaspis minuta, Whitfield, p. 130, Fig. 16, j, k.
Illænurus quadratus, Hall, p. 130, Fig. 16, l, m, n, o, p.
Crepicephalus gibbsi, Whitfield, p. 130, Fig. 16, q.
Conocephalites wisconsensis, Owen, p. 131, Fig. 17, a, b, c.
    calymenoides, Whitfield, p. 131, Fig. 17, d.
Agnostus josepha, Hall, p. 131, Fig. 17, e, f.
Ellipsocephalus curtus, Whitfield, p. 131, Fig. 17, g.
Agraulos woosteri, Whitfield, p. 131, Fig. 17, h, i.
Pemphigaspis bullata Hall, p. 131, Fig. 17, j.
Climactichnites youngi, Chamberlin, p. 132, Fig. 18.
    fosteri Chamberlin, p. 132, Fig. 18.

The species *Orthis remnichia* and *O. sandbergi* are described in 1886 by Prof. N. H. Winchell from the St. Croix sandstone.[1]

In 1890, Mr. C. D. Walcott described the following species from the Upper Cambrian of Wisconsin and Minnesota:[2]

Metoptoma ? minneiskensis, p. 267.
    ? peracuta, p. 267.
Conularia cambria, p. 270.
Spirodentalium, n. gen., p. 271.
Spirodentalium osceola, p. 271.
Ptychoparia connata, p. 272.
    pero, p. 274.
Agraulos ? thea, p. 277.

RED SANDSTONE OF LAKE SUPERIOR.

On Pl. I C and II, Figs. 1 and 2 of the illustrations in the Geological Report of Wisconsin, Iowa, and Minnesota, 1852, Dr. D. D. Owen figures certain markings he observed on sandstones from the northwest shore of Lake Superior. He considered they probably indicated the remains of fossil sea-weeds or fucoids.

There is a specimen in the collections of the National Museum, labeled "Plants of Lake Superior, D. D. Owen." The specimen looks very much like the sandstones of the interior of Wisconsin, and is covered with casts of annelid trails, more or less crushed and matted down, which gives a resemblance to fucoids. Of traces of life other than that of annelid trails and borings nothing has to my knowledge been made known to the scientific world.

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[1] New species of fossils. 14th Ann. Rep. Minn. Geol. Nat. Hist. Surv., 1886, pp. 317–318.
[2] Description of new forms of Upper Cambrian fossils. U. S. Nat. Mus. Proc., vol. 13, 1890, pp. 267–279.

MISSOURI.

The only description of a fossil referred to the Cambrian of Missouri is that of *Lingulella lamborni* by Meek.[1]

EASTERN BORDER OR ADIRONDACK SUB-PROVINCE.

The first notice of anything of an organic nature in the strata now referred to the Potsdam or Upper Cambrian zone, about the Adirondacks, was by Mr. J. H. Steele in 1825, who described certain large calcareous concretions.[2] These were subsequently described in detail by Prof. J. Hall and named *Cryptozoon proliferum*.[3]

The second notice is by Dr. E. Emmons, who states that near Keeseville, in the bottom of the fissure at the high bridge, he found numerous specimens of small bivalve mollusca, a lingula.[4]

Lingula acuminata was described by Mr. T. A. Conrad as occurring in the Calciferous sandrock, and in the table of classification he places it as occurring in the gray Calcareous sandstone at the base of the Lower Silurian above the Cambrian system.[5] It is now known to occur in abundance in association with Dikelocephalus and Upper Cambrian fossils in a calcareous sandrock and limestone, both at Whitehall and in Saratoga County, and in the Potsdam sandstone on Marble River, Franklin County, New York.

In his description of the Potsdam sandstone at Au Sable Chasm, Jefferson County, New York, Dr. Emmons figures and names *Lingula antiqua*.[6] The same woodcut is used by Prof. Hall to illustrate *Lingula acuminata* of Conrad.[7]

In volume I of the Paleontology of New York, Prof. J. Hall defines the genus Scolithus of Haldeman (p. 2), and describes *S. linearis* Haldeman (p. 2); *Lingula prima* of Conrad is described and illustrated; and *Lingula antiqua* is proposed as a new species for the specimen figured by Emmons as *Lingula antiqua* (p. 3). These species are illustrated on Plate I.[8]

Attention was called to the presence of a track and footprint of an animal in the Potsdam sandstone of Lower Canada by Sir W. E. Logan

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[1] Notice of a new brachiopod from the lead-bearing rocks at Mine la Motte, Missouri. Phila. Acad. Nat. Sci., Proc., vol. 23, 1871, p. 185.

[2] A description of the Oolitic formation lately discovered in the county of Saratoga, and State of New York. Am. Jour. Sci., vol. 9, 1825, pp. 16–19.

[3] Cryptozoon, n. gen., Cryptozoon proliferum, n. sp. Description of Pl. VI. 36th Ann. Rep. State Mus. Nat. Hist., 1884.

[4] Report of the geologist of the 2d geological district of New York. Second annual report of the Geological Survey of N. Y. Albany, 1838, p. 230.

[5] Second annual report of the paleontological department of the survey, Third annual report of the Geological Survey of New York. Albany, 1839, pp. 63, 64.

[6] Geology of New York, Part 2, comprising the survey of the 2d geological (northern) district. 1842, p. 268, fig. 68.

[7] Geological survey of New York; its influence on the productive pursuits of the community. N. Y. State Agric. Soc. Trans., for 1843, 1844, p. 252.

[8] Paleontology of New York, vol. 1, containing descriptions of the organic remains of the lower division of the New York System. Albany, 1847.

in 1851. He described its mode of occurrence and stratigraphic position.[1] This paper was followed by one by Prof. Owen, who refers the tracks to a species of tortoise.[2]

At a meeting of the British Association for the Advancement of Science, held at Ipswich in 1851, Sir W. E. Logan exhibited a slab of sandstone and a cast from a larger one, showing what Prof. Owen had, in a communication to the Geological Society, pronounced to be a track and footsteps of a species of tortoise, thus proving the existence of reptiles at the very earliest period of known animal life.[3]

In describing in 1852 the sandstone occurring in Beauharnois County, Canada, Sir W. E. Logan makes the following observation upon *Scolithus linearis*:[4]

> In this part it [the sandstone] is abundantly marked over considerable surfaces by what the geologists of New York have called *Scolithus linearis*, which consists, where the rock is weathered, of straight, vertical cylindrical holes, of about an eighth of an inch in diameter, descending several inches, and where the rock is unweathered of corresponding solid cylinders, composed apparently of grains of sand, cemented by a slightly calcareous matrix, more or less tinged with peroxide of iron. Mr. Hall and other American geologists include them among the Fucoids of the rock, but they appear to me more like worm holes. In one or two instances I have perceived that the tubes are interrupted in their upward course by a thin layer of sand, of a portion which descends into them and stops them up; and from this it would appear that the cylinders were hollow when the superincumbent sand was spread over them. Whatever may be the origin of the tubes, they strongly mark many beds in the upper part of the sandstone throughout the Canadian portions of its distribution already mentioned; and it is stated by Mr. Hall that the same characteristic accompanies the Potsdam sandstone in New York and Pennsylvania and as far as Tennessee.

He also speaks of the presence of Fucoides and of *Lingula antiqua*. This is followed by a detailed account of the strata containing the footprints described in the same volume by Prof. Owen.

This paper by Mr. Logan was followed by one by Prof. Owen, who described the various footprints and impressions under the following names:[5]

Protichnites septem-notatus, p. 214.
Protichnites octo-notatus, p. 217.
  latus, p. 218.
  multinotatus, p. 219.
  lineatus, p. 220.
  alternans, p. 221.

The descriptions are accompanied by admirable illustrations of the varieties designated. He concludes that the impressions appear to have been made by animals allied to Limulus.[6]

[1] On the occurrence of a track and footprints of an animal in the Potsdam sandstone of Lower Canada. Quart. Jour. Geol. Soc., London, vol. 7, 1851, pp. 247–250.

[2] Ibid., p. 250–252.

[3] On the age of the copper-bearing rocks of Lake Superior and Huron, etc. British Assoc. Rep. Trans., of sections for 1851–'52, p. 62.

[4] On the footprints occurring in the Potsdam sandstone of Canada. Quart. Jour. Geol. Soc. Lond., Proc., vol. 8, 1852, pp. 200, 201.

[5] Description of the impressions and footprints of the Protichnites from the Potsdam sandstone of Canada. Quart. Jour. Geol. Soc. London, vol. 8, 1852, pp. 214–225.

[6] Op. cit., p. 224.

In 1856 Dr. Emmons published a description of *Lingula prima* Emmons, *Lingula antiquata* Emmons, and *L. acuminata* Conrad. The two latter species are illustrated on Pl. IV, but in the description of the plate the figure of *Lingula antiquata* is called *L. prima* by error.[1]

In 1860, Prof. F. H. Bradley described and illustrated *Conocephalites minutus* from the Potsdam sandstone at Au Sable Chasm, near Keeseville, New York.[2]

The announçement of the discovery of another type of track in the Potsdam sandstone was made by Sir W. E. Logan, in 1860. For this he proposed the name *Climactichnites wilsoni*.[3]

In 1869 Prof. O. C. Marsh described a new species of Protichnites from the Potsdam sandstone of Essex County, New York, naming it *Protichnites logananus*.[4]

As the result of comparative study of different tracks, Dr. J. W. Dawson concluded that Protichnites of Owen was possibly made by some Limuloid crustacean.[5]

From collections made at Keeseville, New York, Messrs. Hall and Whitfield described the genus Palæacmæa, the type species being *Palæacmæa typica* and *Hyolithes gibbosa*.[6]

In 1877 Mr. E. J. Chapman says that the fossil tracks known as Protichnites and Climactichnites are of such a nature that he does not consider them to be of animal origin; and he suggests that they are nothing more than impressions of large fucoids. If this idea be accepted he proposes to change the names to Protichnides and Climactichnides.[7]

From the limestone in Saratoga County, New York, in which Mr. J. H. Steele noticed the large concentric concretions, Mr. C. D. Walcott described in 1879 the following species:[8]

Platyceras minutissimum, p. 129.
Metoptoma cornutiforme, p. 129.
Conocephalites calciferus, p. 129.
Conocephalites harttii, p. 130.
Ptychaspis speciosus, p. 131.

The presence of a species closely allied to *Bathyurus armatus* of Billings was noticed; also Stromatopora sp. ?, *Lingula acuminata*, *Metop-*

[1] American Geology, containing a full statement of the principles of the science, with full illustrations of the characteristic American fossils. Albany, 1856, vol. 1, pt. 2, pp. 202, 203.

[2] Description of a new trilobite from the Potsdam sandstone. Am. Jour. Sci., 2d ser., vol. 30, 1860, p. 241.

[3] On the track of an animal lately found in the Potsdam formation. Canadian Nat., vol. 5, 1860, pp. 282–285.

[4] Description of a new species of Protichnites from the Potsdam sandstone of New York. Am. Jour. Sci., 2d ser., vol. 48, 1869, pp. 46–49.

[5] Impressions and footprints of aquatic animals and imitative markings on Carboniferous rocks. Am. Jour. Sci., 3d ser., vol. 5, 1873, p. 17.

[6] Notice of two new species of fossil shells from the Potsdam sandstone of New York. 23d Rep. New York State Mus. Nat. Hist., 1873, p. 242.

[7] On the probable nature of the supposed fossil tracks known as Protichnites and Climactichnites. Canadian Jour. Sci., Lit. and Hist., new series, vol. 15, 1877, p. 490.

[8] Descriptions of new species of fossils from the Calciferous formation. 32d Rep. N. Y. State Mus. Nat. Hist., 1879, pp. 129–131.

toma simplex, Murchisonia sp.?, and a Lamellibranchiate shell. The fauna was correlated with that of the Potsdam sandstone of Iowa and Wisconsin, although the rocks were referred to the Calciferous formation. This reference was corrected in 1884.[1]

In 1883, Mr. W. F. Ferrier called attention to the presence of tracks on the Potsdam sandstone at the head of Au Sable Chasm in Essex County, New York. They were referred to the genus Gyrichnites of Whiteaves.[2] Later the tracks discovered by Mr. Ferrier were made the subject of a note by Sir J. W. Dawson, who proposed the generic name of Clydichnites for them.[3]

In a note on some obscure organisms in the roofing slates of Washington County, New York, Prof. James Hall redescribes *Buthotrephis ? asteroides* Fitch as *Dactyloidites bulbosus*.[4]

A revision of the fauna occurring in the limestone beds of Saratoga County was made by Mr. C. D. Walcott in 1886, and the following list was published:[5]

NEW YORK.	WISCONSIN.
Cryptozoa proliferum	
Lingulepis acuminata	Lingulepis pinnæformis.
Platyceras minutissimum	Platyceras minutissimum.
Platyceras hoyti	
Metoptoma cornutiforme	Metoptoma cornutiforme.
simplex	
Billingsia saratogensis	
Matthevia variabilis	
Dicellocephalus hartti	Dikelocephalus pepinensis.
speciosus	lodensis.
Ptychoparia calcifera	Ptychoparia wisconsensis.
(A.) saratogensis	oweni (of Hall).

As the result of the comparison of an extended series of specimens from the Potsdam sandstone of Buckingham, Quebec, Messrs. Ami and Sowter concluded that *Scolithus linearis* and *S. canadensis* were identical species; the main differences existing between the two being principally in the preservation, *S. canadensis* occurring in hollow tubes or burrows, while *S. linearis* occurs as casts of the interiors of burrows or holes.[6]

In 1890 Mr. C. D. Walcott described[7] the following species from the limestone in the vicinity of Saratoga Springs, New York:

Platyceras hoyti, p. 268.
Trochus ? saratogensis, p. 268.
Agraulos saratogensis, p. 276.

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[1] Potsdam fauna at Saratoga, New York. Science, vol. 3, 1884, pp. 136, 137.

[2] Notes on a fossil track from the Potsdam sandstone of northern New York State. Canadian Nat. new ser., vol. 10, 1883, pp. 466, 467.

[3] Impressions on Potsdam sandstone. Science, vol. 1, 1883, p. 177.

[4] Note on some obscure organisms in the roofing slates of Washington County, New York. 39th Rep. N. Y. State Mus. Nat. Hist., 1886, p. 160, pl. 11, fig. 1, 2.

[5] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, p. 21.

[6] Report of the geological branch [of Ottawa Field Naturalists' Club]. Ottawa Naturalist, vol. 1, 1887, pp. 96, 97.

[7] Description of new forms of Upper Cambrian fossils. U. S. Nat. Mus., Proc., vol. 13, 1890, pp. 276-279.

WESTERN BORDER OR ROCKY MOUNTAIN SUBPROVINCE.

In a letter from Messrs. Meek and Hayden to Lieut. G. K. Warren, dated February 8, 1858, attention is called to the identification of fossils from a sandstone in the Black Hills equivalent to the Potsdam sandstone of the New York series. They recognized Lingula, Obolus?, and fragments of trilobites, belonging to species known to occur in the Potsdam formation in Wisconsin and Minnesota.[1] This notice was followed in 1861 by the publication of the first description of the Cambrian fauna of the Rocky Mountains. The new species described but not illustrated include *Obolella nana*, *Theca* (*Pugiunculus*) *gregaria*, and *Arionellus* (*Crepicephalus*) *oweni*.[2] The descriptions of the species were republished in 1862, in the American Journal of Science, in connection with figures illustrating them. The last species is described as *Arionellus? oweni*. There were also identified from the same horizon *Lingula prima* Conrad and *Lingula antiqua* Hall.[3]

The Black Hills fauna was again described by Messrs. Meek and Hayden in 1864, in their account of the paleontology of the Upper Missouri. *Lingula antiqua*, mentioned in their letter of 1858, is identified as *Lingulepis pinnaformis* Owen (p. 2), and the name *L. dakotensis* proposed in the event of the shell being subsequently determined to be a new species (p. 3). A description and illustration is also given of *Lingulepis prima* Conrad (p. 3), *Obolella nana*, M. & H. (p. 4), *Theca gregaria*, M. & H. (p. 5), *Agraulos oweni*, M. & H. (p. 9), (*Arionellus* (*Crepicephalus*) *oweni*, of the paper of 1861), and an undetermined species of Agraulos (p. 10). All of the species are referred to the Potsdam or Primordial sandstone.[4]

In 1876, when reporting upon the fossils collected by Captain Ludlow's expedition to the Yellowstone National Park, Prof. R. P. Whitfield described two species that are now referred to the Upper Cambrian zone, *Crepicephalus* (*Loganellus*) *montanensis* and *Arionellus tripunctatus*, referring them to the limestone of the Potsdam group overlying the quartzite near Camp Baker.[5]

A preliminary report on the paleontology of the Black Hills by Prof. R. P. Whitfield contains a description of *Palæochorda prima*, *Palæophycus occidentalis*, *Lingulepis cuneolus*, *L. perattenuatus* *Crepicephalus* (*Loganellus*) *centralis*, and *C.* (*L.*) *planus*. All of these species are referred

[1] Fossils of Nebraska. Letter from F. B. Meek and F. V. Hayden. Am. Jour. Sci., 2d ser., vol. 25, 1858, p. 439.

[2] Descriptions of new Lower Silurian (Primordial), Jurassic, Cretaceous, and Tertiary fossils, collected in Nebraska, with some remarks on the rocks from which they were obtained. Phil. Acad. Sci., Proc., vol. 13, 1861, pp. 435, 436.

[3] The Primordial Sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 73, 74.

[4] Paleontology of the Upper Missouri; a report upon collections made principally by the expeditions under command of Lieut. G. K. Warren in 1855-'56. Invertebrates. Smithsonian Contributions No. 172, 1864, pp. 1-10.

[5] Descriptions of new species of fossils. Report of a reconnaissance from Carroll, Montana Terr., on the Upper Missouri, to the Yellowstone Park and return, made in the summer of 1875 by Wm. Ludlow, 1876, p. 141.

to the Potsdam formation of the Black Hills of Dakota.[1] In the final report, which appeared in 1880, the species described in the preliminary report are illustrated, and descriptions and illustrations given of *Palæophycus* sp. undet., *Arenocolites* sp. undet. (p. 333), *Lingulepis pinnaformis* (p. 331), *Lingulepis dakotentis* (p. 337), *Obolus? pectenoides* (p. 338), *Obolella polita* (p. 339), *Obolella nana* (p. 340). In the preliminary remarks to the paper it is stated that the horizon of the Potsdam formation of the Black Hills appears to be, so far as the fossils will serve to determine, about the same as that of Wisconsin and the neighboring States.[2]

The only fossils of the Cambrian fauna identified in Colorado are a species of Dikelocephalus from Quandary Peak of the Mosquito Range,[3] and the Lingulepis found in the Trout Creek section (p. 62).

In 1890 Mr. C. D. Walcott[4] described three species from the Upper Cambrian of the Black Hills of Dakota. They were *Hyolithes newtoni* (p. 270), *Ptychoparia vacuna* (p. 275), and *P.* (*Liostracus*) *panope* (p. 275).

TEXAS.

The first notice of the presence of a fauna in Texas subsequently assigned to the Cambrian is by Dr. Roemer in 1849. A description of *Lingula acutangula* (p. 420) and *Pterocephalia sancti-sabæ* (p. 421) is given by him in that year without illustrations.[5]

In his more extended work on the geology of central Texas he describes and illustrates *Lingula acutangula* (p. 90), *Pterocephalia sancti-sabæ* (pp. 92, 93), and the genus *Pterocephalia* (p. 93). He also illustrates the head of a trilobite, allied to Arionellus, and the pygidium of another species, on Table XI.[6]

The primordial character of the fauna referred to the Silurian by Dr. Roemer was announced by M. J. Barrande the following year. He compared it with the fauna of the Potsdam sandstone of New York and Wisconsin.[7]

As geologist of the State of Texas, Dr. B. F. Shumard described in 1861, the strata referred to the Potsdam sandstone. Of the fossils collected he describes as new;

Agnostus coloradoensis, p. 218.
Arionellus (Bathyurus) texanus, p. 218.
planus, p. 219.

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[1] Preliminary report on the Paleontology of the Black Hills. U. S. Geol. and Geog. Surv. of the Rocky Mountain region, 1877, pp. 7–11.

[2] Paleontology of the Black Hills of Dakota. Report on the geology and resources of the Black Hills of Dakota, 1880, pp. 329-344.

[3] Geology and Mining Industry of Leadville, Colorado. U. S. Geol. Surv., Monograph vol. 12, pt. 1, 1886, p. 60.

[4] Description of new forms of Upper Cambrian fossils. U. S. Nat. Mus. Proc., vol, 13, 1890, pp. 267–279.

[5] Texas. Mit besonderer Rücksicht auf deutsche Auswanderung und die physischen Verhältnisse des Landes nach eigener Beobachtung geschildert. Bonn, 1849, pp. 420–421.

[6] Die Kreidebildungen von Texas und ihre organischen Einschlusse. Bonn, 1852.

[7] (Silur-Gebilde in Texas und am Obereñ See.) Neues Jahrbuch für Miner, 1853, pp. 446, 447.

Conocephalites depressus, p. 219.
billingsi, p. 220.
Dikelocephalus roemeri, p. 220.
Discina microscopica, p. 221.

and he mentions Camerella sp. ?, and Capulus sp. ? (p. 221).[1] He correlates this fauna with that provisionally designated as "being very analogous to the Potsdam of Iowa, Wisconsin, and Minnesota,"[2] and refers it to the Potsdam sandstone.

In the collections obtained by Mr. C. D. Walcott in his reconnaissance of the central area of Texas the following species have been identified:

Eocystites sp. ?
Lingula acuminata, Conrad.
perattenuata, Whitf.
Obolella polita, Hall.
Triplesia primordialis, Whitf.
Orthis coloradoensis, Shumard.
remnichia, Winchell.
Platyceras texanum, Walcott.
Bellerophon antiquatus, Whitf.
Dikelocephalus minnesotensis, Owen (?).
belli, Billings.
Ptychaspis granulosa, Owen.
Chariocephalus tumifrons, H. & W.
Ptychoparia occidens, Walcott.
affinis, Walcott.
burnetensis, Walcott.
llanoensis, Walcott.
? metra, Walcott.
pero, Walcott.
? urania, Walcott.
similis, Walcott.
patersoni, Hall.
perseus var., Hall.
wisconsensis, Owen.
Agraulos convexus, Whitf.
Agraulos ? sp. ?
Illænurus dia, Walcott.

This fauna will be illustrated in connection with a review of the Upper Cambrian fauna of North America now in course of preparation.

In 1890 Mr. Walcott[3] described the following new species from Upper Cambrian strata of Burnet and Llano Counties:

Platyceras texanum, p. 268.
Ptychoparia burnetensis, p. 272.
llanoensis, p. 272.
? metra, p. 273.
pero, p. 274.
? urania, p. 274.
Illænurus ? dia., p. 277.

ARIZONA.

The paleontologic work on the Cambrian fauna found in Arizona has, thus far, been confined to the identification of the species discovered in the Tonto formation of the Grand Cañon. A preliminary study of the fauna has been made and drawings prepared of the species, but up to the present time nothing has been published in relation to them.

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[1] The Primordial zone of Texas, with descriptions of new fossils. Am. Jour. Sci. 2d ser., vol. 32, 1861, pp. 213-221.

[2] Op. cit., pp. 217, 218.

[3] Description of new forms of Upper Cambrian fossils. U. S. Nat. Mus. Proc., vol. 13, 1890, pp. 267-279.

CHAPTER III.

NOMENCLATURE EMPLOYED IN THE DESCRIPTION OF THE FORMATIONS.

Several considerations are to be borne in mind relative to geologic nomenclature:

(*a*) The name in itself is nothing unless it conveys to the mind a clear impression of what it refers to and enables the student to make a correlation between its entity and some other entity that has another terminology.

(*b*) Priority of discovery and naming should be sustained by the proof of the accuracy of the original observations, the latter to be judged by the testimony of the formations in the areas where they were first made. If the original proposer of a name bases it upon such errors of observation and interpretation that subsequent observers can not verify his work, and the name can be used only by dropping a name proposed as the result of accurate observation and definition, the latter should be retained and the law of priority should not be used to bolster up an indefinite term.

(*c*) Long use of, and the general acceptance of, a well defined term by the scientific world gives that term a standing that even the claims of a half understood, badly defined term supported by priority should not displace. This may be called the law of usage.

(*d*) From the fact that all the strata of the geologic series do not exist in any one geologic province and that unconformities between different portions of them are not contemporaneous in all provinces, it necessarily follows that the rock series of any one geologic province can not possibly be the chronological equivalent of the rock series of other provinces. Overlappings of series of different chronologic age must occur, and it is therefore impossible for any one geologic province to afford a nomenclature that is applicable to the geologic provinces of the entire world or to the entire geologic series.

(*e*) Each geologic province should have a nomenclature denoting by name each formation contained in it and, if necessary, the names to be applied to the groupings of the formations; but, if practicable, the formations and the grouping of formations should be referred to some position within the larger composite groups. For instance, the Potsdam standstone of New York, the Saratoga County limestone, and the Dutchess County limestone are lithologically distinct formations, but they are grouped under the Upper Cambrian terrane as a portion of the Cambrian group.

This method necessitates the multiplication of names, but if it insures accuracy of statement and meaning it is much better than the use of a few old names that have been established in some one geologic province and extended over other upper Cambrian formations in other geologic provinces that can not be proved to be identical or synchronous.

(*f*) The study of the serial relations among rocks by the modern method is of as much importance as that of the specific relations of distinct horizons or of particular formations. The serial relations of one series of rocks in one province can be compared with the serial relations of another group in another province; but the two should receive separate names and be grouped under the greater series to which they belong. For instance, the Trenton series of New York may be compared with the Lebanon series of Tennessee and united as a portion of the Lower Silurian (Ordovician) and respectively compared with the same portion of the Lower Silurian (Ordovician).

(*g*) If it is found that the strata included in a named formation, terrane, or group embraces portions of other formations, terranes, or groups it is allowable to remove portions of such formations, terranes, or groups and still apply the original name, if the portion remaining is distinct or was first described and included under the name.

(*h*) Geologic nomenclature should, in all its parts, be the natural expression of the inter-relationships and mutual subordination of the facts it is the especial aim to associate and systematize.[1]

CAMBRIAN.

The term Cambrian was first introduced to the attention of geologists at the Dublin meeting of the British Association for the Advancement of Science in August, 1835. A joint paper was read by Prof. Adam Sedgwick and R. I. Murchison, entitled "On the Silurian and Cambrian Systems, exhibiting the order in which the older sedimentary strata succeed each other in England and Wales." An abstract of this paper appeared in the account of the proceedings of the British Association published in the Edinburgh New Philosophical Journal for April–October, 1835, page 390. In this the name Cambrian is spelled Cumbrian, probably by a typographical error. The paper appeared in 1836, in volume 5 of the Reports of the Association. In the account of the Transactions of the Sections it says:[2]

Prof. Sedgwick commenced by pointing out the imperfection of the sections exhibited in the north of England and some portions of north Wales, in consequence of the entire want of continuity between the Carboniferous series and the interior schistose group. * * * Prof. Sedgwick then described in descending order the group of slate rocks as they are seen in Wales and Cumberland. To the highest he gave the name of *Upper Cambrian* group. It occupies the greatest part of the chain of the Berwyns, where it is connected with the Llandeilo flags of the Silurian system, and

[1] On the tripartite classification of the Lower Paleozoic rocks; Charles Lapworth, Geol. Mag., new series, dec. II, vol. 6, 1879, p. 11.

[2] Brit. Assoc. Report for 1835, part 2, Trans. of Sections, 1836, p. 60.

is thence expanded through a considerable portion of south Wales. In one part of its course it is based on beds of limestone and calcareous slate, but on the whole it contains less calcareous matter than the Silurian system and has fewer organic remains. Beds of good roofing slate occur, and a perfect slaty cleavage is often observed in it transverse to the stratification, but other parts of it are of a coarse mechanical texture. To the next inferior group he gave the name of *Middle Cambrian*. It composes all the higher mountains of Caernarvonshire and Merionethshire, and abounds in fine roofing slate, alternating with and apparently passing into irregularly interstratified masses of porphyry. Some portions of it are coarse and mechanical, and it contains (for example at the top of Snowdon) a few organic remains and a few samples of highly calcareous slates, but no continuous beds of limestone. The same group, with the same mineral structure, and in the same position, but without organic remains, is greatly developed in Cumberland. The *Lower Cambrian* group occupies the southwest coast of Caernarvonshire and a considerable portion of Anglesea; it consists chiefly of chlorite schist, passing here and there into mica schist and slaty quartz rock and contains subordinate masses of serpentine and white granular limestone. It contains no organic remains.

In this first description, Archean rocks are included in the lower division; the Middle Cambrian embraces the roofing slates, and the Cambrian group as now generally accepted; while the Upper Cambrian included much of the Lower Silurian of Sir R. I. Murchison, or the Ordovician of Prof. Charles Lapworth.

At a meeting of the Geological Society of London in the spring of 1838, Prof. Sedgwick read a paper entitled "A Synopsis of the English series of stratified rocks inferior to the Old Red sandstone, with an attempt to determine the successive natural groups and formations."[1] When describing the sections of North Wales, etc., the chlorite slates, quartz rock, and mica slates of Anglesea and Caernarvonshire are not included in the Cambrian as was done in 1835.[2] The Lower Cambrian system includes the old slate series of Caernarvonshire and Merionethshire, and ends with the calcareous beds, which range from Bala to the neighborhood of Dinas Mowddy.

The next group, the Upper Cambrian series, commences with the fossiliferous beds of Bala. It includes all the higher portion of the Berwyns, and all the slate rocks of South Wales, which are below the Silurian system. * * * Many of the fossils are identical in species with those of the lower division of the *Silurian system*, nor have the true distinctive zoological characters of the group been well ascertained.

In this arrangement, the Lower Cambrian of 1835 is referred to the primary stratified group, to which he gave the provisional name of Protozoic.[3]

It is further stated that at the north end of the Berwyn chain the Upper Cambrian appears to pass by insensible gradations into the lower division of the upper system, the Caradoc sandstone. Prof. Sedgwick does not appear to have been aware at this time that his Bala series was a portion of Murchison's Lower Silurian, as described by the latter in 1835.

Many geologists have insisted upon restricting the Cambrian to the Lower Cambrian of the scheme of 1835, which Prof. Sedgwick cut off

[1] Proc. Geol. Soc., London, vol. 2, 1838, pp. 675-685. [2] Op. cit., p. 685. [3] Op. cit., p. 684.

in the revision of 1838. It is also well to notice that the Cambrian of 1838 includes exactly the same representative formations as Emmons's Taconic System of 1842–1860, or the Cambrian and Lower Silurian (Ordovician) as now known.

In 1852 we find the Lower Cambrian divided into the Festiniog group above and the Bangor below. The Bangor group is composed of the Llanberris slates and Harlech grits; and the Festiniog group of the Lingula flags, Tremadoc slates, and Arenig slates and porphyry, the whole having a thickness of 10,000 feet. The Upper Cambrian includes the Bala group, which was divided into the Lower and Upper Bala, with a thickness of 8,000 feet. Above this the Caradoc sandstone, limestone, and shale of the Silurian occur with a thickness of 1,500 feet.[1]

In the paper on the Caradoc sandstone of Shropshire, by Messrs. J. W. Salter and W. T. Aveline, it is stated that the fossils of the supposed typical Caradoc sandstone are identical in species, and in association and proportionate numbers of the prevailing species, with those of the Bala group; and there is no admixture of other or new forms, or of those characteristic of higher parts of the system.[2] By priority of definition and description, the Llandeilo and Caradoc beds belong to Murchison's Silurian system; and the Bala series of Sedgwick are stratigraphically and paleontologically the equivalents of the Llandeilo and Caradoc series. They were fairly removed from the Cambrian system by the work of Messrs. Murchison, Sedgwick, and Salter; and in 1854 the Cambrian system included of the original Cambrian the middle member only, the lower division having been removed by Prof. Sedgwick in 1838. The distinguished founder of the Cambrian system did not admit the exclusion of the Bala series from the Cambrian, but with all the facts assembled, as in a recent paper by Prof. J. D. Dana,[3] I think we are compelled to restrict the Cambrian to the original middle division.

The last tabulation given by Prof. Sedgwick of his Cambrian system appeared in the preface of Mr. J. W. Salter's Catalogue of Cambrian and Silurian Fossils in 1873, as follows:[4]

Cambrian:	Upper	Upper Bala.
		Middle Bala.
		Lower Bala.
	Middle	Arenig or Skiddaw.
		Tremadoc.
		Ffestiniog.
		Menevian.
	Lower	Harlech.
		Bangor.
		Longmynd.
		Llanberris.

[1] On the classification and nomenclature of the Lower Paleozoic rocks of England and Wales. Quart. Jour. Geol. Soc., London, vol. 8, 1852, p. 147.

[2] On the "Caradoc Sandstone" of Shropshire. Quart. Jour. Geol. Soc., London, vol. 10, 1853, p. 63.

[3] Sedgwick and Murchison; Cambrian and Silurian; Am. Jour. Sci., 3d ser., vol. 39, 1890, pp. 167–180.

[4] (On the classification of the Cambrian rocks). "Preface to a Catalogue of the Collection of Cambrian and Silurian fossils contained in the Geological Museum of the University of Cambridge," by J. W. Salter, 1873, p. xv.

With the exception of the Bala and Arenig series the system is essentially the same as that generally accepted by the English geologists at the present day.

As geologist of Tennessee, Dr. Gerard Troost read Sir R. I. Murchison's Siluria, and also the observations of Prof. Sedgwick on the Cambrian rocks of Wales. Discussing the changes in nomenclature made necessary in expressing the views of Messrs. Murchison and Sedgwick, he says in 1841:[1]

After having pointed out, in my last report, the line of junction of the primordial or crystalline rocks in East Tennessee, I mentioned that the country west of the line which separates Tennessee from the State of North Carolina is composed of graywacke, slate, limestone, etc. All this country, according to the views of Murchison and Sedgwick, belongs to a new division, which they call the *Cambrian system.*

He then proceeds to describe the geographic distribution of the rocks that he referred to the Cambrian system, identifying the series in Tennessee with that of Wales entirely upon its lithologic characters and the absence of organic remains, and from the fact of its being succeeded by a series of limestones from which he obtained and identified Silurian fossils.

The presence of the equivalent of the Cambrian system in America was clearly recognized by Dr. E. Emmons, who, in 1844, wrote:

There are, however, if I understand Mr. Sedgwick and Mr. Murchison, rocks still lower; those which are now considered by them as metamorphic. They are the lower masses which I considered as equivalent to the Taconic rocks; the Lower Cambrian of Sedgwick, and not the Upper, which latter I proved to belong to the New York system. That the Taconic slate is precisely that in which the *Nereites* in Wales occur, there is not the slightest doubt in my own mind, and this is that part of the Taconic system which we can see lying unconformably beneath the oldest member of the New York system, and hence of the Silurian also. I know not, however, whether in Wales the same limestones, slates, and quartz rocks are to be found which we have here, and which are the oldest parts of the Taconic system. These are facts to be determined. Their non-existence in Wales, however, does not destroy the system. Very important members are known there, and should the lower slates and quartz be found wanting, it only proves the absence of that development which is so well known here in New York, Massachusetts, Vermont, and Maine, and I may add, in Michigan also.[2]

Under the influence of the publications of Sir R. I. Murchison, American geologists, other than Drs. Troost and Emmons and the latter's followers, classified all the Lower Paleozoic rocks under Lower Silurian, entirely ignoring Cambrian except to state that it was equivalent to the Lower Silurian. In 1872, however, Dr. T. S. Hunt published his history of the names Cambrian and Silurian in geology, advocating the recognition of the term "Cambrian."[3]

[1] Sixth annual report of the geological survey of Tennessee by the State geologist. Nashville, 1841, p. 171, doc. ed., p. 4 of special ed.

[2] The Taconic System, 1844, p. v.

[3] Canadian Naturalist, new ser., vol. 6, 1872, pp. 281-312, 417-448. Geological Magazine, vol. 10, pp. 385-395, 453-461, 504-510, 561-566, 1873.

The view of Dr. Hunt was concurred in by Sir J. W. Dawson, who in 1872 wrote as follows:

I concur in the view that it may well have the name *Siluro-Cambrian*, while the name Cambrian or Primordial will remain for those great and important fossiliferous deposits extending downward from the Potsdam in America and the Tremadoc in England, and constituting an imperishable monument to the labors of Sedgwick and Barrande.[1]

A notice of the proposed change from "Potsdam or Primordial" of the first edition of Dana's Manual of Geology to "Primordial or Cambrian" in the second edition, was published in 1874;[2] and the term was used in a subordinate sense in another edition of the Manual of Geology (1876) as a subdivision of the Lower Silurian (p. 163).

The term "Cambrian" came into general use in the Canadian and Fortieth Parallel Surveys and in the U. S. Geological Survey in 1882. With the exception of a few that prefer to use Taconic, the term is generally employed by geologists of all countries.

Most of the English geologists of the present time draw the line between the Cambrian and Silurian at the summit of the Tremadoc and the base of the Arenig terranes. From a study of the list of genera and species of the fauna of the Lower and Upper Tremadoc slates, I think that the line of demarkation between the two systems would naturally fall between these two subdivisions of the Tremadoc. The fauna of the Lower Tremadoc, in its general facies, is essentially the type of the Cambrian fauna, and there are only a few genera and species more characteristic of the Silurian. The large fauna of the Upper Tremadoc slate is characteristic of the Lower Silurian and the presence of a few genera and species of essentially Cambrian type are not sufficient to include it in the Cambrian. The fact that there is a slight unconformity at the summit of the Tremadoc and the base of the Arenig is not of sufficient general importance to warrant the placing of the line of demarkation between the groups at this horizon.

In a table showing the classification of the British sedimentary rocks, by Prof. A. J. Jukes Brown,[3] the Tremadoc slates are placed in a stage between the Cambrian and Ordovician.

This view of the Tremadoc slates was held by Mr. J. W. Salter,[4] who wrote:

But a few words must be said about this band of slate, which so intimately connects the Lingula flags below with the rocks above, and which is nevertheless so distinct in fossil characters from either.

[1] Canad. Nat., new ser., vol. 7, 1873, p. 7.

[2] Dana, J. D. Reasons for some of the changes in the subdivisions of geological time in the new edition of Dana's Manual of Geology. Am. Jour. Sci., 3d ser., vol. 8, 1874, p. 213.

[3] The classification of stratified rocks. Geol. Mag., new ser., dec. III, vol. 2, 1885, p. 297.

[4] Memoirs of the Geological Surveys of Great Britain. Geology of North Wales, second edition, 1881, p. 355.

Dr. Henry Hicks[1] says of it:

The Tremadoc group, therefore, may be said through many of its types of fossils to link the Cambrian and the overlying Ordovician (Lower Silurian) formations together, while it yet marks very distinctly the horizon in which all the truly characteristic types in the Primordial faunas are lost.

TACONIC.

The first proposition to apply the name Taconic to a system or series of rocks is found in a gazetteer of the State of New York, published in 1842.[2] The article is unsigned, but it bears internal evidence of having been written by Dr. Ebenezer Emmons as his first presentation of the views which were more fully elaborated and published later in the same year. He describes the Taghkanic range, and states that the rocks composing the same are situated between the gneiss of Hoosic Mountain on the east and the slates of the transition on the west; that they bear a very close resemblance to the primary on the east, and, on the other hand, a great similarity to the transition slates on the west.[3]

He says:

It is not proposed in this plan to separate these rocks from the primary, but to consider them as belonging to the upper portion and to speak of them as the Taghkanic rocks, or perhaps as the Taghkanic system. * * * Considering them for the present as belonging to the upper portion of the primary, the Taghkanic rocks will be composed, first, of a peculiar talcose slate, or a magnesian slate in part; in other parts it is plumbaginous, which strongly soils the fingers. * * * Second, of white, gray, and clouded limestone varying in texture from fine to coarse granular, often interlaminated with slate, the latter often merely coloring the limestone so as to impart the clouded appearance. * * * Third, of granular quartz, or a sandstone generally siliceous and of a brown color.[4]

In the concluding remarks on the Taghkanic system, we read:

On the whole, in regard to those rocks we have denominated "Taghkanic," we believe they ought to be separated from those on the east, being, as a whole, clearly distinct from them.[5]

A second memoir appeared in 1842, in which the term "Taghkanic" is changed to Taconic, and a detailed description given of the geographic distribution and character of the rocks forming the Taconic system. A typical section is presented with the following comment:[6]

The following section, extending from Petersburgh, Rensselaer County, to Adams, Massachusetts, embraces all the rocks in this system. Its direction is nearly east and west, or perpendicular to the strike of the system over which it passes.

[1] On some recent researches among Lower Paleozoic rocks in the British Islands. Proc. of the Geologists' Association, vol. 7, p. 9.

[2] Topography, geology, and mineral resources of the State of New York. Gazetteer of the State of New York, by James Disturnell. Albany, 1842, pp. 5–25.

[3] Op. cit., p. 11.

[4] Op. cit., p. 11.

[5] Op. cit., p. 12.

[6] Geology of New York, part 2, comprising the survey of the 2d geological (northern) district, 1842, p. 145.

In 1844, a separate memoir[1] was published in which a great addition, was made to the Taconic system west of the Petersburg end of the section of 1842. This addition was in 1856[2] separated as the Upper Taconic.

TACONIAN.

This name was proposed by Dr. T. S. Hunt, in 1877, to include the Lower Taconic of Dr. Emmons,[3] or the Granular Quartz, Berkshire limestone, and Taconic slates of the latter's typical Taconic section of 1842. At the time of the proposal of the name the author was uncertain whether the strata included under it should be referred to the basal beds of the Cambrian or to a pre-Cambrian system of rocks.

In a later paper he refers the Taconian system of the Appalachians to a pre-Cambrian horizon as compared with the Cambrian rocks from that region. This is stated by him as follows: "This Appalachian-Cambrian series is wholly uncrystalline, and is separated from the Taconian by a stratigraphical break, and by a great interval of time, which includes the Keweenian period."[4] As we now know that the Granular Quartz is characterized by the Lower Cambrian or Olenellus fauna, the Berkshire or Stockbridge limestone by the Chazy-Trenton and perhaps at its base by an Upper Cambrian fauna, and the original Taconic slate of the Lower Taconic of Dr. Emmons is correlated by its stratigraphic position with the Hudson shales, the term Taconian ceases to be of value in geologic nomenclature.

PRIMORDIAL.

This name was used by M. J. Barrande to designate the First fauna, in contradistinction to the Second and Third.[5]

The name was applied at first to the fauna, but, in 1854, in the first edition of "Siluria," Sir Roderick Murchison designated the formation containing the Primordial fauna as the Primordial Silurian, dividing the Silurian into the Upper Silurian, the Lower Silurian, and the Primordial Silurian. The use of the latter term has been advocated more or less by those who oppose the use of the term Cambrian; but the name Primordial is now rarely used except when mentioning the First fauna of Barrande.

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[1] The Taconic System; based on observations in New York, Massachusetts, Vermont, and Rhode Island. Albany, 1844, pp. i-vii, 67.

[2] Emmons, Ebenezer. American Geology, containing a full statement of the principles of the science, with full illustrations of the characteristic American fossils. Albany, 1856, vol. 1, pt 2, pp. 49-66.

[3] On the geology of the Eozoic rocks of North America. (Abstract). Boston Soc. Nat. Hist., vol. 19 1878, p. 278.

[4] Hunt, T. Sterry. The Taconic Question in Geology. Mineral Physiology and Physiography. A second series of chemical and geological essays. With general introduction. 1886, p. 677.

[5] Système Silurien du centre de la Bohême, vol. 1, 1852, p. 88.

POTSDAM.

There are several early references to a sandstone occurring at the base of the section in the Upper Mississippi Valley and about the Adirondack Mountains in New York; but it was not until 1838 that it was well defined and given a distinct name. This was done by Dr. E. Emmons. In describing this sandstone, Dr. Emmons says: [1]

I shall not enter upon its geological relations any farther than to state that, in Potsdam and other towns in which it appears, it uniformly rests on the primary strata; and in no part of the county is there any rock which interposes itself between it and the primary, so that it appears here as the oldest representative of the transition series. The identification of this rock with the sandstones along the southern border of Lake Ontario will be a matter of some difficulty. It is geologically below the transition limestone, and never in the northern district alternates with it, but always holds the relation of an inferior rock. * * *

This rock is a true sandstone, of a red, yellowish red, gray, and grayish white colors. It is made up of grains of sand, and held together without a cement. Intermixed with the siliceous grains are finer particles of yellowish feldspar, which do not essentially change the character of the sandstone, but they show the probable source from which the materials forming it were originally derived, viz, some of the varieties of granite.

On the Lake Champlain side of the Adirondacks it is described as follows:

Its position is evidently beneath the transition limestone and calciferous sandrock. It is very deficient in organic relics, though not entirely destitute of them. It is unnecessary to repeat what has already been said of this rock; it is purely quartzose or siliceous in its composition and finely stratified. It dips to the northeast at Port Kent at an angle varying from 5° to 10°. The places where it occurs along Lake Champlain are indicated on a map of a part of this [Clinton County], to which I refer the reader. This rock at Keeseville has been rent in the most remarkable manner; several fissures, the principal one of which extends nearly a mile, and through which the Au Sable flows, have been opened by some convulsion in nature to the depth, in some places, of a hundred feet and from five to twenty wide. Near the bottom of the fissure at High Bridge, as it is called, I discovered numerous specimens of a small bivalve molusca, a lingula. I found, also, on examination, that the same fossil occurred through an extent of 70 feet at least, and so far as I could discover, it was the only fossil inclosed in the rock. It is extremely thin and delicate, yet the shell is perfectly preserved, and is probably one of the oldest inhabitants of the globe, as the rock in which they occur is the oldest of the transition series.[2]

The name "Potsdam sandstone" was quickly accepted by the New York State geologists, incorporated in their annual reports, and used in the final report on the geology of the State. The extension, by correlation, of the name to the Southern Appalachians, through Pennsylvania, Virginia, North Carolina, Tennessee, and Alabama; westward through the Mississippi Valley and the Rocky Mountains, and north into Canada, and down the St. Lawrence Valley, rapidly followed, until the name Potsdam is now used to typify the Upper Cambrian zone in all parts of America.

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[1] Report of the geologist of the 2d geological district of New York. Second annual report of the Geological Survey of N. Y. Albany, 1838, pp. 214, 215.

[2] Op. cit., p. 230.

ST. CROIX.

The name St. Croix was proposed by Prof N. H. Winchell in 1873 for the fossiliferous sandstone beneath the Lower Magnesian limestone of the Mississippi Valley. The reason given is that the sandstone identified by Dr. D. D. Owen as the Potsdam sandstone is unconformably superjacent to a series of quartzites in Wisconsin and Minnesota that are the true equivalents of the Potsdam sandstone of New York.[1]

The presence of the same fauna in the typical Potsdam sandstone on the northern side of the Adirondack Mountains as that found in the upper sandstone of St. Croix Falls negatives this view and correlates the sandstones that are unconformably superjacent to the lower quartzites with the typical Potsdam, and refers the lower quartzites to the Algonkian. The name St. Croix, however, is retained for the fossiliferous Cambrian sandstones of the upper Mississippi Valley in Wisconsin, Iowa, and Minnesota.

MADISON.

The name Madison sandstone was proposed by Prof. R. D. Irving,[2] in 1877, for a band of sandstone consisting, in large part, of nearly pure white quartz sand, with a thickness of 35 to 50 feet, and lying between the base of the Magnesian limestone of the Lower Silurian (Ordovician) and the Mendota limestone in Wisconsin.

MENDOTA.

This name was proposed by Prof. R. D. Irving, in 1877, for a calcareous stratum near the upper portion of the "Potsdam" formation of Wisconsin. It is formed of alternating sandy and calcareous material that, in the upper portion, is almost a well marked and very persistent yellow limestone layer, with a thickness of 30 feet.[3]

TONTO.

This name was applied by Mr. G. K. Gilbert, in 1874,[4] to a series of sandstone and shale between the subjacent granite and the superjacent massive limestones that occur in the section at the mouth of the Grand Cañon of the Colorado River, Arizona. He considered the formation of Primordial age, and it has since been found to contain an Upper Cambrian fauna. It was more fully described by him in the following year.[5]

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[1] General sketch of the geology of Minnesota. Geol. and Nat. Hist. Survey, Minnesota, 1st Ann. Rep. for 1872, 1873, pp. 70–72.

[2] The Lower Silurian rocks. (Geology of central Wisconsin.) Geol. Wisconsin, survey of 1873–1879, vol. 2, 1877, p. 525.

[3] Ibid., 525.

[4] On the age of the Tonto sandstone. (Abstract.) Washington Phil. Soc. Bull., vol. 1, 1874, p. 109.

[5] Explorations and surveys west of the 100th Merid., vol. 3, 1875, p. 163; pp. 521–522.

HAMBURG.

The Hamburg limestone and the Hamburg shale are names used by Mr. Arnold Hague, in 1881, to designate the Upper Cambrian limestone and shale of the Cambrian section of the Eureka district, Nevada. The limestone is superjacent to the Secret Cañon shale and subjacent to the Hamburg shale. The latter is characterized by a well developed Upper Cambrian fauna.[1]

SECRET CAÑON.

This name was applied by Mr. Arnold Hague, in 1881, to a band of shale in the Cambrian section of the Eureka district, superjacent to the Prospect Mountain limestone and subjacent to the Hamburg limestone, characterized by a fauna that may be referred to the upper portion of the Middle Cambrian.[2]

KATEMCY.

Prof. Theodore B. Comstock, in describing the Upper Cambrian rocks of the central area of Texas, proposed the name "Katemcy" for the "Potsdam series," or Upper Cambrian.(?)[3] This terrane is named from the beds exposed in the valley of Katemcy Creek, Mason County.

RILEY.

This name was proposed by Prof. Theodore B. Comstock, for a series of sandstones which he considered to be superjacent to the Hickory series of the Central Texas, Cambrian section, and subjacent to the Katemcy or Potsdam series. He referred it provisionally to the Middle Cambrian zone.[4]

HICKORY.

This name was proposed by Prof. Theodore B. Comstock, for a series of strata that he considered to underlie the typical Potsdam Sandstone of the central Texas section. He referred the series provisionally to the Lower Cambrian.[5]

CONNASAUGA.

This name was proposed by Mr. C. Willard Hayes, for the Cambrian shales at the summit of the Cambrian section in northwestern Georgia. He correlated it with the Knox shale of Safford's Tennessee section, assigning to it a thickness of 1,600 to 2,000 feet.[6]

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[1] Report (on work in Eureka District). U. S. Geol. Surv., 2d Ann. Rep., 1880-'81, 1881, p. 27; 3d Ann. Rep., 1883, p. 255.

[2] Ibid., pp. 27, 253.

[3] Comstock, T. B.: A preliminary report on the geology of the central mineral region of Texas. First Ann. Rept. Geol. Surv. Texas, 1889, p. 289.

[4] Ibid., p. 286.

[5] Ibid., p. 285.

[6] The overthrust faults of the southern Appalachians. Bull. Geol. Soc. America, vol. 2, Feb. 1891, p. 143, pl. 3.

This name seems to be a synonym of Montevallo shales proposed by Prof Eugene A. Smith.

MONTEVALLO.

The name Montevallo, or Choccolocco, shales was proposed by Prof. Eugene Smith, for a series of sandy shales of a great variety of colors, such as olive, green, brown, chocolate, yellowish, etc., that occur above the Coosa shales in northeastern Alabama.[1]

This name appears to be equivalent to Connasauga shales proposed by Mr. C. Willard Hayes.

CHOCCOLOCCO.

This is apparently a synonym of Montevallo.

COOSA.

The name Coosa shales was proposed by Prof. Eugene A. Smith for the shales in the Coosa Valley at the base of the Cambrian section. They are described as thin-bedded limestones with clay seams between.[2]

This name is also used by Mr. C. Willard Hayes in a paper read before the Geological Society of America, December 29, 1890, and published February 9, 1891. It was applied to the series of shales, some 3,000 feet in thickness, occurring at the base of the Cambrian section in northwestern Georgia.[3]

ROME SANDSTONE.

This name was proposed by Mr. C. Willard Hayes for a sandstone of Cambrian age occurring at Rome, Georgia. In connection with the Weisner quartzite it is given a thickness of from 2,000 to 3,500 feet. The correlation is with the Knox sandstones of Tennessee.[4]

BRETONIAN.

This name is applied by Mr. G. F. Matthew to the upper series of Cambrian rocks as found in the vicinity of St. John, New Brunswick, and on the island of Cape Breton, where the fauna of the division is well developed. It will be arranged as an Upper Cambrian formation.[5]

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[1] Geological structure and description of the valley region adjacent to the Cahaba Coal Field. Geol. Surv. Alabama. Report on the Cahaba Coal Field, pt. II, 1890, p. 148. (Issued January, 1891.)

[2] Ibid., p. 148.

[3] The overthrust faults of the Southern Appalacians. Bull. Geol. Soc. America, vol. 2, Feb., 1891, p. 143, pl. 3.

[4] Ibid., p, 143.

[5] Illustrations of the fauna of the St. John group, No. 5. Trans. Roy. Soc. of Canada, vol. 8, 1890, p. 129.

ACADIAN.

The name Acadian was proposed by Sir J. W. Dawson in 1867 for the series of rocks represented in New Brunswick by the St. John slate of Mr. G. F. Matthew.[1] In 1868 these observations were reprinted, with the statement that the discovery adds a new formation to the Paleozoic period in America. He says:

> This formation has as yet been known as the "St. John group," but I think this name unsuitable, both on account of the number of places known as St. John and on account of the variety of formations occurring near St. John, in New Brunswick, and would propose for the group now under consideration, characterized by *Paradoxides*, *Conocephalites*, etc., and the oldest known member of the Paleozoic of America, the name Acadian group, by which I hope it will be known to geologists in whatever part of America it may be recognized.[2]

In a recent paper on the fauna of the St. John group, Mr. G. F. Matthew limits the term Acadian to his Division 1 of the New Brunswick Cambrian section. This includes the fauna of the Paradoxides zone.[3]

ST. JOHN'S.

Prof. J. Beete Jukes in 1843[4] used the name St. John's slate for the slate as seen near St. John's, Newfoundland, beneath the Signal Hill sandstone. When referring, in 1862, to this work[5] he states he did not find any fossils in the lower slate formation, but that Mr. C. Bennett, subsequently found trilobites of the genus Paradoxides in the slates on the west side of St. Mary's Bay. These were named *P. bennetti* by Mr. J. W. Salter. On the map accompanying the report of 1843, the slates of St. John's extend southward from St. John's and around the southern point of the Avalon Peninsula to and about the Bay of St. Mary's.

The investigation of Dr. Alexander Murray and Mr. J. P. Howley in connection with the geological survey of Newfoundland, have shown that the slate carrying Paradoxides about St. Mary's Bay is a later formation than the slate at St. John's; and that the Paradoxides slates are unconformably superjacent to the slates to which Prof. Jukes gave the name of St. John's in 1843. This restricts the name as given by Prof. Jukes to the slate series of St. John's, described as from 2,000 to 3,000 feet thick. It was in this series of slates that the Rev. Moses Harvey discovered the fossil which Mr. Billings described as *Aspidella terranovica*. The entire series, along with the Signal Hill sandstone of Prof. Jukes, was referred to the intermediate or Huronian

[1] On recent geological discoveries in the Acadian provinces of British America. Proc. Am. Assoc. Adv. Sci., vol. 16, 1867, pp. 117-119.

[2] Acadian geology. The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Islands. 2d ed., London, 1868, p. 638.

[3] Illustrations of the fauna of the St. John Group No. 5. Trans. Roy. Soc. of Canada, vol. 8, 1891, p. 129.

[4] General report of the geological survey of Newfoundland in 1839 and 1840. London, 1843, p. 59.

[5] The Student's Manual of Geology. 2d edition, Edinburgh, 1862, p. 457.

system by Dr. Murray; and in the classification used in this memoir it is included under the Algonkian, as a pre-Cambrian formation.

In proposing a classification for the formations in the vicinity of St. John, New Brunswick, Mr. F. G. Matthew proposed the term, "St. John group" for several zones of soft black and dark gray, finely laminated shales alternating with zones of coarser grained slates, containing numerous thin beds of fine-grained sandstone.[1] The fossils were Lingula, a Conchifer, Annelids, and Coprolites. This was republished in 1865, and is used in all the latest publications by Mr. Matthew.

In view of the fact that the term "St. John's" was used for a distinct formation by Prof. Jukes in 1843, it appears best to continue to apply it to these slates of the Algonkian; and to use the later name "Acadian" for the slates at St. John, New Brunswick.

JOHANNIAN.

This name is proposed by Mr. G. F. Matthew for a local series of strata in the St. John basin of New Brunswick that occur between the Paradoxides zone, or Division No. 1, and the Upper Cambrian Zone, or Division No. 3, which he calls Bretonian.[2]

GEORGIA.

The name Georgia was incidentally used by Prof. Jules Marcou in 1860, when stating that "Prof. Emmons has always regarded the black slates of Georgia as a part of his Taconic system."[3] In the following year the name was used in volume 1 of the Geology of Vermont, in the systematic description of a group of formations, the typical one of which is a series of slates and shales above the "Red sandrock" in the town of Georgia, Vermont. There was also included in the group the roofing slate belt of Rutland County, Vermont, that passes into Washington County, New York. A provisional reference was made of a series of clay slates that occur in the central part of the State.[4] A full description of the formations referred to the group is given in the text, and their geographic distribution is delineated on an accompanying map.

Prof. Jules Marcou advanced the claim that he first used the name Georgia in October, 1860, which was followed in December, 1861, with a full definition of the group.[5] Prof. Hitchcock in reply to this, states

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[1] Matthew, G. F.: Observations on the geology of St. John County, New Brunswick. Canadian Nat. vol. 8, 1863, p. 244.

[2] Illustrations of the fauna of the St. John Group No. 5. Trans. Roy. Soc. of Canada, vol. 8, 1891, p. 129.

[3] On the Primordial Fauna and the Taconic System, by Joachim Barrande, with additional notes by Jules Marcou, Proc. Boston Soc. Nat. Hist., vol. 7, 1860, p. 375.

[4] Hitchcock, C. H. Geology of Vermont, vol. 1, p. 357.

[5] The Taconic of Georgia and the Report on the Geology of Vermont. Memoirs Boston Soc. Nat. Hist., vol. 4, 1888, pp. 123, 124.

that excerpts from volume 1 of the Geology of Vermont were distributed prior to December, 1861, and that it was in print by July, 1861.[1]

On a map, in the atlas accompanying the Geology of Canada for 1863, published in 1865, the Georgia group of Prof. Hitchcock is included with the "Red Sandrock" in a common color, and is so referred to in the legend. This includes the "Red Sandrock" series and the Georgia series of Prof. C. H. Hitchcock as one formation under the name of Potsdam.

In 1886 the "Red Sandrock" was included by Mr. C. D. Walcott with the shales of the Georgia series, in the Middle Cambrian or Georgia group.[2] The reference to the Middle Cambrian was changed to Lower Cambrian three years later.[3]

GRANULAR QUARTZ.

This is one of the first formations differentiated and named by Prof. Amos Eaton.[4] He referred it to the Primitive class and indicated its stratigraphic position on a section accompanying the index. The name was accepted by Dr. E. Emmons[5] in 1842 and placed as the second member of his Taconic system, between the second bed of Stockbridge limestone and the third bed of limestone. This section was corrected in 1844, so as to place the "Granular Quartz" at the base of the Taconic system.[6]

In 1887 the Olenellus fauna was discovered by Mr. C. D. Walcott in the "Granular Quartz" near Bennington, Vermont, thus determining its pre-Potsdam age.[7]

RED SANDROCK.

The occurrence of a red sandstone at Burlington Falls, Vermont, was mentioned by Prof. C. T. Jackson in 1844.[8]

In the scheme of Dr. C. B. Adams, illustrating the rocks of Vermont, as expressed in the nomenclature of the New York system, the Red Sandrock occurs above the Hudson River shales.[9]

The correlation thus indicated is that of the reddish brown Medina sandstone of the New York series with the reddish colored "sandstone" of Vermont, and the name Red Sandrock was applied to the latter, thus originating a term that has continued in geologic literature, not-

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[1] Date of the publication of the report upon the Geology of Vermont. Boston Soc. Nat. Hist. Proc., vol. 24, 1888, p. 34.

[2] U. S. Geol. Survey, Bull. No. 30, 1886, p. 44.

[3] Stratigraphic position of the Olenellus Fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, 1889, p. 383.

[4] An index to the Geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, p. 21.

[5] Geol. of N. Y., Part 2, comprising the survey of the 2d Geol. (Northern) District, 1842, p. 144.

[6] The Taconic System; based on observations in New York, Massachusetts, Vermont and Rhode Island. Albany, 1844, p. 18.

[7] Discovery of fossils in the Lower Taconic of Emmons. Am. Assoc. Proc., vol. 36, 1888, p. 212.

[8] Final report on the Geology and Mineralogy of the State of New Hampshire, 1844, p. 161.

[9] First Ann. Rep. on the Geology of Vermont. Burlington, 1845, p. 61.

withstanding the fact that the rock itself is a magnesian limestone, with more or less siliceous and sandy beds alternating with the limestone.

In the second annual report of Vermont by Dr. Adams, in the description of a section of Snake Mountain, Addison County, the strata capping the mountains are designated by the name of Red Sandrock.[1]

PRIMAL.

The term Primal was proposed by the brothers Rogers in 1844 and defined as follows:

> Our Primal series embraces the four great rocks between the base of the Paleozoic strata and the base of the first limestone, the Calciferous sandstone of New York.[2]

The equivalent expression was Formation No. 1, and both terms have been used in the geologic work of Pennsylvania, Maryland, and Virginia, but they have not come into general use.

CHILHOWEE.

The name Chilhowee was proposed by Prof. J. M. Safford in 1856 for a series of sandstones and shales superjacent to the Ocoee conglomerates and shales and subjacent to the Magnesian limestone and Shale group, or what was subsequently called the Knox shale and the Knox limestone.[3]

By the discovery of the Olenellus fauna in the shale resting upon the quartzite of Chilhowee Mountain, the Chilhowee Mountain quartzite is referred to the Lower Cambrian and correlated with the Granular quartzite upon the western slope of the Green Mountains of Vermont.

WEISNER.

This name is proposed by Prof. Eugene A. Smith for the lenticular masses of quartzite that occur in the Montevallo shale of northeastern Alabama. He correlates the quartzite with the Chilhowee Mountain quartzite of Tennessee. This correlation is probably incorrect, as the latter quartzite is of Lower Cambrian age.[4]

This name is also used by Mr. C. Willard Hayes for a series of quartzites that occur between the Coosa shales and the Connasauga shales of the Cambrian section of northwestern Georgia. In connection with the Rome sandstone he mentions the correlation of it with the Knox sandstone, Potsdam or Chilhowee, Prof. Safford's Tennessee section, by Profs. Smith and Safford.[5]

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[1] Second Ann. Rep. of Geol. Surv. of Vermont, 1846, p. 163.

[2] On American geology and present condition of geological research in the United States. Am. Jour. Sci., vol. 47, 1844, p. 155.

[3] A geological reconnaissance of Tennessee; first biennial report. Nashville, 1856, p. 152.

[4] Geological structure and description of the valley region adjacent to the Cahaba Coal Field. Geol. Surv. Alabama. Rept. on the Cahaba Coal Field. Pt. II, 1890, p. 149.

[5] The overthrust faults of the southern Appalachians. Bull. Geol. Soc. America, vol. 2, Feb., 1891, p. 143.

OCOEE.

This name was proposed by Prof. J. M. Safford in 1856 for a series of conglomerates and slates that he considered to be superjacent to the Mica-slate group and subjacent to the Chilhowee sandstone.[1]

PROSPECT.

For the lower members of the Cambrian section, in the Eureka district, Nevada, Mr. Arnold Hague proposed, in 1881, Prospect Mountain quartzite and Prospect Mountain limestone.[2] As now known the upper portion of the Prospect Mountain quartzite is characterized by the Olenellus or Lower Cambrian fauna, and the Prospect Mountain limestone by the Middle Cambrian fauna of the Rocky Mountain section.

EASTERN AND WESTERN SANDSTONE.

These names were applied to the horizontal, evenly bedded sandstones of the south shore of Lake Superior, east and west of Keweenaw Point, by Dr. R. D. Irving in 1883 as convenient terms under which to describe the character of the sandstone and its geographic distribution.[3]

LAKE SUPERIOR SANDSTONE.

Dr. J. J. Bigsby described the red and white sandstone along the south shore of Lake Superior as early as 1825, and in the account of the geology of Lake Superior by Capt. H. W. Bayfield, he speaks of the sandstones of Lake Superior.[4] As used by Capt. Bayfield, the Lake Superior sandstone included both the Cambrian sandstones of the south shore, and the pre-Cambrian sandstones of Keweenaw Point and the north shore of the Lake. It has been used by various authors in the same general manner, and has little value as a term in stratigraphic geology.

POTSDAMIC.

Prof. C. H. Hitchcock proposed in 1888 for the rocks[5] containing the Cambrian fauna, the name Potsdamic or Taconic.

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[1] A geological reconnaissance of Tennessee; first biennial report. Nashville, 1856, p. 151.

[2] U. S. Geol. Survey, Second Ann. Rep., 1880–'81, 1882, p. 27; 3d Ann. Rep., p. 254.

[3] The copper-bearing rocks of Lake Superior. U. S. Geol. Survey, Monograph, vol. 5; 1883, pp. 351, 365.

[4] Outlines of the Geology of Lake Superior. Quebec Lit. and Hist. Soc. Trans., vol. 1, 1829, pp. 15–22.

[5] Date of the publication of the report upon the Geology of Vermont. Boston Soc. Nat. Hist. Proc. vol. 24, 1888, p. 37.

CHAPTER IV.

SUMMARY OF THE PRESENT KNOWLEDGE OF THE FORMATIONS.

The data under this heading is assembled for each of the following Geologic Provinces:

Atlantic Coast Province.
Appalachian Province.
Rocky Mountain Province.
Interior Continental Province.

A brief résumé is given at the end of the description of the formations of each province and a general résumé of the Cambrian Group at the end of the chapter.

ATLANTIC COAST PROVINCE.

This includes the rocks referred to the Cambrian group on the Island of Newfoundland and the adjoining coast of Labrador, the provinces of Nova Scotia and New Brunswick, and Cape Breton, and the States of Maine, New Hampshire, and eastern Massachusetts.

NEWFOUNDLAND AND THE ADJOINING COAST OF LABRADOR.

The detailed knowledge we have of the Cambrian rocks of Newfoundland is obtained largely from the publications of the Geological Survey of Canada for the northwest and west coast and the Labrador coast, and from the descriptions by the Newfoundland Survey of the eastern and southeastern coast. To the latter there is added the results of a season's work on the Avalon peninsula, by the writer.

NORTHWESTERN NEWFOUNDLAND.

The Cambrian strata on the adjoining coast of Labrador are included with those of the Cambrian area of northwestern Newfoundland, as the two are considered to belong to one geologic province.

The section at L'Anse au Loup, on the north side of the straits of Belle Isle[1] shows 231 feet of arenaceous beds at the base, overlain by

[1]Logan, W. E.: Geological Survey of Canada; report of progress from its commencement to 1863. Montreal, 1863, p. 288.

143 feet of gray, reddish and greenish limestones. The section is, in detail, as follows:

	Feet.
1. Red and gray sandstones, sometimes of a reddish gray; consisting, in the lower part, of a conglomerate composed of rounded pebbles of white quartz from an eighth of an inch to 3 inches in diameter, in a matrix of fine-grained sandstone, made up of whitish and reddish quartz, and white and red feldspar. A similar fine-grained mixture constitutes the great mass of rock in the upper part. The beds vary in thickness from 3 inches to 3 feet, and many of them are penetrated vertically by *Scolithus linearis*, about a quarter of an inch in diameter, and always of a lighter color than the surrounding mass. Four feet below the summit there is a bed 3½ feet thick, of a mammillated or concretionary character; the concretions, which are from 1 to 10 feet in horizontal diameter, being composed of concentric layers from a quarter to half an inch thick	231
2. Gray, reddish, and greenish limestones, presenting on the strike great diversities of character. They sometimes consist of yellow-weathering, massive, nodular, argillaceous limestones, probably magnesian, holding lenticular patches of pure limestone, as well as of red and green shale from 3 to 6 feet in horizontal diameter. On the strike these yellow-weathering limestones pass in some parts into gray, compact, pure limestone, in thick, massive beds, while in others they are evenly divided into layers of only 2 or 3 inches thick. In Forteau Bay the whole mass appears to be more or less fossiliferous	143
	374

I examined the collections from these limestones now in the Canadian Geological Survey collections, and found the following species, most of which had been recognized and described by Mr. Billings:

Palæophycus incipiens.
Archæocyathus profundus.
Spirocyathes atlanticus.
Coscinocyathus billingsi.
Iphidea bella.
Kutorgina cingulata.
    labradorica.
Obolella chromatica.
Orthis 2 sp.
Stenotheca elongata.
    rugosa.
Hyolithes billingsi.
Salterella pulchella.
    rugosa.
Olenellus thompsoni?
Ptychoparia miser.
Protypus senectus.
Solenopléura (like S. nana).

In describing the extension of the rocks along the north shore of the Straits of Belle Isle, Sir William E. Logan states that they rest on the Laurentian gneiss, and extend along the coast for nearly 80 miles, with a probable breadth of 10 or 12 miles, and slope towards the water at an average of about 60 feet to the mile. In this stretch along the coast they are divided into five or six tabular masses, separted from one another by narrow denuded portions of the gneiss.[1]

On the Newfoundland shore sandstones occur that were referred to the Potsdam sandstone from their stratigraphic relations to superjacent limestones containing *Lingulepis acuminata*.[2] The data, however, does not fully sustain this reference. Following south along the west

[1] Op. cit., p. 287.
[2] Op. cit., p. 289.

coast nearly 200 miles, to Bonne Bay, a more extended section of Cambrian strata is met with that is described in detail, as follows:[1]

Between 1 and 2 miles inland from the northeast side of the east arm of Bonne Bay there arises a range of hills of Laurentian gneiss, 2,000 or 3,000 feet in height, on the flank of which is exposed the following measured section:

A.

	Feet.
1. Blackish blue, fine-grained slate, with a cleavage independent of the bedding. Of this slate only 105 feet of the upper part are seen; the lower part is concealed in the space between the upper portion and the gneiss, and may comprise a thickness of about 230 feet	335
2. Blackish blue slate interstratified with gray quartzites, in beds of from 6 inches to 3 and 4 feet. In the 80 feet at the bottom the quartzites greatly predominate, and they constitute 15 feet at the top, while the intermediate 175 feet consist chiefly of slate	270
	605

B.

1. Light gray, yellow-weathering limestone, in beds of from 1 to 3 inches thick, interstratified with blackish-blue, slightly calcareous slate, both containing small specks of silver-white mica, which are more abundant in the limestone than in the slate. The limestones hold in abundance fragments of trilobites, chiefly belonging to three or four species. Among them is *Paradoxides* (*Olenellus*) *vermontana*, a new species of Bathyurus, and the pygidium of a species so closely resembling *B. extans* of the Birdseye and Black River formation, that it can scarcely be distinguished from it and may possibly be the same	80
2. Grayish green, micaceo-arenaceous shale, interstratified with a few beds of grayish quartzite weathering slightly yellow	80
3. Strata concealed	30
4. Reddish granular quartzite in thick beds, with numerous parallel joints in two directions, dividing the beds into rhomboids	105
5. Gray and grayish green, micaceo-arenaceous shale in beds from a quarter of an inch to an inch thick, interstratified with a few beds of gray, very ferruginous, sandy dolomite, and fewer of gray quartzite	127
6. Reddish quartzite, in beds of from 1 to 2 feet thick	34
7. Gray arenaceous dolomite, weathering yellowish brown, interstratified with reddish quartzite in beds of from 1 inch to 1 foot thick, and with reddish and grayish micaceo-arenaceous shale predominating toward the top. The beds of dolomite and shale contain fossils, among which are *Obolella chromatica* ?, *Obolus labradoricus*, *Paradoxides vermontana*, *Conocephalites*, a new species of Bathyurus, and one or more undetermined species of Salterella	27
	483

C.

1. Whitish quartzite in beds of from 6 inches to 2 feet, interstratified with light gray, micaceo-arenaceous shale, in layers of from 6 inches to 1 foot, which occur at intervals of from 5 to 10 feet	150

[1] Op. cit., pp. 865–867.

	Feet.
2. White and reddish quartzite, in beds of from 1 to 3 feet thick, interstratified toward the bottom with a gray arenaceous dolomite, weathering yellowish brown	160
3. White and reddish quartzite, in beds of from 1 to 3 feet thick, interstratified with greenish micaceo-arenaceous shale, constituting about one-half the amount	90
4. Gray, pure limestone, in beds of from 1 to 3 feet thick, marked with a few reticulating strings of yellowish-weathering dolomite. The rock is a mass of comminuted organic remains, among which are *Paradoxides vermontana*, and undetermined species of Bathyurus and Salterella, as before	20
5. Blackish blue, soft shale, interstratified with gray yellow-weathering limestone, probably magnesian, in beds of 1 or 2 inches thick. The quantities of shale and limestone are about equal, and the whole is intersected by reticulating strings of calc-spar	35
6. Gray, pure limestone, composed of comminuted organic remains, belonging to Paradoxides, Bathyurus, and Salterella, as before	27
7. Bluish black, soft shale, interstratified with gray yellow-weathering dolomitic bands, as before	60
8. Gray, pure limestone, probably composed of comminuted organic remains as before; underlaid by bluish black shale, inclosing nodules of blue compact limestone, some of which weather yellowish-brown, and are probably magnesian	13
9. Bluish black, soft shale of the same character as before, interstratified with a few beds of quartzite	68
	623
Total	1,711

I examined the species of Bathyurus referred to in No. 1 of Division B, and also some other fossils labeled as coming from Bonne Bay, and there can be no doubt that some mistake was made in labeling the specimens, for they certainly belong to the Trenton fauna and could not have been associated with the Lower Cambrian fauna of the section. All the Paradoxides referred to belong to the genus Olenellus or Mesonacis and several of the specimens of Bathyurus to the genus Protypus. If the section was correctly measured and the Cambrian fossils occur as mentioned all the strata belong to the Lower Cambrian, and the fauna is a part of the Georgian fauna of the Cambrian. From the accessible data I am not able to discover that the Upper Cambrian or Potsdam fauna has been found on the northwest coast of Newfoundland or on the Labrador shore.

SOUTHWESTERN NEWFOUNDLAND.

On the "Map showing the distribution of the Silurian and Carboniferous Formations (etc.) in St. George's and Port au Port Bays, Newfoundland," by Dr. Alexander Murray, 1873–'74, a considerable area is designated as Potsdam that is continued north into the valley of the Humber. The reason given for the identification of the Potsdam Terrane, in the Reports of the Geological Survey of Newfoundland for 1873–'74, '75, is that the strata placed within it are subjacent to the beds containing fossils of the Calciferous formation of the Lower Silurian.

This is not sufficient in the absence of Upper Cambrian fossils to establish the presence of the Potsdam horizon on the southwestern side of the island. It is quite probable that strata of Cambrian age occur, but as yet the proof of their presence is very defective.

EASTERN AND SOUTHEASTERN NEWFOUNDLAND.

The section at Canada Bay is as follows, according to Dr. Alexander Murray:[1]

	Feet.
A. Clouds Mountain bluish gray slates, conglomerates, and diorite	2,500
B. Salt Water Pond bluish gray, black, blue, reddish, and white limestones, yellowish gray and black slates, and gray and white sandstones, in some parts holding *Olenellus vermontanus*, Lingula, Scolithus and fucoids	2,000
C. Light and dark blue limestones and brown slates, with cherty limestone at the top	900
	5,400

The strata referred to the Cambrian system in southeastern Newfoundland are well exposed on the peninsula of Avalon and westward along the coast to the northern shore of Fortune Bay, and northward, on the western shores of Trinity Bay. Dr. Murray has given a general description of the terrane in the reports of the Geological Survey of Newfoundland for 1868 and 1870; and a fine geological map of the Peninsula of Avalon, by Dr. Murray and Mr. James P. Howley, 1881, shows the distribution of the Cambrian rocks. The correlated section is described as superjacent to pre-Cambrian "Huronian" rocks and as having a thickness of nearly 6,000 feet, of which 138 feet are limestone and the remaining portion argillaceous and arenaceous deposits. The section in descending order is as follows:[2]

	Feet.
(*s*) Brown and black micaceous shales, with gray micaceous sandstones of Bell Island, Conception Bay. Organic contents are: two species of Lingula, four species of Palæophycus, *Eophyton linnæanum* (Torrell), and another Eophyton, *Cruziana semiplicata* (Salter) and some others	476
(*r*) Red and green sandstones and slates, with some calcareous beds at the base. Estimated thickness	1,426
(*q*) Kelly's Island sandstones and shales. A few fucoids were the only fossils observed in this division	720
(*p*) Black slate or shale. At Fortune Harbor this division was found to contain *Paradoxides bennettii*	150
(*o*) A bed of dark gray limestone. Fossils consist of broken fragments of trilobites and shells, among which latter a Lingula was observed	5
(*n*) Red, green, and black slates, or shales, which occasionally pass into a finely laminated argillaceous shale, as at Topsail Head. The fossils are *Paradoxides bennettii*, *Conocephalites gregarius*, and probably some other species not yet recognized	1,045

[1] Sequence and distribution of the rocks of the great Northern Peninsula. Geol. Survey Newfoundland, Report of progress for 1864. Revised edition, London, 1881, p. 15.

[2] Murray, Alexander: Of Primordial Silurian and Related formations. Rep. Geol. Surv. Newfoundland for 1870, St. John's, 1871, pp. 36-39. Geology of Newfoundland, 1881, London, pp. 237-239.

	Feet.
(*m*) Hard, thick beds of gray and sometimes reddish limestone. Two species of Conocephalites have been recognized by Mr. Billings, and a small fragment supposed of Paradoxides from a loose stone at Topsail Head; also Salterella and *Crania labradorica*. Thickness at Topsail Head......	100
(*l*) Red, green, and blackish argillaceous slates. A few remains of trilobites were found at Random Island, one of which resembles *Bathyurus gregarius* (Billings)	250
(*k*) Conglomerate of Manuel's Brook, not recognized elsewhere	50
(*j*) Red and green argillaceous shales or slates. Thickness at Brigus South Head........	150
(*i*) Red and flesh-colored limestones, in which some obscure fossils have been found, and an Archæocyathus detected by Mr. Billings..............	20
(*h*) Red slate	30
(*g*) Thin bed of impure red limestone	10
(*f*) Red slate........	40
(*e*) Red, green, and gray sandstones, with occasional beds of conglomerate. The upper beds flaggy........	750
(*d*) Green and reddish brown or purple slates, with smooth and regularly parallel cleavage, independent of the bedding, splitting into slabs under half an inch thick. This is the position of the workable slates of Smith's Sound and Random Island........ 137	
(*c*) A bed of impure flesh-colored limestone 3	
(*b*) Green slate, same character as *d* 10	
	150
(*a*) Hard, dark green-gray sandstones with slaty divisions, the sandstone beds varying in thickness from 4 inches to 1 foot	600
Total........	5,972

On page 160 of the reprint of the report of the Geological Survey of Newfoundland for 1868[1] a section is given of the strata of Great Bell Isle, as follows:

ASCENDING.

	Feet.
(1) Black or dark brown shales, with thin beds of sandstone from 2 to 6 inches thick, of a gray color on fracture, mica being thickly disseminated in both shales and sandstones, and especially at the division of the harder members	20
(2) Thin bands of sandstone like the preceding, weathering a rusty brown color, and divided by layers of black shale........	6
(3) A hard, strong bed of gray sandstone, with conchoidal fracture, irregularly bedded, average thickness about	4
(4) Alternations of black shale and sandstone towards the top of the vertical cliff	60
(5) A heavy mass of strata, mostly sandstone, forms the crest of the cliff........	10
(6) Alternations of very micaceous gray sandstone and shale, the former mostly thin-bedded, varying from 1 to 6 or 8 inches, with Cruziana in great profusion on many surfaces. Nodular concretions, holding Lingulæ among the shales	100
(7) The upper strata are a good deal concealed, but beds of sandstone occasionally crop out on the bed and banks of a small brook near the line of section, some of which is of a pale yellowish color, in some cases nearly a foot thick, estimated........	196

[1] Murray, Alex.: Of the sequence and distribution of the formations. Report upon the geological survey of Newfoundland for 1868. St. John's, 1868. Revised edition, 1881.

	Feet.
(8) The upper stratum is also in great part concealed, but large, angular-jointed fragments of it are abundant on the surface all along the summit level, which are clearly in place, or only slightly removed. Some of these beds appear to be from 1 to 2 feet thick, are rather coarsely granular, of a grayish or greenish color on fracture, and contain crowds of organic remains, chiefly a species of Lingula. Estimated	80
Total	476

In No. 2 of this section I found, in 1888, a small species of Lingula (?), abundant remains of Cruziana, and an entire specimen of Olenus. Numerous trails of annelids occur on the surfaces of the sandstones, from one to six, inclusive.

Mr. E. Billings described the fossils obtained by the Newfoundland survey from Great Bell Island and named *Eophyton jukesi*, *Arthraria antiquata*, *Lingula murrayi*, *Lingulella ? affinis*, *L.? spissa*, and *Cruziana similis*.[1]

In the upper portion of No. 6 *Lingula murrayi* occurs in considerable abundance, and from No. 8 a large number of specimens of *Lingula spissa* were collected; *Eophyton linnæanum* Torrell and *Arthraria antiquata* occur in Nos. 2 and 4.

There is no detailed section given of the strata of Little Bell Island. The section, as determined by the writer in 1888, is made up of dark argillaceous and sandy shale, with beds of gray and dark sandstone, both thin-bedded and in massive layers. In the argillaceous shales *Lingula billingsiana* is very abundant and ranges through about 150 feet of strata. Toward the summit of the section on the west shore of the island a species of Hyolithes, and a long, slender shell, that may be provisionally referred to Lingulella, occurs in a light gray sandstone. A few feet below this horizon a new species of Lingula was found in a micaceous sandstone associated with the Lingula ? occurring below in the shales.

All the strata of Little Bell Island have a dip of about 7° westward toward Great Bell Island. If this dip be retained and the section be unbroken, the higher beds would pass beneath the strata on Great Bell Island, at a depth of about 1,200 feet. Dr. Murray in the generalized section mentioned, has given a thickness of 1,426 feet for the strata of Little Bell Island and that concealed beneath the waters of Conception Bay before reaching Great Bell Island.

A detailed section of the strata of Kelly's Island of what appears to be the same series as on Little Bell Island is published by Dr. Murray.[2] A small Lingula (*L. billingsonia*) was found midway of the 713 feet of strata. I found the same species to be very abundant in the shales of the lower portion of the Little Bell Island section.

[1] On some fossils from the Primordial rocks of Newfoundland. Canadian Naturalist, new ser., vol. 6, 1872, pp. 465-479.

[2] Of the sequence and distribution of the formations. Report upon the geological survey of Newfoundland for 1868. St. John's, 1868; revised edition, 1881, pp. 157-159.

The section on the mainland beneath Topsail Head, Conception Bay, was found to be as described by Dr. Murray.[1] The limestone at the base is separated from the "Huronian" rocks by a fault line. Over the limestone 100 feet or more of greenish shale completes the section. In the limestones were found:[2]

Obolella atlantica.	Microdiscus speciosus.
Kutorgina labradorica.	Microdiscus, sp. undet.
Scenella reticulata.	Olenellus (H.) bröggeri.
Hyolithellus micans.	Avalonia manuelensis.
H. micans var. rugosa.	Solenopleura bombifrons.
Hyolithes princeps.	Agraulos (S.) strenuus.
impar.	Agraulos (S.) sp. ?

In the superjacent green shales a few fragments of a trilobite were observed that indicated by a portion of the glabella and eye-lobe a large species of Paradoxides. The evidence here obtained of the relation of the Olenellus and Paradoxides faunas being somewhat inconclusive, the section at Brigus Head, on the west side of Conception Bay, was next examined and found to be essentially the same as that at Topsail Head, with the addition of a greater thickness of green and red shales above the limestone, and a sandy deposit beneath the limestone which rested unconformably against the "Huronian." The limestone series is divided into three bands. In the lowest, a specimen of *Hyolithes impar* was found, similar to that in the limestone at Topsail Head, associated with fragments of *Olenellus* (*H.*) *bröggeri*, *Microdiscus helena* and *Ptychoparia ?* sp. (?). In the second bed of limestone, fragments of trilobites were seen; and in the upper bed *Olenellus* (*H.*) *bröggeri* and *Agraulos strenuus* were observed, the latter in great abundance. No fossils were discovered in the superjacent slates.

The stratigraphic succession on Manuel's Brook, as measured by me in August, 1888, is as follows:[3]

MANUEL'S BROOK SECTION.

	Feet.
(1) Coarse conglomerate, in massive layers. The material next to the gneiss varies in size from bowlders of quartz and gneiss 6 feet in diameter down to small pebbles, and in the upper beds from pebbles to fine sand. Strike N. 80° E. (Magnetic); dip 12° to 13° N.	35
(2) Irregular beds of calcareous sandstone, siliceous limestone, and greenish-colored argillaceous shale, covering the irregular upper surface of the conglomerate .... Fossils: *Obolella atlantica*, *Hyolithellus micans*, *Helenia bella*, *Hyolithes princeps*, *H. impar*, *H. quadricostatus*, *H. similis*, *H. terranovicus*, *Scenella reticulata*, *Stenotheca rugosa*, varieties *acuta-costa*, *erecta*, *lævis* and *pauper*, *Platyceras primævum*, *Microdiscus helena*, *M. speciosus*, *Olenellus* (*H.*) *bröggeri*, *Avalonia manuelensis*, *Agraulos* (*S.*) *strenuus* and var. *nasutus*, *Solenopleura bombifrons*, *S. harveyi* and *S. howleyi*.	0 to 25

[1] Op. cit., p. 154.

[2] Walcott, C. D: Stratigraphic position of the Olenellus fauna in North America and Europe. Am. Jour. Sci, 3d ser., vol. 37, 1889, p. 378.

[3] Op. cit., pp. 380, 381.

		Feet.
(3)	Greenish argillaceous shale, conformably subjacent to 2	40
(4)	Reddish-colored argillaceous shale	4
(5)	Calcareous sandstone, with pinkish limestone in irregular masses	2
(6)	Green argillaceous shale with thin layers of hard, dark, ferruginous sandstone, interbedded at several horizons	270

Strike N. 80° E.; dip 12° N.

Fossils: Near the base the head of an Olenellus was found; also fragments of an Agraulos or Ptychoparia. At 218 feet from the base a layer of pinkish limestone contained the head of an Agraulos, like *A. strenuus*, and many fragments of trilobites. Fifty-two feet higher up quite an abundant fauna was found, and the following species were collected: *Lingulella* sp. *a.*, *Acrothele matthewi*, *Agnostus* sp. *a.*, *Agnostus* sp. *d.*, *Paradoxides hicksi*, *Conocoryphe matthewi*, and *Liostracus* sp. *a.*

(7)	Dark argillaceous shales with thin layers of limestone and sandstone at various horizons	295

Fossils: Zone A: From 10 to 20 feet from the base the following species were collected: *Lingulella* sp. *a*, *Linnarssonia misera*, *Acrothele matthewi*, *Hyolithes* sp. *a*, *Agnostus* 3 sp. *a*, *b*, *c*, *Microdiscus punctatus*, *Paradoxides hicksi*, *Conocoryphe* (*C.*) *matthewi*, *C. elegans*, *Agraulos socialis*, and *Liostracus tener*.

Zone B: Forty-five feet higher the fauna is much larger and includes: *Linnarssonia misera*, *Lingulella* sp. *a*, *Orthis* sp. ?, *Stenotheca* sp. ?, *Agnostus punctuosus*, *Agnostus* 5 sp. *b*, *e*, *f*, *g*, *h*, *Microdiscus punctatus*, *Paradoxides davidis*, *P. hicksi*, *Paradoxides*, sp., *Anopolenus venustus*, *Conocoryphe elegans*, *Ctenocephalus matthewi*, *Erinnys venulosa*, *Ptychoparia robbi*, *P. variolaris*, *Holocephalina inflata* and *Agraulos socialis*.

From 235 to 250 feet from the base a belt occurs in which a small species of Aristozoa occurs in large numbers, associated with *Lingulella* sp. *a*, *Agnostus* sp. ?, and the heads of a small *Ptychoparia* ? sp. undet.

(8)	Alternating bands of dark shale and dark, compact sandstone that carry a small species of Orthis in large numbers	400

The section is here cut off by the shore of Conception Bay.

The fauna of No. 2 is essentially the same as that of the limestones of the Topsail Head and Brigus sections, and proved conclusively that the Olenellus fauna is subjacent to the Paradoxides fauna.

Beneath the conglomerate beds of Manuel's Brook and between them and the subjacent Archean gneiss, there is, according to Messrs. Murray and Howley, a series of red and green sandstones, conglomerates and massive sandstone strata, which, according to their tabulated section, have a thickness of 1,800 feet. They are exposed on the north side of Trinity Bay and partially on St. Mary's Bay. I think we should have more data before deciding that this series of 1,800 feet is really subjacent to the Manuel's Brook conglomerate; although it is extremely probable that such is the case, judging from the character of the Trinity Bay and Conception Bay sections.

On the islands in the bay the Upper Cambrian horizon is well developed. In the lower arenaceous shales at Lance Cove, on Great Bell Island, were found *Eophyton* sp. ?, *Cruziana semiplicata*, *Arthraria antiquata*, *Olenus* sp. undet., and at a higher horizon, near the center of the island, *Lingulepis affinis* and *Lingula* ? *murrayi*, with fragments of Cruziana. In the sandstone at the summit of Little Bell Island, 20 feet above a band of sandstone carrying *Lingula ? billingsiana* and an elongate, narrow species of Lingulella, a long slender Hyolithes ? and a broad species of Hyolithes occur. In the dark argillaceous shales beneath *L. ? billingsiana* occurs in great numbers.

The conglomerate (No. 1 of the section) was traced, just north of the outcrop of the gneiss, a mile to the west of Manuel's Brook, and the shales and limestone of No. 2 were seen in a number of sections, resting directly upon it. On the brook the stratigraphic succession is unbroken up to the summit of No. 8, and the strata are conformable and undisturbed with the exception of the dip of 12° to the north.

The Manuel's Brook section is the only one known to me on the North American continent where the typical Olenellus and Paradoxides faunas occur in an unbroken stratigraphic section. The Olenellus fauna is well developed and typical, and the same is true of the Paradoxides fauna.

As shown on the Avalon Peninsula the early Cambrian Sea transgressed across all the pre-Cambrian rocks, including the Aspidella slates and Signal Hill sandstone and the great series of altered slates and sandstones and, subjacent to them, the Laurentian gneisses. This unconformity is of a similar type to that between the Algonkian formations of the Lake Superior and Adirondack regions and the Upper Cambrian sandstone. In each, three groups of rocks have been deposited and subsequently elevated by an orographic movement and eroded before the deposition of the Cambrian sediments. The relations of the Cambrian and pre-Cambrian rocks are all well shown upon the geological map of the peninsula of Avalon, Newfoundland, 1881, prepared by Mr. James P. Howley.

NOVA SCOTIA.

It is very probable that the Cambrian group is represented in the gold-bearing slates of the Nova Scotia section, but as yet the only means of correlation is the supposed stratigraphic position. The principal details and arguments for including this series in the Cambrian have already been given under the historical review. (Ante, pp. 56–59.) It may be that they represent in large part a pre-Cambrian, Algonkian group equivalent to the St. John slates of Newfoundland.

NEW BRUNSWICK AND CAPE BRETON.

Our present knowledge of the Cambrian geology of the area under consideration is obtained from the reports of the Geological Survey of Canada, and the numerous papers on the geology and paleontology of southern New Brunswick by Mr. G. F. Matthew.

In the report of the Geological Survey of Canada for 1870–'71, a detailed description is given of the geographic distribution of the St. John group (pp. 134–143); and other details are added in the report for 1878–'79 (pp. 6D–8D). From these reports and the map accompanying the latter, Mr. G. F. Matthew has compiled a summary of the information relating to the St. John terrane. He says:[1]

The strata of the St. John group fill a number of narrow, trough-like basins, lying between the Bay of Fundy and the central carboniferous area of New Brunswick. Of these basins, that on which the city of St. John is situated is the most important, and it is here also that the life of the period can be studied to the best advantage. The St. John basin lies diagonally across the ridges of Huronian rock that are found in the eastern part of St. John County and touches the ridge of Laurentian rocks that divides this county from King's. As might naturally be expected, the coarser sediments found at the base of the St. John group are largely derived from those older rocks, chiefly the Huronian; and the line of division between it (the St. John group) and the Huronian formation is marked by conglomerates of mechanical origin which show no trace of the hardening process by which the Huronian conglomerates and breccias have been so firmly cemented.

The Conglomerates of the St. John group are most fully developed in the eastern part of the St. John Basin, under the lee of the high ranges of Huronian hills which exist in that direction. In Portland and the city of St. John, at the western end of the basin, the following section represents the succession of members in this group in ascending order:

	Feet.
Division 0:	
(*a*) Red Conglomerate—wanting at that part of the basin where this section was made	
(*b*) Red and green sandy slates	150
Division 1:	
(*a*) Coarse gray sandstone or quartzite	50
(*b*) Coarse gray sandy slate (Linguloid shells)	50
(*c*) Fine gray and dark gray slaty shales (Trilobites, etc.)	25
(*d*) Fine black carbonaceous slaty shales (Trilobites, etc.)	75
Division 2:	
(*a*) Dark gray slates with thin seams of gray sandstone	220
(*b*) Coarse gray slates and gray flagstones	200
(*c*) Gray sandstones and coarse slates (Linguloid shells)	130
Division 3:	
(*a*) Dark gray finely laminated slates	450
(*b*) Black carbonaceous and dark gray slates, less fissile than the last	300
Division 4:	
Slates and flags, resembling 2*a* and 2*b* (Linguloid shells)	800
Division 5:	
Black carbonaceous slate like, 3*b* (Orthids, Trilobites, etc.)	450
	2,900

Beyond Division 5 the beds are supposed to be repeated by an overturn, and have a width across nearly vertical measures of 3,000 feet. Owing to this folding of the measures there is some uncertainty as to where the summit of the formation is, and the section given may not include the whole series of deposits. The faunæ of Divisions 2 and 5 are very imperfectly known, but there are much larger species of Linguloid shells in these divisions than in Division 1, and the orthids of Division 5 are different from *Orthis billingsi* of Division 1.

The Conglomerate at the base of the St. John group marks the time when the sea of the Acadian epoch invaded the valleys of the Huronian formation near St. John. No trace of life has yet been found in these coarse sediments, nor in the red and green

[1] Illustrations of the fauna of the St. John group. Royal Soc. Canada, Proc. and Trans., vol. 1, section 4, 1883, pp. 87-108. Supplementary section, pp. 271-279.

slates into which they pass. After the colored mud of which these slates are composed was deposited, an abrupt change took place in the character of the deposit, and white sands were evenly spread over the whole basin. It is in the upper part of these sands that one meets with the earliest traces of primordial life. These first forms are linguloid shells of several genera. Such shells become more abundant in the upper part of the white and gray sandy beds, and were evidently littoral species, as on tracing the sandstones westward for half a mile they are found to change into a gray slaty and pebbly deposit—evidently an old beach line—and finally disappear.

Probably the physical condition of the St. John Basin at this early period was unfavorable to the growth of the trilobites; but the land was sinking, and an additional depth of water in this sheltered area soon encouraged the growth and multiplication of the crustacean fauna. As the sediment which settled from the sea water in this deepening bay became finer, the remains of marine animals were preserved in greater numbers and variety, so that in the layers of fine slate in Group *c* of Division 1, many genera chacteristic of the early Cambrian age are found.

In Group *d* the slaty mass becomes quite fine and dark colored, but near St. John is much affected by slaty cleavage, and the fossils are so much distorted, especially in the upper part, as to be unrecognizable.

In the beds of Division 2, a return of littoral conditions, and the influx of sand, interfered with the prosperity of the crustacean fauna, and as in the lower sand beds of Division 1, linguloid shells become the prevailing fossils. The Paradoxides which I will describe in this article are those of the intermediate mud beds, now converted into a mass of slaty rock (Division 1, *c*).[1]

On the evidence of the contained fauna, Mr. Matthew correlated the fauna of the Paradoxides zone of the St. John group with that of the Solva group of Wales, as defined by Dr. Hicks.[2]

In addition to the section as found at St. John there is to be added a series described by Mr. Matthew, occurring below Division 1, on Hanford Brook, in the eastern part of St. John County. In the report upon the geology of southern New Brunswick, by L. W. Bailey, in 1865, this mass of sediments was spoken of as the upper member of the Coldbrook group and distinct from the St. John group; it was subsequently joined to the St. John group by Messrs. Bailey and Matthew in a report of progress of the geological survey of Canada, 1870–'71, p. 59, because the want of conformity existing between the two formations could not then be established; but it is now found that this series is unconformable not only to the St. John group, but also, as had been previously discovered, to the underlying Coldbrook group.[3] The section is as follows:[4]

	Thickness in feet.
1 (*a*) Coarse purplish red Conglomerate, resting on an amygdaloidal greenstone (toadstone) of the Coldbrook group	60
(*b*) Gray and purplish flags and sandstones with worm-casts, seaweeds (Palæochorda and Buthotrephis), and numerous spicules of sponges	70
(*c*) Purplish red sandstones, with greenish layers. Remains of seaweeds (Phycoidella), animal tracks (Psammnichnites and Helminthites), worm-burrows (Arenicolites) etc	240

[1] Op. cit., pp. 87–89.

[2] The geologic age of the Acadian fauna. The Primitive Conocoryphean. British Assoc. Rep., 54th meeting, 1884, pp. 742–744.

[3] On a basal series of Cambrian rocks in Acadia. Canadian Record Science, vol. 3, 1888, p. 22.

[4] On Cambrian Organisms in Acadia. Royal Soc. Canada, Trans., vol. 7, Proc., sec. 4, 1890, p. 138.

		Thickness in feet.
2 (*a*)	Purplish red Conglomerate, more friable than 1 *a*	35
(*b*)	Soft purplish red shales, with green glauconite grains, the upper part firmer and more sandy, greenish gray layers interspersed especially towards the base. Platysolenites, Obolus, Volborthella, etc	175
(*c*)	Purplish sandy shales, with a few bands of greenish shale. Worm-casts (Scolites)	300
	Measures concealed, probably of this series	320
		1,200

In this series of 1,000 or more feet of beds, the very oldest layers which are fine enough to preserve organic markings, have trails and casts of marine worms, and also contain seaweeds, one a Palæochorda or allied genus, the other a weed with a flat frond similar to Buthotrephis. That these beds are marine is clearly shown by the great numbers of spicules of hexactinellid sponges which they contain.

About 350 feet above the base, where the measures are flaggy, tracks of annelids are again abundant. Besides the smaller trails and burrows, there are frequent tracks of a marine animal, possibly a worm, similar to the markings on the Fucoidal sandstone of Sweden, which, by Prof. O. Torrell, have been referred to the genus Psammichnites. A very similar track, with corresponding casts, occurs on the surfaces of the purple streaked sandstones (Assise 3) of Band *b* in Division 1, of the St. John group, and a similar trail occurs as high up as the lower band of Division 2 of that group. Above this point, such markings have not been found, though the kind of rock—flags and slates—is favorable to their occurrence. The flags of the middle of Division 2, of the St. John group, seem to be the horizon of *Cruziana semiplicata* (Salter) and *C. similis* (Billings); but I have not found them here.

About 100 feet or more above the horizon where Psammichnites appears, separated from it by a Conglomerate, indications of the Olenellus fauna show themselves. These consist of Volborthella (a chambered cell resembling an Orthoceras), the cystidean genus Platysolenites, Pander, and a large Obolus, allied to *Michwitzia* (formerly *Obolus?* or *Lingula?*) *monilifera*, Linrs., of the Eophyton sandstone of Sweden and the upper part of the "Blue Clay" of Russia. Some of the layers in this part of the series abound in soft green grains similar to the glauconite grains of the Cambrian rocks in Russia. The paste enveloping them is red.

A number of beds between this point and the top of the Basal series contain worm-casts and burrows, and some have remains of small strap-like seaweeds.

In summing up the facts bearing on the comparative age of this part of the Cambrian rocks in Acadia we get no aid from the typical genera of this horizon, Olenellus and Mesonacis, but the Acadian rocks contain other genera of this fauna which serve to fix their age with a certain degree of accuracy. Some of these genera, however, are such as may have a wider range of existence in time than the trilobites, and therefore are not of the same homotaxial value. The trilobites that do occur are not so definitive as some others.[1]

In his latest table of classification Mr. Matthew arranges the Cambrian System as it occurs in Acadia as follows:[2]

	Localities.
D.—Upper Cambrian (Potsdam series)	Unknown.
C.—Middle and Lower Cambrian, Acadian series	St. John, etc.
B.—Lower Cambrian, Georgian series	C. Breton.
A.—Basal Cambrian, Etcheminian series	St. John, etc.

[1] Op. cit., p. 143.

[2] On the classification of the Cambrian rocks in Acadia. No. 2. Canadian Record of Science, vol. 3, 1889, p. 310.

In describing in 1888 (at that time called series B) the Paradoxides zone, or C of the preceding tabulation, the term "stage" replaces the word "division" as heretofore used by Mr. Matthew, and the divisions of the series are given as follows:[1]

Stage 1.—This includes the lower part of the series as high up as Paradoxides are found. The divisions of this stage are as follows:—

Band (assise) *a*. Hard gray sandstone or quartzite. Fossils, none known.

Band (or assise) *b*. Dark-gray sandstones and gray sandy shales. Fossils: Ellipsocephalus, Agraulos, Hipponicharion, Beyrichona, etc.

Band (or assise) *c*. Gray shales. Fossils: Paradoxides, Conocoryphe, Liostracus, Microdiscus, Agnostus, etc.

Band (or assise) *d*. Dark gray shales. Fossils: Paradoxides, Ptychoparia, Solenopleura, Microdiscus, Agnostus, etc., of different species from those in assise *c*.

Stage 2.—This consists of gray flags and sandy shales. The subdivisions have not been worked out, but the stage corresponds to the lower half of the Olenus zone in Europe. No species of the genus Olenus have been found in it.

Stage 3.—Dark-gray and black shales. Fossils: Ctenopyge, Kutorgina, Orthis, etc. This corresponds to the upper half of the Olenus zone of Europe. The shales in Cape Breton, which contain Peltura and Sphæropthalmus, belong here. There are in the St. John Basin gray flags, which overlie the Ctenopyge beds, but no higher stage than the Olenus zone has been established by fossils.[2]

In a series of sections of Cambrian rocks in Acadia,[3] the upper Cambrian or Olenus beds are shown to be present in St. John County in the Portland section.

Just as this report is going to press (May 1, 1891) I received the fifth contribution of Mr. G. F. Matthew upon the fauna of the St. John Group. In the introduction he gives a description of the structure of the St. John basin and sections of the measures at St. John. He finds that all three of his divisions of the Cambrian are present. Division 1 he names Acadian, Division 2 Johannian, and Division 3 Bretonian.[4]

The Cambrian rocks of Cape Breton Island are described with many details by Mr. Hugh Fletcher in 1877 and 1878, but the various outcrops do not appear to have been well correlated. The section in McLean Brook, on Little Bras d'Or Lake, is as follows:[5]

	Feet.
(1) *Carboniferous conglomerate* and related rocks	
(2) Feldspathic sandstone and impure limestone, of white, green, amber, red, and other colors, mixed, and in distinct beds of different thickness; sometimes associated with greenish, soft, soapy rocks, probably decomposed felsites; films of hematite in the joints	254

[1] On the classification of the Cambrian rocks of Acadia. Canadian Rec. Sci., vol. 3, 1888, p. 73.

[2] Mr. Matthew writes me under date of October 25, 1890, that he has found the Arenig graptolitic fauna in the St. John series, thus establishing the presence of the Lower Silurian (Ordovician) fauna above the Olenus zone.

[3] Matthew, G. F. On the classification of the Cambrian rocks in Acadia. No. 2. Canadian Rec. Sci., vol. 3, 1889, p. 308.

[4] Illustrations of the fauna of the St. John Group, No. 5. Royal Soc. of Canada, Trans., vol. 8, 1891, p. 129.

[5] Report on the geology of part of the counties of Victoria, Cape Breton, and Richmond, Nova Scotia. Geol. Sur. Canad. Rept. Prog. for 1876–'77. Montreal, 1878, p. 431.

	Feet.
(3) Blackish and gray slate, fine sandstone, and argillaceous limestone; also, compact, feldspathic rock, mixed with limestone of different colors. Not well seen	84
(4) Dark and pale gray slates, with thin layers of quartz, spotted with iron pyrites and mined for gold	66
(5) Greenish gray, fine-grained, pyritous rock, resembling sandstone and yielding easily to the knife	19
(6) Black and gray argillite, full of small twisted layers of quartz, which are sometimes so numerous as to constitute an impure quartzite, spotted with pyrites. Associated with and overlie dark-blue, plumbaginous argillite, also full of pyritous quartz layers	65
(7) Bluish-gray, pearly, papery slates, cleft in every direction and traversed in the bedding and across it by streaks of calcspar and quartz	30
(8) Bluish felsite, crystalline limestone and quartz, confusedly mixed in contorted beds	37
(9) Bluish-gray coherent argillite	60
(10) Greenish, decomposed, feldspathic rock, of uncertain thickness	110
(11) *Red syenite* in steeply rising hills	
	725

The Cambrian rocks occur as long narrow areas resting on the subjacent Laurentian rocks, as shown on the map accompanying Mr. Fletcher's report of 1876–'77; and on the map accompanying the report for 1875–'76. In the text of the latter report the rocks are described as they occur on St. Andrew's Channel, and the geographic distribution is given on the map. From a small outcrop on the Mira River a collection of trilobites was obtained that indicate the upper Cambrian fauna. They include, as identified by Mr. Matthew, *Peltura scarabeoides*, *Sphærophthalmus alatus*, and *Agnostus pisiformis*.[1] It is not certain that all the rocks referred to the Lower Silurian by Mr. Fletcher belong to the Cambrian group, but as far as known all the fossils that have been found indicate the upper Cambrian series.

MAINE.

The presence of typical rocks of the Cambrian group in the State of Maine is not yet proved. It is quite probable, as in the case of Nova Scotia, that the series of slates referred to the Cambrian actually belong at that horizon. But until paleontologic evidence is obtained, the question will be an open one. The stratigraphic position of the slates and their lithologic character enable us to speak of them tentatively as belonging to the Cambrian group. That they were deposited in the same basin as the Cambrian series of New Brunswick and Massachusetts is not probable.

NEW HAMPSHIRE.

All the references of strata to the Cambrian group in New Hampshire are of a provisional character. They are based upon more or less im-

[1] On the Cambrian faunas of Cape Breton and Newfoundland. Royal Soc. Canada, Proc. and Trans. vol. 4, sec. 4, 1887, p. 147.

perfectly determined stratigraphic horizons and the fact that there is a thick mass of sediments, usually without fossils and largely argillaceous in character, that appear to be pre-Silurian in age. By their lithologic character they are correlated with formations referred to the Cambrian group, as found in Maine and Nova Scotia, that have similar lithologic characters and occur in a similar stratigraphic position. All these doubtful formations are in turn correlated by their lithologic characters and supposed stratigraphic position with the Cambrian beds of Newfoundland and New Brunswick.

In speaking of the Mica-schist series of New Hampshire, Prof. C. H. Hitchcock says[1] that there unquestionably exists an enormous thickness of mica-schists in southern New Hampshire above the Huronian series. "No author who has devoted any attention to these groups has suggested an inferior position for them. They may be called Silurian, Cambrian, or pre-Cambrian, according as each author is inclined to regard New England, very ancient, or on the verge of the Paleozoic."

It is doubtful if these exposures should be referred to the Atlantic Coast Province. It is done at present as a matter of convenience.

EASTERN MASSACHUSETTS.

The description of the Cambrian rocks of the Boston Basin, by Prof. W. O. Crosby, is the most recent and the most thorough of any we have, and the summary of our present knowledge of them is taken mainly from his paper. He says:[2]

> The oldest rocks which we have found are the Primordial slates and quartzites, and the age of these is certainly and definitely known only at the Paradoxides quarry, in Braintree. We appear to be justified, however, in regarding them, provisionally at least as all of about the same age, partly on account of a general lithologic resemblance, but mainly because their relations to the different classes of eruptive rocks are everywhere the same. In Weymouth and Braintree, where we first met these rocks, they are either typical clay slates or slightly calcareous; but along the northern base of the Blue Hills occasional layers are distinctly siliceous. They probably underlie a large part of the Boston Basin, being covered by the conglomerate and the newer slate; and north of the basin, as shown in the ninth lecture, they occur in isolated areas among the eruptive rocks. In some of these areas, especially in the Middlesex Fells and Melrose, and in Woburn, clay slate similar to that in Quincy and Braintree is repeatedly interstratified with quartzite, while toward the southwest, in Natick, and also in Reading and Lynnfield, there are extensive developments of quartzite with little or no slate. It is very clear that the quartzite north and west of the Boston Basin is the source of the quartzite pebbles which play such a prominent part in the composition of the conglomerate, especially in the central and northwestern sections of the basin. In general, the quartzite is more and the slate less abundant northwestward, indicating that the ancient shore line along which these strata were deposited lay in that direction, and originally the Primordial strata were probably spread continuously over all the region to the southeast of that line.

[1] Geological sections across Vermont and New Hampshire. Am. Mus. Nat. Hist. Bull., vol. 1, 1884, p. 168.

[2] Physical History of the Boston Basin. Lowell free lectures, 1889-1890. Boston, 1889, pp. 19, 20.

The deposition of the Primordial strata was followed by a period of disturbance of this part of the earth's crust, during which they were strongly compressed, being thrown into sharp folds having, in general, a northeast and southwest direction. This appears, also, to have been a period of intense volcanic activity. The quartzite and slate were shattered and isolated by great volumes of basic lava, which we now call diorite; and, as indicated by the compact and scoriaceous diorite of the Middlesex Fells and other localities, immense floods of lava were also poured out on the surface, concealing the sedimentary rocks. In breaking through the quartzite and slate, the diorite has often followed the planes of stratification in those rocks, and thus appears in many cases to be regularly interstratified with them; and this bedded appearance of the diorite is greatly increased by the very perfect flow-structure which was developed in large masses of it, as well as by the distinctly schistose or foliated structure sometimes resulting from the subsequent action of both mechanical and chemical forces. We are thus able to explain the fact that the diorite has been frequently mistaken for a stratified or sedimentary rock.

The eruption of the diorite was probably followed by a prolonged period of quiet erosion, which was finally terminated by the advent of a second period of intense and long continued igneous action, during which only acid rocks—the granites and felsites—were formed. All over this region the granite has broken through the Primordial strata and the diorite in the most irregular and intimate manner.

Prof. Crosby considers that after the deposition of the argillites and the eruption of the rocks occurring as dikes the series was raised above the sea level and subjected to long-continued erosion, prior to a downward movement or subsidence. As the surface passed slowly below the level of the sea a thick bed of conglomerate was spread over the earlier series of rocks and a fine silt or clay carried out into the deep water of the ocean. At the same time eruptive rocks were repeatedly poured out over the sea floor, where the beds of gravel and sand were accumulating, thus forming alternating beds of conglomerate and sandstone with beds of melaphyr and porphyrite.[1]

Of the subsequent depositions of sediment, he says:

Alternations of the conglomerate with beds of both sandstone and slate are also of common occurrence, indicating oscillations of level during this period. But the downward movement prevailed, until finally the water became too deep and quiet and too remote from the shore, in this vicinity, to permit the formation of conglomerate and sandstone; but these coarse sediments were gradually replaced by slate during the dying out of the volcanic activity. These tranquil, deep-sea conditions must have continued for a very long time, for the argillaceous sediments accumulate very slowly and yet the slate series has a thickness of from 500 feet to fully 1,000 feet or more. The slates are probably somewhat thicker than the conglomerates, and were doubtless several if not many times longer in forming. Of the life existing in the sea at this time we unfortunately know but little, as the slate is very generally destitute of fossils; and the full chronologic significance of the few organic remains that have been obtained from the layers of limestone in the slate at Nahant is still undetermined.[2]

There is evidently an error in Prof. Crosby's interpretation of the stratigraphic succession of the formations he describes, as the fauna at Nahant is of an older date than that found in the argillites at Braintree. If, however, the conglomerates, with their contemporaneous eruptive

[1] Op. cit., p. 20.

[2] Op. cit., p. 21.

rocks, belong to the same series as the East Point slate and limestone the entire series must be referred to the Cambrian.[1]

In his report of 1880 Prof. Crosby considers that the strata of the Boston Basin were deposited in a depression excavated in the crystalline formations and that there are several formations belonging to the Cambrian. First, a conglomerate, represented by the Roxbury puddingstone. Second, a slate series which incloses the Paradoxides zone in South Braintree. He assigns to the conglomerate a maximum volume not exceeding 1,000 feet, and considers that the greatest thickness of the slate can not be much less than that of the conglomerate, although in some cases certainly falling below 500 feet.[2] At the trilobite quarry in Braintree, the known locality of Primordial fossils, the slate is described as of a greenish gray color, "somewhat siliceous, fine-grained, and remarkably uniform. Minute grains of pyrite are pretty generally diffused. In the quarry the rock is apparently only very coarsely jointed; but the weathered surface reveals much finer division by this means. The stratification is very massive and can hardly be detected, except by means of the trilobite remains; these may be supposed to lie in the plane of the bedding, and according to this indication the strike is E.–W., and the dip S. 80°–85°. Across the strike, southerly, the slate, still apparently maintaining a high dip in that direction, is met at a distance of perhaps 300 feet by fine-grained grayish and reddish Huronian granite, while on the west the same granite cuts off the slate at about twice the above distance from the trilobite quarry; that is, the contact of the two formations, as shown on the map, is oblique to the strike of the slate."[3] On the map the slate series throughout the Boston Basin is correlated with the slates at Braintree, and represented by a common color.

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[1]In a letter received from Prof. Crosby, dated January 27, 1891, he says: "The Nahant slate is entirely isolated, and concerning its relations to the conglomerate we *know* nothing. I have supposed, however, that it should be referred to the newer series, above the conglomerate." Of the general geology of the Boston Basin he says:

"Assuming that the slates of the Boston Basin now *known* to be Cambrian are overlain in succession by the conglomerates and a newer slate series (my present working hypothesis), it is still possible, I suppose, that all these rocks, in the Boston Basin, may be Cambrian; notwithstanding the marked uniformity between the conglomerate and lower slates.

"The weak points in the stratigraphy are (1) the general (not entire) absence of slate pebbles in the conglomerate; (2) the absence of clear sections showing the conglomerate resting upon a lower slate series. Wherever the base of the conglomerate is seen, it reposes *upon* the *granite* or *felsite.* Some of the sections are *very clear* and unmistakable in this respect; and apparently the same granite and felsite are eruptive through the Braintree slates. It would, of course, be difficult to *prove* that the granites and felsites are all of the same age; but it seems best to assume that until the contrary clearly appears.

"The best general statement of the stratigraphy of this region appears therefore to be this: A lower slate, known to be Cambrian; cut in succession by diorite, granite and felsite; all these rocks overlain *un*conformably by the conglomerate of unknown age; and the conglomerate in turn overlain conformably by a newer slate of unknown age.

"The chief problems are, then, to determine which are older and which are newer slates, and to determine the age of the conglomerate and upper slate.

"As an indication of progress, we have the discovery by Mr. Woodworth, just reported, of fossils in the slate of both Somerville and Newton."

[2]Contributions to the geology of Eastern Massachusetts. Boston Soc. Nat. Hist. Occasional papers, No. 3, 1880, p. 266.

[3]Op. cit., p. 192.

According to Dr. M. E. Wadsworth[1] the strata at the trilobite quarry dip a little west of south at an angle of 55°. This is nearly as given by Mr. Isaac Lea in 1858.[2] It is quite probable that the variation in angle of dip mentioned by different observers is owing to the position of the exposures in the quarry, at the time of their respective visits, and by their mistaking the cleavage for the plane of bedding.

Dr. Crosby[3] describes the rocks at East Point, Nahant, as composed of a very dark gray, almost black, compact slate, with a strike N. 60° E.; and nearly uniform northerly dip of about 40°. The slate is inclosed in, and extensively cut by, the coarsely crystalline pyroxenic rock of the Naugus Head series. The slate, except where it is vesicular, is of a uniform grayish black color and holds thin beds of limestone aggregating, perhaps, 20 feet of calcareous matter. The character of the limestone and its mode of occurrence are precisely like those of Mill Cove, in Weymouth, 13 miles distant. The limestones are interstratified with the slate and not always distinguishable from it. The color is light gray and its texture varies from compact to finely crystalline or saccharoidal. Thin seams and veins of siliceous material become evident on the weathered surface.

In the interbedded limestones Mr. A. F. Foerste discovered in 1889 traces of a species of Hyolithes which he identified as specifically the same as a species found in the decomposed limestones of North Attleborough[4] He proposed the name *Hyolithes inæquilateralis*, but I think it is identical with *Hyolithes communis*, var. *emmonsi*, of the Lower Cambrian horizon at Troy, New York. He states that the Nahant limestones are the equivalent of the red slates in North Weymouth; and that it is very probable the red slates and included limestones are stratigraphically beneath the Braintree Paradoxides beds. Also that the red slates of Mill Cove, in North Weymouth, are of Olenellus age and beneath the Paradoxides strata.

The district embracing the Cambrian rocks of Bristol County, Massachusetts, is well described by Prof. N. S. Shaler. He says:

Several geologists have observed the fact that between Providence, Rhode Island, and Wrentham, Massachusetts, we have an extensive development of interbedded conglomerates, shaly slates, and sandstones, the whole separated from the other detrital deposits of this region by peculiarities of color. * * * Various conjectures have been made as to the age of these deposits. They have been thought by one observer to resemble the Trias, while others, owing partly to their position, have assigned them to the Devonian age.[5]

Prof. Shaler discovered fossils of the Lower Cambrian or Olenellus zone in this series of rocks in 1883, which for the first time gave data

[1] On the relation of the Quincy granite to the primordial argillite of Braintree, Massachusetts. Boston Soc. Nat. Hist. Proc., vol. 21, 1883, pp. 274–277.

[2] [On the trilobite formation at Braintree, Massachusetts]. Phil. Acad. Sci. Proc., vol. 9, 1858, p. 205.

[3] Contributions to the geology of Eastern Massachusetts. Boston Soc. Nat. Hist. Occasional papers, No. 3, 1880, pp. 195, 261, 262.

[4] The Paleontological horizon of the limestone at Nahant, Massachusetts. Boston Soc. Nat. Hist. Proc., vol. 24, 1889, pp. 261–263.

[5] On the geology of the Cambrian district of Bristol County, Massachusetts. Bull. Mus. Comp. Zool., Harv. Col., vol. 16, 1888, pp. 13, 14.

for determining the geologic age of the deposit. On the east the Coal Measures of the Narragansett Basin occur. On the west side he considers the rocks to be of pre-Cambrian age, as they consist mainly of gneissoid rocks of various composition, and a great area of dark greenish chloritic deposits which appear in part at least to be metamorphosed conglomorates and shales. Owing to the large amount of drift material covering the country, no absolute contact with the pre-Cambrian rocks was observed, nor is the overlap of the Carboniferous upon the Cambrian shown in any section.

Of the rocks he says:

The Cambrian rocks exhibit very little sign of metamorphic action. The shales indicate a slight amount of infiltration, and in the conglomerates the pebbles all retain essentially their original character, save that they are sometimes slightly indented one into the other. The cement of the mass is not more altered than is usual with our unchanged conglomerates. Its general characters, save for its reddish color, is undistinguishable from the deposits of Millstone grit age in the neighboring coal fields.[1]

So far fossils have been found in rocks of this section which probably do not in the aggregate include more than 100 feet or so of the total section of the Cambrian series. However, as these deposits are of the same aspect, as all the red slates and conglomerates of the area, it appears at present reasonable to include all rocks of this description with the above-mentioned series. The total thickness of the section which I have termed Cambrian is not accurately determinable. It probably amounts to not far from 2,000 feet. In the main it consists of thin bedded shaly layers which occasionally pass into moderately thick, fine grained, greenish and reddish slates. Intermingled with these in several levels we have a number of layers of conglomerate, perhaps as many as half a dozen distinct beds, varying in thickness from 200 to 300 feet. In all cases these conglomerates are frequently interrupted by thin layers of shale or sandstone. * * * The rocks from which the pebbles were taken are mainly identifiable in the western portion of the field before described.[2]

The sediments composing this Cambrian section appear to have been derived from rocks substantially the same as those which now lie in the field west of the area. Although fossils have been found in a small part of the section, close study makes it plain that by far the greater portion of the strata are clearly azoic. The frequent return of conglomerate layers and the coarseness of the pebbles show that during most of the time when the beds were accumulating the region was near shore; so, too, the large amount of sandy matter even in the slates affords a presumption that the region was not remote from the coast line. About 100 feet of shale beds have been subjected to a very careful search for organic remains. The total thickness of the deposits in which any trace of life has been found probably does not exceed 100 feet, and even in this section only a small part of the rocks actually contain fossils.[3]

Prof. Shaler suggests that the conglomerates were accumulated during an ice epoch; and he presents several arguments for this view. He states that the relations of the beds carrying the fauna at North Attleborough with those of the Paradoxides zone of Braintree are not discoverable by comparison with the Massachusetts Bay and Narragansett deposits. At the time he wrote the stratigraphic relation of the Olenellus fauna as found at North Attleborough with the Paradoxides fauna was not known, except that the Scandinavian geologists state

[1] Op. cit., pp. 16, 17. [2] Op. cit., p. 18. [3] Op. cit., p. 20.

that in their country, the Paradoxides zone occupied a superior position to the Olenellus zone. With the knowledge we now have of the stratigraphic succession of the Cambrian faunas, the Paradoxides beds of Braintree are considered to be superior to the Lower Cambrian rocks of Attleborough.

RÉSUMÉ.

The physical characters and condition of the rocks constituting the formations referred to the Cambrian in this province indicate that they were accumulated not far from the shore line, and that several fluctuations in the level of the sea bed occurred during Cambrian time. On the coast of Labrador the accumulation of sand was followed by a deepening of the sea and the deposition of calcareous mud. That the depth was not profound, is shown by the character of the limestone and its fauna, and the presence of lenticular masses of red and green shale. The 231 feet of sandstone, and 140 feet of limestone in the section represent only a portion of the Lower Cambrian or Olenellus zone. Two hundred miles to the south, on the west coast of Newfoundland the presence of 605 feet of slate beneath the alternating series of limestone and quartzite, over 1,000 feet in thickness, tell the same story of relatively shallow water accumulation.

On the Atlantic coast side, at Canada Bay, there are 2,500 feet of slate, conglomerate and eruptive rock, subjacent to a series of limestones and slates nearly 3,000 feet in thickness. There is here a greater development of limestone than anywhere to the south along the Atlantic coast line. It appears to have accumulated upon the bed of a protected sea not far distant from the shore and to have been frequently interrupted in deposition by the throwing down of a considerable thickness of argillaceous mud.

In southeastern Newfoundland the assembled sections have, according to Messrs. Murray and Howley, a thickness of nearly 6,000 feet, of which 128 feet are limestone, and the remaining portion argillaceous and arenaceous deposits. In the section on Manuel's Brook a conglomerate rests upon the pre-Cambrian gneiss, and upon the upper bed an irregular, arenaceous limestone in which layers of more or less pure limestone occur. This limestone-forming epoch was of very short duration, and was succeeded by an accumulation of clay that now forms a series of shales nearly 1,000 feet in thickness before sandy layers appear. When once the sandstones begin to alternate with the shales, they continue on up to the summit of the group and are very abundant in the Upper Cambrian. The sediments of southeastern Newfoundland were accumulated in bays of the pre-Cambrian sea and derived almost entirely from the adjacent shore, either as sand and silt, worn from the rocks by the sea, or brought down to it by tributary streams.

The 4,000 feet or more of rocks in the New Brunswick section are almost entirely shales with a few sandstones and basal conglomerates.

It is the record of the accumulation of sediments in a gradually deepening sea.

The eastern Massachusetts section is largely formed of shale, except in the lower part, where a small proportion of limestone occurs in the Olenellus zone, much as in the southeastern Newfoundland section.

The great thickness of shales referred to the Cambrian in Nova Scotia, Maine, and New Hampshire probably represents much more than the Cambrian group, or it may be entirely a pre-Cambrian formation or a post-Cambrian formation. It is only *probable* that they are of Cambrian age. They may represent deep-water accumulations in which no organic remains were buried.

As a whole, we may regard the Atlantic Coast Province, during Cambrian time, as including bays and the adjacent shores of the Algonkian land, in and along which sediments, mostly of an argillaceous and arenaceous character, accumulated. The relative level of the sea bed varied, but in the main the depression greatly exceeded the elevation. The depth of water in which the sediments forming the limestones and shales accumulated was probably considerable, but not a deep sea in the present sense of the term. A few hundred or a thousand feet on a gradually sinking sea bed (in relation to the coast line) would give the required conditions. From the character of the sediments and the faunas it is probable that land barriers existed to the eastward of the present coast, and that none of the deposits were accumulated off the shore facing the open ocean.

As left by erosion the Lower Cambrian now occurs on the Labrador coast, on the western and eastern sides of Newfoundland, in New Brunswick, and eastern Massachusetts. The Middle Cambrian has been recognized on the eastern coast of Newfoundland, in New Brunswick, and eastern Massachusetts. The Upper Cambrian is known in southeastern Newfoundland, Cape Breton Island, New Brunswick and doubtfully on the southwestern coast of Newfoundland. (See Pl. II.)

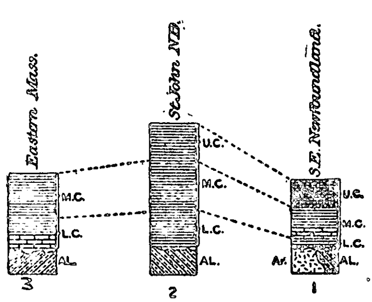

FIG. 1.—Typical sections of the Atlantic Coast Province. Vertical scale, 6,400 feet to the inch.

APPALACHIAN PROVINCE.

The Appalachian Province includes the outcrops of Cambrian strata on the line of the Appalachian System of Mountains, from the Gulf of St. Lawrence on the north to Georgia and Alabama on the south.

For convenience in presenting geologic data the Appalachian Province is divided into:

A.—Northern Appalachian District.

B.—Southern Appalachian District.

NORTHERN APPALACHIAN DISTRICT.

The Northern Appalachian District includes the Hudson River and Lake Champlain area, east of the river and lake, and an extension northeastward into Canada as far as the vicinity of Cape Rosier on the Gulf of St. Lawrence.

The geographic distribution of the Cambrian strata of the Northern Appalachian District, south of the Canadian extension, is delineated on a geologic map of eastern New York and western Vermont published in 1888 by Mr. C. D. Walcott.[1] On this map the "Granular Quartz," "Red sandrock," "Georgia slate," and Potsdam sandstone are differentiated as far as the known data would permit. The stratigraphic relations of the various divisions in Vermont are shown in a series of sections by Prof. C. H. Hitchcock,[2] and for New York by a section on the above-mentioned map.

The "Granular Quartz" is found on the western side of the Archean rocks, from southeastern New York and western Connecticut northward to Massachusetts, and into Vermont nearly to the Canadian border. The exposed outcrop is more or less interrupted because of the removal of the rock by erosion or its concealment by superjacent deposits.

In Vermont the "Granular Quartz" is a very compact, hard rock that passes into a number of varieties. It is described in the Geology of Vermont[3] as granular, gray, or reddish quartz rock; fine granular or arenaceous quartz rock: granular porous quartz, or pseudo-buhrstone; quartzose aggregate; quartzose breccia; quartzose and micaceous conglomerate. There are also associated with it talcose and mica schists and limestone. The quartzite is remarkably compact and enduring, and it occurs in bowlders all over the southern part of Vermont, in Massachusetts, New York, and Connecticut, many miles from the parent ledges. Along the range of the rocks the bowlders cover the surface, and in some instances this is the only way in which the line of outcrop of the formation is indicated. Details of the geographic distribution in Vermont are given in volume 1 of the Geological Survey. A section of 973 feet was measured in East Dorset by Prof. C. H. Hitchcock, and the thickness of the formation in Vermont is estimated at 1,000 feet. It retains its essential characters in passing southward into Massachusetts, New York, and Connecticut.

On the western summit of Clarksburg Mountain, northeast of Williamstown, the basal bed of the quartz series is a conglomerate, resting unconformably upon pre-Cambrian gneiss. The conglomerate is succeeded by beds of quartzite, usually compact, hard, fine grained, and

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[1] The Taconic system of Emmons and the use of the name Taconic in geologic nomenclature. Am. Jour. Sci., 3d ser., vol. 35, 1888, pp. 229-242, 307-327, 394-401.

[2] Geological sections across Vermont and New Hampshire, Am. Mus. Nat. Hist. Bull., vol. 1, 1884, pp. 155-179, pl. xvi, xvii.

[3] Hitchcock, C. H. Hypozoic and Paleozoic rocks. Report on the geology of Vermont, vol. 1, 1861, p. 342.

of a light gray color, in layers varying from a few inches to 2 or 3 feet and even up to 6 feet in thickness, on the spurs to the north of Clarksburgh Mountain. In the town of Bennington, a few miles further north, the writer measured a section of the quartzite 400 feet in thickness. It is formed largely of light gray, nearly white, compact, fine grained, and massive bedded quartzite, with alternating beds of hyaline quartz. At this locality fossils other than the Scolithus borings, which were known to occur at a number of localities in Vermont, were found in 1887 for the first time in situ in the quartzite. The species belong to the genera Nothozoe, Hyolithes, and Olenellus. Traces of a trilobite, apparently of the genus Olenellus, were also found 100 feet above the gneiss on the western summit of Clarksburg Mountain. In the bowlders on the line of the outcrop of quartz, to the north of Bennington, traces of fossils have long been known, among which are *Nothozoe vermontana*, *Hyolithes communis*, and *Olenellus thompsoni*.

Prof. J. D. Dana describes the quartzite in its extension into western Massachusetts, western Connecticut, and eastern New York. It varies very little from the characteristic features shown at the north, and from its disturbed condition no sections were obtained of its entire thickness. At Stissing Mountain, in Dutchess County, New York, it rests upon the Archean, and is a massive bedded, compact quartzite, in which the genus Olenellus and *Camerella minor* have been found. It here passes above into a limestone in which *Hyolithellus micans*, a characteristic Lower Cambrian species, occurs.[1]

In a paper read before the Geological Society of America at its second annual meeting, December 30, 1890, Dr. J. E. Wolff gave an account of the discovery, by Mr. A. F. Foerste and himself, of fossils of Lower Cambrian age in the limestones of the East Rutland Valley. The limestones rest conformably upon the quartzite which carries Olenellus in Bennington County. Dr. Wolff identified the species as *Kutorgina* sp. ? and Salterella.[2] The evidence of the Lower Cambrian age of the limestones is not fully proved, as the two genera may range up into the Middle Cambrian.

He mentioned that in the West Rutland Valley, and in the valley between the West Rutland and East Rutland Valleys, the limestones contain fossils of Calciferous Chazy-Trenton age, or those which will be found above the Cambrian horizon. From his section it is probable that the Middle and Upper Cambrian faunas will be found to range up into the limestones beneath the Calciferous horizon, as has been discovered by Prof. W. B. Dwight in Dutchess County, New York, and Prof. Frank Nason, in Sussex County, New Jersey.

As a whole, the "Granular Quartz" may be said to consist of a shore deposit accumulated along the western shore of the Green Mountains

[1] The Taconic system of Emmons and the use of the name Taconic in Geologic nomenclature. Am. Jour. Sci., 3d ser., vol. 35, 1888, p. 236.

[2] Bull. Geol. Soc. Am., vol. 2, 1891, pp. 334, 335.

during early Cambrian times; the sediments vary from pure quartz sand to mixtures of sand and argillaceous and calcareous mud.

The "Red Sandrock" series is confined almost entirely to northern Vermont, not appearing south of Addison County. In the northern part of Addison County it comes into contact with and merges into the "Granular Quartz" series. It has not been recognized in contact with the Archean rocks of the Green Mountains. From this, and its having less of the character of a shore deposit and from its occurring west of the line of outcrop of the "Granular Quartz," it is quite probable it is a deeper water accumulation, though contemporaneous with the "Granular Quartz." The Georgia slates, in the town of Georgia and in northern Vermont, are conformably superjacent to the "Red Sandrock." As the formation is traced to the south, the "Red Sandrock" series disappears, and the Georgia slates and shales, with their interbedded limestones and sandstones, represent the entire Cambrian section; so it is very probable that the Georgia series as found in southern Vermont and eastern New York represents or is equivalent to the "Granular Quartz" and the "Red Sandrock." The "Granular Quartz" has been described separately, but it is more convenient to unite the "Red Sandrock" and the Georgia slates, because the sections usually show the latter resting conformably upon the "Red Sandrock" series throughout northern Vermont. The geographic distribution of the Canadian extension of the "Red Sandrock" and the Georgia slates is shown on a map by Sir Wm. E. Logan, entitled "The distribution of the rocks belonging to the Potsdam, Quebec, and Trenton groups of the east side of Lake Champlain," accompanying an Atlas of maps and sections of the Report of Progress of the Geological Survey of Canada for 1863, published in 1865. The formations extend north of the boundary line about 5 miles, where they appear to have been cut out by faults that bring the superjacent formations into contact with them.

The "Red Sandrock" series consists of white and red dolomites and sandy layers. Some of the strata are mottled red and white, and a few are brick red or Indian red. Some beds contain a considerable amount of siliceous sand, and all weather a yellowish or reddish brown. They are also interbedded with gray argillaceous limestones and buff sandy dolomites weathering brown. This description is taken from Logan's notes on the formation near the Canadian boundary. To the south, in the town of Georgia, Franklin County, Vermont, they form a bluish gray dolomitic limestone, followed by a steel-gray dolomitic limestone that passes into a mottled limestone or the Winooski marble. This in turn is subjacent to gray dolomitic limestones in massive layers, some of which are mottled reddish and white, though the larger part are gray and yellow. Still higher up the reddish pink dolomitic limestones appear. There are many variations in the color and composition of this series between the Canadian border and its point of disappearance 40 miles to the south.

The Georgia slate series, according to Prof. C. H. Hitchcock, consist in Vermont of several varieties of rock.[1] They are (1) clay slate; (2) roofing slate; (3) clay slate approximating to micaceous sandstone; (4) various kinds of limestone; (5) brecciated limestone; (6) conglomerate formed of pebbles of limestone.

A carefully measured section extending up through the "Red Sandrock" and Georgia series, beginning at the base of the western face of the cliff overlooking the level that reaches to the shore of Lake Champlain, in the town of Georgia, Franklin County, Vermont, and extending southeastward to Parker's quarry, a little south of the Georgia post-office, gives the following:[2]

	Feet
(1) Massive bedded, bluish gray dolomitic limestone, with many inosculating threads and bunches of a yellowish-drab sandy limestone that weathers in relief[3]	35
(2) No. 1 passes into a steel-gray dolomitic limestone that weathers to a dark buff and bluish black, with angular fragments of bluish gray limestone appearing irregularly at the surface. At 160 feet from the base the first band of mottled limestone, "Calico" or Winooski marble, is met with. The latter grades into a reddish dolomite, free from mottling, and then in a gray limestone. (Fossils, Hyolithellus ?)	200
(3) Gray dolomitic limestone in massive layers, some of which are mottled, reddish and white, but the larger part are gray and yellow. Many of the gray layers break up into a columnar structure, the columns being at right angles to the bedding. In a reddish-colored limestone, 200 feet from the base, a slender elongate tube occurs, probably *Hyolithellus micans*	475
(4) Reddish pink, dolomitic limestone, weathering to a reddish brown and decomposing on the exposed edges to an arenaceous, dark, brownish-red rock that shows numerous fragments of fossils: *Kutorgina labradorica, Obolella* (?) sp., *Salterella pulchella* (?), *Ptychoparia adamsi, Olenellus thompsoni*	100
(5) Gray arenaceous limestone in rough, massive layers, passing into more evenly bedded, light gray, arenaceous limestone. Fossils similar to those in 4 occur in the lower portion	190
Total thickness of limestone	1,000
(6) Georgia shales.—Argillaceo-micaceous and arenaceous shales, containing numerous fossils, at Parker's ledge, and showing deposition contact on No. 5	200

Strike at Parker's Quarry, N. 30° E., dip 8° to 12° E.

The fossiliferous shales at Parker's Quarry contain: *Palæophycus incipiens, P. congregatus, Diplograptus simplex* [now, 1891, *Phyllograptus* (?) *cambrensis*], *Climacograptus* (?) *emmonsi, Kutorgina cingulata, Orthisina orientalis, O. festinata, O. transversa, O. sp.* (?), *Microdiscus parkeri, Mesonacis vermontana, Olenellus thompsoni, Olenoides marcoui, Bathynotus holopyga, Ptychoparia adamsi, P. vulcanus, Protypus hitchcocki, P. senectus,* and *P. senectus* var. *parvulus.*

[1] Hypozoic and Paleozoic rocks. Report on the geology of Vermont, vol. 1, 1861, p. 358.

[2] Walcott, C. D. Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, pp. 15, 17.

[3] A mile south of the line of the section about 75 feet of arenaceous limestone occurs beneath this bed. Fifty feet from the base I found during the summer of 1890 *Obolella crassa ?, Salterella sp. ? Hyolithes* 2 sp., and fragments of a species of Olenellus. A few feet higher in the section the heads of Protypus sp. ? and of Olenellus sp. ? were found. Traces of the Olenellus fauna were also found at points 85, 153, and 193 feet above the lowest horizon.

	Feet.
(7) East of the Parker quarry the rocks are argillaceous shales, with occasional layers of hard gray limestone one-half of an inch to 2 inches thick, that carry numerous fragments of a linguloid shell	3,500

Strike of shales near top of 7, N. 40° to 60° E., dip 60° SE.

(8) Light gray quartzite	50
(9) Gray limestone in massive layers, with occasional intercalated bands of hard argillaceous shale similar to that beneath the limestone. Many of the beds of limestone appear to have been broken up into fragments and recemented in situ	1,700

Average strike of limestone beds N. 50° E., dip 50° to 90°; average dip 60° SE.

In this limestone belt, 1 mile north of where the section crossed, a few fossils were found; *Lingula*, n. sp., *Orthisina* undt. (fragment), *Camerella* undt. (probably new), *Agnostus* like *A. orion*, and *Ptychoparia* like *P. adamsi.*

(10) Argillaceous shales, very similar to those in the Parker ledge, continue on up to the opposite side of the line of the Vermont Central Railroad track. At the base the shales rest conformably against the limestone of 9, and above appear to be cut off by a fault.

Strike N. 50° E., dip 60° to 80° SE., for a distance beyond the limestone; the dip then decreases and does not exceed 20° for a long distance, until within 1,000 feet of the railroad track, where the shales become coarser and changed by addition of arenaceous material, and the dip increases.

Total thickness to fault line of No. 10, 3,500 to 4,500 feet.

No. 8 of the section when traced on its strike to the southwest increases in force very rapidly to the thickness of 500 feet or more, and also changes from a quartzite to a more or less calcareous sandstone, containing irregular fragments of argillaceous shale. Followed to the northeast, it soon disappears and the limestones rest directly on the shales. Continuing northeast on the limestone (9), it is found to decrease rapidly, and a mile northeast of where it is over 1,500 feet in thickness the width across the outcrop is not over 150 feet, and soon the shales above it and those below it come together, the limestone having disappeared. Southwest of the line of the section the width of the outcrop narrows, and north of Georgia Plains post-office the entire section is covered by beds of sand.

No. 9 appears to be a great lenticular mass of limestone (lentile of Marcou) with intercalated beds of argillaceous shale, and more rarely with arenaceous beds imbedded in the argillaceous shales. The fauna is Cambrian in character, and, in the absence of Olenellus and other typical Middle [now Lower] Cambrian fossils approaches that of the Upper Cambrian or Potsdam sandstone.

A section taken east of Highgate Springs beginning on the east side of the same fault as the Georgia section, gives a slightly greater thickness, and more arenaceous matter in the limestone series beneath the Georgia shales. The limestones are here 1,170 feet in thickness and the Georgia shales 1,000 feet, above which there is apparently a conformable series of calcareous sandstones, with a thickness of 850 feet, to where they are cut off by a fault line. A section measured east of the village of Swanton, does not show as great a thickness of the limestone beneath the Georgia shale, and a fault line cuts obliquely across the shale. On the east side of the fault 200 or 300 feet of shales occur, and many layers of conglomerate limestone, the fragments of limestone varying in size from small pebbles to masses 6 feet in diameter. The fossils in the limestone conglomerate have an Upper Cambrian aspect, and include *Lingula sp. ?*, *Agnostus sp.?*, *Amphion sp.?*, *Bathyurus sp. ?* Below the horizon of the conglomerate and in situ in the shales, there were found the genera Lingulella, Agnostus, Ptychoparia and Solenopleura. With the exception of the Solenopleura the species appear to be identical with those of the limestone lentile (9) of the Georgia section. A section measured east of Swanton by Sir William E. Logan gave but 520 feet of the limestone (Red Sandrock) series.[1] But farther to the north, nearly on the line of the Canadian boundary, he found 1,410 feet of limestone in the section, proving that this portion of Cambrian terrane thickens rapidly to the north.

The section measured in the town of Georgia is the most complete yet taken in Vermont (ante., pp. 278, 279). At the base a great belt of dolomitic limestone 1,000 feet in thickness rests against, and, by an overthrust fault, overlaps the Trenton limestone of the Lower Silurian (Ordovician). What was originally beneath the Cambrian limestone is yet undetermined. In the Highgate section the limestone belt is nearly 1,200 feet thick. The base is unknown, and it does not appear, so far as I know, in the section between the boundary of the United States and Canada and the outcrop in the town of Georgia. I have suggested that the great mass of shaly argillite east of the Vermont Central Railway track in the Georgia section may be older than the limestone at the base of the section, but until further evidence is obtained this is merely conjectural.[2]

During the field season of 1890 I studied the "Red Sandrock" series of the Georgia section, and found a little to the south and at the base of the original section that there was a band of buff-colored calcareous sandstone some 50 feet in thickness. In the upper beds of this, Obolella, like *Obolella crassa*, *Hyolithes americanus*, *H. communis*, *H.* sp. undt., *Hyolithellus micans*, and fragments of Olenellus occur. In a lead-colored magnesian limestone, passing into a buff-colored limestone 15 feet above the sandstone, fragments of Olenellus and the head of Ptychoparia, apparently identical with *P. trilineata*, were found, and in the superjacent pinkish magnesian limestone with interbedded drab-colored limestone, at horizons of 85 feet, 113 feet, and 198 feet above the sandstone, fragments of fossils that I recognized as portions of Olenellus and very perfect specimens of Salterella sp.? occur in the decomposed silicious limestones.

The discovery of the Olenellus fauna in the lower portion of this magnesian limestone series gives the fauna a range through 1,000 feet of limestone and the 250 feet of superjacent Georgia shale.

The fragments and heads of the genus Olenellus that were found in the lower beds were not sufficient to determine whether it was the equivalent of the *Olenellus asaphoides* of the Washington County section or not.

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[1] Geological Survey of Canada: Report of progress from its commencement to 1863. Montreal, 1863, p. 281.

[2] Walcott, C. D.: Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Surv., Bull. No. 30, 1886, p. 19.

It is quite probable that it is, from the character of the associated fossils. As the vertical distribution of the fauna in the Olenellus zone will be treated of in a future paper, further reference will not be made to it at present.

The shales and slates superjacent to the Olenellus-bearing beds of the Georgia slate, at Parker's quarry, do not apparently belong to the Lower Cambrian, but are the representative of the middle portion of the Cambrian section. This view was advanced by Prof. Jules Marcou, in 1885,[1] except that he placed the same series of shales which occurs at St. Albans beneath the Georgia slates or Olenellus zone. The stratigraphy was erroneous, but the suggestion that the St. Albans slates correspond to the Paradoxides belt of the Atlantic Coast area will probably be found to be correct. In such an event Professor Marcou's name St. Albans will be a useful addition to the nomenclature of the Cambrian group in northern Vermont. It will, however, be difficult to differentiate between the St. Albans group and the superjacent beds carrying the Upper Cambrian fauna.

In the group of sections taken across New Hampshire and Vermont by Prof. C. H. Hitchcock[2] the Georgia series is called Potsdam and Cambrian; and in section XI, on Pl. 17, the Georgia shales (Cambrian of section) are represented as resting conformably on the magnesian limestone (Potsdam of section) in the town of Milton. This is the same as in the Georgia section a few miles to the north. The great mass of argillites, east of the railroad track in the Georgia section, are placed under the term Cambrian by Prof. Hitchcock, and the reference may possibly be correct; but as yet there have not been any recognized Cambrian fossils obtained in it, either at this point or to the north or south.

In southern Vermont the Georgia slate series widens out, and includes the great roofing-slate belt that extends through Rutland County and into Washington County, New York. The outcrop of this series is narrow in the south part of Washington County, but it widens rapidly in Rensselaer County, occupying nearly the entire width of the county at its southern boundary. At its greatest point of development in Washington County it consists of the following strata, as shown in a section crossing the county in the towns of Greenwich and Salem, with its base 1½ miles west of North Greenwich post-office:

	Feet.
(1) Massive layers of impure, shaly limestone embedded in irregular argillaceo-arenaceous shale, with numerous fossils of the Olenellus fauna in the limestone	340
(2) Massive layers of fine-grained, bluish gray, arenaceous limestone, that become almost a pure limestone in places	670
About halfway of the mass *Lingulella cœlata*, *Hyolithellus micans*, and *Leperditia dermatoides* occur.	

[1] The Taconic System and its position in stratigraphic geology. Am. Acad. Proc., vol. 20, 1885, table on p. 224.

[2] Geological sections across Vermont and New Hampshire. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, pls. 16, 17.

	Feet.
(3) Shaly limestone in massive layers; argillaceous shales interbedded in the layers	380
(4) Calcareous, argillaceous shales, in massive layers, with interbedded arenaceous limestones below, and passing into an argillaceous shale above	240
(5) Dark, argillaceous, and arenaceous shales becoming fissile in places; occasional layers of a hard, gritty limestone 1 or 2 inches thick occur at various horizons. Near the summit of this section *Hyolithes americanus*, *Microdiscus pulchellus*, *Olenellus asaphoides*, and *Conocoryphe trilineata* occur near the roadside. This is the trilobite bed from which the original specimens described by Dr. Emmons were obtained	370
The section to this point gives a total of 2,600 feet, and is considered Division A of the section.	
(6) Compact, steel-gray, massive-bedded argillaceo-argillaceous shale, breaking into irregular fragments, and weathering a rust-brown color	2,200
At a point 1,300 feet up in this I found *Stenotheca rugosa*, *Hyolithes americanus*, and fragments of *Olenellus asaphoides*. At 2,100 feet up fragments of Olenellus occur in a stratum of calciferous shale.	
(7) Massive beds of a thinly banded, cherty, and argillaceous rock, capped by a band of calciferous sandrock	400
(8) Argillaceous shale, more or less arenaceous and calcareous throughout its extent	2,400
(9) Calciferous sandrock, light colored, weathering to a reddish brown, crumbling sandy rock. This is embedded in a calcareo-argillaceous rock, that breaks into angular fragments of a shaly character. The only fossils observed were *Obolella crassa*, Hyolithes, fragments of Olenellus, on the decomposed surfaces of the more calciferous layers	900
(10) Argillaceous and arenaceous shales, much like those of Nos. 8 and 9, with bands of bluish gray, evenly bedded, and conglomerate limestone carrying fossils. As shown in the section, this division appears to have a thickness of 4,500 feet; but it is assumed that there is much repetition by faulting, so that it is given a thickness of 2,250 feet	2,250

The combined thickness of the section to this point is 10,750 feet. Its continuity is here broken by a fault, that brings the rocks of the Hudson (?) terrane against it and between it and the purple and green slates that form a large portion of the Cambrian section east of the rocks of the Hudson (?) terrane. The section is again taken up on the east side of Salem Village, at the base of the green and purple slates and interbedded limestones, carrying characteristic Lower Cambrian fossils of the Olenellus fauna.

	Feet.
(11) Green, purple, and higher up, gray and dark shales and slates and interbedded limestones, in very thin layers	2,500
(12) Nonfossiliferous green and purple slates	2,150
In the township of Hampton to the north, the green and purple slates appear to have a thickness of 4,300 feet; and 2 miles north of that point there are over 5,000 feet of these beds, if no repetition occurs.	
The lower portion of this division is characterized by the Olenellus fauna in association with some other species that indicate the Middle Cambrian zone. The entire thickness of the lower and upper divisions, according to the section, is 15,350 feet.	
(13) Above the green and purple slate belt is a series of greenish, schistose, hydro-mica slates, estimated to have a thickness of 3,700 feet. They are not fossiliferous, and appear to pass beneath the limestones characterized	

by the Chazy-Trenton fauna. I have referred them to the Potsdam zone provisionally.[1] If this reference be correct and the rocks in the section are not duplicated by faulting, the Cambrian system has a thickness of 19,000 feet in Washington County.

This section may be greater than the actual thickness of the sediments deposited in this region during Cambrian time. The upper 3,700 feet of greenish, hydro-mica shales probably do not belong to the Cambrian, and there may be some reduplication in the section as measured. Eliminating the probable sources of error, I think there is at the least from 10,000 to 12,000 feet of strata that may be referred to the Cambrian group.

A section 35 miles to the south, across the extension of this series, exhibits a great development of the shaly portion similar to that in the lower part of the Washington County section, that passes above into the red and purple slate belt. In this section the upper member of the Washington County section is apparently represented by a coarse, greenish sandstone, and in places a fine conglomerate. At the base of this formation the red and green shales are interbedded with the sandstone, the passage from the slates to the sandstone being by intercalation of sand and slate for a distance of several hundred feet, the slate gradually diminishing in volume as the intercalation of the sandstone increases. The sandstone is estimated to have a thickness of 2,000 feet or more, and it corresponds in stratigraphic position, and is on the strike of the 3,700 feet of greenish hydro-mica schistose shales of the Washington County section. The recent work of Mr. T. Nelson Dale proves this series (Berlin grit) to be of Lower Silurian (Ordovician) age, and indicates that the series of green and purple slates beneath may represent the base of the Lower Silurian (Ordovician) and the summit of the Cambrian.

Our knowledge of the rocks of the Cambrian group in their southern extension into Dutchess County, New York, is obtained from the observations of Prof. Wm. B. Dwight. The base of the series is the "Granular Quartz" of Stissing Mountain, that had been referred to the Potsdam zone by Profs. W. W. Mather, J. D. Dana, and others. Occurring between the gneiss of Stissing Mountain and the superjacent limestone carrying the Calciferous fauna, it was natural that this should be correlated with the Potsdam sandstone about the Adirondacks; and it was not until the fall of 1886 that fossils of the Lower Cambrian or Olenellus zone were found in the quartzite, and in the limestone resting upon the quartzite.[2] Prior to this Prof. Dwight had discovered in the more or less arenaceous limestone and argillaceous shaly limestone near Poughkeepsie the presence of the Potsdam or Upper Cambrian

[1] Walcott, C. D.: The Taconic System of Emmons and the use of the name Taconic in geologic nomenclature. Am. Jour. Sci., 3d ser., vol. 35, 1888, p. 241.

[2] Dwight, W. B.: Primordial rocks of the Wappinger Valley limestones and associate strata. Vassar Brothers Inst. Trans., vol. 4, 1887, pp. 206-214. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 27-32.

fauna.[1] It includes *Lingulepis acuminata*, *Obelella prima*, *Ptychoparia calcifera*, and *P. saratogensis*, species identical with those found at the upper horizon of the Potsdam in association with Dikelocephalus of Saratoga County, New York. Subsequently he discovered in the limestone above the quartzite, at the south end of Stissing Mountain, fossils that indicated the Middle Cambrian or Paradoxides zone. The species are *Hyolithes billingsi?*, *Leperditia ebenina*, *Kutorgina stissingensis*, and *Olenoides stissingensis*.

The stratigraphic succession is more or less interrupted by faults and the rocks are masked by the drift deposits. The succession as determined by the known stratigraphy, and the fauna is, first, at the base a massive bedded quartzite, resting upon the gneiss below, and subjacent to a bed of hard, compact limestone. In the quartzite the Olenellus fauna has been found, and in the bed of limestone immediately superjacent to it one of the characteristic fossils of the Lower Cambrian fauna, *Hyolithellus micans* occurs. In the superjacent limestone, the thickness of which could not well be determined but which appears to be considerable, the Middle Cambrian fauna was found in an arenaceous limestone, passing frequently into a calcareous shale; and in the vicinity of Poughkeepsie the Upper Cambrian fauna occurs in a somewhat similar limestone.

The contrast of the sedimentation of this section with that of Washington County is very striking. In the latter, the quartzite of Stissing Mountain is represented by the great thickness of shales, and interbedded limestones, slates, and sandstones; and the limestone of the Middle and Upper Cambrian of the Dutchess County section are entirely replaced by slates, schists, and sandstones, both in Rensselaer and Washington Counties. This difference in sedimentation is shown all along the northern Appalachian Province from Dutchess County to the Canadian border, and on to Quebec and down the St. Lawrence River to Cape Rosier. It represents the accumulation of sediments in a gradually sinking area and in a relatively shallow sea. It is a curious fact that near the old shore line the basal sandstone, "Granular Quartz" of the Lower Cambrian is almost directly succeeded by the massive limestones of the "Marble" belt. Unless there is here an area of nondeposition, the lower portion of the limestones of Berkshire County, Massachusetts, Rutland and Addison Counties, Vermont, represent the sedimentation of Middle and Lower Cambrian time.

The preceding paragraph was written several months prior to the discovery of Cambrian fossils in the limestones of the East Rutland Valley by Dr. Wolff, in 1890.

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[1] Discovery of fossiliferous Potsdam strata at Poughkeepsie, N. Y. Am. Assoc. Proc., vol. 34, 1886, pp. 204–209.

[2] Recent explorations on the Wappinger Valley limestone of Dutchess County, New York., No. 5 discovery of fossiliferous Potsdam strata at Poughkeepsie, N. Y. Am. Jour. Sci., 3d ser., vol. 31, 1886, pp. 125–133. Vassar Bro. Inst., Trans., vol. 4, 1887, pp. 130–141.

CANADIAN EXTENSION.

The Canadian extension of the northern Appalachian district is from the United States boundary northeast to the vicinity of Point Levis, Quebec, on the western side of the extension of the Green Mountains, or Sutton Mountain anticlinal, and from Quebec down the south shore of the St. Lawrence River to Cape Rosier, Gaspé. On the eastern side of the anticlinal the supposed Cambrian rocks of New Hampshire, crossing the southeastern portion of the Province of Quebec to the Maine boundary, are also included.

The stratigraphic succession of the rocks referred to the Cambrian in the eastern Province of Quebec and down the St. Lawrence River to Cape Rosier is not yet clearly determined, owing to the faulting, plication, and absence of clearly defined Cambrian faunas in situ in the strata. In the vicinity of Quebec, on the authority of Dr. R. W. Ells, the stratigraphic succession is as follows:[1]

(1) Black, green, and gray shales, with hard and heavy bands of grayish, sometimes yellowish white, quartzose sandstone, which are thickest in the lower portion, and with occasional thin bands of limestone conglomerate, the pebbles being generally small and the paste highly quartzose. The quartzites have occasional scattered pebbles of grayish limestone.

(2) Greenish, grayish, and blackish, with occasionally dark-reddish or purplish-tinted shales, with bands of hard grayish sandstone, generally fine-grained, and in thickness from 1 inch to 1 foot, the massive quartzites being absent and many of the greenish layers being covered with fucoidal markings, well seen on the shore above Cape Rouge and in the cutting along the road above that village.

(3) Bright red shales, often with thin greenish or grayish bands, which in places are calcareous. The rocks on a smoothed surface have a striped red and green aspect; in the upper part occasional beds of a foot or more of hard green-gray sandstone occur.

(4) Red, greenish gray and black shales, with interstratified masses, often lenticular, of greenish and grayish Sillery sandstone, ranging in thickness from 2 feet upward, in which the Sillery quarries are located. This is the typical Sillery sandstone, which ranges from a fine-grained homogeneous rock to a fine quartz conglomerate, much of the rock being characterized by the presence of small flaky pieces of shale and scattered small pebbles or large grains of clear quartz, the bands of sandstone being separated by partings of various colored shale. The local and lenticular character of the sandstone is well seen in the Sillery section, some of the heaviest beds inland thinning out before reaching the shore in either direction. In the upper part, at Sillery church, *Obolella pretiosa* occurs, from which point an anticlinal crosses the river to Point Levis, and appears in the cliffs at the Victoria hotel, where the same Obolella is found.

Above the Upper Sillery Dr. Ells places the Levis shales and conglomerates of Levis City, the shore extension below South Quebec and St. Joseph and the west end of Orleans Island. In the Levis shales, the conglomerate limestone, embedded in a calcareous matrix, carries numerous bowlders in which the Upper Cambrian fauna is found; and in what is supposed to be the equivalent of No. 2, a conglomerate lime-

[1] Second report on the geology of a portion of the Province of Quebec. Geol. Surv. Canada, new ser., vol. 3, part 2, 1889, pp. 63 K, 64 K.

stone occurs in which the Olenellus or Lower Cambrian fauna is present. The thickness of the strata referred to the Cambrian is not given by Dr. Ells in his publication, but he told me that the measurements given by Mr. Logan were as nearly correct as could be determined. These were 5,000 to 6,000 feet for the Sillery and Lauzon series.

The little shell *Obolella pretiosa* ranges through from 1,500 to 2,000 feet of the Upper Sillery; and the lower or Olenellus fauna conglomerate occurs in the lower portion of this range.

Dr. Ells refers the entire Sillery series to the Cambrian, and in this I mainly agree with him, except that the upper portion is evidently a passage formation between the Cambrian and Silurian (Ordovician). On lithologic and stratigraphic evidence the line would be drawn at the summit of the red shale; on paleontologic evidence, as furnished by the Graptolites, I would include the upper portion of the Sillery red and green shales in the Silurian (Ordovician), as I think they are above the typical Potsdam zone of America.[1]

The strata doubtfully referred to the Cambrian group between Quebec and Cape Rosier, on the south shore of the St. Lawrence River, have already been described in the notice of the work of Mr. James Richardson, reported upon by him in 1870. (Ante., pp. 118, 119.) As they may or may not be of Cambrian age, no further description will be given.

The strata referred to the Cambrian on the western side of the Sutton Mountain anticlinal, or the belt extending southeasterly from Quebec to the Vermont boundary, are described by Drs. Selwyn and Ells as consisting for the most part of hard quartzites interstratified with mica-schists and black slates. All of this series, as described by them is unconformably overlapped by the Sillery red slates, conglomerates, and sandstones. Limited outcrops of grayish subcrystalline limestones are found occasionally in association with the black slates and quartzites.

The volcanic portion of the Cambrian, or group No. 2 of Dr. Selwyn,[2] presents a great variety of crystalline, subcrystalline, and altered rocks, including "coarse, thick-bedded, feldspathic, chloritic, epidotic, and quartzose sandstones, red, gray, and greenish siliceous slates and argillites, great masses of dioritic, epidotic and serpentinous breccias, and agglomerates, diorites, dolorites, and amygdaloides, holding copper ore; serpentines, felsites, and some fine-grained granitic and gneissic rocks, also crystalline dolomites and calcites. Much of the division, especially on the southeastern side of the axis, is locally made up of altered volcanic products, both intrusive and interstratified, the latter being clearly of contemporaneous origin with the associated sandstones and slates."

As far as known this zone has not afforded any fossils. Dr. Selwyn

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[1] Walcott, C. D.: A review of Dr. R. W. Ells's second report on the geology of a portion of the Province of Quebec, with additional notes on the "Quebec group." Am. Jour. Sci., 3d ser., vol. 39, 1890, p. 113.

[2] Report of observations on the stratigraphy of the Quebec group and the older crystalline rocks of Canada. Geol. Surv. Canada: Report of progress, 1877-1878, 1879, pp. 5A, 6A.

thinks that if found they would indicate a lower horizon than the Levis formation, probably not far removed from the St. John group and Atlantic Coast series of Nova Scotia, or Lower Cambrian. Details of the lithologic and stratigraphic features of the strata referred to the Cambrian and their geographic distribution may be found in the reports by Dr. Ells on the Eastern Townships of the Province of Quebec.[1]

SOUTHERN APPALACHIAN DISTRICT.

The Southern Appalachian District includes the outcrops of strata referred to formations of the Cambrian group in northern and central New Jersey, southeastern and southern central Pennsylvania, western Maryland, Virginia, and North Carolina, eastern Tennessee, northwestern Georgia, and northeastern Alabama.

NEW JERSEY.

As far as known the rocks of New Jersey referred to the Cambrian are found in the northern central portion as outcrops of a nonfossiliferous sandstone resting upon Archean gneiss and subjacent to a Magnesian limestone that has been referred to the Calciferous zone of the New York section. The greatest thickness assigned to it is 20 feet.

The correlation with the Potsdam sandstone of New York is based entirely upon the lithologic characters of the sandstone and its stratigraphic position. There is no positive evidence of its being the equivalent of the Potsdam sandstone of New York. It may be Lower, Middle, or Upper Cambrian, and possibly of Calciferous age. From the stratigraphic conditions to the north and south it will probably be found to be of Lower Cambrian age, or the equivalent of the "Granular Quartz" of New York and Vermont. The lower portion of the limestone series may be of Cambrian age, as in Dutchess County, New York.

Among the papers presented to the Geological Society of America at its second annual meeting, December 31, 1890, was one by Prof. Frank L. Nason on "The post-Archean Age of the White limestones of Sussex County, New Jersey," in which he describes the discovery of the Olenellus fauna in the lower Primal sandstone of Rogers that rests unconformably upon the pre-Cambrian rocks. He said also that fossils (Obolella or Lingulella) extended up into the superjacent limestone.

In Prof. Nason's collection I recognized *Olenellus thompsoni*, Obolella or Lingulella sp.?, and the cast of a coral-like organism that is probably a species of Ethmophyllum. These were found at Hardistonville and Franklin Furnace, Sussex County, New Jersey.

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[1] Second report on the geology of a portion of the Province of Quebec. Geol. Surv. Canada, new series, vol. 3, 1889, pp. 1K–120K.

Report on the geology of a portion of the Eastern Townships of Quebec. Geol. Surv. Canada, 1886, new ser., vol. 2, 1887, pp. 1J–70J.

DELAWARE.

The outcrop of the sandstone referred to the "Potsdam" in northwestern Delaware is very limited, and is noted only to indicate its occurrence within the limits of the State.[1]

PENNSYLVANIA.

The rocks referred to the Cambrian System in Pennsylvania by the latest authorities include the Primal quartzite of Prof. Rogers; and Prof. Lesley is inclined to consider the sandstone and slate of the South Mountain proper as of Cambrian age. The line of outcrop of the quartzite extends along the boundaries of the various Archean areas from the Delaware River on the northeast, in Bucks, Lehigh, and Northampton Counties, southwesterly, with more or less interruption, across Berks, Montgomery, Chester, Lancaster, York, and Adams Counties, to the Maryland line. Prof. J. P. Lesley's summary is as follows:

The lowest Paleozoic formation in Pennsylvania, No. 1, logically identified with the Potsdam sandstone of northern New York, makes its appearance along the edges of the limestone No. 2 at the north foot of the Azoic Mountain Range between Bethlehem and Reading in Lehigh and Berks Counties; in Mulbaugh Hill, on the Lebanon County line; in Chicques ["Chickis" of Frazer] Ridge, on the Susquehanna, above Columbia; in the Welsh Mountain in northern Chester, and in the North Valley Hill, which stretches for 60 miles from the heart of Lancaster to the Bucks-Montgomery county line north of the city of Philadelphia. Its only fossil as yet discovered is a *Scolithus*, but its position next beneath the Calciferous limestone is too well marked to admit of doubt. Formerly it entirely covered the mountain districts north and south of the Schuylkill River, because it still spreads in sheets upon their sides, and in many places makes their summits, lying unconformably upon the gneiss.

The South Mountains proper, which separate Cumberland from York and Franklin from Adams County, do not thus exhibit the fundamental gneiss covered by a coating of Potsdam, but are composed of peculiar sandstone and slate strata several thousand feet thick, which occupy the place of the Potsdam in the series, but can not certainly be identified with it. They may be considered the equivalents of the Ocoee and Sewanee strata of east Tennessee. * * * We may consider our South Mountain rocks, therefore, those lying north of the turnpike fault, as of Cambrian age.[2]

The sandstone referred to the Potsdam in Lehigh and Northampton Counties is described by Mr. Frederick Prime, jr., as "a hard, compact quartzite, of a yellowish color where weathered, and when freshly quarried of a grayish tint. * * * The thickness, where it could be measured, was 21 feet.[3]"

The quartzite varies in thickness from 20 to 300 feet, the greater thickness being in the "Chickis" section of Lancaster County, where, according to Dr. Persifor Frazer, it reaches 300 feet. Southwest of the

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[1] Chester, Frederick D.: Preliminary notes on the geology of Delaware—Laurentian, Paleozoic, and Cretaceous areas. Phil. Acad. Sci. Proc., vol. 36, for 1884, pp. 237-259.

[2] A geological hand atlas of the sixty-seven counties of Pennsylvania, embodying the results of the field work of the survey from 1874 to 1884. Second Geol. Surv. Pa., X, 1885, pp. xvi, xvii.

[3] Geology of Lehigh and Northampton Counties. Second Geol. Surv. Pa., D^3, vol. 1, 1883, p. 205.

Susquehanna River it is difficult to measure its exact thickness, owing to its disturbed condition. The characters of the sandstone appear to be very much alike throughout the State, and the only traces of organic remains found are the straight, vertical tubes of Scolithus.

Prof. H. D. Rogers referred a series of slates, between the sandstone, called Potsdam, and the base of the superjacent limestone to the Primal period, but the geologists of the Second Geological Survey consider them as belonging to the limestone series. If a comparison be made with the Tennessee sections, where the schists and shales between the quartzite and the limestone are characterized by Cambrian fossils, this series of schists will certainly be referred to the Cambrian, as it is subjacent to the great limestone series and superjacent to the quartzite. According to Prof. Rogers, the highest or Primal newer slate is a greenish and bluish talcose argillaceous slate, sometimes very soft and shaly, and has a thickness of about 700 feet. Dr. Frazer refers about 1,600 feet of "Hydromica schist" to the interval between the quartzite and limestone in York County.[1]

The upper part of the Primal slates does not appear to be developed to the northeastward in Lehigh, Northampton, Bucks, Montgomery, Berks, and Chester Counties. It first appears with any considerable thickness in Lancaster County, near the Susquehanna River, and south of the quartzites of the Chickis Hills. From thence it extends southwesterly, across York and Adams Counties, to the Maryland line, increasing in thickness in Maryland and Virginia.

As a whole, the Cambrian System in Pennsylvania appears to be represented by the lower quartzite and the superjacent shales and schists as originally defined by Prof. Rogers, and it may be that the lower portion of the superjacent limestone will be included.

In a letter received from Prof. Lesley, dated May 8, 1890, he says:

Reading Ells's paper and Brainerd & Seely's paper in Bull. Geol. Soc. America, just published, with your remarks at the meeting, I naturally reverted to my South Mountain surveys (20 years ago) east of Chambersburgh, Pennsylvania (Fulton and Adams counties), and the strange and powerful impression made on me then by the outcrop of a low ridge of *purple shales*, running *from the pike southward, just back* (east) *of the western mountain ridge.* I never saw anything like them, and feel strongly inclined to consider them the Sillery *purple shales* (Cambrian) of the North. I can't find or remember any description of this outcrop by Frazer. It lies in Fulton County, outside the Adams County line.

MARYLAND.

I have been unable to find any detailed account of the rocks referred to the Primal series of Prof. Rogers, and have depended upon the general account given by Prof. P. T. Tyson in 1860, in his report as State agricultural chemist. His description is short and will be quoted in full:

(*Primal of Pennsylvania survey.*)—*Potsdam of New York.*—This division includes:

(1) A hard sandstone made up of grains of quartz, with occasionally grains of

[1] General notes.—Sketch on the geology of York County, Pennsylvania. Am. Phil. Soc. Proc., vol. 23, 1886, p. 401.

feldspar and kaolin. The siliceous cement seems to have completely filled up the interstices between the grains so as to give a firm compact structure to the rock. Portions of this rock seem to have been subjected to such changes as to render it doubtful whether it should not be considered a granular quartz and be classed among the metamorphic rocks. Vegetable life seems to have commenced at the period of the formation of this rock, because it contains fossilized stems of plants.

(2) A slate varying in color from gray to brownish and greenish. It is ranked as an argillite, but portions of it assume a marked talcose appearance, especially in the Catoctin Mountain and in parts of Middletown Valley, where it has been much disturbed and altered by proximity to intrusive rocks. These last consist of amphibolites (trap), porphyries, amygdaloid, serpentine, and epidote. This last-named rock is extensively developed both in large masses and intercalated between the slates, and has largely contributed to produce the highly fertile soils of Middletown Valley.

Approximate measurements of the thickness of these strata have been made in New York and Pennsylvania, but I have not as yet been able to obtain reliable information upon this point in our State.[1]

From this description and the geographic distribution of the Primal series as indicated on the accompanying map, it is evident that the quartzite of South Mountain, Pennsylvania, extends nearly north and south, across Maryland, and that the slates and associated eruptive rocks which form the main mass of South Mountain are included by Prof. Tyson in the Primal series. In the sections of these slates and accompanying rocks in Virginia they are recognized as pre-Cambrian, and it is very probable that those of Maryland and north into South Mountain of Pennsylvania are also of pre-Cambrian age. The presence of the upper Primal slate of Rogers between the quartzite and the Auroral limestone is not noted by Prof. Tyson. The fossilized stems of plants referred to are probably the Scolithus borings found so abundantly in the sandrock of Pennsylvania and Virginia. If the lower portion of the limestone series of Pennsylvania is of Cambrian age it is probable that the extension into Maryland is the same.

VIRGINIA.

Prof. William B. Rogers's description of the geographic distribution, stratigraphic position, and character of the strata that he referred to the Primal series, has been proved to be in a large measure essentially correct by the observations of geologists who have more recently studied the formations referred to the Cambrian group. He described formation No. 1 as consisting in the most part of a close-grained white or light gray sandstone, in some places containing beds of a rather coarse conglomerate of white siliceous pebbles. Near the bottom, in many instances, a brownish slaty sandstone occurs, alternating with the former, whilst toward the top or approaching the next formation the sandstone passes into reddish and brownish and olive-colored argillaceous slates. As far as known to him in his earlier work the formation in Virginia was exclusively confined to the western slope of the Blue Ridge and the narrow belt of rugged hills and mountains extending

[1] Tyson, Phillip T.: First report of the State agricultural chemist of Maryland. Annapolis, 1860, pp. 34, 35.

thence to the commencement of the Valley limestone.[1] At some later date, however, he discovered a small outcrop of the Primal series on the eastern slope of the Blue Ridge, in Rockbridge County, and drew it in on section 9 of the plates of sections published in connection with "The Virginias" in 1884. The Primal sandstones and shales are represented as occupying a narrow, deep basin on the eastern slope of the Archean rocks of the Blue Ridge. In this beautiful series of illustrations the twenty sections crossing the Primal series at subequal distances from the Potomac River to the Tennessee line illustrate very fully Prof. Rogers's interpretation of the geological structure, character, and thickness of strata forming the Primal series.

Prof. W. M. Fontaine in 1875 supplemented the work of Prof. Rogers by a detailed description of the sections of the "Primordial" strata at Balcony Falls in Rockbridge County, Rockfish Gap in Augusta County, and at Harper's Ferry on the Potomac. He concludes that the entire thickness of the Primordial strata at Harper's Ferry can not be much over 1,000 feet, and that they are composed of slaty rocks, similar to the variety of the lowest slate seen at Rockfish Gap, and a sandstone which much resembles some of the quartzites of the lower strata of the same locality. The section differs from that of Rockfish Gap and Balcony Falls in the absence of the coarser materials and the succession of shales and sandstones, with the subjacent conglomerate that rest on the Archean. The lower argillites, forming the main portion of the ridge and which Prof. Rogers included in his Primal series in section No. 2 accompanying "The Virginias," Prof. Fontaine refers to the Archean; whether of Laurentian or Huronian age, he does not undertake to decide.[2]

At the second annual meeting of the Geological Society of America, at Washington, D. C., December 31, 1890, a paper was read by Messrs. H. R. Geiger and Arthur Keith on the structure of the Blue Ridge near Harper's Ferry.

Several sections, taken on both the north and south sides of the Potomac River, show that the geologic succession at the base is a limestone upon which rests a series of shales, subjacent to a quartzite which corresponds to the Medina sandstone of the sections farther to the north and south. This section is the one described by Prof. Rogers as an *overturned section*, the quartzite corresponding to the primal quartzite of the Pennsylvania section, its present position being accounted for by the complete overturning, thus reversing the section. The authors of the paper mentioned conclude that the succession is a normal one from the pre-Paleozoic rocks through the limestone and

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[1] Second report of the progress of the geological survey of the State of Virginia for the year 1837. Richmond, 1838, pp. 14, 15.

Geology of the Virginias, 1884, pp. 167–169.

Report of the progress of the geological survey of Virginia for 1838 (Richmond, 1839) pp. 6, 9–12. Geology of the Virginias, N. Y., 1884, pp. 197, 198, 203–209.

[2] On the Primordial strata of Virginia. Am. Jour. Sci., 3d ser., vol. 9, 1875, p. 425.

shale to the sandstone. The basal limestone is of Calciferous—Chazy-Trenton age; the shales then would correspond to the Lorraine series, and the sandstone to the Medina series of the New York section. As as far known this is the only break in the continuity of the outcrops of the "Granular Quartz," where a quartzite is present, from central Vermont to Alabama.[1]

At Rockfish Gap the massive chloritic argillites, that form the mass of the Blue Ridge, are shown in unconformable contact with the lowest Primordial strata. The Archean argillites are firm and hard, of a dark greenish color, and present a strong contrast to the first stratum of the Primordial rocks, the line of junction being strongly defined. Summarized, Prof. Fontaine's description of the section is as follows, beginning at the base:[2]

	Feet.
(1) Very thinly laminated slates or shales	300
(2) On the side next to (1), the layers of this rock in color, do not differ much from (1), but are thicker than the preceding slates, and more sandy. The bedding thickens, and the amount of siliceous matter increases to the west, until a fine-grained white kaolin sandstone is the result	75
(3) Conglomerate of brownish-red color, in massive layers from 5 to 6 feet thick, with thin seams of shaly matter between several of the layers. The coarser materials are rounded grains of quartz of the size of a garden pea and under; inclosures of angular fragments of the slates of the Blue Ridge are not rare	60
(4) This is a partially concealed interval of 200 feet in which the rocks are, when seen, kaolin shales and kaolin sandstone, principally the former. To the west of this is a band of kaolin sandstone, with layers of cellular, much indurated quartzite, and some subordinate beds of an indurated, gray, coarse sandstone. This series contains one bed of the gray sandstone 20 feet thick. Thickness 420 feet or including the partly concealed band	620
(5) The first rock in this series is a highly indurated gray sandstone, the type of the beds above mentioned as forming occasional layers in No. (4). It is of a dark gray color, and composed of coarse grains which by metamorphic action are changed to a nearly compact texture. The thickness of the sandstone is 50 feet. A band of diorite 20 feet thick interrupts the section, next to which is a band of bluish gray, coarse shales, 75 feet wide; a partially concealed interval of 300 feet, occupied by similar rocks; then for 200 feet, several alternations of the same shales with bluish argillaceous sandstones. In these a layer 6 feet wide of red argillaceous hematite is found. Then a second band of diorite 12 feet wide, resembling in all respects the first.	
(6) The beds of No. (5) which are mostly sandy shales, and are rather thickly-bedded in layers of from 1 to several feet, are succeeded by a band of very thinly-laminated, firm olive slates or shales, having a total thickness of	300
Indurated brown sandstone, with some chlorite	30
Interval of concealed rock	100
Alternations of brownish argillaceous sandstones with greenish shaly beds.	150
Very finely fissile, pink-colored slaty shales, which weather purplish-red	200
Then for 100 feet a bluish shale is found	100
	880

[1] Bull. Geol. Soc. Am., vol. 2, 1891, pp. 155-163.
[2] Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 416-421.

Feet.

The two last series of beds, 5 and 6, appear to be the equivalent of No. (9) of the Balcony Falls section. Their combined thickness is about 1,450 feet, that is, provided no reduplication from folding occurs. This is possible, though not probable, I think.

(7) "The strata now to be described are the equivalent of the Potsdam sandstone, and resemble No. (10) at Balcony Falls in their almost total freedom from iron and other coloring matters. * * * The system here consists of a vast number of thin layers, in which we may distinguish three classes of rock: (*a*) A shale pale gray to bluish gray when fresh, composed almost entirely of kaolin, and occurring in thin plates. (*b*) This is associated with a very fine grained kaolin sandstone, the quartz grains being now perceptible to the naked eye. * * * (*c*) A kaolin sandstone of moderately fine grain, often with a thickness of several feet in the individual layers. The quartz grains are mixed with an equal amount of kaolin 300

"The beds last described have a thickness of 300 feet, and are succeeded by a partially concealed interval, in which 50 feet of a similar rock are shown." The strata between this point and the Auroral limestone are largely concealed.

The section as studied at Balcony Falls by Prof. Fontaine is as follows:[1]

	Feet.
(1) Unbedded quartzite, with crystals of feldspar	120
(2) Brown, crumbling, argillaceous rocks or sandy shale, conglomerate in its upper portion	40
(3) Brown, decomposing, thinly laminated and contorted shale	10
(4) Conglomerate, like the upper portion of (2)	20
(5) Shales, like (3)	12
(6) Conglomerate, like (4)	15
(7) Crumbling, brownish shales, passing in the upper portion into argillaceous sandstones of the same hue and texture	200
(8) Massively bedded, coarse white quartzite (apparently Rogers's typical No. 1)	500
Up to this point the rocks are well exposed in the cliffs which closely border the canal. Proceeding west across the strike, we next encounter a series that forms No. (9).	
(9) Thinly laminated, gray and reddish shales. Probable thickness	600
(10) Alternating beds of quartzite and kaolin shales. Probable thickness	700
(11) The first rock seen next to the mountain is thinly laminated, fragile shale, of yellowish and reddish hues not fully exposed. Next, to the west, we have bluish calcareous slate, and slaty limestone, 50 feet. Then very thinly laminated, firm, deep red slates, 60 feet. Next a similar slate of blue color, 15 feet. Then a bed of dark blue, hard, and dense limestone, used for cement, 13 feet. Then thinly laminated red slates, 20 feet. Then coarser and thicker bedded blue slates, 40 feet. Lastly, a coarse, rough, massive, siliceous limestone, 40 feet	238
	2,455

He compares the Balcony Falls section with that of Rockfish Gap, stating that the thickness of Nos. 5 and 6 in the latter section is much greater than that estimated for their equivalent, No. 9 in the Balcony

[1] Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 363-365.

Falls section, showing that the proportion of shaly matter in the entire group at Rockfish Gap has greatly increased.[1]

In summing up the physical characters of the sections as described, he says:

It will be seen from the above notes that in Virginia we have below the calciferous limestones a great development of sandstones, shales, and conglomerates, which attain in the middle portion of the State a thickness of over 2,000 feet, and increase in the proportion of coarse materials to the southwest. They probably attain greater thickness in that quarter, while to the northeast the amount of sediment diminishes, and the proportion of fine matter increases. This change is plainly due to the increasing development to the southwest of the syenitic rocks which formed the shores of the ancient seas and to the greater violence in that direction of disturbing forces. The Potsdam sandstone forms one of the upper members of this group. Much further study of these strata is required to settle the question whether the entire series is a great expansion of the Potsdam or whether divisions may be made corresponding to other epochs. The fact that at Rockfish Gap, and to the southwest, a great body of ferruginous slaty shales separates the lower highly siliceous and altered, sandstones from the upper Kaolin sandstones of probable Potsdam age, seems to indicate a change in the conditions of sedimentation sufficient to justify such a division, in which the Acadian strata may be found.[2]

With the single exception of a Scolithus, no fossils have been found in these rocks which would indicate their age.

In 1883 Prof. Fontaine supplemented his detailed description of the sections by a synoptic description, embracing the general character of all the formations that he considered belonging to the Primordial series.[3] Beginning with the base of the Primordial he recognized six divisions as follows:

	Feet.
1. Lower Primordial conglomerate	0 to 30
2. Lower gray shales and flags	500
3. Red shales and flags	400
4. Upper gray shales and flags	600
5. Potsdam quartzite	350
6. Ferriferous shales	500
	2,380

The description of the various formations is so clear and full that I quote them:

(1) *Lower Primordial conglomerate.*—I would confine this appellation to the lowest conglomerate that forms the base of the Primordial where it is present, excluding the conglomerate bands that follow higher up, but are separated from the basal conglomerate by shale and slate. * * * This member, thus limited, I have not seen at all the places where the junction of the Primordial with the Azoic is exposed. * * *

The conglomerate now in question is of special importance, since, when it is found, we may be sure that we have the true base of the Primordial. I have never seen it without finding the Azoic rocks immediately under it. It consists of a finer matrix that is shaly or slaty in texture, in which particles, angular or rounded in shape, of the Azoic strata are imbedded. The lithological character of the pebbles varies

[1] Op. cit., p. 421.

[2] Op. cit., p. 424.

[3] Notes on the mineral deposits at certain localities on the western part of the Blue Ridge. The Virginias, vol. 4, 1883, pp. 22, 42–44.

with the nature of the adjoining Azoic. To the south they are more commonly composed of gneissoid rock, but to the north the Huronian schists furnish the material. * * *

In the more southerly portions of the belt a good deal of partly decayed feldspar may be detected in the finer matrix, but to the north argillaceous material forms the cementing matter (p. 22).

(2) *Lower Gray Shales and Flags.*—The lower portion of this member of the Primordial frequently contains bands of conglomerate, composed of quartz pebbles, often purplish in color, imbedded in a fine-grained matrix of shale or slate * * * (p. 42).

The lower gray shales and flags vary in character more than any other member of the Primordial. The predominant rocks are shales, that sometimes become slaty in firmness and thinness of lamination, or various more siliceous flaggy rocks that range from purely argillaceous shales, through argillaceous sandstones, into massive and highly siliceous quartzites. These latter have the character described above. The predominant color is gray, but reddish, yellowish, or purplish and greenish colors sometimes occur.

Some of the grayish white, argillaceous strata form a species of claystone that weathers to a sort of kaolin. For the sake of distinction these may be called kaolin flags. This kind of rock is much more common in the member next under the Potsdam quartzite. The conglomerates occurring in the lower part of this member have been already described.

The general features of the quartzite members of this group have been already sufficiently discussed. Towards the southern portion of the belt, they attain great dimensions. This is especially true of the space between the southern border of Augusta County and Balcony Falls. At this latter place a quartzite formation occurs about 150 feet above the base of the Primordial, forming the Balcony Rock. It lies in huge beds of a highly siliceous character, and is not less than 250 feet thick. Here the massive character of the beds has prevented the cracking and smashing, accompanied with the infiltration of silica, so often seen in the smaller beds of quartzite at this horizon in other places; otherwise the character is as given above for the lower quartzites. I have never seen any casts of Scolithus borings in these quartzites. The great quartzite at Balcony Falls disappears almost entirely in the northern portion of the belt, its place being taken by minor beds of quartzite, and by shales and flags. The subdivision of the Primordial beds now being described forms the lower portion of the Primal older slates of the brothers Rogers.

(3) *Red Shales and Flags.*—This also is quite a variable group, and it changes its character very materially as we go south. In the northern portion of the belt, as far as Mount Torrey, the greater portion of this group is composed of a fine-grained, very thinly laminated, and tender slate. When fresh this rock has a steel gray color and pearly or nacreous luster, but on weathering many portions become deep blood red in color. Some of the lower and upper portions become yellow, but red is the predominant color from weathering. Some bands have small pebbles of the size of bird shot graduating into sand. Some of the red and yellow colors may be original and not due to weathering. This can not be decided, as all the exposures seen were much weathered. This member, in its northern exposures, is often affected by faults that cause it to extend over greater breadths than it could occupy in virtue of its thickness. Quartz veins occur in it, having the nature of fissure veins. Bands of this slate are impregnated with more or less specular iron, and this is the highest member of the Primordial that shows iron in the specular form. Some greenish, much indurated quartzite occurs in this member. This group to the south becomes more siliceous and the amount of red coloring matter diminished.

At Big Mary Creek the slaty character is nearly lost and the amount of red matter is much less. The strata are now chiefly rather siliceous gray flags, and this character is maintained to Balcony Falls; there the rocks at this horizon are nearly all flaggy and gray in color; some reddish and brownish beds, however, are found. This change to a more siliceous nature is accompanied by a great increase in the accompanying quartzites. These strata everywhere, owing to their comparatively greater capacity for yielding to strains, have suffered much from contortions and minor faults.

(4) *Upper Gray Shales and Flags.*—This group, as the name implies, is somewhat like No. 2, but in it the conglomerates and specular ledges are wanting and the amount of quartzite is usually much less. Owing to the brittleness of the material of the beds and the ease with which many of them yield to crushing, portions of the strata are often found crushed to loose fragments. In the fractured and crushed portions important deposits of limonite are sometimes found that are evidently produced by the concentrating action of percolating waters. The reddish and brownish rocks found in No. 2 are also wanting here. The predominant rocks are shales and flags, usually all highly argillaceous, and when fresh of a gray or greenish gray color, but on weathering apt to assume a grayish white color. Towards the top quartzite ledges are interstratified with these and cause a gradual passage into the Potsdam quartzite. In some places the amount of quartzite here is very large and should properly be counted as a portion of the Potsdam member of the Primordial. Perhaps the predominant rock is a gray shale that resembles a hardened mudstone and which graduates into a sandy shale. This rock often decays to a pure white clay, and no doubt furnishes the material for the pure potter's clay sometimes found immediately west of the Blue Ridge. These strata for the sake of distinction may be called kaolin shales or flags.

(5) *Potsdam Quartzite.*—The members of the Primordial below this, so far as observed by us, show no indications of the former existence of life. This portion of the formation, however, shows in some beds numerous casts of Scolithus borings, some of which are remarkably long, being visible for at least 3 feet. The brothers Rogers considered this member as identical with the Potsdam sandstone of New York. This portion of the Primordial is more constant in lithological character than the subdivisions that underlie it. Quartzite is always the predominant rock in it, the remaining portions being mostly composed of the kaolin shales and flags. To the south, and especially in the interval from Mount Torrey to Buena Vista furnace, the quartzite is very massive and siliceous, composing nearly all of the rock at this horizon. The material is more properly called a quartzite than a sandstone. The upper and lower portions are often flaggy, and cause a passage into the underlying and overlying shales and flags. So far as observed, these quartzites are never conglomeratic, and they are free from the infiltrations of silica, the diffused chlorite, and other characters that mark the lower quartzites. Near the junction of this member with No. 4, the strata are often crushed, the crushed band holding important deposits of a dark limonite. The Quartzite members of this subdivision are sometimes broken up and crushed, forming a curious band of breccia, cemented by iron or manganese. Sometimes workable deposits of limonite are found in these disturbed portions.

(6) *Ferriferous shales.*—It might be a question whether these shales ought not rather to be counted with the Calciferous group. It is certain that there seems to be a gradual passage from the shales into the pure Magnesian and Siliceous limestones, that correspond to the Calciferous sandstones of New York. No fossils are found to settle the matter, and it seems best to draw the dividing line at the first marked change in the lithological character of the strata. This change occurs with the lowest limestone beds, that usually occur interstratified with reddish and yellowish shales.

The Ferriferous shale group is noteworthy for containing throughout it deposits of limonite which are often suited for the manufacture of a neutral iron. These deposits seem to be of concretionary origin, formed by the decay of the shales which contain the iron in a diffused form, probably, for the most part, as a carbonate, but sometimes as pyrite. These ores are consequently usually imbedded in clay. They assume the form of lenticular masses, usually built up of concretionary forms. These ores are unlike those found in and under the Potsdam sandstone, and not rarely are mingled with oxide of manganese or associated with it, forming ferro-manganese. In the same shales, occurring under conditions similar to the iron and formed in like manner, we find, not rarely, deposits of quite pure manganese oxide. This is always in the form of Psilomelane or hard manganese.

The lowest of the strata of this group have the character of kaolin shales and flags. They graduate insensibly into the Potsdam quartzite member. In ascending they become purely argillaceous shales, generally of lead, or bluish gray color, when fresh. With these, moreover, occur strata yellowish-reddish in color, the red often assuming a pinkish shade. Towards the top, ledges of pretty firm pure purplish shales and flags are found that are sometimes of the nature of fine-grained sandstone. The shales towards the top are often calcareous, and graduate into the impure limestone with which the Calciferous group may be assumed to begin.

We thus have in the Primordial formation, in the belt now being described, at least three horizons of iron ore. The lower strata contain specular iron ore usually of low grade, the middle portions, extending as far as the Potsdam quartzite, containing limonites, either impregnating definite strata, or filling what were once fissured and crushed bands. Hence all of these usually appear in massive or rocky outcrops. Finally, in the Ferriferous shales, we have interrupted deposits of limonite, inclosed in clay and often mixed with manganese. (No. 12885, U. S. G. S. Library.)[1]

The Balcony Falls section has also been studied by J. L. and H. D. Campbell with a slightly varying result. As measured by Prof. J. L. Campbell the section is as follows:

	Feet.
1. Conglomerates	50
2. Sandstones	350
3. Slates	600
4. Sandstones (thickness not given).	
5. Slates	180
6. Scolithus sandstone	340
7. Shales	600
Total	2,120

A comparison of this with the sections measured by Prof. Fontaine, in 1879, shows essentially the same succession of strata, although differing materially in the thickness of the various divisions based on the character of the rocks. Subsequently, Prof. Campbell added to the preexistent information of the section at Balcony Falls, by showing that the primal series is present upon the southeastern slope of the Blue Ridge, a short distance north of the James river. This was followed by a paper on the Snowdon slate quarries, by himself and his son, in which it is said that the sandstones are penetrated with Scolithus and dip beneath the Snowdon roofing-slate quarries.[2] An accompanying ideal section, crossing the Blue Ridge 3 miles north of James River Gap, represents the Primal series at the summit dipping to the westward and on the eastern slope dipping at a high angle to the eastward and resting unconformably upon the Archean gneiss.[3]

[1] Op. cit., p. 43.
[2] The Snowdon slate quarries. The Virginias, vol. 5, 1884, pp. 162, 163.
[3] Op. cit., p. 170.

Prof. J. L. Campbell concludes, from the structure, that this portion of the Blue Ridge has been formerly spanned by a grand arch or series of arches of Cambrian strata, upturned, perhaps, at the time of their upheaval.[1]

In 1885 Mr. H. D. Campbell published a more detailed section of the Blue Ridge at Balcony Falls, to illustrate the view that the Blue Ridge at this point is a portion of an anticlinal fold, over which the Cambrian strata formerly extended from the west to the east, forming a synclinal basin on the western side of the Blue Ridge. He described the Cambrian section at Balcony Falls as follows:

	Feet.
1. Conglomerate	120
2. Sandstone	360
3. Slates	500
4. Hard sandstone	150
5. Slates	700
6. Sandstone	90
7. Slates	120
8. Scolithus sandstone	350
Total	2,390

He further states that, away from the river some distance, there is about 600 feet more of sandstone and friable slate before reaching the limit of the Potsdam formation.[2] This gives a greater thickness to the Cambrian section of Balcony Falls than that measured by either Prof. J. L. Campbell or Prof. Fontaine.

The next complete description of the Cambrian in the southwestern portion of the State is that of Prof. J. J. Stevenson, in his account of a reconnaisance of Bland, Gyles, Wythe, and portions of Pulaski and Montgomery Counties. On the map accompanying the paper, the geographic distribution of the Cambrian rocks is shown for Montgomery, Pulaski, and Wythe Counties. He includes in the Cambrian the lower Knox shales and the Potsdam, stating that the former are probably equivalent to the hydromica schists of Pennsylvania and the lower part of the Calciferous of New York; the latter is the Potsdam of New York, vastly increased in thickness.[3] The Knox shales are described as being reddish, sometimes streaked with white color, usually more or less greasy, often talcose-looking on the slipped surfaces. The shales are hard enough to form bluffs. The thickness could not well be ascertained, but it can not be less than 600 feet.

The Potsdam forms the great mass of Lick Mountain, is the sandstone of Draper Mountain, and is found along the southern border of Wythe, Pulaski and Montgomery Counties. The upper beds are alternations of sandstones and shales.

[1] Geology of the Blue Ridge near Balcony Falls, Virginia; a modified view. Am. Jour. Sci., 3d ser., 1884, vol. 28, p. 223.

[2] The Potsdam group, east of the Blue Ridge, at Balcony Falls, Virginia. Am. Jour. Sci., 3d ser., vol. 29, 1885, p. 472.

[3] A geological reconnaissance of Bland, Giles, Wythe, and portions of Pulaski and Montgomery Counties of Virginia. Am. Phil. Soc. Proc., vol. 24, 1887, pp. 86, 87.

The base of the series was not observed by Prof. Stevenson, but he thinks that the sandstone of Draper Mountain is not less than 2,000 feet in thickness. The only fossils observed were *Scolithus linearis*, on Lick Mountain.

In Dutchess County, New York, on the north, and in Tennessee on the South, the lower portions of the limestones are of Cambrian age. Whether the same is true of the arenaceous limestones above the Cambrian shales is one of the problems to be studied in Virginia.

NORTH CAROLINA.

The Cambrian rocks in North Carolina are the extension across the border from Tennessee of the Chilhowee series with, perhaps, some of the Knox shales. The best section is that along the line of the French Broad from Paint Rock on the State line eastward up the river to the vicinity of Warm Springs. The Paint Rock sandstone apparently is the representative of the Chilhowee sandstone, and the shales the Knox shales, or Upper Cambrian. The relation of the other portions of the section on the French Broad to these formations is, as yet, undetermined.

TENNESSEE.

Ocoee conglomerate.—The descriptive details of the Cambrian rocks of Tennessee are almost entirely derived from the work of Prof. J. M. Safford as published in the "Geology of Tennessee" in 1869. A large amount of additional data has been obtained by the geologists of the U. S. Geological Survey. At my request Mr. Bailey Willis, chief of Appalachian Division of Geology, prepared the following notes upon the geologic position of Prof. Safford's Ocoee formation:

The Appalachian Paleozoic area is bordered on the eastern side by a belt of clastics of very great thickness, which forms conspicuous ridges between the Archean granites and the calcareous Paleozoic strata. The slates, sandstones, and conglomerates of this belt, characterized by lithologic similarities among themselves and distinguished by marked lithologic contrasts from other rocks, fall into a natural group. Semimetamorphic, they occupy mineralogically a position between the crystallines and the unaltered sediments. Resting in many localities directly on the Archean and containing fragmental granitic minerals, their apparent stratigraphic position is also intermediate between the Archean and the unaltered sediments. For these reasons, and in the absence of fossils, they have been placed by all the older geologists at the base of the stratigraphic column. Structural facts sometimes fall in with this stratigraphic arrangement, and where they do not faults have been assumed to account for the superposition of the supposed older on younger strata.

In Tennessee the type localities of these clastics are Chilhowee Mountain and the Ocoee gorge, and quartzites of the Chilhowee type, but not in Chilhowee Mountain, have been correctly placed above slates of the Ocoee type by Safford. Your own discovery of fossils in the upper shales of Chilhowee Mountain appears to determine the age of all these sediments as Lower Cambrian or pre-Cambrian. But there is an assumption which must be sustained, or the conclusion fails in its broad application. That is, that the natural grouping of these strata by physical characters into a single series proves them to be of one period; this may be the result of similar conditions which existed at different periods, and the natural group may include strata of widely separated horizons. The latter is the fact. The Chilhowee formation in Chilhowee Mountain has been proved by fossils to be Lower Cambrian, but it is a synclinal mass isolated by faults, and the definite determination does not apply beyond its limits. It is not connected with the Ocoee area, and the Ocoee rocks in the type locality are so separated from strata of known age, that nothing definite can now be asserted as to their correlations. Starrs Mountain, a "Chilhowee" outlier 24 miles southwest of Chilhowee Mountain, contains a fossiliferous limestone apparently conformably underlying the quartzite; if further study confirms this apparent relation, the quartzite is near or above the top of the Lower Silurian. Meadow Creek Mountain and the Big Butt range, extending from 25 to 70 miles east by north from Chilhowee Mountain and assigned by Safford to the Chilhowee and Ocoee formations, are determined on stratigraphic and structural evidence to belong to the Nashville period, the last of the Lower Silurian deposits. "Ocoee" strata of Safford, occurring southeast of Chilhowee Mountain about Cades, Tuckaleechee, and Weirs Coves, are known to belong to the Nashville on evidence of strict structural conformity to the Knox dolomite over three extensive quaquaversals and through transition beds from the dolomite to the slates. The Nashville "Ocoee" strata in this locality and in the Big Butt exceed 12,000 in thickness and form some of the highest ranges along the North Carolina boundary.

If, as these facts prove, the great natural group of clastics along the eastern Paleozoic border is the result of conditions repeated in different periods, we should seek an explanation for recurrence of like conditions, and this is found in the relative extent of subsidence in the Cambrian and Silurian times.

The Cambrian sea transgressed over the granitic continent under such conditions that the constituent minerals entered into shore deposits, without complete decomposition; these conditions probably existed in the deep disintegration of the granite, as suggested by Pumpelly. The subsidence ceased during Knox time and the deposition of the Knox was followed by uplift which exposed the dolomite to the waves of the Nashville sea. The evidence of this and of subsequent subsidence is found in conglomerates of Knox dolomite at the base of and interstratified with the strata of the Nashville-Ocoee in many localities. The beds associated with these conglomerates are arenaceous shales and sandstones, but higher in the Nashville series conformably stratified with these, and extending to basal conglomerates resting on the Archean, are deposits containing granitic fragments like those of the Cambrian-Ocoee. The stratigraphic and geographic relations leave no doubt that the Nashville was a period of great transgressions beyond the limits of any previous subsidence, and the deposits derived from the granites in the later time were identical with those earlier accumulated from the same source.

The semi-metamorphic character of both Cambrian and Nashville-Ocoee strata demands explanation which may possibly be found in their original composition and in their common relations to thrust and resistence during Appalachian formation. Both series of rocks are thin bedded piles, both rest against the unyielding Archean masses. Whatever pressure they received they were forced to conform to and they appear to have suffered changes of form, which were both mechanical and chemical and which were induced by dynamic conditions.

The generalizations herewith submitted are derived from the detailed work of Messrs. Arthur Keith and C. Willard Hayes as well as from my own studies and the conclusions as to the age of formations have been reached through mutual cooperation.

Chilhowee sandstone.—The lithologic character of the Chilhowee sandstone is given as follows by Prof. Safford:

It is a great group of heavy-bedded sandstones, often dark, but generally weathering to a grayish white, and containing great beds of whitish quartzose sandstone, or quartzite. Interstratified with the heavy-bedded rocks are, at some points, sandy shales, and thin flags, often containing scales of mica. Some of the sandstones are coarse and approach fine conglomerate. It may be mentioned, too, that not unfrequently the strata have green grains (glauconite) disseminated through them.

The sandstones of this group very often show the worm-holes, and the sandy rods within them, belonging to Hall's species *Scolithus linearis*. It is the exception not to meet with them. In addition to these, the surfaces of the strata sometimes show impressions of fucoids. No other fossils, that I know of, have been found in this horizon of Tennessee.

This formation is by no means as thick as the Ocoee series; yet it has volume enough to form conspicuous mountain ridges. It is not easy to determine its thickness; its maximum is not less, however, than 2,000 feet, and it may be considerably more.[1]

This general description is followed by the detailed description of a number of sections. The lithologic features of this formation are much the same in all of its presentations, from Virginia to Georgia.[2]

Knox sandstone and shale.—In the table of geological formations the Knox group is next in order above the Chilhowee sandstone, and its basal member is formed by the Knox sandstone.[3] The principal rocks of the Knox sandstone are hard shales and thin sandstones, heavier sandstones being interstratified with these. The heavier sandstones are fine or coarse grained, sometimes quartzose. They occasionally abound in green grains. In the section of Webb's Ridge, near Knoxville, the hard, dark, gray sandstone referred to occurs six times in beds from three to ten feet thick, and weathers into a buff, softer material. In general, the included layers vary much in appearance. As before stated, beds of dolomite are met with in the division.[4]

The thickness of these rocks can not be much less than 800 or 1,000 feet. In Webb's Ridge, where they are in less force than at many other points, the thickness is 540 feet.

The strata are often ripple-marked, and sometimes covered with fucoidal impressions and ridges. Aside from fucoids, I have not met with any fossils in these rocks. * * *

It may be mentioned as a prominent feature of this division and of the Knox shale overlying it that they present shales and sandstones of many different colors. The rocks are pale green, brown, and red, chestnut-colored, buff, gray, and other colors. Brownish red, greenish, and buff are, perhaps, the prevailing tints. The colors are often bright, and notably agreeable.

In reading the description of the Knox sandstone by Prof. Safford, I have failed to find any general or detailed section or description that connects the Chilhowee sandstone and the Knox sandstone. Apparently there is not any section known in which the two are seen in stratigraphic relation to each other. From the character of the section and the sedimentation, it may be that the Knox sandstone is the representative of a portion of the Chilhowee series, the former being the off-shore deposit, while the Chilhowee sandstone accumulated near the shore.

The Knox shale is largely a variegated shale, with interstratified beds of thin layers of blue limestone, which is often oolitic.

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[1] Geology of Tennessee, pp. 198, 199.
[2] Op. cit., 1869, p. 203.
[3] Op cit., p. 158.
[4] Op. cit., p. 209.

The calcareous bands in the lower part of the division are not numerous; toward the top, they generally become more abundant, increasing as we ascend, until finally the shales disappear, and the blue ooliticlime stone, and dolomites are the only rocks. In this way the shale division runs into the uppermost one.

In the northeastern part of the State the shales, as a division, are not well characterized. As already stated they are much mixed with beds of limestone and dolomites, and lose, in good part, their distinctive features. Moreover, in this region there is little oolite rock. A portion of the shale appears to be replaced by a blue limestone containing thin clayey seams, which give the surface, especially when weathered, a striped appearance. This striped rock occurs, too, further south, its place being at the top of the shale.

The thickness of the Knox shale is not easily determined. What is said in reference to the thickness of the strata in Poor Valley * * * applies generally. We may place it as an approximation at 1,500 or 2,000 feet.[1]

Prof. Safford states that fossils occur in a blue limestone intercalated with shales, sometimes quite abundantly, both in the compact and oolitic layers. Toward the top of the division and in the blue rocks of the succeeding division they are seen at many points. The shales themselves are occasionally fossiliferous. It was his intention to describe the species in the appendix of the volume, but we find only a list of names, as follows:[2]

Crepicephalus similis, Safford.
  roanensis, Safford.
  tennesseensis, Safford.
Lonchocephalus fecundus, Safford.
Agnostus arcanus, Safford.
Lingula prima?, Conrad.

A large collection has been made within the last few years at the localities from which he obtained his specimens, and from many others in Tennessee, that indicate this fauna to be a portion of the Upper Cambrian or Potsdam fauna. The same fauna extends up into the base of the limestone for a short distance. The entire dolomitic series is referred to the Knox group by Prof. Safford, but I think that the line of demarcation must be drawn near the base of the dolomite.

As a whole, the Cambrian group in Tennessee is represented by a great series of sandstones at the base, succeeded by a series of shales that become more and more calcareous toward the top, where they pass into the dolomitic series, forming the base of the Silurian (Ordovician) system. During the progress of the resurvey of eastern Tennessee by the geologists of the U. S. Geological Survey Dr. Cooper Curtice found a few fossils in the shales interbedded in the quartzite of Chilhowee Mountain, and in 1889 I found a few specimens in the shale about 20 feet above the quartzite in the upper shale bed. The study of the fossils collected by Dr. Curtice and myself proves that the Olenellus or Lower Cambrian fauna occurs in the shales of the quartzite series of Chilhowee Mountain. This fauna, with that found in the upper portion of the Knox shales and the base of the dolomite, gives two distinct

[1] Op. cit., p. 211.
[2] Op. cit., p. 212.

horizons in the Cambrian of Tennessee—the Lower Cambrian and the Upper Cambrian. Between the two there is an unknown thickness of shale, in which fossils have been found sparingly, but not in sufficient numbers to determine the presence of the Middle Cambrian fauna. If the definition that the base of the Cambrian is to be drawn at the lowest horizon in which the Olenellus fauna is found is applied in Tennessee, the Chilhowee sandstone will be referred to the Cambrian.

GEORGIA.

The published information relative to the Cambrian rocks of Georgia is largely contained in the work of Mr. George Little. It is summed up in the compilation prepared for the Department of Agriculture, under the direction of Mr. Henderson, as follows:

Acadian.—Along the western escarpment of the Cohuttas exist beds of semimetamorphic slates, and conglomerates, apparently of very great thickness. To this formation, in Tennessee, has been given the name of Ocoee group, from the Ocoee River, along which, near the line of Tennessee and Georgia, the rocks appear to have their greatest development, or at least are most prominently displayed.

The group as yet is not known to contain fossils, but has been referred on the ground of its supposed stratigraphic relations to the Acadian epoch. A sandstone of several hundred feet in thickness is conspicuously displayed in steep ridges or mountains skirting the western base of the Cohutta, Pine Log and Allatoona Mountains. This is the Chilhowee sandstone of Tennessee, and is believed to be the equivalent of the Potsdam sandstones. In Tennessee, *Scolithus* impressions—worm holes filled with sandy rods, somewhat softer than the body of the rock—are mentioned as a common characteristic of the sandstone by Prof. Safford, and indicate a probable identity in age with the Potsdam sandstone of New York. These markings have not yet, so far as known, been observed in this State, but the sandstones are often filled with small rounded concretions, that disappear from the weathered surface, and give much the appearance presented by a cross-section of the Scolithus rods in sandstone.

This is succeeded by hard glauconitic shales and glauconitic sandstones, associated with siliceous limestones, found in a broad belt of country along the Coosa River, and give rise here to what is known as the Flatwoods. Some portion of the same group is found in a belt of country in the eastern portions of Gordon and Bartow and the southern part of Murray, and also come to the surface again for a few miles in sterile ridges on the western side of Whitfield County, between Dick's Ridge and Chattoogata Mountain. Trilobites are found in some of the shales and limestones, and are abundant in the Flatwoods, near Livingston, in Floyd County.

A prominent mineral characteristic is the common appearance of green sand or glauconite in the shales and sandstones, and sometimes in the limestones. This green sand may be found, on close examination, in most of the shales and sandstones, and is sufficiently abundant in some to give them a decided green color. * * *

Knox shale.—Shales and limestone of an estimated thickness of 3,500 feet. The shales are more or less calcareous, and are generally of a light green shade of color, below the water surface, but weather into a great variety of shades from buff to red, blue, green, brown and black, but is most generally some shade of brown. These shales exist in all the counties in northwest Georgia except Dade, and are found in a number of long valleys, varying from half a mile to 1 or 2 miles in width, constituting a large part of the area of cultivated lands in this section of the State. Among these are the Oothkalooga Valley of Bartow and Gordon, the Cooehulle and Dogwood Valleys of Whitfield, and the Chattooga Valley of Walker and Chattooga.[1]

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[1] Henderson, J. T.: Geology (of Georgia). The Commonwealth of Georgia; the country, the people, the productions. Atlanta, 1885, pp. 83, 84.

As noticed in the historical review, Mr. McCutchen's estimates of the thickness of the formations referred to the Primordial is 8,000 feet, and to the Knox shale series 2,400 feet, making a total thickness of 10,400 feet. The estimates of the author we have just quoted assign to the Knox shale a thickness of 3,500 feet, which will give a still greater thickness for the total Cambrian section. I think, however, that all such estimates must be carefully revised, as the rocks of the Knox shale series are very much disturbed by plications and faulting.

An unpublished section, by C. Willard Hayes, of the Appalachian Division of the U. S. Geological Survey, extending from Rome, Georgia, to Gadsden, Alabama, gives the following series, extending from the top downward:

			Feet.
Silurian.		Knox dolomite	4,000–5,000.
Cambrian.	Connasauga shale.	Thin bedded seamy limestone, sometimes blue and massive.	
		Yellow shales, calcareous, grading into seamy limestone.	
		Earthy limestone interbedded with shales, often wanting; locally carries nodules of chert.	
		Yellow shales.	
		Oolitic limestone; thin beds in light green or yellow shales.	
		Variegated sandy shales, purple, green, brown, etc	1,600–2,000
	Rome Sandstone and Weisner Quartzite.	Thin beds of highly colored sandstone; red, purple, and green; show ripple marks and sun cracks. Beds 1 to 12 inches thick with interbedded shales. Maximum thickness shown between Rome, Georgia, and Big Cedar Creek	1,300–1,800
		Green shales, with thin, hard, siliceous beds, ½ to 2 inches thick, or layers of flat nodules. Maximum thickness at Georgia-Alabama line	700–1,500
	Coosa shales.	Fine yellow or brown shales, containing some beds of blue limestone	1,000+
		Heavy beds blue, seamy limestone	600±
		Yellow or green clay shales, with thin beds of blue limestone contorted and filled with calcite veins. Sometimes the shales contain siliceous nodules. Always highly contorted. Cover a large area between Rome and Gadsden, and form the "Flatwoods" of Coosa Valley. Thickness not known; probably not less than	3,500

In a recent paper on the valley rocks of northwestern Georgia, Mr. Hayes assigns a thickness of 1,600 to 2,000 feet to the Connasauga (=Montevallo of Smith) shales; 2,000 to 3,500 feet to the Rome sandstone and Weisner quartzite, and 3,000 feet plus to the Coosa shales.[1]

In a section at Mount Weisner, Alabama, Mr. Hayes found a quartzite that he considers to correspond to the Rome sandstone. It has a thickness of about 800 feet, and is in the form of lenticular masses of white quartzite; sandstone and conglomerate occur at the base and

[1] The Overthrust faults of the southern Appalachians. Bull. Geol. Soc. America, vol. 2, Feb., 1891, p. 143, pl. 3.

replace a portion of the Rome sandstone. In Indian Mountain it is much thicker than in Mount Weisner, and consists of several beds of quartzite, with intervening masses of yellow sandy shales.

The fossils collected from the Coosa shales by Dr. Cooper Curtice indicate, as studied by me, the Middle Cambrian fauna of the northern Appalachian section. The Connasauga shale is correlated by its stratigraphic position with the Knox or Upper Cambrian shales of the Tennessee section. In Mr. Hayes' table the Rome sandstone and Weisner quartzite are placed on the same horizon with the Knox sandstone, Potsdam or Chilhowee of Smith and Safford. That the correlation by Messrs. Smith and Safford of the Weisner quartzite with the Chilhowee is probably incorrect is supported by the fact that the fauna of the Coosa shales belongs above the Chilhowee sandstone in sections where the succession is undisturbed. The Chilhowee sandstone fauna is the type of the Lower Cambrian, and the Coosa shale fauna is that of the Middle Cambrian.

When the maps of the Paleozoic region of Georgia and Alabama are published geologists will have the data for the geographic distribution of the Cambrian rocks, and also sections showing the relative position, thickness, and the variations in the character of sedimentation from the south to the north as the formations pass to the north into Tennessee.

ALABAMA.

Our knowledge of the Cambrian rocks of Alabama is largely obtained from the Report of Progress for 1875. The nomenclature adopted for the fossiliferous sedimentary rocks up to the base of the Knox dolomite, by Prof. Safford, in Tennessee, is followed by Prof. E. A. Smith in this report. To the Primordial or Cambrian series he assigns the Acadian epoch, or the conglomerates and slates corresponding to the typical Ocoee section in Tennessee. To the Potsdam epoch he confines the Chilhowee sandstone of the Tennessee section. The Knox sandstone and Knox shales are referred to the Canadian period. The term "Calciferous sandstone" is used as the equivalent of Knox sandstone, and "Quebec shales" of the Knox shales. The section of the Acadian slates and conglomerates in Talladega County is considered by Prof. Smith typical of this series in Alabama.[1] The description is as follows:

> The western border of the Metamorphic rocks in Alabama is formed by a belt of slates and conglomerates, semi-metamorphic in aspect, and of varying width, but perhaps of an average width of six miles. These rocks, which in every respect seem to be the exact equivalents of Prof. Safford's Ocoee Slates and Conglomerates, are referred like them to the Acadian epoch.[2]

The stratigraphic succession of the beds is not well determined. There is a belt of greenish talcoid, or hydro-mica slate, and a series of conglomerates which are sometimes a slaty, arenaceous rock, but often

[1] Report of Progress of the Geological Survey of Alabama for 1875. Montgomery, 1876, pp. 13–17.
[2] Op. cit., p. 127.

quite massive, and made up of lumps of pebbles of opalescent quartz and opaque white feldspar, held in a matrix of greenish talcoid matter.

Of the second division, or the Potsdam, it is said:

Next in ascending order, to the slates and conglomerates of the preceding group, comes a series of sandstones which form the most conspicuous mountains outside the Metamorphic and Acadian areas. The direct superposition of this sandstone upon the slates of the Acadian age, I have not seen in Alabama, unless on the eastern edge of that belt, the prominent sandstone or quartzite ridge be, as seems quite probable, metamorphosed Potsdam sandstone. In the disturbed region of the Kahatchee Hills, also, half metamorphosed slates are seen, some of which may belong to the Acadian epoch, whilst others are evidently altered Knox shales.

Fine-grained conglomerates, heavy-bedded sandstones, and sandy shales make up the great mass of the rocks of this formation. I have noticed, also, occasionally, masses of a brownish porous chert, which, from its association with the sandstones, seems to be of the same age.

In general, the rocks of this formation are heavy bedded, almost massive, and the higher crests of the Potsdam Mountains are usually covered with huge blocks of sandstone and fine-grained conglomerate. In the lower parts of these ranges, sandy shales are the prevailing rocks. * * * The most characteristic markings of the rocks of this formation are the sandy rods, caused by the filling in with sand of the burrows of a marine worm, *Scolithus linearis*. Upon the bedding planes of the sandstones, small rounded depressions or dots mark the cross-sections of these Scolithus burrows. As yet I have found no other marks of organic origin in strata of this horizon. * * *

The nature of the rocks of this group, conglomerates, sandstones, and sandy shales, the fossil markings, principally the burrows of marine worms, etc., all point to a seashore origin.[1]

From the preceding descriptions, the equivalency of the Chilhowee sandstone and quartzite with that of Alabama is extremely probable, if not certain.

Of the succeeding formation, the Knox sandstone, the following description is given:

The rocks of this group succeed next, in ascending order, the Potsdam sandstone, and they are often, no doubt, found resting directly upon that rock. I have not, however, often seen them in this position; but much oftener just on the southeast side of a fault by which they have been raised to the level of a much higher formation. This sandstone is more generally associated with the shales of the next higher group, and these with dolomite, so that three groups are usually closely associated *geographically* as well as *lithologically*.

A calcareous sandstone, sometimes thick, sometimes thin bedded, is the characteristic Knox sandstone.

It is associated with hard calcareous shales much like the shales of the next higher division. The bedding planes of the sandstone commonly show ripple marks and irregular raised markings, which are commonly supposed to be fucoidal impressions. The bedding planes are also frequently smooth and shining as if polished. Green grains of glauconitic mineral are usually to be seen upon a fresh fracture of the sandstone; upon weathered surfaces the brown color of hydrated ferric oxide is often the result of the decomposition of this mineral. The colors of the Knox sandstone are pleasing to the eye, and are gray, greenish brown, buff, chestnut colored, etc. Beds of dolomite, impure and cherty, are found in the upper part of this formation; two such calcareous beds were noticed in the exposure of Knox sandstone at the Jackson shoals and also at Helena. * * *

[1] Op. cit., p. 13-15.

It [Knox sandstone] would naturally be looked for overlying directly the Potsdam sandstone of the mountains enumerated in a previous section; but it is not always easy to distinguish it; since, however, these ridges of Potsdam sandstone have a well defined belt of Knox shales on their eastern and southeastern flanks, the Knox sandstone, probably in most cases, intervenes between the two.[1]

It will be noticed in the description given of the Knox sandstone that its direct superposition upon the massive "Potsdam" sandstone has not been observed. I think that as in Tennessee the Knox sandstone may be, in part, the equivalent of the sandstone referred to the Potsdam or the Chilhowee sandstone. It is probably the accumulation of sand and shale deposited while the sediments of the more massive sandstones were accumulating nearer the coast line.

The Knox shales rest conformably upon the Knox sandstone series and correspond in their description closely with the Knox shales of Tennessee. Of these beds Prof. Smith says:

The characteristic rocks of this subdivision of the Knox group are calcareous shales of bright and agreeable colors, usually gray, buff, greenish, brown, chestnut colored, and red. The shales are tolerably soft, and in some portions in weathering, break up into small angular pieces resembling shoe pegs. Strata of dark blue limestone, sometimes banded with argillaceous layers, are found, especially in the upper part of this division. The weathering of such limestones brings into relief the bands or stripes of argillaceous matter, and the limestone appears very distinctly banded. Where these impurities are not so regularly disposed in layers, but in patches, the prominence given to them by the weathering away of the limestone gives them a striking resemblance to half-exposed fossils.

In some places layers of dark colored oolitic limestone have been observed, one of the best localities of this peculiar rock being at the foot of the mountain at Alpine Station in Talladega County.

In the upper part of the division blue limestone layers become more frequent, and the transition into the overlying Dolomite is so gradual that a line between them lithologically is hard to draw.[2]

The only instance mentioned to indicate the relations of the so-called Potsdam sandstone to the Knox shales is in the following paragraph:

Between the Ladiga Mountain and the hills of Acadian slate in Calhoun County, there are numerous small ridges of Potsdam sandstone, on the flanks of which the Knox shales seem never to be wanting.[3]

No fossiliferous strata were observed in this division.

The distribution of the Cambrian rocks of Alabama is shown on a map accompanying Prof. E. A. Smith's outline of the geology, published in 1878. On this map the geographic distribution of both the Cambrian and Lower Ordovician rocks is delineated under one color called the Silurian. It includes all the formations from the Clinton down to the Acadian. Of these formations the Cambrian includes, at the summit, the Quebec or Knox shale and Knox dolomite, or at least the lower portion of it, and subjacent to this the Calciferous or Knox sandstone, beneath which the Potsdam and Acadian are placed, the latter forming the base of the Paleozoic series.[4]

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[1] Op. cit., pp. 17, 18. [2] Op. cit., p. 19. [3] Op. cit., p. 20.
[4] Outline of the geology of Alabama. Berney's Handbook of Alabama, 1878, p. 139.

In a report on the geology of the Cahaba Coal Field Prof. Eugene A. Smith describes the Cambrian rocks as they occur in the Coosa Valley of northeastern Alabama. The maximum thickness given is 10,000 feet in the eastern part of the Coosa Valley. The subdivisions of the Cambrian recognized are, in ascending order, as follows: "The Coosa shales, the Choccolocco or Montevallo shales, and, interbedded with the last named, the Weisner quartzite."[1]

The Coosa shales are described as thin-bedded limestones with clay seams at the base, and pass above into the Montevallo shales, which form a considerable thickness of sandy shales of a great variety of colors, such as olive, green, brown, chocolate, yellowish, etc. In the upper part of the Montevallo shales beds of blue limestone and gray dolomite occur which are difficult to distinguish from similar rocks occurring in the superjacent dolomite series. Lenticular masses of quartzite many hundreds of feet in thickness occur in the Montevallo shales. This quartzite is named the Weisner quartzite from its typical locality at Weisner Mountain, east of Jacksonville, and is correlated with the Chilhowee formation of Prof. Safford in Tennessee.[2]

From our present knowledge of the formations referred to the Cambrian in Alabama it appears that they are the continuation of those referred to the same group in Georgia and Tennessee, though varying somewhat in the local details of sedimentation, thickness of beds, and lithologic characters.

The section of Mr. C. Willard Hayes, described under Georgia, embraces much of the Cambrian strata that passes into Alabama, and should be referred to in this connection. (Ante, p. 304.)

RÉSUMÉ.

For a distance of over 1,200 miles the pre-Cambrian lands formed the eastern boundary of this province during the deposition of the sediments of Cambrian time. From below Montreal to the foot of Lake Champlain and thence southward to the crossing of the Hudson, below Poughkeepsie, New York, and on across New Jersey, Pennsylvania, Virginia, Tennessee, and into Georgia and Alabama, the rocks of this pre-Cambrian land form an almost continuous outcrop at the present day. The Cambrian rocks extend 400 miles farther to the northeast from Quebec to the northern portion of the peninsula of Gaspé; but there is now an interval of over 200 miles between the Archean ridges of eastern Quebec and the long, narrow Archean axis of the Gaspé peninsula. The exposures of the Cambrian on the coast of Labrador, opposite the Straits of Belle Isle, and those of the west shore of Newfoundland, have been included in the Atlantic Coast Province, but they are quite as much a

[1] Geological structure and description of the valley region adjacent to the Cahaba Coal Field. Geol, Survey of Alabama. Report on the Cahaba Coal Field, pt. II, 1890, p. 148, (issued January, 1891).
[2] Op. cit., pp. 148, 149.

part of the Appalachian Province by fauna and physical character and are considered as a connecting link between the two provinces. The Labrador deposits are on the north shore of the Cambrian sea, but those of the west shore of Newfoundland are, in physical character and organic remains, the practical continuation of the sediments of the eastern side of the Appalachian Province. If this correlation be made, the pre-Cambrian shore line is carried 400 miles farther to the northeast and thence to the Straits of Belle Isle, giving a nearly direct line of over 2,000 miles that may be included in the Appalachian Province with its Canadian extension. Along such a great extent of coast line one expects to find evidences of varying sedimentation, both in character and amount; and an examination of the various geological sections of Newfoundland, the river St. Lawrence, Vermont, New York, and south along the Appalachian range to Alabama, shows the most marked variation, both on the strike of the strata and in proceeding westward from the ancient shore line.

On the Labrador coast the rocks are sandstones followed by more or less impure limestone. On the western shore of Newfoundland, over 1,000 feet of alternating limestones, shales, and quartzites rest conformably upon 600 feet or more of slates. For 375 miles along the south shore of the St. Lawrence, from Cape Rosier of Gaspé to the vicinity of Quebec, the strata referred to the Cambrian consist, according to Mr. James Richardson, of quartzite, with intercalated beds of conglomerate holding limestone pebbles, the whole forming a series 600 feet in thickness. This is superjacent to 700 feet of gray sandstone, also carrying conglomerate, while beneath this a limestone, with conglomerates and bedded sandstones towards the lower portion of the section, extends down some 700 feet more, giving over 2,000 feet as the entire thickness of the section. Owing to the absence of paleontologic data there is some uncertainty in referring all of this series to the Cambrian. In some of the pebbles in the conglomerates of the upper portion a number of species of the Olenellus fauna were found; but no one of the three great divisions of the Cambrian has been distinctly recognized.

In the vicinity of Quebec the stratigraphic succession from below upward consists of a succession of black, green, and gray shales, with hard and heavy bands of green, sometimes yellowish white, quartzose sandstones. This is succeeded by greenish, grayish, and blackish, with occasionally dark reddish or purplish tinted shales, with a band of hard grayish sandstone. Above the latter bright red shales, with thin greenish or grayish bands, which in places are often calcareous, extend up through red, greenish gray, and black shales with interstratified masses, often lenticular, of greenish and grayish Sillery sandstone. In the upper part of this last series *Obolella pretiosa* occurs. A thickness of from 5,000 to 6,000 feet is estimated for the Cambrian series, beneath the graptolitic shales of Point Levis.

It will be noted of this section that the limestones of western Newfoundland and the lower portion of the south shore of the St. Lawrence are absent, and that the section is composed almost entirely of arenaceous and argillaceous sediments. A limestone conglomerate, near the upper portion of the Sillery, contains bowlders carrying the Olenellus fauna, and the Upper Cambrian fauna occurs in the basal conglomerates of the Point Levis, graptolitic,Lower Silurian (Ordovician) shales. These bowlders appear to have been derived from a limestone series similar to that now found in Labrador and Newfoundland.

The strata referred to the Cambrian, on the western side of the Sutton Mountain anticlinal or the belt extending southwesterly from Quebec to the Vermont boundary, consist of more or less of the Sillery series, as found in the vicinity of Quebec; and, according to Drs. Selwyn and Ells, of a subjacent series of hard quartzite rocks interstratified with mica schist and black slate. The volcanic series, referred to the Cambrian in this region, indicates that during earlier Cambrian time the volcanic products were deposited contemporaneously with the included sandstones and slates, thus giving a phase of sedimentation not known elsewhere in the Cambrian of the Appalachian province. For this reason and from the fact that there is not any paleontologic evidence of the age of this volcanic series I am inclined to think that it may belong to some pre-Cambrian terrane.

Entering the northern end of the valley, between the Green Mountains and the Adirondacks, a sudden change occurs in the sedimentation. At the base, the Olenellus fauna ranges through 1,000 feet of magnesian limestone, and for 250 feet higher up in arenaceo-argillaceous shales. More or less arenaceous matter is associated with the limestones, and, about 2,000 feet above, a great lenticular mass of limestone occurs in the argillaceous shales, in which a fauna of Upper Cambrian aspect is found. At other localities this fauna occurs in the shales themselves and in a brecciated limestone at the same relative horizon. As far as known the upper portion of the Cambrian is formed of the shales. Proceeding southward and nearer the old coast line in Addison County, Vermont, the limestone series is found to graduate into the Granular Quartzite or the beach sand. From this point this shore deposit is traced without interruption to the Massachusetts boundary; and then, with more or less interruption, to the Hudson River below Poughkeepsie, New York. It is taken up again in New Jersey, and thence may be followed, with some interruption, across Pennsylvania to Maryland, whence it extends as an almost continuous formation across Virginia into Eastern Tennessee, and thence, with some interruption, into Georgia and Alabama. On all this long line it forms the basal member of the Cambrian; and wherever fossils have been found in it they belong to the Olenellus or Lower Cambrian fauna.

The offshore, or deeper water deposits, are represented by finer-grained sandstones, shales, slates, and limestones. In southern Vermont they form the roofing-slate belt that passes into New York, where the section comprises some 12,000 feet of shales, slates, and inter-

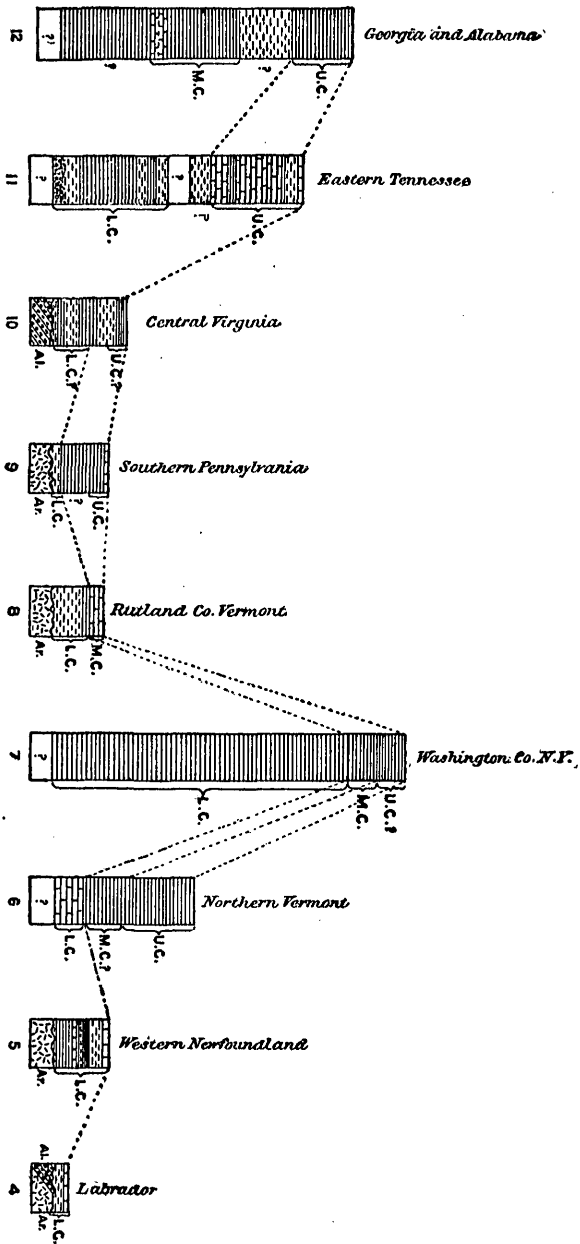

FIG. 2.—Sections of the Appalachian Province, Vertical Scale, 6,400 feet to the inch. The number beneath the sections correspond to the locality numbers on maps I and II.

bedded sandstones, with more or less calcareous matter, either as brecciated conglomerate or as thin-bedded, intercalated limestones. These extend, with some change in their character and regularity of exposure, to the Hudson River in Dutchess County. Near Stissingville, in this county, the basal sandstone rests upon the pre-Cambrian and contains the Olenellus fauna. A few remains of the latter have also been found in the immediate superjacent limestone. The Middle Cambrian and Upper Cambrian faunas occur in bedded limestones As the quartzite exposed on the eastern side of the limestones of the "Marble Belt" represents but a very small portion of the great series of shales, slates, etc., of the Cambrian on the western side of the "Marble Belt," it is probable that the lower portion of the limestone is of Cambrian age, the same as in Dutchess County. This observation also applies to the basal limestone in New Jersey and Pennsylvania, where there is very little thickness of shales between the basal quartzites and the limestone.[1]

In central Virginia the lower 1,000 feet of the section is composed of an alternation of shales and sandstones, while the upper 1,400 feet is nearly all shales and slates, capped at the top by a rough siliceous limestone.

In Tennessee the quartzite is developed to a great thickness. The quartzite is of Lower Cambrian age, and the Knox series of shales are characterized in their upper portion by the Upper Cambrian fauna, which passes above into the base of the great limestone series. As far as known, the conditions in the sedimentation of the Alabama and Georgia sections are very much like those of Tennessee.

Briefly summarized, the sediments along the southern portion of the coast line are sandstones followed by shales and limestones. More or less variation occurs, but, as a whole, the change is gradual as we follow the coast line to the north. In central Virginia, 300 miles to the northeast, the argillaceous deposits are more abundant in the lower portion, and they form the greater part of the upper series to the base of the limestone.

From Virginia northward across Maryland, Pennsylvania, and New Jersey, and into New York, the argillaceous material accumulated in relatively small proportion to the arenaceous beneath and the calcareous above. How much of the latter is to be referred to the Cambrian, is yet undetermined. Our knowledge of the series in Pennsylvania and New Jersey is too limited to make an accurate comparison with other sections.

In western Massachusetts and Vermont and eastern New York there are immediate coast-line deposits and also those of deeper water. Along the coast line there was a great accumulation of sand, followed by some argillaceous and then calcareous mud. Farther to the west the argillaceous material predominates and the arenaceous and calcareous forms but a slight proportion of the great thickness of sediment. To the north these conditions remain until, in northern Vermont, the calcareous matter predominates in the lower portion of the

[1] The announcement was made at the December meeting of the Geological Society of America at Washington that the Olenellus fauna had been found in the quartzite in New Jersey, and Cambrian fossils in the limestones above the quartzite in New Jersey and at Rutland, Vermont.

section, and the upper portion is almost entirely argillaceous. In the vicinity of Quebec, sandstones and shales make up the section, and along the Lower St. Lawrence, shales, sandstones, and limestones.

As a whole, the Appalachian Province is one of varied sedimentation, and, from the character of the sediments and determined fossils now found in them, they were largely accumulated along a gradually sinking coast line. The northern and western shore line exhibits only the contact of the sandstones of the Upper Cambrian that overlap upon the pre-Cambrian rocks. Erosion has removed them to a large extent, and south of the Adirondacks the western coast line is unknown. (Fig. 2.)

ROCKY MOUNTAIN PROVINCE.

For the purpose of description the area of Cambrian rocks in the Rocky Mountain Province includes the Cambrian outcrops of northern and western Utah, Nevada, eastern Idaho, the Gallatin River district of Montana, and the Canadian extension.

UTAH AND NEVADA.

The Cambrian rocks of Utah and Nevada are considered together, owing to their having a common base in the presence of the Olenellus zone, the strata of which rests conformably upon a great series of siliceous and arenaceous shales and sandstones, and massive quartzites. In Nevada the section is much more complete and reaches a far greater development both in amount of sedimentation and the presence of organic remains. The section studied by Messrs. Hague and Walcott in the Eureka district may be considered typical of the Cambrian rocks of central Nevada. It embraces five formations, all of which are described by Mr. Arnold Hague in the abstract of his report on the Geology of the Eureka district.[1]

The Prospect Mountain quartzite that lies at the base of the series has a thickness of 1,500 feet on Prospect Peak. It is distinctly bedded and conformably subjacent to a band of arenaceous shale, in which the Olenellus fauna occurs. It is referred to the Cambrian by Mr. Hague, and I am now of the opinion that this should be done, although I have held the view that the Olenellus zone should be considered the base of the Cambrian, and the Prospect Mountain quartzite I tentatively referred to an Algonkian formation. The subjacent band of arenaceous shale is mentioned by Mr. Hague in his report of 1881,[2] but not in the more complete description of 1882. In the review of the Eureka section by Mr. C. D. Walcott in 1886 this formation is spoken of as follows:

> At the summit of 1 the quartzite becomes more thinly bedded and passes into an arenaceous shale which is more or less calcareous and, in its extension northward, is replaced by limestone. This belt of shale and limestone is from 100 to 200 feet in thickness and carries numerous fragments of fossils, among which we have determined

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[1] U. S. Geol. Surv., 3d annual report, 1881–'82, 1883, pp. 254–259.

[2] Report (on work in Eureka District). U. S. Geol. Surv., 2d Ann. Rep., 1880–'81, p. 29, 1882.

six species, viz, *Kutorgina prospectensis*, *Scenella conula*, *Olenoides quadriceps*, *Olenellus gilberti*, *O. iddingsi*, *Anomocare parvum*, and *Ptychoparia* sp.?[1]

The second formation is the Prospect Mountain limestone. This is a massive limestone crystalline and granular in texture.

Interstratified in the limestone are irregular beds of shale, lenticular or wedge-shaped bodies, varying greatly in width. Indeed they form a characteristic feature in the limestone, which passes readily from massive to shaly beds. Two of the shale bands are quite prominent to the north, but are lost to the southward. The thickness of the beds may be taken at 3,050 feet.[2]

Formation No. 1, the arenaceous shale, between the quartzite and the limestone on Prospect Peak, is more or less a local formation, but it is apparently the zone of Olenellus, and the limestones above are not known to be characterized either by Olenellus or the typical forms of that fauna. Five hundred feet above the base of the Prospect Mountain limestone there occurs in a band of shale *Scenella conula*, *Agnostus interstrictus ? Olenoides quadriceps*, *Ptychoparia prospectensis*. All but the last are closely related to species from the upper beds of the Georgia horizon, in either Vermont or Canada. One other species, *Stenotheca elongata*, which is found associated with *Olenellus thompsoni*, *Protypus senectus*, etc., at L'Anse au Loup, is found 2,000 feet higher up in the limestone. Another species, *Olenoides spinosus*, is found in association with species characteristic of a lower horizon than the typical Potsdam of Eureka, at Pioche, Nevada."[3]

Within a short distance of the summit of this limestone the fauna has the general facies of that of the upper Cambrian or Potsdam horizon; still as a whole it occupies the position of the middle Cambrian fauna as the faunas are now classified. That it sustains this view was pointed out by Dr. W. C. Brögger, in his admirable paper on the "Age of the Olenellus zone in North America."[4] He compares the fauna of the Prospect Mountain limestone with that of the Paradoxides zone of Europe and concludes that with the exception of the lowest part of the Olenellus zone it must correspond most nearly to the middle and upper part of the Paradoxides deposits of Scandinavia. His conclusions are based almost entirely upon the presence of the various species of the genus Agnostus. From the results of my studies since 1886, I am prepared to accept this view of Dr Brögger's and to consider the Prospect Mountain limestone as representing the Middle Cambrian or Paradoxides zone of the Atlantic Coast Province. A list of species published in 1886 is as follows:[5]

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[1] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, pp. 30, 32.

[2] Hague, Arnold. Abstract of Report on Geology of the Eureka District, Nevada. U. S. Geol. Surv., 3d annual report, 1881–'82, 1883, p. 255.

[3] Second Contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, p. 32.

[4] Om alderen af Olenellus zonen i Nordamerica. (On the age of the Olenellus zone in North America.) Aftryk ur Geol. Fören. i Stockh. Förhan, No. 101, Bd. 8, 1886, pp. 182–213.

[5] U. S. Geol. Surv., Bull. No. 30, p. 32.

Obolella (like O. pretiosa).
Lingula manticula.
Kutorgina whitfieldi.
Orthis eurekensis.
Stenotheca elongata.
Agnostus communis.
bidens.
neon.
richmondensis.
Protypus senectus.
expansus.
Dicellocephalus ? nasutus.
Ptychoparia oweni.
haguei.
occidentalis.
dissimilis.
Olenoides spinosus.

Of the succeeding formation, or the Secret Cañon shale, Mr. Hague says:

The Prospect Mountain limestone passes, by gradual transition, from shaly limestone into brown and yellow argillaceous shales. * * * In their broadest development they measure 1,600 feet, although in places where they are encroached upon by the Hamburg limestone they occur considerably thinner.[1]

Only a few scattering fossils are found in the lower portion of the Secret Cañon shale, but near the summit of the fauna is large and characteristic. It includes, according to Mr. C. D. Walcott, the following:[2]

Protospongia fenestrata.
Lingulepis macra.
minuta.
Lingula ? manticula.
Iphidea depressa.
Acrotreta gemma.
Kutorgina minutissima.
Hyolithes primordialis.
Agnostus communis.
bidens.
neon.
seclusus.
Dicellocephalus ? nasutus.
Dicellocephalus richmondensis.
Ptychoparia pernasuta.
laticeps.
bella.
linnarssoni.
oweni.
haguei.
similis.
unisulcata.
læviceps.
Chariocephalus tumifrons.
Ogygia ? problematica.

Of the species in this list *Dikelocephalus ? nasutus*, and *D. richmondensis* do not belong to the genus Dikelocephalus and the form referred to *Ogygia ? problematica* represents an undefined genus. As a whole, as suggested by Dr. Brögger, this horizon may possibly be referred to the Paradoxides zone.

Number 4 of the section, or the Hamburg limestone, is a dark gray and granular limestone; surface, weathering rough and ragged; only slight traces of bedding. Very few traces of fossils were found in the entire 1,200 feet of rocks referred to this formation.

No. 5, or the Hamburg shale, resembles the Secret Cañon shale except that it is by no means as uniform in composition, showing very rapid changes in conditions of deposition and becoming more or less arenaceous and calcareous throughout its development as well as in its lateral extension. Throughout its entire thickness of 350 feet fossils are more

[1] Abstract of Report on Geology of the Eureka District, Nevada. U. S. Geol. Surv., 3d Annual Report, 1881-1882, 1883, p. 255.
[2] Ibid., p. 32.

or less abundant, but especially so near the summit where there were obtained the following:

Lingulepis mæra.
minuta.
Lingula ? manticula.
Obolella discoidea.
Acrotreta gemma.
Kutorgina minutissima.
Agnostus communis.
bidens.
neon.
prolongus.
tumidosus.
tumifrons.
Dicellocephalus ? nasutus.
Dicellocephalus angustifrons.
marica.
bilobus.
osceola.
Ptychoparia affinis.
oweni.
haguei.
granulosa.
simulator.
unisulcata.
breviceps.
Arethusina americana.
Ptychaspis minuta.

"Three of these species, *Hyolithes primordialis*, *Dikelocephalus osceola* and *Ptychaspis minuta*, are identical with forms from the Potsdam sandstone of Wisconsin."[1] As a whole the fauna is of the general facies of that of the Potsdam zone of New York and the Mississippi Valley. This is found in the Hamburg shale, but in the overlying Pogonip limestone there is an assemblage of species that combine both Cambrian and Lower Silurian (Ordovician) types. A short distance above, the fauna is comparable to that of the Calciferous and Chazy groups of the New York section.

The transition from the Cambrian to the Silurian [Ordovician] fauna is very gradual, and such as would occur where there was no marked physical disturbance to influence the faunal change resulting from the natural dying out and development of species or the influx of new species from other areas.

Of the species occurring below the passage beds three are identical with species occurring in the Potsdam sandstone of Wisconsin, viz: *Hyolithes primordialis*, *Dicellocephalus osceola*, and *Ptychaspis minuta*; one, with *Acrotreta gemma* of the Calciferous formation of Newfoundland; and *Ptychoparia oweni* is a common species of the Potsdam horizon in Montana and Dakota. These specific identifications and the great development of species of the genera Agnostus, Dicellocephalus, and Ptychoparia in the middle and upper portion of the Cambrian section, furnish abundant evidence upon which to correlate the fauna and the geologic horizon at which it occurs with the Potsdam fauna and formation, as was done by Messrs. Hall and Whitfield (Geol. Expl. Fortieth Par., vol. 4, 1877, p. 199). Of the Potsdam fauna eleven genera and fifteen species continue on into the passage fauna, viz: (species of the Potsdam fauna are printed in italics); *Lingulepis mæra*, *L. minuta*, *Lingula ? manticula*, Discina (sp. undt.), *Acrotreta gemma*, Schizambon typicalis, Obolella ambigua, *O. discoidea*, *Leptæna melita*, Orthis hamburgensis, O. testudinaria, Triplesia calcifera, Tellinomya ? hamburgensis, *Agnostus communis*, *A. bidens*, *A. neon*, Dicellocephalus finalis, D. inexpectans, Ptychoparia ? annectans, *Ptychoparia affinis*, *P. granulosus*, *P. haguei*, *P. oweni*, *P. unisulcatus*, *Arethusina americana*, Amphion (sp. undt.) Barrandia maccoyi, Illænurus eurekensis, Asaphus caribouensis.

In the next superior grouping, about midway of the Pogonip group, all the middle Cambrian genera, with the exception of Orthis and Illænurus, have disappeared, and higher up the genera Receptaculites, Chætetes, Pleurotomaria, Maclurea, Cyphasis, Bathyurus, and Asaphus carry the fauna up to the summit of the formation where the genera Receptaculites, Ptilodictya, Chætetes, Strophomena, Orthis, Tellinomya,

[1] Op. cit., p. 33.

Modiolopsis, Maclurea, Crytolites, Orthoceras, Endoceras, Coleoprion, Leperditia, Beyrichia, Amphion, Ceraurus, and Asaphus give it a facies approaching that of the Lower Trenton and indicating a horizon that is considered to be in a measure the equivalent of that of the Chazy formation of New York and Canada. The fauna of the lower portion of the Pogonip group corresponds in the same manner to that of the Calciferous sand-rock of the same region. The large number of individuals of the species of Receptaculites, *R. mammillaris* especially, gives the fauna of the upper beds a character that this horizon has not hitherto had. This, united with several of the Trenton species, viz, *Orthis testudinaria, O. tricenaria, O. perveta, Tellinomya contracta*, two species of Modiolopsis allied to Trenton forms, and *Raphistoma nasoni*, strongly foreshadows the opening of the Trenton period.[1]

The section of the Highland Range, 125 miles south of the Eureka section, gives a greater variation of sedimentation in the lower portion and less in the upper as compared with the Eureka section. The Highland Range has a more abundant and more varied fauna in the lower 1,500 feet above the quartzite, while in the Eureka section the upper or Potsdam fauna is much larger than in the Highland section. In each instance a massive limestone has replaced a succession of limestones and shales. The Highland Range section measuring from the base is as follows:[2]

	Feet.
(1) Dark reddish brown quartzite, evenly bedded, and ripple-marked in some places	350
(2) Bluish gray limestone	35
Fossils: *Olenellus gilberti.*	
(3) Buff argillaceous and arenaceous shales, more or less solid near the base and laminated in the upper portions	80
Fossils: Annelid trails and fragments of Olenellus in the lower part. Higher up the heads of *Olenellus gilberti* and *O. iddingsi* occur in abundance.	
(4) Light-colored gray limestone and bluish black limestone	16
(5) Sandy, buff-colored shale	40
Fossils: Annelid trails, Cruziana sp.?	
(6) Dark bluish black limestone	46
(7) Finely laminated buff argillaceous shale	80
Fossils: *Hyolithes billingsi* and *Ptychoparia piochensis.*	
(8) Gray to bluish black compact limestone	18
(9) Buff arenaceous shales	64
(10) Compact cherty limestone	50
(11) Compact shaly sandstone in massive layers	40
(12) Hard siliceous gray limestone, almost quartz at base	12
(13) Yellow to buff, sandy shale	70
(14) Bluish black limestone	16
(15) Yellow to buff sandy shales	40
(16) Bluish black, hard, compact limestone	12
Fragments of fossils.	
(17) Shaly sandstone in massive layers	52
(18) Gray arenaceous limestone	2

[1] Walcott, C. D.: Paleontology of the Eureka District. U. S. Geol. Surv., Monograph, vol. 8, 1884, pp. 3, 4.

[2] Walcott, C. D.: Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Surv., Bull. No. 30, 1886, pp. 33, 34.

		Feet.
(19) (*a*) Buff, sandy shale	40	
(*b*) Gray arenaceous limestone	30	
(*c*) Sandy, calcareous shale	3	
		73
(20) (*a*) Massive-bedded, bluish gray limestone. Fragments of fossils.	200	
(*b*) Compact gray siliceous limestone, almost quartzite in some places	400	
(*c*) Bluish black, evenly bedded limestone	6	
		606
Strike N. 30° W., dip. 10° E.		
(21) Buff to pinkish argillaceous shale, with fossils, and a few interbedded layers of limestone from 3 to 15 inches thick		125
Fossils: *Eocystites ?? longidactylus*, *Lingulella ella*, *Kutorgina pannula*, *Hyolithes billingsi*, *Ptychoparia piochensis*, *Olenoides typicalis* *Bathyuriscus howelli*, and *B. producta*,		
(22) Massive-bedded, siliceous limestone; weathering rough and broken into great belts, 200 to 300 feet thick, by bands of color in light-gray, dark-lead to bluish black; on some of the cliff faces the weathered surface is reddish		1,570
(23) Bluish black limestone in massive strata, that break up into shaly layers on exposure to the weather. The latter feature is less distinct 850 feet up, and the limestone becomes more siliceous, with occasional shaly beds		1,430
Fossils; near the summit specimens were found that are referred to *Ptychoparia minor*.		

Quite a fauna occurs in 23, as found one mile farther south an the line of the section.

Summary of section.

	Feet.
1. Quartzite	350
2. Limestone and shales (argillaceous and arenaceous)	1,450
3. Massive limestones	3,000
Total	4,800

As in the Eureka section, the species of Olenellus have a very narrow range near the base of the limestone series above the quartzite.

The fauna found in No. 21 of the section materially strengthens the correlation of the fauna of the Prospect Mountain limestone and the Secret Cañon shale with that of the Paradoxides zone of the Atlantic Basin.

The fauna of the great limestone belt above 23 of the section is represented by only a few specimens on the line of the section. A mile south, however, on the strike of the strata a strongly marked Upper Cambrian (Potsdam) fauna occurs. The species identified are as follows:

Bellerophon antiquatus.	Dicellocephalus sp.?
Pleurotomaria, 3 undt. sp.	Ptychoparia (Euloma?) dissimilis
Hyolithes, 3 n. sp.	P. sp.?
Dicellocephalus pepinensis.	Arethusina americana.
D. (type of D. minnesotensis).	Illænurus sp.?

Of this fauna two species are identical with those from the higher Potsdam fauna at Eureka, viz: *Ptychoparia* (*E.*?) *dissimilis* and *Arethusina americana*; and *Bellerophon antiquatus*, and *Dicellocephalus pepinensis* occur in the upper Potsdam of Wisconsin

The presence of the Pleurotomaria-like shells and the species just mentioned correlates the fauna with that of the upper horizon of the Potsdam faunas of Wisconsin and Nevada.[1]

We have no details of the section of Silver Peak, Nevada, to which attention was called by Prof. J. D. Whitney. The fossils are from a limestone and silico-argillaceous shale and identical with species found elsewhere. The most noteworthy occurrence is that of *Archæocyathus* = *Spirocyathus atlanticus* and a large brachiopod like *Kutorgina cingulata*, both of which occur on the Labrador coast over 3,000 miles to the northeast on the opposite side of the continent. The abundant and peculiar type of sponge *Archæocyathus profundus* of the L'Anse au Loup locality is represented by the nearly identical species *Ethmophyllum whitneyi* of Silver Peak, and the tribolite *Olenellus gilberti* is scarcely distinguishable from *O. thompsoni*, as it occurs in L'Anse au Loup. The species now known from Silver Peak are:[2]

Spirocyathus atlanticus.	Kutorgina (like K. cingulata).
Archæocyathus undt. sp.	Hyolithes princeps.
Ethmophyllum whitneyi.	Olenellus gilberti.
Strephochetus ? sp. ?	

The Cambrian rocks of Utah, as determined by the presence of the Cambrian fauna, form a narrow horizon in the vast series of sediments of which they are a conformable portion. Messrs. Emmons and King refer the 12,000 feet of siliceous slates and quartzites of the Big Cottonwood section to the Cambrian. If we provisionally drew the basal line of the Cambrian at the base of the strata known to contain the Olenellus fauna, all but 250 feet of this section would be referred to the Algonkian, but from the known range of Olenellus in the stratigraphically equivalent series to the north in British Columbia, the view is no longer tenable. The upper portion of the section consists of 250 feet of hard silico-argillaceous shale, a little sandy in places. At the base a species of Cruziana was found, associated with *Olenellus gilberti*, and 100 feet higher in the section a band of shale afforded *Lingulella ella*, *Kutorgina pannula*, *Hyolithes billingsi*, *Leperditia argenta*, *Ptychoparia quadrans*, and *Bathyuriscus producta*. This list was published in 1886, along with Cruziana and *Olenellus gilberti*, as characterizing the shales at the summit of the great series of quartzites and slates. As in the Eureka and Highland Range sections, the Olenellus zone is confined to a very narrow belt just above the quartzite. The silico-argillaceous shales above occupy the position of the 4,650 feet of Prospect Mountain limestone and Secret Cañon shale of the Eureka section. The Hamburg limestone and Hamburg shale of the latter are absent in the Big Cottonwood section, causing an unconformity by nondeposition.[3] The section in the Oquirrh Range above Ophir City has a quartzite at the base with shales above it carrying *Lingulella ella*, *Olenellus gilberti*, and *Bathyuriscus producta*, as determined by the collections brought in

[1] Op. cit., pp. 35, 36. [2] Op. cit., p. 38. [3] Op. cit., p. 39.

by the Wheeler survey. It is probable, however, that as in the case of the Big Cottonwood section, *Olenellus gilberti* occurs at the base of the shale, and the other two species at a higher horizon. At Antelope Spring, in western Utah, there is a considerable development of the Middle Cambrian zone corresponding to No. 21 of the Highland Range section and a portion of the Prospect Mountain limestone of the Eureka section. The section at this locality as measured by Mr. G. K. Gilbert is as follows:[1]

	Feet.
1. Gray, massive limestone	200
2. Blue gray, calcareous shale; fossils (as corrected by C. D. W.); *Acrothele subsidua, Agnostus interstrictus, Olenoides nevadensis, Ptychoparia kingi, P. housensis, and Asaphiscus wheeleri*	200
3. Gray limestone, light and dark, chiefly massive	900
4. Vitreous sandstone, umber-brown on weathered face; base not seen	1,000
Total	2,300

No. 4 of this section corresponds to the basal quartzite of the Eureka and Highland Range section, and No. 3 with the Prospect Mountain limestone. No. 2 may correspond to the upper portion of the latter limestone or to the lower portion of the Secret Cañon shale of the Eureka district. There is not enough known of the Antelope Spring section to enable us to make any closer correlation.

A comparison of the sections of Utah with those of Nevada shows that in the former the earlier conditions of sedimentation were apparently the same from the base of the Wasatch Mountains westward into central Nevada. But during the deposition of the Middle and Upper Cambrian rocks the immediate vicinity of the Wasatch was an area of minimum deposition, while that of central Nevada was one of maximum deposition of sediments. What the conditions were during the deposition of late Middle and Upper Cambrian time in the Wasatch area are unknown. The appearance of the rocks indicate a shallow sea with very little deposition of sediment.

IDAHO.

What is known of the Cambrian rocks of Idaho is obtained from the writings of Messrs. Bradley and Peale. The report of the former is more that of an explorer who, passing over the ground, made such geologic notes as time permitted. In the vicinity of Malade City, in southeastern Idaho, he discovered in a limestone resting on a quartzite, fifteen species of trilobites of the genera Conocoryphe, Bathyurus, Dikelocephalus, Agnostus, etc., five brachiopods, two gasteropods, and one pteropod. He referred this fauna to the Quebec group, and the

[1] Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872. Report on Geog. and Geol. Expl. and Survey west of the 100th merid., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 167.

quartzitic sandstone beneath is spoken of as occupying the relative position of the Potsdam, although he subsequently refers to it as a part of the true Quebec.[1] Mr. F. B. Meek agreed with Prof. Bradley that the fauna belonged to the Quebec horizon; and he[2] described *Bathyurellus* (*Asaphiscus*) *bradleyi* and *Asaphus* (*Megalaspis?*) *goniocercus*. The latter species probably comes from the upper portion of the limestone referred to the Quebec group by Prof. Bradley.

From the data obtained by Dr. A. C. Peale of the Gallatin River Cambrian, and our more accurate knowledge of the fauna of the Quebec group, the faunas occurring in the lower portion of the limestone at Malade City are referred to the Upper Cambrian, and those from the upper portion of the limestone to a portion of the Lower Silurian (Ordovician). In this connection reference should be made by the reader to Prof. Orestes St. John's work upon the same beds in Wyoming.

Near the south end of Portneuf Range, north of Malade City, Dr. A. C. Peale measured the following section:[3]

Top.

		Feet.
1.	Blue limestone	130
2.	Laminated blue limestones, with Conocoryphe, Dikellocephalus, Obolella, and two species of Bathyurus	315 (nos. 2–3)
3.	Bluish gray limestones	
4.	Laminated limestones, with bands of greenish shales in the upper portion. The limestones are separated by shaly layers. The limestones are fossiliferous at the base, containing quantities of a trilobite like Conocoryphe. The limestone resembles an oolite, but the structure is probably due to the presence of some peculiar organic remains. Fragments of Discina were seen	120 (nos. 4–6)
5.	Rather massive limestones	
6.	Laminated blue limestones, in bands of from 1 to 2 inches thickness, the surfaces of which are yellow-stained.	
7.	Rather massive limestones	
8.	Green shales or slates, 15 feet	118 (nos. 7–9)
9.	Bluish gray limestone	
10.	Bluish limestones, with bands of shales	155
11.	Massive blue limestones. The dip here appears to be about 40°	100
12.	Laminated limestones with interlaminated green shales	70
13.	Greenish sandstones and shales, passing below into silvery gray slates	210
14.	Slates and shales with a band of limestone about the middle	185
15.	Blue limestones with irregular structure. The strike is about south 5° east, and beyond the station it appears to curve to the south; dip is 60°	70
16.	Rusty yellow quartzite	150
17.	Gray and yellowish quartzites	450
18.	Greenish gray slates	180
19.	Rusty yellow quartzite, somewhat conglomeritic and containing a considerable percentage of iron	130
20.	Rusty quartzites, about	600
21.	White quartzites	500 to 600 (nos. 21–22)
22.	Pink and white quartzites	
23.	Red slates, thickness not taken	
	Total	3,483 to 3,583

[1] Report of Frank H. Bradley, geologist of the Snake River division. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, p. 201.

[2] Preliminary paleontological report; with remarks on the ages of the rocks, etc. U. S. Geol. Surv. of the Terr., embracing portions of Montana, Idaho, Wyoming, and Utah, 6th Ann. Rep., Ibid. 1873, pp. 480–485.

[3] Report on the geology of the Green River District. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, p. 568.

Below this last layer there are probably the limestones of the Red Rock Pass.

This section is one of considerable interest, from the fact of its having the Upper Cambrian fauna in the upper portion and an alternating series of limestones, shales, and quartzites below, which, from a comparison with the sections of western Utah and central Nevada, occupy the stratigraphic position of the Middle Cambrian. In their downward continuation, they may also include the Lower Cambrian zone. This is a question which is to be settled by future investigation.

In the adjoining Bannock range to the west, Dr. Peale studied a section of the series of quartzites and slates that apparently correspond to those of Nevada and Utah, occurring beneath the Lower Cambrian (Olenellus) zone. The section figured by Dr. Peale includes 5,710 feet of quartzites and slates, with a little interbedded limestone. He compares it with the section on the western side of the Wasatch range, referred to the Cambrian by Messrs. Emmons and Hague.[1] In his résumé of the formations, the Cambrian or Primordial is made to include the quartzites and slates that may be tentatively assigned to the Algonkian, or to the Cambrian, but preferably to the latter. To the Canadian Period there are referred 1,300 feet of interlaminated limestones and quartzites that occur above the quartzite and slate series now referred to the Cambrian. Dr. Peale states that west of Malade City the section gives 2,000 feet of strata placed in the Quebec series by Prof. Bradley.[2]

The northern end of the Port Neuf range was studied by Prof. Orestes St. John, in the vicinity of Mount Putnam. He there found the section to be formed of quartzites, chloritic schists, slates, and micaceous shales at the base, above which comes the dark red, finely laminated sandstone in thick beds. These he referred to the Potsdam with a query. In speaking of this section, Dr. Peale says he thinks Prof. St. John is inclined to refer the base of the section to the Huronian.[3]

With the information afforded by his own survey and that of Prof. St. John, Dr. Peale constructed the following table as embodying their knowledge of the Lower Paleozoic section of Idaho:[4]

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[1] Op. cit., p. 570. [2] Op. cit., p. 614. [3] Op. cit., p. 615. [4] Op. cit., p. 615.

Silurian section.

Canadian.	Quebec.		Blue and gray limestones, with characteristic Quebec fossils.	1,000 + ft.	1,500 + ft.	Section No. 21, station 133.
	Calciferous?		Blue limestones, generally laminated, with alternations of greenish sandstones and shales and siliceous slates.	500 ft.		
Cambrian or Primordial.	Potsdam.	Cambrian quartzites.	Pink and white quartzites, conglomeritic at top, with thin layer of limestone at the base.	2,000 + ft.	7,060 + ft.	Section No. 22, station 77.
	Acadian?	Cambrian slates.	Olive-green and gray chloritic slates and indurated clay slates.	1,560 ft.		
			Silvery and steel-gray micaceous slates.	1,900 ft.		
			Dark quartzites with interlaminated slates.	1,600 ft.		
	Possibly Huronian?	Red quartzites and quartzitic sandstones, with conglomeritic and shaly layers.		350 ft.	1,250 ft.	Section No. 32, station 132.
		Limestones.				
		Very dark green chloritic schists, containing quartz and serpentine seams and interlaminated bands of metamorphosed argillaceous slates, and a band of pink quartzite 200 feet thick.		900 ft.		

In copying the table it has been reversed, so as to follow the natural order. As interpreted in the light of our present knowledge of the Cambrian rocks in the Rocky Mountains, the Quebec and Calciferous of this section are referred to the Upper Cambrian. Whether the rocks referred to the Potsdam and Acadian are of Cambrian age or not will remain undetermined until some paleontologic proof is obtained.

MONTANA.

As far as known, the Cambrian rocks of Montana are restricted to the southern portion of the State. Two areas are well defined, one about the northern end of the Big Horn range and the other within the area drained by the Gallatin and the Yellowstone Rivers.

The character of the strata forming the Cambrian about the Big Horn Mountains will be spoken of in connection with the extension of that range in Wyoming. The Gallatin section of the Cambrian includes 1,250 feet of strata, of which 835 feet are limestone, resting upon 415 feet of sandstone. Conformably subjacent to the latter, there are 5,000 feet of alternations of conglomeritic, micaceous sandstones, with bands of siliceous limestones and indurated clay shales, referred to the Algonkian by Dr. A. C. Peale.[1]

A more detailed manuscript section, that Dr. Peale kindly prepared at my request, is as follows:

Gallatin limestones 835 feet...	Pebbly limestones 145 feet. (fossils, *Leptæna melita*, *Ophileta sp.?* *Triplesia calcifera*, *Ptychoparia* sp.? *Ptychoparia* (*E.*) *affinis*). Dry Creek shales 30 feet. Mottled limestones 160 feet. (fossils, *Ptychoparia* sp.? *Hyolithes* sp.?) Obolella shales 280 feet. (fossils, *Obolella* sp.?) Trilobite limestones 120 feet. (fossils, *Lingulella* sp., *Acrotreta gemma*. *Kutorgina sculptilis*, *Agnostus bidens*. *Hyolithes gregaria*, *Olenoides serratus*. *Ptychoparia gallatinenses*. *Bathyuriscus? haydeni*).
Gallatin sandstones 415 feet...	Gallatin shales 290 feet. (fossils, *Lingulella* sp.? *Hyolithes* sp.? *Ptychoparia* sp.?) Gallatin quartzite 125 feet.

It is probable that the 5,000 feet of strata referred to the Algonkian in the published section will ultimately be referred to the Lower Cambrian as they occupy the stratigraphic position of the Bow River series to the north in British Columbia through the upper 3,000 feet of which the Olenellus fauna has been found to range.

The section near the mouth of the East Gallatin River was studied in detail by Dr. Peale in 1884, and two lithologically well defined groups determined and characterized as follows:

To the lower one, which was carefully searched, without success, for organic remains, the name of East Gallatin group has been provisionally applied. It is composed of a series of alternations of green and greenish gray micaceous sandstones and clay slates (almost argillites), with thin bands of laminated limestones; 2,300 feet of these beds were sectionalized in detail without any traces of fossils being found.

The sandstones are in heavy beds and present a somber appearance, weathering on exposed surfaces to steel-gray and almost black colors and frequently breaking into cubical blocks. The slates are blue, yellowish, olive-green, and at some places red. In the limestone a concretionary structure is frequently noticed. For the upper group, lying above a well defined pink quartzitic sandstone, we have retained the name Potsdam. Green and dark purplish red micaceous shales, mostly arenaceous, with occasional thin bands of limestone, make up this group, and many of the beds are highly fossiliferous. The collections have not been carefully studied yet, and we therefore simply refer to them in this general way at this time.[2]

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[1] Report of Dr. A. C. Peale (on the Montana division of geology). U. S. Geol. Surv., 10th Ann. Rep., 1890, p. 131.

[2] Hayden, F. V.: Report Montana Division. U. S. Geol. Surv., 6th Ann. Rep., 1884-'85, 1885, p. 50.

The fauna collected in the Gallatin River section by Dr. Hayden in 1872 was studied by Mr. Meek, who recognized eighteen species. From the lowest division he identified the genera Cruziana, Lingulepis, or Lingula, Conocoryphe, Bathyurus, or Asaphus. From the third division he described *Bathyurus serratus*, *B.? haydeni*, *Conocoryphe* (*Conocephalites*) *gallatinensis*, *Iphidea subtilis*, and *Agnostus bidens*; and identified a species of *Conocoryphe*, *Hyolithes gregaria*, and *Acrotreta subconica*. From the second division the genera Acrotreta and Lingula are identified, and from the upper or first division Asaphus ?, Bathyurus? Conocoryphe, and Lingulepis.[1] This fauna has the facies of the Upper Cambrian zone, although that of the fourth or lowest division may prove to belong to the Middle Cambrian. As a whole the Cambrian of the Gallatin region is formed of a sandstone at the base, above which occur limestones carrying a fauna characteristic of the upper portion of the group.

The presence of the Upper Cambrian on the southwestern side of the Little Belt Mountains and on the southern side of the Elk Range was proved by Messrs. Dana and Grinnell when they discovered fossils of this age. The section near Camp Baker, southwest of the Little Belt Mountains, is estimated as follows:[2]

Quartzite, 20 feet; variegated shales, mostly bright red, also green and blue, 150 feet; limestone in a double series of ledges, 80 feet; quartzite, reddish, slightly micaceous, then a series of colored slates, mostly green, followed by shales and thin beds of sandstones and limestones, in all probability 1,500 feet; still further conformable shales, 1,000 feet. These extend toward the north farther than we could follow them. It is enough to say that the total thickness of the conformable strata underlying the fossil-bearing limestone can not be less than 3,000 feet, and is probably much more.

The same authors state that they identified similar rocks at Moss Agate Springs, at the south extremity of the Elk Range of mountains. The strata there are red shales, quartzites, and limestones like those at Camp Baker, the limestones containing many fragments of trilobites. The fossils collected were studied by Prof. R. P. Whitfield, who described *Crepicephalus* (*Loganellus*) *montanensis* and *Arionellus tripunctatus*,[3] species that occur in the Upper Cambrian horizon, the former in the Black Hills and Big Horn Range, and the latter in central Texas.

From his observations at numerous points Dr. F. V. Hayden concluded that the outcrop of the sandstone referred by him to the Potsdam extended entirely around the Big Horn Mountain Range. Near the sources of Powder River he found a series of sandstones underlying the Carboniferous limestone, resting unconformably upon the schistose and clay slates of the Azoic series in very nearly the same manner as

[1] Preliminary paleontological report . . . with remarks on the ages of the rocks, etc. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, pp. 463, 464.

[2] Geological report. Report of a geological reconnoissance from Carroll, Montana Terr., on the Upper Missouri to the Yellowstone Park and return, made in the summer of 1875, by Wm. Ludlow, 1876, p. 133.

[3] Descriptions of new species of fossils. Ibid. p. 141.

in the Black Hills. The Potsdam sandstone in this region is quite well developed, attaining a thickness of 200 feet, and exhibiting, as usual, various lithologic characters. Near the base, the rock is of a reddish flesh color, very compact, composed of an aggregation of quartz pebbles, varying in size from a minute grain of quartz to masses half an inch in diameter, cemented by siliceous matter. Above, the rock is in thin ferruginous layers, slightly calcareous but mostly siliceous, and with many small particles of mica. These thin layers are also charged with fossils, such as *Lingula antiqua*, *Obolella nana*, *Theca gregaria*, and *Arionellus? oweni.* Many of the slabs are covered with fucoidal markings and what appear to be tracks and trails of worms.[1]

CANADIAN EXTENSION.

Our knowledge of the Cambrian rocks of this region is mainly limited to the vicinity of the line of exploration across the Rocky Mountains in the vicinity of the Canadian Pacific Railway. They occur in western Alberta and eastern British Columbia, as is shown in the plates and sections accompanying Mr. R. G. McConnell's paper.[2] The geographic distribution and the localities mentioned by Mr. McConnell are represented on the map accompanying the report of the Geological Survey of Canada for 1882.

The Cambrian section, identified by fossils, includes the upper portion of the Bow River group and the lower part of the Castle Mountain group. The Bow River group forms the basal member of the section in the Bow River Valley and Cathedral Mountains. It consists mainly of a series of dark colored argillites, associated with some sandstones, quartzites, and conglomerates. The argillites are usually dark grayish in color, but become greenish and purplish in places; are very impure, and frequently grade into flaggy sandstones that are often slightly calcareous. The conglomerates of this series are characterized by pebbles of milky or semitransparent quartz, and by pieces, similar in size and fresh looking, of whitish feldspar, and the matrix contains an abundance of pale mica. These constituents have evidently been derived from some not far distant exposures of coarse granite or gneissic rock. The conglomerates characterize more especially the top of the formation, and occur in thick, massive looking bands, alternating with quartzites and shales. The quartzites, like the conglomerates, are mostly found in the upper part of the formation, and sometimes, as in Cathedral Mountains, replace the latter altogether. The only fossils detected in the Bow River series are specimens of *Olenellus gilberti*, found about 2,000 feet below the top of the formation and at the summit of Vermilion Pass.

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[4] The Primordial Sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 71, 72.

[5] Report on the Geological Structure of a portion of the Rocky Mountains, with a section. Geol. Surv. Canada, new ser., vol. 2, 1886-'87, pp. 24D-30D.

Attention was called to the resemblance of the strata of the Bow River series to those of the Big Cottonwood Cañon section of the Wasatch Mountains of Utah, by Dr. G. M. Dawson, in 1885. A comparison of the two leads to their correlation as equivalent formations, on the evidence of their lithologic characters and stratigraphic position and the fact that the Olenellus fauna occurs in the upper portion of each section. In his paper of 1889 Mr. R. G. McConnell[1] states that specimens of Paradoxides and other fossils were found at the junction of the Bow River and the superjacent Castle Mountain group. A collection made at this horizon was sent to me for examination, and I identified Olenellus sp. undt., *Protypus senectus*, and a species of Ptychoparia undistinguishable from *P. adamsi* of the Olenellus zone of Vermont. The occurrence of the Olenellus fauna at this horizon and of *Olenellus gilberti*, 3,000 feet lower in the section, corresponds to the great range of the fauna in the New York and Vermont sections.

The Castle Mountain group, in the Castle Mountain section, commences with a thin band of shaly limestone, above which come 1,500 feet of massive dolomites. These are subjacent to some yellowish, compact, impure dolomites, above which 300 feet of reddish shales occur subjacent to several hundred feet of shaly magnesian limestones. The Mount Stephen section shows about 5,000 feet of beds, consisting mainly of heavy dolomites, with shaly bands at intervals. One of these, occurring at the base of the formation and another about 2,000 feet higher up, are rich in trilobites.[2]

Reference has already been made to the fauna occurring at the base of Castle Mountain. From the next fossiliferous zone, 2,000 feet up in the section, the following species have been obtained:

Lingulella macconnelli.
Crania? columbiana.
Kutorgina prospectensis.
Acrotreta gemma, var. depressa.
Linnarsonnia sagittalis.
Orthisina alberta.
Platyceras romingeri.
Hyolithellus micans.
Agnostus interstrictus.
Olenoides nevadensis.
Zacanthoides spinosus.
Ptychoparia cordilleræ.
Bathyuriscus howelli.
(K.) dawsoni.
Karlia stephenensis.
Ogygopsis klotzi.

Where the line between the Cambrian and the Lower Silurian (Ordovician) is to be drawn in the Castle Mountain group is still undetermined. The discovery of a specimen of *Ptychoparia oweni* in the débris washed down by the Cascade River from the Cascade Mountains indicates the presence of the Upper Cambrian fauna in this region, and it is not improbable that it will be found in the Castle Mountain or Mount Stephen section.

[1] Notes on the geology of Mount Stephen, British Columbia. American Geologist, vol. 3, 1889, pp. 22-25.

[2] Report on the Geological Structure of a portion of the Rocky Mountains, with a section. Geol. Surv. Canada, new ser. 1886-87, 1887, pp. 24-29D.

RÉSUMÉ.

The sedimentation of the western area is much more varied and larger than that of the eastern side of the Rocky Mountains. The southern portion, represented by the Eureka District section, extending from the basal quartzite to the base of the Lower Silurian (Ordovician), is a continuous conformable succession of limestones and calcareous shales, with the exception of a narrow belt of arenaceous shales resting directly upon the lower quartzite. The calcareous sediments are 6,200 feet in thickness and include the faunas of the Middle and Upper Cambrian. The Lower Cambrian fauna is well developed in the shales between the limestone and the quartzite. The Highland Range section, 125 miles to the south, has a thickness of 4,800 feet of limestone, between the quartzite and the Lower Silurian (Ordovician). Proceeding eastward from central Nevada to northern central Utah, the Cambrian formations thin out, and on the flanks of the Wasatch Mountains are represented by 250 feet of argillaceous and siliceous shales above the basal quartzite. In this section only the Lower and Middle Cambrian faunas are found. The three thousand or more feet of limestone, with an abundant Upper Cambrian fauna, found in central Nevada, is unrepresented.

A comparison of the section in the Wasatch Mountains with that of Nevada shows that in both the earlier conditions of sedimentation were apparently the same. But during the deposition of the Upper and Middle Cambrian rocks, in the immediate vicinity of the Wasatch Range, it was an area of minimum deposition of argillaceous sediment, while that of Central Nevada was one of a great accumulation of calcareous sediment.

What the conditions were in the vicinity of the Wasatch Range during the deposition of the great calcareous deposits of central Nevada of Upper and Middle Cambrian times is largely conjectural. The physical appearance of the rocks indicates a shallow sea with very little deposition of sediment during the earlier portion of Cambrian time, and either a very shallow sea without deposition of sediment or a very deep sea without deposition of sediment, during the latter part of Cambrian time. It may be that some sediment was deposited and subsequently was removed by erosion, but this is exceedingly doubtful. The pure limestones of the Lower Silurian (Ordovician) rest directly upon the shales of the Cambrian, without any apparent unconformity.

To the north, near Malade City, Idaho, there are 1,200 to 1,400 feet of limestones that occur above the series of quartzites and slates. The sedimentation is essentially the same as that of central Nevada with the exception of a less amount of calcareous sediment above the basal quartzite. The Upper Cambrian fauna has been found, but not the Middle or Lower fauna. Still farther to the north, in western Alberta, and eastern British Columbia, the same series is represented in the Bow

River quartzites and slates. The Cambrian section at this point also agrees closely with that of Nevada. The Olenellus fauna occurs at the base of a thick series of limestone, and in calcareous shales, 2,000 feet higher up, the Middle Cambrian fauna is well developed. Where the line between the Cambrian and Lower Silurian (Ordovician) is to be drawn in this great series of limestone and calcareous shales is still undetermined.

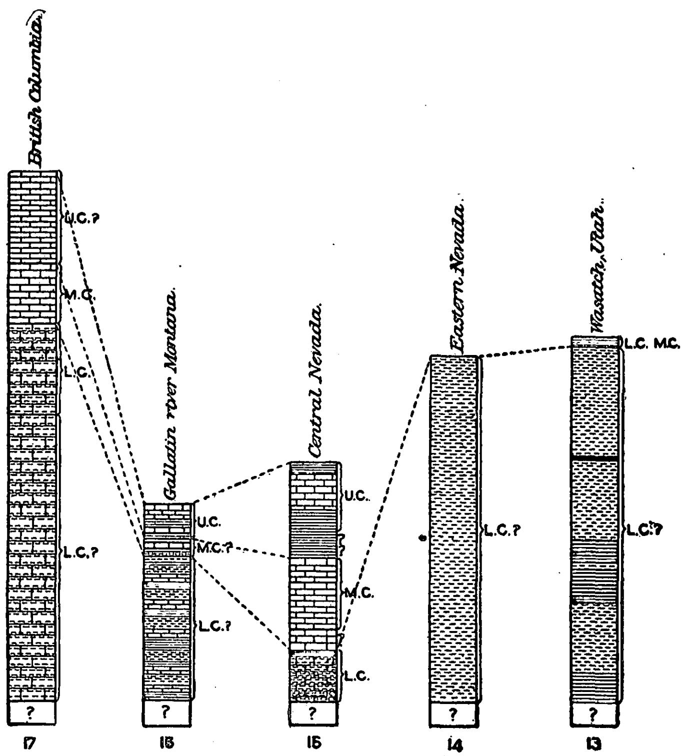

FIG. 3.—Sections of the Rocky Mountain province, vertical scale 6,400 feet to the inch. The number beneath each section corresponds to the locality number on Pls. I and II.

The presence of *Olenellus gilberti* 3,000 feet down in the Bow River quartzite and shales gives strong reason for referring the entire Bow River, Idaho, Wasatch, and Nevada quartzite and shales series to the Lower Cambrian. We know that the vertical range of the fauna is great in the Appalachian sections and also in British Columbia.

As a whole the sedimentation in the vicinity of the shore line of Utah was limited in amount in later Cambrian time, and consisted mainly of siliceous and argillaceous muds. In the deeper sea to the westward a great accumulation of calcareous sediment rests upon the basal quartzite, and this continues to southern central Nevada. To the northward there is a decrease in thickness of the limestones across Idaho. In British Columbia the section is more like that of central Nevada.

A comparison of the sections of the area on the eastern side of the Rocky Mountains with that of the western sustains the view that during late Algonkian ?, Lower Cambrian, and Middle Cambrian time the eastern Rocky Mountains and the plains to the eastward were above the sea level, whilst to the west the sediments of the later Algonkian ?, Lower Cambrian, and Middle Cambrian were accumulating west of the line of the Wasatch Mountains and the extension of this line nearly due north into British Columbia. Over all this region the coast line and sea bed appear to have undergone a gradual depression during early Cambrian time, and a relatively rapid depression at the beginning of Middle Cambrian time. (Fig. 3.)

THE INTERIOR CONTINENTAL PROVINCE.

This province includes the Upper Mississippi area; the eastern border or Adirondack sub-Province, the western border or Rocky Mountain sub-Province, and the Llano County area of central Texas and the Grand Cañon of Arizona as a minor southwestern sub-Province.

The Lake Superior sandstones and the controversy in relation to them will be noticed under a separate heading, after the description of the recognized Upper Cambrian rocks of Wisconsin, Iowa, and Minnesota and their Canadian extension.

UPPER MISSISSIPPI VALLEY.

In the historical review the literature pertaining to these rocks has been considered under the headings of "Wisconsin," "Minnesota," and "Iowa," but as the strata all belong to one geologic basin it is considered best to speak of them collectively.

The formations that have been correlated with the Potsdam sandstone of New York will be treated of under two headings: (1) The St. Croix or "Potsdam" sandstone proper, and (2) the sandstone of the south shore of Lake Superior.

The St. Croix ("Potsdam") sandstone.—The greater portion of the exposures of the St. Croix or Lower sandstone occurs in Wisconsin, and it here also presents many variations in sedimentation and fauna. Its lower beds rest on the great pre-Cambrian nucleus of the center of the State, extending about it from the Michigan line on the northeast to where it passes into Minnesota on the northwest. Its line of contact with the superjacent Magnesian limestone is also very extended owing to the numerous streams that have cut through the limestone down into the sandstone throughout its line of outcrop. The epoch was one of accumulation of sand. The rocks are mainly light-colored sandstones in central and southern Wisconsin, but embrace some beds of limestone and shale. The maximum known thickness is about 1,000 feet. The fauna is large and varied, and contains trilobites, gasteropods, pteropods, and brachiopods. The succession of beds is, according to Prof. T. C. Chamberlin, as follows:[1]

On the southern side of the Archean Island the lower part of the formation usually consists of coarse quartzose sand, of an exceedingly open, porous nature, with but little aluminous or ferruginous and almost no calcareous matter. Higher in the series the sandstone becomes finer grained and the accessory substances named more abundant. Somewhat above the middle of the series a stratum of shale occurs, attaining a known thickness of 80 feet. This is not everywhere present and seems to be mainly developed at some distance from the ancient shore line. It appears to indicate that for a time there was a deepening of the waters, admitting of the accumulation of fine sediment, except near the shore, where the deposit of sand continued. Above the shale the sandstone, reaching a thickness of 150 feet, is again found. This is medium or coarse-grained and slightly calcareous. It, in turn, is overlain by a deposit of associated shale and limestone (the *Mendota limestone*), which attains a thickness of 35 feet in the vicinity of the lake from which it derives its name. These beds indicate a modification of the conditions of deposition, such as to permit not only the settling of fine sediment, but the accumulation of calcareous mud as well. The latter was doubtless derived from the calcareous remains of life, since the sea then swarmed with living organisms whose shells and skeletons are found entombed in the strata. The frequency of broken and worn fragments implies that the greater portion were ground to powder, forming the calcareous flour that subsequently hardened into limestone. These beds appear to point quite surely to a moderate deepening of the waters.

Overlying this impure limestone is a third and thinner bed of sandstone (the *Madison*) with which the Potsdam series closes. This, on the whole, is finer grained than that below, and is bound more firmly together by cementing material, which is mainly a calcareous and ferruginous infiltration. The thickness of this bed is about 30 feet.

In eastern Wisconsin the formation is divided by Prof. Chamberlain into six parts, as follows, beginning at the top:

	Feet.
Sandstone (Madison)	35
Limestone, shale, and sandstone (Mendota)	60
Sandstone, calcareous	155
Bluish shale, calcareous	80
Sandstone, slightly calcareous	160
Very coarse sandstone, noncalcareous	280

The thicknesses given are subject to considerable variation. As a general rule they grow less toward the northeast. Where the total thickness of the formation is reduced by the inequalities of its Archean bottom it is by the loss of the lower members of the group and not by the thinning of all.[2]

The Upper or Madison sandstone is described as a rather coarse-grained, thick-bedded, compact, but soft, slightly calcareous, light-colored sandstone. In its upper portion, immediately beneath the lower Magnesian limestone, it is at most localities coarse, and the topmost layer is often broken up and mixed with calcareous material, giving it a coarsely brecciated structure. The subjacent limestone (Mendota) consists of a group of alternating strata of arenaceous magnesian limestone, sandy calcareous shales, and shaly and calcareous sandstones.[1]

[1] General Geology. Historical Geology. Paleozoic Era. Geology of Wisconsin. Survey of 1873-'79, vol. 1, 1883, pp. 121, 122.

[Geology of eastern Wisconsin.] Chapters 7 and 8. Lower and Upper Silurian. Geology of Wisconsin, Survey of 1873-'79, vol. 2, 1877, pp. 259, 260.

[2] Op. cit., p. 260.

The upper and lower limits of the Mendota group are scarcely definable. It graduates above into Madison sandstone, so as to make it difficult to draw a line between the two, and below the alteration of calcareous and arenaceous rock make it equally difficult to say where the series ends. The Mendota beds are regarded as the eastern equivalents of Dr. Owen's Fifth Trilobite bed, the common horizon being characterized by the presence of *Dikelocephalus minnesotensis*, *D. pepinensis*, *Lingula aurora*, *L. mosia*, and a few other species of limited horizontal distribution. The lower divisions constitute the main body of the Potsdam sandstone and present but very few exposures in this region. They are divided into four parts.[1]

The strata referred to the Potsdam sandstone by Prof. R. D. Irving in central Wisconsin have a surface distribution of over 6,000 square miles.[2] In the vicinity of Madison the following succession of layers between the Mendota base and the Archean occurs:[3]

	Feet.
1. Greensand layer	1
2. Calcareous and dolomitic, friable, fine-grained, greenish sandstone	31
3. Not known	31
4. Light colored sandstone, for the most part purely siliceous, being made of rolled quartz grains; but no specimens obtained from the uppermost layers	704
5. Red shale	10
Total	777

The generalized section given above for the Potsdam series, below the Mendota base, holds true for a large part of the central Wisconsin district, and would be satisfactory for all of it but for the facts next to be stated.[4]

Prof. Irving then proceeds to describe layers of sandstone and bowlder-conglomerate occurring near the pre-Cambrian quartzite, which apparently occupy a higher position and extend downward across the upper portion of the eastern Madison section. He explains this occurrence on the theory of the accumulation of these conglomerates and sandstones near the shore line at a higher level than the sandstones that accumulated offshore.

The beds of passage between the Potsdam and Lower Magnesian series include, as already said, two well marked beds, 60 to 90 feet in combined thickness—the Mendota limestone and the Madison sandstone.[5]

Of the fauna in the rocks he says:

To the list of fossils of the lower sandstone series given by Prof. Hall but little has been added by the present survey, as far as central Wisconsin is concerned. * * * The general grouping of upper, middle, and lower species appears to hold true as regards the order, but his lower species must really be assigned to the middle of the series, since its thickness is about twice as great as Mr. Hall supposed.[6]

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[1] Op. cit., pp. 261, 262.

[2] The Lower Silurian rocks. (Geology of central Wisconsin.) Geology of Wisconsin, survey of 1873–1879, vol. 2, 1877, p. 529.

[3] Op. cit., p. 534. [4] Op. cit., p. 536. [5] Op. cit., p. 542. [6] Op. cit., p. 545.

In the Mississippi Valley, in southwestern Wisconsin, Mr. Moses Strong estimated the total thickness of the Potsdam at 800 to 1,000 feet, the inequalities in the surface of the underlying Archean rocks being the principal source of its variation.[1] The formation is composed almost entirely of sandstone. The only exception to this is the stratum of magnesian limestone and shale found in the upper part of the formation.

The strata of the formation are usually composed of fine siliceous sand, generally in small, rounded, water-worn grains of almost every color, the most frequent being the various shades of yellow and red, sometimes green, and often snow white. The strata vary greatly in consistency, and in different localities the same stratum may present different degrees of hardness. Some of the layers, and especially the white ones, are frequently almost as compact as quartzite, and from this all degrees are found, to a loose, friable sand that crumbles in the hand. * * * The stratification of the Potsdam is very regular and even, and the beds usually lie in a nearly horizontal position over large tracts of country. Indeed, so little do they deviate from an apparent level that the dip can not be distinguished by the eye, but only by a careful measurement. The dip is usually to the northwest, and seldom exceeds 8 or 10 feet to the mile, but more frequently it is less.[2]

The most highly fossiliferous portion of the formation occurs in western Wisconsin. The formation is divided in the lower St. Croix district, by Mr. L. C. Wooster, into four horizons, as follows:[3] (1) "Eau Claire grit; (2) Eau Claire trilobite beds; (3) Hudson trilobite beds, and (4) line of junction with the Lower Magnesian limestone." In this region it borders upon the metamorphic and igneous rocks to the north and east, and touches the Lower Magnesian limestone on the south and west.

The four horizons mentioned are described as follows:

The Eau Claire grit, exposed at the mouth of Eau Claire River, is a very coarse sandstone, with Scolithus tubes in one or two of the layers. The rock is so coarse that it has been termed a conglomerate, not without reason.

The Eau Claire trilobite beds are characterized by several species of trilobites not found at any other horizon, and also by being the lower limit at which brachiopods were found in the sandstone. These beds likewise mark the lower limit of calcareous matter in the formation.

The Hudson trilobite beds lie at the best defined horizon in the sandstone. These beds lie in close relationship to and between the *Lower Calcareous band* and the layers which are richest in green sand, and thus can not well be mistaken. * * * The shaly layers below the trilobite beds are intensely green from the presence of green sand (a variety of glauconite), which, so far as known, is true of no other horizon.

The line of junction with the Lower Magnesian limestone may, in nearly every instance, be recognized by the heavy brecciated beds of limestone just above. But this character may fail in the extreme southeastern border of the district, where it is possible that beds of sandstone are interstratified with the lower layers of the Lower Magnesian limestone, as in eastern Wisconsin.[4]

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[1] Geological formations. (Geology of the Mississippi regions north of the Wisconsin River.) Geology of Wisconsin, survey of 1873-1879, vol. 4, 1882, p. 45.

[2] Op. cit., pp. 39, 40.

[3] Detailed geology: [Geology of the lower St. Crox district.] Geology of Wisconsin, survey of 1873-1879, vo.. 4, 1882, p. 109.

[4] Op. cit., p. 110.

Another horizon is mentioned in which lies the Upper Calcareous band, possibly marking the horizon of the Mendota limestone of central Wisconsin.

At no one point in the district is the entire formation exposed, and so, to obtain the entire thickness from the Lower Magnesian limestone to the granite below, the sum of the thicknesses of the subdivisions is taken:

	Feet.
From the Lower Magnesian to the Hudson trilobite bed	200
From the Hudson trilobite bed to the Eau Claire Trilobite bed	200
From the Eau Claire Trilobite bed to the Eau Claire grit	240
From the Eau Claire grit to the granite (at Eau Claire), estimated	100
Total	740

The last division is probably much thicker to the south and west, making the thickness of the formation range to 800 and 1,000 feet.[1]

The report of Prof. Wooster contains details of numerous local sections that show the lithologic and paleontologic characters of the formation.

The outcrops in Iowa are the continuation of those of southwestern Wisconsin; and very little is added to the knowledge of the formation in Minnesota, where it is called the St. Croix sandstone by Prof. N. H. Winchell. At Winona and Stockton there are about 303 feet of the formation exposed.[2]

A generalized section in Minnesota, as given by Prof. Winchell,[3] is as follows:

		Feet.	
St. Croix	Jordan sandstone	75–100	= Madison of Wisconsin.
	St. Lawrence limestone	0– 30	= Mendota of Wisconsin.
	Dresbach sandstone and shales	200.	
Shales		(?)	

CANADIAN EXTENSION.

In the account of a deep boring at Rosenfeld Station, on the Canadian Pacific Railway, Dr. G. M. Dawson correlates the upper portion of the section with the Maquoketa shales, beneath which occurs the Galena limestone, passing below into Trenton and then to the St. Peters sandstone. Below this, before reaching the granite, there are 110 feet of dark red, reddish and greenish, bluish and grayish shales, passing below into red shales, which are referred with doubt to the Lower Magnesian limestone.[4] Whether the St. Croix sandstone is represented in this section can not be determined in the absence of paleontologic evidence, but it is not improbable that the horizon of the St. Croix and the Lower Magnesian limestone of the Minnesota section may both be included between the limestone and the granite at the bottom of the well.

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[1] Op. cit., p. 112.

[2] The Geology of Minnesota, vol. 1 of the final report. 1884, p. 258.

[3] Winchell, N. H.: 14th Ann. Rep. Minn. Geol. and Nat. Hist. Survey, 1886, pp. 325–337.

[4] On certain borings in Manitoba and the Northwest Territory. Royal Soc. Canada, Proc. and Trans., vol. 4, section 4, 1887, p. 86.

LAKE SUPERIOR SANDSTONE.

The earlier geologists speak of the Keweenawan series and the horizontal Lake Superior sandstones as forming part of the same terrane, and this view has been sustained by some more recent writers. Many others, however, have held the view that the horizontal sandstones were the equivalents of the fossiliferous sandstones beneath the Magnesian limestone of central Wisconsin, and that the sandstones of the Keweenawan series were unconformably subjacent to the horizontal sandstones. Prof. R. D. Irving, taking the latter view, says:

The constant horizontality of the sandstone series, its restriction to low levels, the actual unconformity visible in Douglas County, the proximity of the horizontal sandstones to the enormously thick perpendicular fragmental beds of the Montreal River, and the relations of the two series on the St. Louis appear to amount to demonstration. In the Thunder Bay region the Canada geologists have proved a similar nonconformity, and Sir William Logan's arguments would seem to show that the same is true for the southeastern shore of the lake. That it may at times be difficult to tell whether we have to do with the Keweenawan or the newer sandstones is undoubtedly true in some of those cases where the Keweenawan beds have a low inclination, but such cases of difficulty are rare.[1]

Of the relation of the horizontal sandstones on the north side of the Wisconsin pre-Cambrian area and the fossiliferous sandstone on the southern side he says:[2]

An absolute proof of their exact relations is wanting, because nowhere as yet have the two been traced into each other. Judging from the low altitude above the lake to which the Lake Superior sandstone has been seen reaching, it appears improbable that any connection ever existed between the two formations in the Wisconsin-Minnesota region. * * * It appears, on the whole, that the evidence is all in favor of an approximate equivalency of the Lake Superior and Mississippi Valley Potsdam sandstones. It seems probable to me, with my present knowledge of the facts, that they were deposited in always disconnected basins, and that their sharply contrasted lithological peculiarities are to be explained by corresponding differences in the ancient rocks from whose ruins they are built.

Under the designations of the "Eastern sandstone" and "Western sandstone" Prof. Irving describes the horizontal sandstones of the south shore of Lake Superior. By the "Eastern sandstone" he means sandstone that fills the valley between the Keweenaw or main trap range of Michigan and the so-called south range. The eastern end of this depression is occupied by the waters of Keweenaw Bay. The sandstones skirt the shores in a band varying in breadth from a few rods to 1 or 2 miles, the older crystalline rocks occasionally reaching down to the lake. These conditions prevail as far eastward as Marquette, beyond which point to the eastward sandstone forms all of the shore cliffs as far as the Sault.[3]

[1] Geological Structure of Northern Wisconsin. (General geology of the Lake Superior Region. Geology of Wis., Survey of 1873-'79, vol. 3, 1880, p. 23.

[2] Op. cit., pp. 24, 25.

[3] The Copper-bearing Rocks of Lake Superior, U. S. Geol. Surv., Monograph, vol. 5, 1883, p. 351.

The characters of the sandstone and its relation to the superjacent rock are stated as follows:

The sandstones of the Keweenaw Bay and its vicinity, and eastward thence to White Fish River, are reddish and often highly argillaceous. At White Fish River the red sandstone is overlain by a light-colored sandstone, which is in turn succeeded by a magnesian limestone, in which are casts of Pleurotomaria. This limestone is the Lower Magnesian of the Wisconsin reports and the Calciferous sandrock of the Eastern States. That it is succeeded in regular order by the fossiliferous limestones of the Trenton, Cincinnati, and Niagara groups was long since shown, and has been demonstrated anew of late years by the labors of the geological surveyors of Wisconsin and Michigan. There thus seems little room for doubt as to the correctness of the view held for years by a succession of geological workers in the Lake Superior region from Owen to Rominger, viz, that in the Eastern sandstone we have to do with the same formation, or with its downward continuation, as the fossiliferous Cambrian sandstone which, in the Mississippi Valley, forms the base of the Paleozoic column.[1]

The Western sandstones, or those of the Apostle Islands and the adjoining coast of Bayfield, Douglas, and Pine Counties, are composed of a horizontally placed sandstone, closely resembling in character the Eastern sandstone of Keweenaw Point. The exposures of the sandstone are almost entirely restricted to the vicinity of the shores of the lake, on the mainland, and the Apostle Islands, and have never been seen reaching more than 50 feet above the lake level. Farther west, however, in Douglas County, the horizontal sandstone reaches to 360 feet above the lake.[2] Prof. Irving states that the prevailing color of this rock is some shade of red, from bright brick red to a brownish red or purplish red. Pinkish, straw-colored, and even nearly pure white varieties occur, either blotching the ordinary red rock in small patches, or occurring in layers from an inch to 2 or 3 feet in thickness. A section typical of many of the cliff exposures of the lake shore is as follows:

	Ft.	In.
Red marly clay (Quaternary)	5	0
Shaly sandstone, in layers from one-fourth to one-half inch thick; light reddish to brown, medium-grained, chiefly made up of subangular quartz grains	4	9
Compact sandstone	2	0
Shaly sandstone	0	3
Compact sandstone; pinkish and moderately coarse-grained, chiefly made up of quartz grains, but many white clay spots, indicating the decomposed feldspar	2	0
	14	0

The shaly and massive layers are, however, not constant, and either will grade into the other in a short distance, the shaly kinds being often merely a result of weathering. Often the massive layers have a thickness of 5 feet and upwards, and lie together in considerable thicknesses without intervening thin-laminated seams. In many places round bunches of red clay, from an inch to several feet in diameter, are seen imbedded in the massive sandstone. In other cases the clay lies in limited and

[1] Op. cit., pp. 351, 352.

[2] The Lake Superior Sandstone. [Geology of the Eastern Lake Superior District.] Geol. Wisconsin, vol. 3, 1880, p. 207.

very irregular seams, from a fraction of an inch to several inches thick. Some of the round clay patches appear as if formed by the decomposition of granite or gneiss bowlders imbedded in the sandstone at the time of its formation.[1]

In speaking of these same sandstones Mr. E. T. Sweet says:

In regard to the *age of the Lake Superior sandstones*, but very little in deed can be learned in the western Lake Superior district. So far as my observations have extended, the sandstones are absolutely devoid of organic remains. They are removed many miles and are separated by intervening older formations from the unmistakable Lower Silurian strata.

He considers it has been conclusively shown that the sandstones are of more recent age than the Keweenawan strata.[2]

Dr. C. Rominger concluded from his studies of the Lake Superior sandstone that its Lower Silurian age was unequivocally proved by its stratigraphic position. In its whole extent it is visibly overlaid by calcareous ledges containing fossils peculiar to the Calciferous formation, or, in other cases, by the Trenton limestone. He describes the sandstone east of the Copper Range of the Keweenaw Point and divides it into two sections, an upper and a lower one. He says:

The upper section is composed of light-colored, almost white, sandstones of generally soft, friable nature. The lower section is intensely red colored by iron pigment, and contains various hard, compact ledges, which are valuable building stones. West of Marquette only the lower section of the group is developed; east of it the heights are formed by the upper division; the lower has exclusive possession of the shore as far as Grand Island Bay. East of Grand Island Bay the upper division sinks down to the level of the water, and only in limited spots the lower red-colored strata come to the surface.[3]

On Laughing Whitefish River a section as determined by Dr. Rominger is as follows in ascending order:

	Feet.
No. 1.—Alternations of thin-bedded, hard, often micaceous sandstone slabs, with arenaceous shales (as exposed)	25
No. 2.—A fine-grained, more or less argillaceous red sandstone in layers of 1 to 3 feet in thickness with seams of red shales	12
No. 3.—A hard, coarser-grained, red, or speckled sandstone in heavy ledges up to 4 and 5 feet in thickness, amounting in the aggregate to 15 or 20 feet	15–20
No. 4.—Light-colored, middling soft sandstone in thick layers with seams of quartz pebbles, followed by a few feet of a dark and coarse conglomerate; thickness not accurately ascertained	00
No. 5.—A series of thin-bedded, soft, whitish sandstones, each layer separated from the other by a narrow seam of bluish shale	75–100
No. 6.—Massive soft white sandrock, projecting in vertical walls	50

Directly above this, strata of the Calciferous sandrock occur with casts of Pleurotomaria.[4]

This section of Dr. Rominger's is not altogether complete, but it shows conclusively that the Lake Superior sandstone in the vicinity of Mar-

[1] Lake Superior sandstone [Geology of the Western Lake Superior district]. Geology of Wisconsin, Survey of 1873-'79, vol. 3, 1880, pp. 208, 209.

[2] Op. cit., pp. 351, 352.

[3] Paleozoic Rocks. Geol. Survey Michigan, Upper Peninsula, 1869-1873, vol. 1, pt. 3, 1873, pp. 80-82.

[4] Op. cit., pp. 88-90.

quette, or east of Marquette, occupies the exact stratigraphic position of the fossiliferous St. Croix or "Potsdam" sandstone of Wisconsin. The description of the character and geologic equivalency of the sandstones of the south shore of Lake Superior as given by Prof. Chamberlin accords with the view I had formed from the study of the literature pertaining to the subject. Although not considering it proved that the two sandstones are exactly contemporaneous, I think that for all practical geological classification they may be considered equivalent deposits. This view is so well expressed by Prof. Chamberlin that it is here quoted:

Lake Superior sandstone.—The sandstones on the southern side of the Archean Island are light-colored, being mainly yellow or white, varying locally to pink, brown, and green. They are nowhere bodily dark. An easy explanation of this is found in the fact that they were derived from the light-colored quartzose and granitic rocks of the southern face of the land. But passing around to the Lake Superior Basin on the northern side of the island, where erosion preyed upon the iron-bearing members of the Huronian series, and more especially upon the traps, sandstones, and shales of the copper-bearing series, the resulting beds are not only reddish brown in color, but contain a notable ingredient of iron and of shaly material derived from those formations. Indeed the deposit bears a very close external resemblance to the sandstones of the Keweenawan series, and the two have been considered as identical by able geologists.

Concerning the distinctness of the two formations we entertain no doubtful opinion. The Potsdam sandstone is habitually horizontal, while the Keweenawan is tilted, indicating that the latter partook of a general stratigrapical movement which did not affect the former, which, considering the attendant circumstances, is equivalent to saying that the horizontal sandstones were not then in existence. The observations of Mr. Sweet in Douglas County are further proof of this.[1] The Potsdam sandstone there abuts unconformably against the Keweenawan traps and contains pebbles derived from them, showing not only that they were earlier formed but that they were tilted and extensively eroded at the time the horizontal sandstones were formed. The local disturbance of the latter does not vitiate the force of the evidence when critically considered. Similar phenomena are presented along the southeastern face of the promontory of Keweenaw Point.[2]

Besides these stratigraphical evidences of distinctness, the microscopical observations of Prof. Irving and the chemical analyses of Mr. Sweet show an important constitutional distinction between them.[3] Whereas the Keweenawan sandstones are largely nonquartzose, the horizontal beds are highly quartziferous.

As the latter are traced eastward along the south shore of Lake Superior they are found, according to Dr. Rominger, to be interstratified with and graduated into the light-colored sandstones which prevail in the eastern portion of the upper peninsula of Michigan, and which are traceable into direct continuity with the light-colored sandstones of Wisconsin. The same geologist (as also Foster and Whitney) is authority for the statement that in the Keweenaw Valley Silurian limestone overlies this sandstone.

The southern light-colored sandstones, like their northern equivalents, abut un-

[1] Geol. Surv. Wis., vol. 3, pp. 340–347; also 350–352.

[2] This has recently been denied by Dr. M. E. Wadsworth, but more recent examination by experienced observers shows his discussion of the subject to be more pronunciative than trustworthy. Bulletin of the Museum of Comparative Zoology, at Harvard College, Geol. Series, vol. 1. The facts in detail as determined by the later observations will be found in Prof. Irving's forthcoming report on the copper-bearing series.

[3] Geol. Wis., vol. 3, pp. 15 and 350, and microscopical Pl. XIX A.

conformably against eroded cliffs of Keweenawan rock. At St. Croix Falls light-colored Potsdam sandstone containing characteristic fossils reposes unconformably upon and against Keweenawan cliffs and occupies depressions and valleys formed through its erosion. Conglomerates derived from it mark the junction of the two formations and contain Potsdam fossils. Hand specimens may be obtained, having Keweenawan rock for one side and Potsdam sandstone containing shells of *Lingulepis pinnaformis* for the other. The phenomena absolutely forbid any explanation based on faulting or intrusion

North of St. Croix Falls the same strata, sustaining a like stratigraphical relationship (though not seen in actual unconformable contact) may be traced more than half way across the Keweenawan series. Passing the remainder of the interval to Lake Superior the horizontal red sandstones are found abutting, in similar unconformable contact, against the eroded Keweenawan series as above stated. The accompanying section illustrates the general relationship, but only a careful study of the details can make clear the full force of the evidence.

When to these considerations there are added others less susceptible of brief statement, to which we are here confined, it appears that the distinctness of the horizontal Lake Superior sandstone from that of the Keweenawan system and the correctness of its reference to the Potsdam series is sustained by a weight of evidence that would not be seriously questioned but for complications with what we deem the misinterpretations of other geological features of the Lake Superior region. The modifications which the formation assumes in that region are precisely those which its method of derivation demands.[1]

CANADIAN EXTENSION.

On the geological map of the Dominion of Canada, published in 1882, the Nepigon series of rocks is colored Cambrian, both on the shores of Lake Superior and about Lake Nepigon. This is in accordance with the views of Dr. A. R. C. Selwyn.

MISSOURI.

The Cambrian rocks in Missouri occur in the southwestern portion of the State, about the Ozark Uplift. As far as known they are of Upper Cambrian age and consist of a sandstone that occurs beneath the third magnesian limestone, or Calciferous, and the fourth magnesian limestone of the Missouri survey, beneath which, according to Prof. G. C. Broadhead, there are other arenaceous and calcareous beds.

The third sandstone is doubtfully identified by Mr. F. B. Meek, in Miller County, as 6 feet of white sandstone, composed of rounded grains of quartz cemented in part by calcareous matter. Subjacent to this there are 27 feet of hard gray and light flesh-colored magnesian limestones in rugged, irregular beds from 5 to 8 feet in thickness.[2] In Morgan County the third sandstone is known to occur at a few localities, where it varies from 25 to 30 feet in thickness. The subjacent fourth magnesian limestone forms a bluff 150 feet high above the Osage River in the southwestern part of the county.[3]

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[1] General geology. Historical geology. Paleozoic era. Geology of Wisconsin, survey of 1873-1879, vol. 1, 1883, pp. 122-124.

[2] Reports on the Geological Survey of the State of Missouri, 1855-1871, 1873, p. 127.

[3] Op. cit., p. 148.

In Madison, St. Francois, and Iron Counties, Prof. G. C. Broadhead found beneath the third magnesian limestone the following downward succession:

(3) Siliceous or grit-stone bed, with intercalated magnesian limestone.

(2) Marble beds.

(1) Sandstones, conglomerates, and shales.

In No. 3 *Lingulella lamborni* Meek has been found. The marble beds or No. 2 appear to be confined to the southwest quarter of Madison and the central and northern parts of Iron and extend into Reynolds County. The greatest thickness is not over 30 feet, and they are not always present.

No. 1 is confined chiefly to the northern part of Iron and Madison, extending to St. Francois. The entire thickness of this as well as the regular order of its various beds is rather difficult to arrive at. But we find both in Iron and Madison Counties coarse conglomerates resting on granite and porphyry. We also find sandstones, which are sometimes very coarse, and at other times fine-grained, resting on conglomerates. We also find shale or slate beds reposing on granite and underlying sandstone. Similar shale beds are also intercalated with the sandstone. In the neighborhood of Mine La Motte this sandstone reaches to over 100 feet in thickness, and is also found to be the lowest rock directly resting on the granite. Borings with diamond drill on the Mine La Motte property indicate magnesian limestone, with some siliceous beds, 80 feet; sandstone, 63 feet; granite.

On St. Francois River, in Madison County, these lower sandstones rest directly on the granite and are unaltered; on Twelve-Mile Creek, Madison County, the marble beds and sandstones rest unaltered on the porphyry, and on Big Creek, Iron County, heavy beds of unaltered magnesian limestone rest directly on the porphyry.[1]

At the deep well of the St. Louis County insane asylum, beneath the third magnesian limestone, the drill passed through, going down—

98 feet of third sandstone.

384 feet of fourth magnesian limestone.

54 feet of Potsdam sandstone.

At the base of the sandstone it entered what was supposed to be granite, although the line of demarkation between the sandstone and the granite was not well defined.[2]

In the descriptive geology of Madison County Prof. Broadhead states that the sedimentary rocks were deposited across the valleys between the mountains and the hills (that is, of the old pre-Cambrian land surface). The order of deposition, commencing at the oldest, is—

(1) Sandstones, conglomerates, and shales.

(2) Marble beds.

(3) Grit-stone beds and rough beds of magnesian limestone.

Above this comes the magnesian limestone referred to the Calciferous.

In the vicinity of Fredericktown there is a series of grits between the grit-stone beds and the superjacent magnesian limestone in which *Lingulella lamborni* has been found. It is stated that in the lower portion

[1] Geological Survey Missouri, including field work of 1873-1874, vol. 1, 1874, pp. 31, 32.
[2] Op. cit., p. 32.

of the magnesian limestone *Lingula lamborni*, Orthoceras, a turbinated Gasteropod, and a coral, resembling in cross-section a Zaphrentis, were observed. He states that probably this magnesian limestone can also be included in the Potsdam zone.[1] This includes all the limestones up to the base of the recognized third magnesian limestone.

A more detailed account of this lower marble belt is given by the same writer in a description of the marbles of southeastern Missouri. The most typical section is that of the northern part of Madison County, which is summed up as follows:

(1) Magnesian limestone.
(2) Eighteen feet of thick beds of siliceous dolomite and thin shaly limestone, with *Lingula lamborni*.
(3) Twenty-three feet of gritty dolomite.
(4) Five to thirty feet of marble.
(5) Five to forty feet (as much as 90 feet near Mine La Motte) of sandstone.
(6) A few feet of slaty sandstone resting on granite.

The presence of *Lingula lamborni* in beds a little above the marble will certainly assign the marble beds to the Potsdam group.[2]

EASTERN BORDER OR ADIRONDACK SUB-PROVINCE AND ITS CANADIAN EXTENSION.

The geographic distribution of the Potsdam terrane about the Adirondacks is delineated on the geological map of New York accompanying the final report in 1842, and that of the Canadian extension on the small map accompanying the 1863 report of Sir W. E. Logan and the large map of Messrs. Logan and Hall, published in 1866.[3]

On the western side of the Adirondacks the outcropping of the sandstone is first seen in the northern part of Lewis County, where it rests unconformably upon the subjacent Archean rocks and passes above into the calcareous layers of the Calciferous formation. The outcrop broadens to the north in Jefferson and St. Lawrence Counties and extends around the northern side of the Adirondack area through Franklin and Clinton Counties to Lake Champlain. The exposures on the eastern side are more or less interrupted, and rarely occur upon the eastern side of the lake in Vermont, except in Addison and Rutland Counties. On the southwestern side outcrops occur in Washington, Warren, and Saratoga Counties.

The Franklin and Clinton County area extends across the boundary into Canada, forming quite an extended exposure within the triangle formed by the St. Lawrence and the St. John's Rivers and the boundary, and at one point it crosses to the north of the St. Lawrence River. From St. Lawrence County the sandstone crosses the river and extends along the western side of the Ottawa Basin.

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[1] Geological Survey Missouri, including field work of 1873–1874, vol. 1, 1874, pp. 357, 358.

[2] Marble of Southeast Missouri. Kansas City Review, vol. 5, 1882, pp. 525, 526.

[3] Geological map of Canada and part of the United States from Hudson's Bay to Virginia and from the Missouri River to Newfoundland. Montreal, 1866.

The typical sections are those of Potsdam, in St. Lawrence County; Chateaugay Chasm, in Franklin County; Au Sable Chasm, in Essex County, and Greenfield, in Saratoga County, in the State of New York, and Hemmingford, in Canada.

Section at Potsdam.—At the type locality of the terrane at Potsdam, in St. Lawrence County, there are but 60 or 70 feet of the rock exposed. It occurs in layers from an inch or two in thickness up to 2 feet, and the general color of the mass is yellowish brown to reddish brown, particularly the latter color in the thicker layers.

Section at Chateaugay Chasm.—At Chateaugay Chasm, Franklin County, one of the best sections of the formation upon the northern slopes of the Adirondacks is exposed. I studied it in 1888 and found that 5 miles south of the Ogdensburg and Lake Champlain Railway the pre-Cambrian rocks are to be seen on the hills west of the river and in a few small outcrops about one-half a mile to the north. It is a bedded, reddish gneissoid and hornblendic rock, probably of Algonkian age. Nearly one mile south of these outcrops the Potsdam sandstone appears in the bed of the river, with a northwest dip of about 3°. The exposures increase rapidly in thickness, and bluffs from 50 to 75 feet in height, formed of evenly-bedded layers, rise above the water. The river has worn a cañon through these beds for three-quarters of a mile down to a mill and pond, where the cliffs break away, and the strata, losing their dip, continue to the south, in nearly horizontal beds, to the crossing of the railroad embankment.

The fall in the river bed is rapid, and at the High Falls of the Chateaugay Chasm a bluff of 125 feet rises from the foot of the fall. The lower 35 feet of the section is formed of coarse reddish and gray sandstone in massive layers. At the Narrows, three-fourths of a mile farther down the stream, the lower beds are 75 feet in thickness and pass into massive bedded grayish and buff-colored sandstones that break up into thinner layers on exposure to the action of the weather. Many of the massive beds are made up of irregular cross-bedded layers; this is best seen about a mile below the falls. The strata below assume a southwesterly dip of 2° to 3°, which carries the entire sandstone formation beneath a hard light gray sandstone a little north of the mouth of the chasm. One hundred and fifty feet of sandstone, not included in the section above the railroad embankment, is exposed in the chasm and 25 feet of the upper beds occur below the mouth of the chasm. This gives a total thickness of 250 feet of sandstone as the known thickness of the Chateaugay section. To this there is to be added an unknown amount at the base and 25 feet of passage beds between the upper sandstone and Calciferous sandrock, to be seen just above the entrance of Marble River into the Chateaugay.

SECTION.

(From the base upward.)

	Feet.
(1) Coarse sandstone with occasional layers of conglomerate near the base...... Color reddish brown near the base, buff, gray, and buff and gray, spotted with grains of reddish brown sand. Texture compact and hard, with bands of a soft friable nature.	75
(2) Massive bedded, grayish and buff, rather coarse sandstone, many of the layers cross-bedded	150
(3) Compact, fine-grained white sandstone, some of the layers of which are discolored and broken by small reddish brown cavities. *Lingulepis acuminata* occurs in the upper portion, and 10 feet higher up *Ophileta compacta*, *Dikelocephalus* sp. ?, *Ptychaspis* sp. ?	25

The stratigraphic exposures are not continuous, the section being broken in places by concealment under the drift. Nos. 1 and 2 are fairly well connected by lithologic features and No. 3 rests on typical strata of No. 2, only a short distance intervening between the outcrops. No. 3 is well shown on Marble River one mile southeast of the Chateaugay Chasm, and the Calciferous sandrock is shown a little farther down the stream. The species found in the upper part of No. 3 are identical with those found in the limestones of the Upper Cambrian in Saratoga County, New York and fully prove that the fauna of the Potsdam sandstone is the same as that of the St. Croix sandstones of Wisconsin.

Section in Hemmingford.—To the northeast of Chateaugay, across the boundary, in Hemmingford, Canada, a section of the sandstone according to Sir W. E. Logan, is 540 feet in thickness. On the south side of Hemmingford Mountain about 180 feet of a coarse gray sandstone are visible, in some parts constituting a conglomerate, with rounded pebbles of white quartz, varying in diameter from an eighth to three-quarters of an inch, while in some parts of the rock there are thinly disseminated flat pieces of black or green shale 1 or 2 inches in diameter by an eighth of an inch thick. The general color of the rock is gray, but greenish and reddish beds occur, and the three colors sometimes follow one another in thin stripes with various alternations. Above the strata of the ravine the hill contains about 120 feet of gray sandstone, the lower half of which is rather coarse grained, and below the same strata 240 feet. Neither the base nor the summit of the sandstone was observed.[1] Farther to the north along the shore of the St. Lawrence occur the celebrated fossil track localities described by Logan.

Section at Keeseville and in Au Sable Chasm.—About one-quarter of a mile above the village of Keeseville, on the Au Sable River, a rounded boss of granite shows on the south bank. Nearly 400 feet lower down the stream, on the opposite side, an evenly bedded and cross-bedded

[1] Geological Survey of Canada: Report of Progress from its commencement to 1863. Montreal, 1863, p. 88.

compact gray sandstone occurs, lying in nearly horizontal beds. Lower down they dip 3° to 5° to the northeast. This dip increases to 7° to 8° at the iron bridge. Following across the strike down the stream to where the beds are horizontal, above the entrance to the Chasm, the measured section shows 333 feet in thickness from near the granite to the highest beds observed.

The section as measured from the mouth of the Au Sable Chasm to the summit beds above the fault is as follows:

SECTION.

	Feet.
(1) Compact, fine-grained, steel-gray, buff, and light gray sandstone, in layers from 6 inches to 5 feet in thickness (20 layers)	45
Strike N. 30° E. Dip. 5° E.	
(2) Massive layers, light gray, fine-grained sandstone, very hard, breaking up into thin layers, ½ to 3 inches thick	6
(3) Compact, gray sandstone in three layers; 1 foot 5 inches, 1 foot 6 inches, 2 feet 1 inch	5
(4) Light gray and buff sandstone, three layers	4·6
(5) Light gray compact sandstone, with *Lingulepis acuminata*, Conrad	1
Strike N. 30° E. Dip 5° E., at foot of rapids.	
(6) Light gray, fine-grained, compact sandstone, in layers varying from 6 inches to 18 inches in thickness	6
(7) Of the same general character as 6, in massive layers, breaking up into thin layers on exposure. Occasional layers contain many small, flat concretions of clay shale and also fragments of Lingulepis. At 34 feet from the base *Hyolithes primordialis?* and *Lingulepis acuminata* occur near the boat-landing in the Chasm. Thirty-five feet higher up in the same light gray compact sandstone *L. antiqua* occurs in association with *Ptychoparia minuta*	117

At this line a fault breaks the section with a down-throw to the northeast. The river and Chasm follow the fault from the Elbow to the Devil's Oven, where the section is taken up again.

(1) Massive layers of light gray, hard, compact sandstone. Prof R. P. Whitfield found at this horizon *Palæacmæa typica, Ptychoparia minuta*	30
(2) Evenly bedded gray, buff, and yellowish sandstone, hard, compact and in layers 1 to 4 feet in thickness	165
(3) Thinner bedded gray and buff sandstone, with Protichnites tracks above the mill-dam and above the bridge at Birmingham	45
Strike NE.; dip 5° SE.	

Ripple marks are very numerous and *Lingulepis acuminata* is abundant 15 feet above the Protichnites bed, and extends about 25 feet to the top of the section. Some of the layers are a little calcareous and full of annelid trails and borings.

Estimating the amount of repetition of strata in the two sections there remains a lower series of 210 feet, and an upper of 140 feet, or a total thickness of 350 feet with the summit and base of the formation unseen.

Section at Whitehall.—There is a fine section exposed at Whitehall, New York, that serves to correlate the sections of Chateaugay and Au Sable Chasm. At the former the upper fauna is present and at Au Sable Chasm the *Ptychoparia minuta* subfauna. At Whitehall the upper fauna occurs in the upper portion of No. 17 of the following section and the lower in the lower part of No. 15. This is the relative position of the same subfaunas in the Wisconsin section.

Section beginning below lower lock of canal at Whitehall:

	Ft.	In.
(1) Massive bedded, compact, dark steel gray sandstone, almost a quartzite.	25	0
(2) Dark clay shale	0	6
(3) Bluish gray, brecciated limestone	0	6
(4) Fine grained, compact, steel gray limestone	1	0
(5) Compact, arenaceous limestone	3	0
(6) Compact, fine grained, steel gray sandstone in layers of 6 inches to 3 feet. Partings of coarser sandstone and small, flattened clay concretions occur, also streaks of light-colored sandstone in the layers, and cross-bedding is of common occurrence	14	5
Annelid trails on the surface of the layers.		
Strike N. 20° E.; dip 6° to 8° E.		
(7) Calciferous sandstone in one layer	2	7
(8) Fine grained, compact, steel gray sandstone	20	0
(9) Thin bedded sandstone and clay shale	1	3
(10) Compact, gray and purplish, fine grained sandstone, streaked with dark sandstone and shaly matter; slightly calcareous in places	16	6
(11) Dark gray calciferous layers, weathering to a reddish brown sandstone..	2	0
Annelid trails and borings.		
(12) Gray, compact sandstone	1	3
(13) Dark gray, calciferous layers, weathering to a reddish brown sandstone.	1	4
Annelid trails and borings.		
(14) Hard, compact, gray sandstone, in evenly bedded layers 6 inches to 3 feet in thickness of the division of the typical Potsdam sandstone. Summit near crossing of private roadway	59	8
(15) Sandstones similar to 14, but with few alternating calcareous layers; the calcareous matter decomposing and leaving streaks of reddish and brown rocks in the layers	113	0
Ripple marks occur on the surface of many layers and annelid trails on the calcareous strata, About 30 feet up found *Palæacmæa typica*, H. and W.		
Strike 25° E.; dip 10° E.		
The light gray compact limestone, with the little flattened concretions of clay and the cross-bedding, give this portion of the section a striking resemblance to that of the upper 150 feet of the Keeseville section.		
(16) Lead colored calciferous sandstone, weathering rough	0	5
(17) Alternating, gray, compact, fine grained sandstone, reddish coarse sandstone and finer calcareous sandy layers. *Lingulepis acuminata* and *Ptychoparia* sp? occur in the upper layers, about 40 feet up	70	0
	332	5

Calciferous.

	Ft.
(18) Calciferous sandstone with a massive bedded light gray compact sandstone; at top 10 feet thick	40
The upper 30 feet of 17 and all of 18 may be considered as the passage beds to the calciferous sandstone above.	
(1) Lead colored, massive bedded, calciferous sandstone	230
(2) Lead colored, brecciated limestone overlain by a compact light gray limestone	20
	290

Section at Saratoga.—The section, as determined north and west of Saratoga Springs, and north as far as Corinth, New York, has, at the base, about 200 feet of evenly bedded, compact, grayish to yellowish colored sandstone, that rests unconformably against or upon spurs or ridges of pre-Cambrian gneiss. Including the upper beds of sandstone, the section 3 miles north of Saratoga village gives in ascending order:

	Feet.
(1) Sandstone	40
(2) Oolitic limestone	30
(3) Dark gray, evenly bedded limestone	50
(4) Unfossiliferous, impure, compact, more or less siliceous limestone	95
(5) Massive-bedded, slightly magnesian, gray and dove colored limestones with numerous small, narrow-chambered cephalopods near the summit	35
(6) Massive layers of steel-gray, more or less arenaceous limestone	125
(7) Bird's-eye limestone	6
(8) Black River limestone	4
(9) Trenton limestone	40

The limestone (2, 3) capping the sandstone (1) of the section is also found at Whitehall and at Comstock's Landing, Washington County, New York, where it has been, as was the limestone (2, 3), referred to the Calciferous. The limestone 2 and 3 appears to have been, on the southwestern side of the Adirondack Mountains, the closing deposit of the Cambrian; and there is but little doubt that if we could find a fauna in the limestone (4) of the section it would serve to connect the Cambrian and Lower Silurian (Ordovician) faunas.[1]

The following fauna was found in No. 3 of the section:

Cryptozoa proliferum.
Lingulepis acuminata.
Platyceras minutissimum.
  hoyti.
Metoptoma cornutiforme.
  simplex.
Billingsia saratogensis.
Matthevia variabilis.
Dikelocephalus hartti.
  speciosus.
Ptychoparia calcifera.
  (A.) saratogensis.

The comparison of the Chateaugay Chasm section with that of Saratoga County proves very clearly by the included faunas that the Potsdam epoch closed on the south side of the Adirondacks with a deposit of limestone carrying the Dikelocephalus fauna. It is found in the upper beds of the quartzite on Marble River in the township of Chateaugay, and in each section the Calciferous formation is superjacent to the closing epoch of the Potsdam.

The greatest depth reached in the formation is that of the section of Hemmingford Mountain. Unfortunately this section has not been studied so as to determine whether there is any fauna present in the sandstones. The section at Au Sable Chasm, however, shows that a second horizon of the Upper Cambrian fauna occurs about the Adirondacks. This is the zone of *Ptychoparia minuta*, corresponding to the zone of *Ptychoparia minor* of the Wisconsin section.

[1] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey Bull. No. 30, 1886, p. 22.

The presence of the Potsdam terrane on the south side of the Adirondacks, along the valley of the Mohawk, has not been positively proved. At Little Falls a thin layer of sandstone, resting unconformably upon the pre-Paleozoic rocks and beneath the Calciferous sandrock, has been referred to the Potsdam. The discovery by Profs. Shaler and Williams of a thin layer of shale, resting upon this layer of sandstone, on the north side of the river at Little Falls, in which specimens of *Lingulepis acuminata* occur, lends more authority for the statement that the Potsdam is present; but as the species *Lingulepis acuminata* ranges up into the Calciferous sandrock, both at Whitehall, New York, and on the north side of the Adirondack Mountains in St. Lawrence County, it is doubtful if we can claim the presence of the Potsdam at any point in the Mohawk Valley. There is not, however, any definite reason why a thin bed of it, with the typical Potsdam fauna, should not be found beneath the Calciferous, if it is not concealed by the overlap of the superjacent Calciferous and Trenton terranes.

The sediments of the Adirondack sub-Province and its Canadian extension, with a single exception, were accumulated in a shallow sea not far removed from the shore-line. Ripple-marked sandstones and trails of marine invertebrates occur. The sandstone is relatively fine-grained with the exception of a small deposit of conglomerate in St. Lawrence County, New York. The formation belongs to the Upper Cambrian, and overlaps upon the sloping shores of the pre-Cambrian land. The one exception to the arenaceous deposit are the limestones in Saratoga County, New York, which were deposited on sandstone and overlap on to the pre-Cambrian rocks. The fauna of the limestone is the same as that of the quartzite at Marble River, near Chateaugay Chasm, on the northern side of the Adirondacks.

WESTERN BORDER OR ROCKY MOUNTAIN SUB-PROVINCE.

This includes the Cambrian rocks of South Dakota, southern central Montana, central and northwestern Wyoming, and Colorado.

SOUTH DAKOTA.

The chief summary of our knowledge of the Cambrian rocks of the Black Hills of Dakota is taken from the reports of Messrs. Newton and Carpenter. The sandstone identified as the "Potsdam" is the lowest member of the fossiliferous series, and in numerous and excellent exposures its character and relations are easily determined and studied. It everywhere rests unconformably upon the upturned edges of the underlying Algonkian slates and schists, filling up irregularities in their surfaces, and its basal member is generally formed of coarse materials derived from the erosion of the subjacent rocks. Consisting mainly of coarse and friable sandstones, with conglomerates easily eroded, it covers superficially very limited areas.

By a reference to the geological map accompanying the report of Mr. Henry Newton the exposures of the "Potsdam" sandstone will be seen to form a very narrow band surrounding the "Archean" area. Though essentially a sandstone formation it has some variety of composition. Usually it carries a conglomerate at the base, but this is sometimes exchanged for a dense quartzite, and in many places there are interstratified beds of quartzite. In a few localities the formation is quite calcareous and in a great number it contains peculiar greensand deposits. Its thickness is quite uniform, ranging generally from 200 to 250 feet, but attaining to 300 feet on the north branch of Redwater Creek. Complete sections from the "Archean" to the Carboniferous are rarely met with, but one measured in the eastern cañon of Spring Creek by Mr. Jenney is as follows:[1]

	Feet.
Archean.	
(1) Argillaceous slates, dipping 60° west	
Potsdam.	
(2) Brownish yellow conglomerate, with quartz pebbles, resting unconformably on 1 and dipping 25° northeast	25
(3) Reddish brown sandstone, thinly bedded at base and alternating with soft, shaly sandstones, containing large fucoids, Lingulepis, and fragments of trilobites	200
Carboniferous.	
(4) Reddish brown, or pinkish calcareous sandstone, thinly bedded, containing *Spirifera camerata*, cyathophylloid corals, and crinoid columns	20
(5) Limestone: *Spirifera camerata*, Productus, etc	335

Many details are given of the local phenomena presented by the sedimentation and mode of occurrence of this formation; extended comparisons are made between it and the correlated sandstones about the Big Horn and Wind River Mountains of Wyoming, the sandstones of the Mississippi Valley, and the typical Potsdam sandstone about the Adirondacks of New York.

The following is a list of the fossils found in the sandstone and identified or described by Prof. R. P. Whitfield:[2]

Palæochorda prima.
Palæophycus occidentalis.
Palæophycus.
Scolithus.
Lingulepis pinnaformis.
  cuneolus.
  perattenuatus.
Lingulepis dakotensis.
Obolus ? pectenoides.
Obolella polita.
  nana.
Crepicephalus centralis.
  planus.

Prof. F. R. Carpenter describes the "Potsdam" in the Black Hills as follows:

The present site of the uplift existed as a slowly sinking island in the Potsdam ocean, probably the last surviving land of a vast area eroded and submerged by

[1] Newton, Henry: Geology. Report on the Black Hills of Dakota. U. S. Geog. and Geol. Survey of the Rocky Mountain region, J. W. Powell in charge, 1880, p. 88.
[2] Op. cit., p. 107.

the advancing waters. The base of the Potsdam entirely around its outcrop is a conglomerate. The ocean advanced upon the land with an action that has been aptly termed that of a horizontal saw. The cliffs were undermined by its action, the débris thus formed worn to bowlders, to gravel, and to sand. As the shore-line advanced and a given point became farther from land, it received finer and finer sediments, until sedimentation, in this area at least, entirely ceased.[1]

He calls attention to the fact that the sandstone thins out towards the central portion of the Black Hills uplift. Near Harney Peak the last outliers are about 50 feet thick between the unconformable subjacent "Archean" rocks and the undisturbed conformable superjacent Carboniferous limestone.

WYOMING.

There has been comparatively little detailed information published relating to the Cambrian rocks of the Big Horn Mountains. Dr. F. V. Hayden visited the range in 1861 and found the nucleus composed of red feldspathic granite and a series of stratified Azoic rocks. Resting on these occur the sandstones which are referred to the "Potsdam." He found a few thin layers of fine calcareous sandstone filled with fossils characteristic of the period.[2] These were studied by F. B. Meek, who identified Conocoryphe and perhaps Dikelocephalus.[3]

According to Prof. T. B. Comstock, the sandstone referred to the Potsdam attains a thickness of about 200 feet in the region of the Wind River Mountains, and above the sandstone on the eastern side, along the central portion of the range is a series of limestones resting on the sandstone, having a thickness of about 200 feet. From specimens collected in the limestone he identified a trilobite of the genus Dikelocephalus, several specimens of what was supposed to be *Orthis tritonia*, and a quantity of a species of Theca.[4] As far as Prof. Comstock's observations extended the sandstone rested unconformably upon the subjacent metamorphic rocks.[5] On the map accompanying the report the "Potsdam" formation is represented as occurring all along the eastern side of the Wind River range, and also along the central portion of the western side. The latter occurrence, however, is denied by Dr. A. C. Peale.[6] Dr. Hayden noted in 1862 the presence of a sandstone resting upon the vertical edges of the Azoic clay slate series in the Laramie Mountains, which he referred to the age of the Potsdam sandstone,

[1] Notes on the geology of the Black Hills. Preliminary Rep. Dakota School Mines, on the Black Hills of Dakota, 1888, p. 31.

[2] Hayden, F. V.: Sketch of the geology of the country about the headwaters of the Missouri and Yellowstone Rivers. Am. Jour. Sci., 2d ser., vol. 31, 1861, p. 234.

[3] Meek, F. B.: Preliminary paleontological report with remarks on the ages of the rocks, etc. U. S. Geol. Surv. of the Terr., Sixth Ann. Rep., 1873, p. 465.

[4] Geological Report. Report upon the reconnoissance of northwestern Wyoming, made in the summer of 1873, by William A. Jones. 1874, pp. 108–110.

[5] Op. cit., p. 106.

[6] Report on the geology of the Green River district. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, p. 524.

although no organic remains were found. In the vicinity of the headwaters of the Niobrara River he measured a section as follows:

	Feet.
(1) Quartzose sandstone, some parts filled with pebbles	22
(2) Red argillaceous slate	5
(3) Sandstone, dull reddish ferruginous, like bed 1, above	37
(4) A series of strata more or less inclined, composed of gneiss with silvery mica in large plates, micaceous and talcose slates, white quartz, etc.	

He states further that he has no doubt the Potsdam sandstone occurs in the form of an outcropping belt all along the Laramie range of mountains, although he was unable to discover any organic remains. He correlated it with the Potsdam on the evidence afforded by the Black Hills section of Dakota. The occurrence of the sandstone at this horizon is noted by him at numerous localities on the flanks of the Laramie Mountains.[1] In opposition to the view of Dr. Hayden may be cited that of Mr. Arnold Hague, who states that all paleontological evidence obtained from the beds associated with the quartzite and above them tend to show that they belong to the Coal-Measure limestone.[2]

In 1871 Dr. Hayden found Obolella and a Lingula in a considerable thickness of Potsdam sandstone on the south side of the Sweetwater River, near the southeastern termination of the Wind River Mountains, thus establishing by paleontologic evidence the Upper Cambrian or Potsdam age of the sandstone referred to that horizon in 1861.[3]

A small area of paleozoic rocks on the northwestern end of the Wind River range has, according to Prof. Orestes St. John, a sandstone at the base that rests on the Archean. It is coarse grained, grayish, buff, reddish stained, thin bedded, with oblique laminated layers and locally quartzitic. The greatest exposed thickness of this bed probably does not exceed 50 feet. Its exact relation to the underlying Archean rocks and to the superjacent strata referred to the Quebec was not determined.[4] On the diagrammatic section accompanying the report formation No. 2, or the Potsdam, is represented as resting unconformably upon the Archean and conformably subjacent to limestones referred to the Quebec.

The Cambrian strata of northwestern Wyoming are contained within the district of the Teton range, Gros Ventre range, and the Buffalo Fork Mountains, all of which are reported upon by Prof. St. John. He quotes Prof. Bradley in relation to the lower quartzite, stating it to be a very compact ferruginous quartzite, with a thickness of from 50 to 75 feet. Above this occurs about 300 feet of sandstone strata on the

[1] Hayden, F. V.: The Primordial Sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci., 2d series, vol. 33, 1862, pp. 70, 71.

[2] Descriptive Geology. U. S. Geol. Expl. of the Fortieth Par.; vol. 2. Washington, 1877, p. 76.

[3] Report of F. V. Hayden (on the geological survey of Wyoming). U. S. Geol. Surv. of the Terr., 4th Ann. Rep., 1871, p. 33.

[4] Report on the geology of the Wind River district. U. S. Geol. Surv. of the Terr., 12th Ann. Rep., 1883, p. 253.

higher slopes of the mountains, according to Prof. Bradley, in the Teton range. The same series of deposits evidently occurs in the Gros Ventre range, and in the Buffalo Fork Peak uplift. In the Gros Ventre range the quartzites were seen in immediate contact with the unconformable Archean schists.[1]

The superjacent limestone, called the "Lower Quebec limestone" by Prof. St. John, occurs in the Teton range and the Gros Ventre. But it is in Buffalo Fork Peak that the best section was obtained. Here there is an exposed thickness of from 50 to 75 feet of bluish and dark drab, brecciated, thin bedded, rough weathering limestone, above which occurs what he calls the passage beds to the "Upper Quebec limestone." These beds are yellowish, arenaceous, micaceous clay, with indurated layers charged with a small orbiculoid shell and thin layers of dirty drab limestone, the weathered surfaces of which are crowded with the fragmentary remains of trilobites and other fossils. Among others there have been identified the genera Conocoryphe and Dikelocephalus. The upper portion of the deposit is here composed of bluish drab shales and brownish gray shaly sandstones. It reaches a probable thickness between 100 and 200 feet.

The superjacent limestone called the "Upper Quebec limestone" shows almost the same development in the Teton and Gros Ventre ranges and the Mount Putnam area of Idaho. The rock consists of generally thin bedded, fragmentary, sometimes brecciated limestones, color gray, grayish buff, and pinkish, carrying small sized trilobites and a gasteropod resembling Raphistoma. In the Teton range the series of rocks has a thickness of 100 feet or more, and forms mural exposures on the cañon walls.

A review of the reports of Messrs. Bradley and St. John shows that the Upper Cambrian horizon is to be recognized in the Teton, Gros Ventre, and Buffalo Peak Mountains, and that it is composed of a basal zone of varying thickness, upon which rests a limestone carrying Upper Cambrian fossils. This limestone is the equivalent of the "Lower Quebec" of Prof. St. John's section. His "Upper Quebec" is to be referred to the base of the Lower Silurian (Ordovician) or corresponding to the Calciferous zone of the New York section.

COLORADO.

The identification of rocks of Cambrian age in Colorado has been made, with one exception, upon stratigraphic and lithologic evidence. The exceptional instance is that mentioned by Mr. S. F. Emmons, who found a distinctly Upper Cambrian genus, Dikelocephalus, in a bed of greenish chloritic shale that he assumed to occur above the main body of the quartzite and near the base of the transition series that passes

[1] Report of the geological field work of the Teton division. U. S. Geol. Sur. of the Terr., 11th Ann. Rep., 1879, p. 481.

into the Silurian limestone.[1] He describes the strata in the Mosquito range referred provisionally to the Cambrian as follows:

The beds assigned provisorily to this horizon * * * are prevailingly of quartzite. To them, therefore, the local name of Lower Quartzite has been given. There average thickness is about 150 feet to 200 feet, of which the lower 100 feet are composed of finely and rather thinly bedded white saccharoidal quartzites, while the upper 50 feet are shaly in character and more or less argillaceous and calcareous, passing by almost imperceptible transition into the siliceous limestone of the Silurian formation above.

At the very base of the series, at the contact with the underlying Archean, wherever this could be observed, is found a persistent bed of fine grained conglomerate, from a few inches to a foot in thickness, made up of rounded and finely polished grains of bluish translucent quartz, generally not larger than a pea in size. Above this is a white quartzite of remarkably uniform and persistent character, always very readily distinguishable as a white band in the numerous sections offered by the cañon walls of the range. Its thickness, when measured on the west side of the range or near the Sawatch Island, is, as mentioned above, 100 feet of purely siliceous beds. On the east side of the range the thickness seems somewhat to diminish, and in places was found to be only 40 feet. * * *

Owing to their similar lithological character and to the general absence of fossil evidence it is difficult to establish a hard and fast line between this and the succeeding formation above. In practice the line has been drawn at the top of the shaly beds, and the commencement of the beds of more massive limestone. The transition beds consist essentially of alternating bands of calcareous quartzite and shales. The name sandy limestones is often applied to them for the reason that on weathered surfaces of the cliff faces they appear like sandstones, the carbonate of lime having been entirely washed out, and only the fine quartz grains left on the thin surface crust.[2]

As already stated, the only fossil remains found in this series occur in a bed of greenish chloritic shales on the east flank of Quandary Peak, about a mile above the Monte Cristo mine. They belong to the genus Dikelocephalus, and closely resemble *Dikelocephalus minnesotensis* of the Potsdam formation of Wisconsin. This band of shales was not found in stratigraphic relation to the quartzite of the limestone of the sections already mentioned, but it occurs above a heavy white quartzite and beneath a bed of white marbleized limestone; and, from analogy with other sections, Mr. Emmons thinks it safe to assume that it occurs above the main body of quartzite and near the base of the transition series.[3]

For the purpose of comparison, a section was measured by Mr. Whitman Cross, in William's Cañon, near Manitou Springs. Of this section Mr. Emmons says:

The purely siliceous beds at the base are much thinner than in the Mosquito Range, the greatest thickness found being 50 feet. They are succeeded by calcareous sandstones and shales of variegated colors, red prevailing, which pass up into white or drab limestones, sometimes containing chert secretions and alternating with shaly beds, with an aggregate thickness of about 200 feet. These beds may be considered as the equivalents of the lower quartzite and white limestone of the Mosquito Range.[4]

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[1] Geology and mining industry of Leadville, Colorado. U. S. Geol. Surv., Monograph, vol. 12, 1886, p. 60.

[2] Op. cit., pp. 58, 59.

[3] Op. cit., p. 60.

[4] Op. cit., p. 62.

From the east bank of Trout Creek, in Manitou Park, Mr. Cross obtained fossils from a reddish brown sandstone, 45 feet above the Archean, among which an elongate form of Lingulepis, allied to *L. pinnaformis* of the Potsdam sandstone of Wisconsin, occurs. From the red calcareous sandstones, alternating with white limestone, 105 to 122 feet above the Archean, the fauna is the type of that of the lower portion of the Lower Silurian (Ordovician).

Two sections measured on Trout Creek by Dr. A. C. Peale gave the following results:[1]

	No. 4.	No. 5.
	Feet.	*Feet.*
1. Granitic	....	....
2. Yellow sandstone 3. Pinkish sandstone	73	65
4. Dark, purplish brown sandstone	16	13
5. Green sandstone	4	3
6. Blood-red calcareous sandstone 7. Pink limestones	54	60

"Beds No. 6 and 7 are fossiliferous and belong in all probability to the Quebec group, while the sandstones below are Potsdam." A list of fossils is given as coming from No. 7 which indicates a grouping of Cambrian and Silurian (Ordovician) genera unknown elsewhere.

Dr. F. M. Endlich's synopsis of the rocks of the Potsdam group found in Colorado sums up all that was known to him of the principal localities and the character and thickness of the strata. Seven localities are mentioned, as follows:[2]

			Feet.
Potsdam Group.	Lime Creek	White sandstone and quartzite	250
	Eagle River	White quartzites	300 to 400
	Four-mile Creek	Red and pink sandstones and quartzites	160
	Trout Creek	Yellow and pink sandstones	80
	North of Mount Ouray	White and pink quartzites	200
	Near Canyon City	Variegated micaceous and calcareous sandstones.	....
	Glen Eyrie	Red sandstones and quartzites	40
	Average thickness of strata		180

That the Upper Cambrian zone is represented is fairly well proved by the Mosquito Range section and that of Trout Creek of the Colorado Range, and it is very probable that the sandstones correlated with the

[1] Report of A. C. Peale, M. D., Geologist of the South Park Division. U. S. Geol. Surv. of the Terr., 7th Ann. Rep., 1874, p. 208.

[2] Report of F. M. Endlich, Geologist of the White River Division. U. S. Geol. Surv. of the Terr., 10th Ann. Rep., 1878, p. 130.

Potsdam really belong within the Upper Cambrian horizon. From our present knowledge the Upper Cambrian zone is the only portion of the group represented in Colorado.

The Cambrian rocks included within the States of Colorado, Wyoming, Montana, and South Dakota are of the type of those of the southern Interior Continental, Upper Cambrian series, and consist usually of a bed of quartzite or conglomerate, resting unconformably upon the Algonkian or Archean, and passing above into calcareous beds that frequently carry the Upper Cambrian or Potsdam fauna. This is the case with the formation about the Big Horn Mountains, Wind River Mountains, and the Teton and Gros Ventre ranges of Wyoming. In some instances, however, as about the Black Hills, a fauna occurs in the basal sandstone similar in character to that of the St. Croix sandstone of the upper Mississippi Valley. Traces of a fauna were found in Colorado, at Quandary Peak, in a schistose rock that is supposed to occur just above the quartzite.

SOUTHWESTERN SUB-PROVINCE.

The widely separated areas of Cambrian rocks in Central Texas and northwestern Arizona are united in one sub-province on account of their similarity in stratigraphic position, general sedimentation, and faunas.

TEXAS.

With the exception of the doubtful occurrence of the Upper Cambrian zone as a sandstone in the Organ Mountains of southwestern Texas, as mentioned by Mr. W. P. Jenney, the Cambrian formation is, as far as known, confined to the Paleozoic uplift in the central part of the State that includes Llano County within its central portion.

A section of the formation measured by Dr. B. F. Shumard in Burnet County, 5 miles northwest of the town of Burnet, is as follows:[1]

	Feet.
No. 1.—Soft, chalky limestone with well marked cretaceous fossils	50
No. 2.—Gray and bluish gray hard limestone, of a sandy texture, in beds from a few inches to a foot thick, and containing *Arionellus* (*Bathyurus?*) *planus*, *Bathyurus depressus*, *Camerella* sp., *Orthis coloradoensis*, *Orthis* sp.?, *Discina microscopica*, and *Lingula* sp.?	81
No. 3.—Mottled gray, purple, and greenish, earthy and subcrystalline limestone, with alternating bands of siliceous limestone—contains the same fossils as No. 2	45
No. 4.—Slope with projecting ledges of No. 3	55
No. 5.—Slope	24
No. 6.—Schistose coarse textured limestone, made up of crystalline particles and abounding with fragments of trilobites, chiefly Arionellus	20
Total	275

[1] The Primordial zone of Texas, with descriptions of new fossils. Am. Jour. Sci., 2d ser., vol. 32, 1861, p. 216.

A second section, taken about 1 mile south of the preceding, is also quoted, as it carries the series down to the granite:[1]

	Feet.
No. 1.—Cretaceous strata in horizontal beds	110
No. 2.—Slope, covered with conglomerate, composed of pebbles of sandstone and calciferous sandrock, rather firmly cemented	12
No. 3.—Potsdam sandstone, consisting of thin layers of variegated green, gray, and purplish sandy limestone, with bands of dolomite and silico-calcareous rock interstratified. Some of the beds are highly charged with trilobites, of which the most common are *Arionellus texanus*, *Dikelocephalus roemeri*, and *Conocephalites billingsi*	40
No. 4.—Highly ferruginous siliceous sandstone, composed of fine grains, loosely cemented, passing downwards into coarse gritstone and conglomerate. The upper beds contain Lingula and Obolus (?)	60
No. 5.—Flesh colored granite, interstratified with veins of milky quartz	6

From the sections it will be observed that the strata consist largely of limestone, with a bed of sandstone at the base.

The section of Packsaddle Mountain, in Llano County, in the valley of Honey Creek, is given as follows by Mr. C. D. Walcott in 1884:[2]

	Feet.
5 = Potsdam limestone	60
4 = Potsdam sandstone	30
3 = Potsdam limestone	310
2 = Massive Potsdam sandstone	205
1 = Llano group.	
	605

The fauna collected included 12 genera and 25 species, all characteristic of the Upper Cambrian zone.

A comparison of the Texas section with that of the Grand Cañon of the Colorado, in northern Arizona, leads to the conclusion that they belong to the same area of sedimentation. In each a massive sandstone at the base is subjacent to alternating sandstones and limestones that carry essentially the same fauna. The sections of the lower sandstones of the eastern slopes of the Rocky Mountains partake somewhat of this character, especially those of the Big Horn range in Wyoming. In Wisconsin, etc., the calcareous beds of the Texas section are absent, but the presence of the Dikelocephalus fauna at the summit of each series above a zone carrying what may be called the *Ptychoparia minor* fauna, proves that the life of the two areas continued on in the same succession despite the change in sedimentation and environment.

In a report on the Cambrian system Prof. T. B. Comstock concludes that at least two and probably three series of Cambrian strata are represented in central Texas.[3] To the basal beds he gives the name Hickory series (Lower Cambrian ?). For the second horizon the name Riley series (Middle Cambrian ?), and for the upper series the name

[1] Op. cit., p. 217.
[2] Note on Paleozoic rocks of central Texas. Am. Jour. Sci., 3d ser., vol. 28, 1884, p. 432.
[3] A preliminary report on the geology of the central mineral region of Texas. 1st Ann. Rep. Geol. Surv. of Texas for 1889-'90, pp. 285-291.

Katemcy (Potsdam) series (Upper Cambrian ?). This upper series is divided into Division A, the Potsdam sandstone; Division B, the Potsdam flags; Division C, the Potsdam limestone.

ARIZONA.

As far as known the Cambrian rocks of Arizona are confined to the sections exposed by the Grand Cañon of the Colorado and along the southwestern margin of the great Colorado Cañon plateau.

A section measured near the head of the Grand Cañon has 300 feet of sandstone at the base that rests unconformably upon the subjacent Algonkian (Chuar) formation. Above the sandstone there are 700 feet of alternating sandstones, shales, and limestones throughout which fossils of the Upper Cambrian zone have been found. These include the genera Cruziana, Lingulepis, Iphidea, and Ptychoparia. At the summit of the lower sandstone a small group of fossils was found which includes the genera Olenoides, Ptychoparia, Lingulepis, and Leperditia. The upper part shows close relation to that of the Potsdam sandstone horizon of central Nevada, the Mississippi Valley, and New York, while that of the lower zone or the summit of the sandstone is more nearly related to that of the Middle Cambrian zone of the Southern Appalachians. There is a large quantity of material in the laboratory of the U. S. Geological Survey yet remaining to be studied, but I think these conclusions will not be materially changed.

At the mouth of Kanab Creek, west of the Kaibab Plateau, there are 100 feet of arenaceous and micaceous shales, subjacent to a massive stratum of mottled limestone. In the lower 450 feet of the latter and in the arenaceous shale fossils were found similar in character to those of the upper portion of the section, as seen near the head of the cañon. They include Lingulepis, Hyolithes, and Ptychoparia.

The section at the mouth of the Grand Cañon, as given by Mr. A. R. Marvine, is as follows:[1]

		Feet.
Red wall limestones.		
Tonto marble limestones.		
Tonto shales	Green	25 / 75
	Snuff-colored	90
	Green	415
Tonto sandstone		80
Granite		90

Mr. Marvine says that in going southward from the mouth of the cañon the Tonto shales seem to diminish in thickness, and at Tinnakah Springs they are estimated at less than 400 feet. A few miles south of this point they were still thinner, being estimated at less than 100 feet. The Tonto sandstone, however, has increased much in thickness and forms the greater portion of the section.

[1] Report on the geology of route from St. George, Utah, to Gila River, Arizona, examined in 1871. Rep. on Geog. and Geol. Expl. and Surv. west of 100th merid., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 199.

On the atlas sheet issued by the Wheeler Survey in 1874 the Silurian (which also included the Tonto formation) is represented as extending from the head of the Grand Cañon along the entire course of the cañon to its mouth, and thence southward along the western margin of the Colorado plateau to Music Mountain, where the outcrop broadens out and extends southwest along the southwestern margin of the plateau. The most southeastern outcrop is on the Rio Verde River near the lower end of Williamtown Valley.

In all the sections on the line of the Grand Cañon and the western and southwestern margins of the Colorado Plateau the Tonto sandstone rests uncomformably upon either Algonkian or Archean rocks. In its greatest development the formation attains a thickness of 1,000 feet and represents the Upper Cambrian zone, and possibly in the lower portion, the Middle Cambrian.

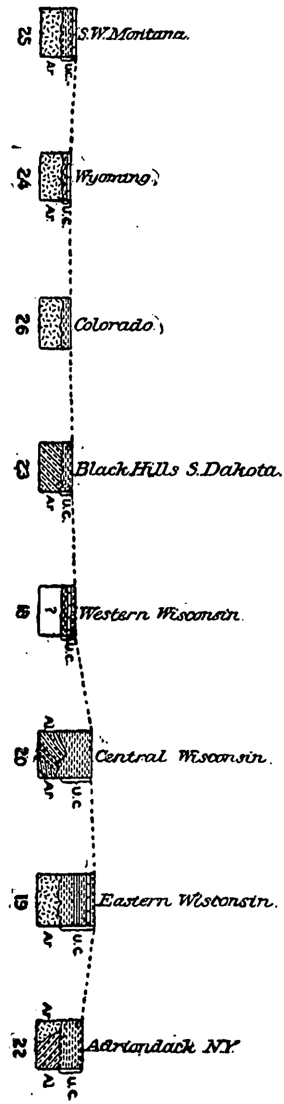


Fig. 4.—Sections of the Interior Continental Province, on its northern border (vertical scale, 6,200 feet to the inch). The numbers beneath the sections correspond to the locality numbers beneath the sections on Pls. I and II.

RÉSUMÉ.

The sediments of this province are those deposited as the sea advanced slowly upon the land and distributed the débris worn from it or brought in by tributary streams as layers of sand along the coast line and in an adjoining shallow sea. From Arizona to Texas, to Missouri, the Black Hills, and the eastern margin of the Rocky Mountains, and all along the northern line in Minnesota, Wisconsin, Michigan, Canada, and the Adirondacks of New York, the record is the same—sandstones resting upon pre-Cambrian rocks and carrying essentially the same fauna. In some regions the depth of water increased more rapidly and calcareous deposits accumulated upon the sand, as in Arizona, Texas, the Black Hills, and in some localities along the eastern base of the Rocky Mountains. That the sea was shallow, wide spread, and advancing along a great extent of coast line is shown by the sediments and the presence of a similar fauna in New York, the Upper Mississippi Valley, the Black Hills, the eastern front of the Rocky Mountains, and far to the south in Texas and Arizona. All over this broad area the relative stratigraphic succession of the sub-divisions of the Upper Cambrian fauna is the same; and nowhere do we know of the existence of formations characterized by the Lower and Middle Cambrian faunas of the Atlantic coast, Appalachian and Rocky Mountain provinces, except, perhaps, the Middle Cambrian fauna in the southwestern Interior Continental sub-Province.

In the Atlantic Coast Province the basal beds of the Olenellus zone rest unconformably upon Archean and Algonkian rocks. The sea deposited the Cambrian sediments across the upturned edges of the Laurentian and those of the superjacent bedded sandstones, quartzites, argillites, and slates forming the Algonkian series, which Dr. Murray referred to the Huronian. The upper St. John's slates carrying the Aspidella were also planed away by the Cambrian Sea. In the Interior Continental Province in Wisconsin and Minnesota the Upper Cambrian sandstones are unconformably superjacent to the corresponding series of rocks, or the Laurentian, Huronian, and Keweenawan series of the Lake Superior region. In the first instance the earlier Cambrian sea transgressed upon the pre-Cambrian rocks, and in the latter case the later or closing epoch of the Cambrian was the one in which the deposits were accumulated upon the Archean and Algonkian rocks. A misapprehension of these facts has led several geologists to refer the Keweenawan and other pre-Cambrian rocks to the Cambrian.

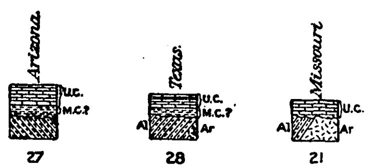


FIG. 5.—Sections of the Interior Continental Province, in the south central and southwestern portions.

DESCRIPTION OF PLATE I.

Geographic distribution of the Cambrian strata shown by surface outcrops in North America.

The geologic provinces are indicated by the dotted lines. The Interior Continental Province is broken up into sub-provinces and these are united by a lighter dotted line. The provinces are:

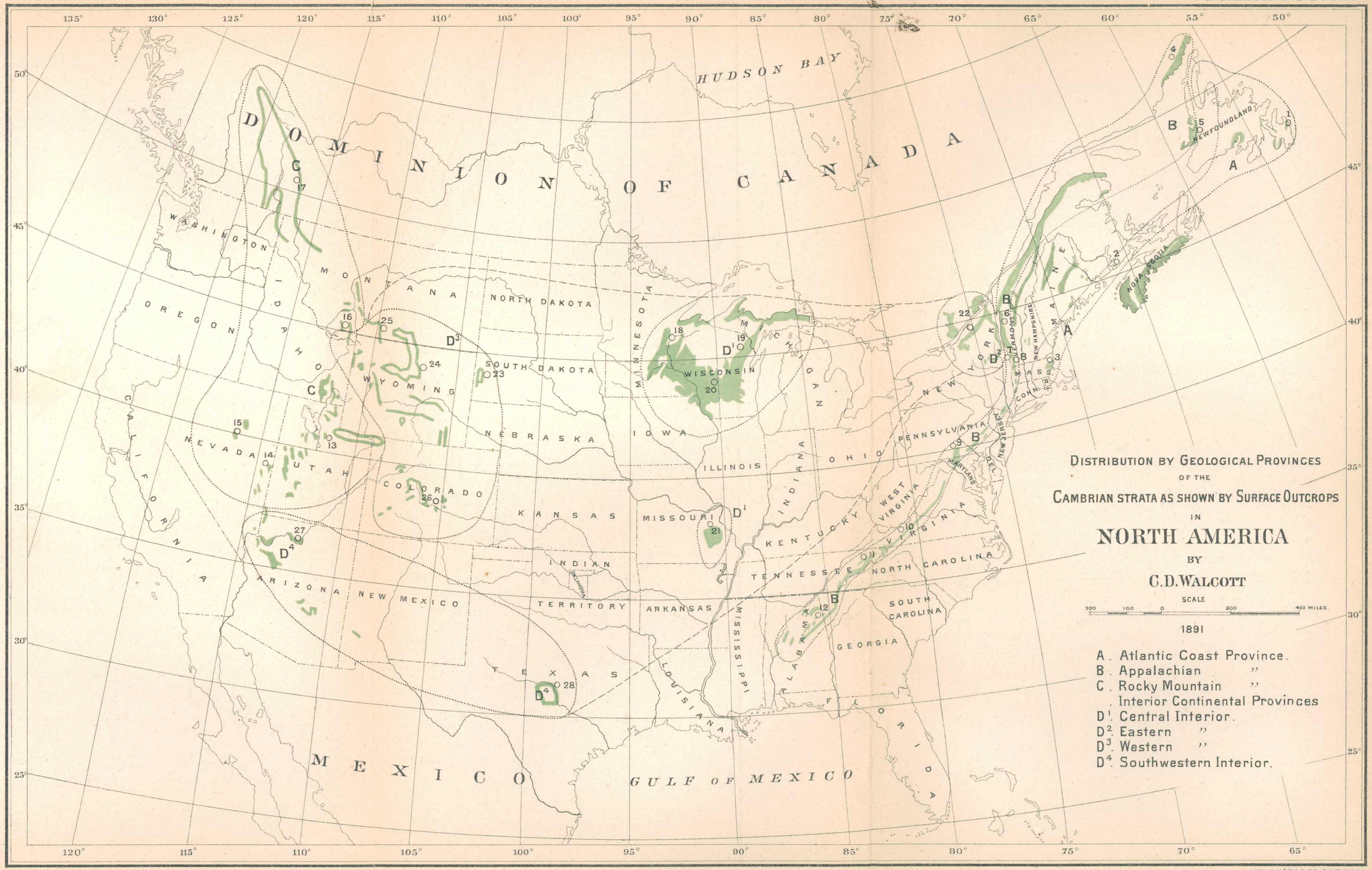
A.—Atlantic or Eastern Border Province.
- *a.* Eastern or Nova Scotia Basin.
- *b.* Southeastern Newfoundland, eastern New Brunswick, and Massachusetts Basin.
- *c.* Interior deposits of Gaspé, Quebec, Maine, New Hampshire, Vermont, and Massachusetts.

B.—Appalachian or Interior Eastern Border Province.

C.—Rocky Mountain or Western Border Province.

D.—Interior Continental Province.
- D^1. Central Interior or Upper Mississippi and Missouri.
- D^2. Eastern Interior or Adirondack of New York, and Canada.
- D^3. Western Interior or Dakota, Wyoming, etc.
- D^4. Southwestern Interior or Arizona and Texas.

The outlines of the provinces are drawn so as to include the outcrops known at present. They are arbitrarily assumed, as we do not know the exact limits of the original Cambrian sedimentation.



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Owing to the uncertainty as to the Cambrian age of the outcrops of Nova Scotia, Maine, New Hampshire, and north into Canada, the indicated areas upon the map have horizontal black lines to distinguish them from the known Cambrian rocks.

SYNOPSIS OF THE CAMBRIAN GROUP.

The coordination of the Cambrian group in America, with the primary subdivisions of the Paleozoic—Silurian, Devonian, and Carboniferous—is largely a devèlopment of the past decade. Although strongly advocated by Dr. T. S. Hunt and used by Sir J. W. Dawson in 1872, and the Fortieth Parallel Survey in 1878, Le Conte's Elements of Geology of 1878 mentions, but does not use the name in classification, and Dana's Manual of 1876 classes the "Primordial or Cambrian" as the lowest formation of the Silurian.

To-day the group is firmly established by (*a*) the presence in the Rocky Mountain province of 6,000 feet of limestone with 10,000 feet or more of quartzite beneath; (*b*) in the Appalachian Province by over 12,000 feet of quartzite, shales, slates, and limestones; (*c*) a continental distribution; (*d*) a characteristic, highly differentiated fauna.

The various formations referred to the group are mentioned in the following table. In some instances it is not practicable clearly to define by name the exact limitations of the formation through which a certain division of the fauna ranges. In such cases reference will have to be made to the text for further description.

Classification of the formations.

		Lower Calciferous.	Lower portion of the Calciferous sandrock of New York and Canada; Lower Magnesian limestone of Wisconsin, Missouri, etc.
Cambrian.	Upper Cambrian.	Potsdam.	*Type.* Sandstones of the north and east sides of the Adirondacks Mountains of New York and adjoining parts of Canada. *Correlated.* Limestones of the south side of the Adirondacks and Dutchess County, New York, and an unknown portion of the limestones of the "Marble Belt" of western Vermont. Shales of Tennessee (Knox), Georgia, and Alabama (Connasauga). Sandstones of the Upper Mississippi Valley (St. Croix), South Dakota, Wyoming, Montana, and Colorado. Sandstones and calcareous beds of northern Arizona (Tonto) and central Texas (Katemcy). Limestones and shales of Nevada (Hamburg), Idaho, and Montana (Gallatin). Black shales of the upper portion of the New Brunswick and Cape Breton Island sections. Shales and sandstones of Conception Bay, Newfoundland (Belle Isle).
	Middle Cambrian.	Acadian.	*Type.* Shales and slates of eastern Massachusetts (Braintree), New Brunswick (St. John), and eastern Newfoundland (Avalon). *Correlated.* Limestones of Dutchess County, New York (Stissing), and central portions of Tennessee and Alabama sections (Coosa). Limestones of central Nevada and British Columbia (Mount Stephen).
	Lower Cambrian.	Georgian.	*Type.* Shales and limestones of western Vermont (Georgia) and Red Sandrock. *Correlated.* Quartzite of western slope of Green Mountains ("Granular Quartz") and Appalachian Range of Pennsylvania, Virginia, Tennessee (Chilhowee), Georgia, and Alabama. Shales with interbedded limestones and roofing slates of southern Vermont, New York, and south to Alabama. Limestone, sandstone, and shales of Straits of Belle Isle (Labrador), northwest coast of Newfoundland, and peninsula of Avalon (Placentia). Basal series of Hanford Brook Section, Caton's Island, etc., New Brunswick (Hanford). Shales and limestones of eastern and southeastern Massachusetts (Attleborough). Lower portion of Eureka and Highland Ranges, Nevada (Prospect). Portion of Wasatch Cambrian section (Cottonwood). Base of Castle Mountain limestone, British Columbia (Castle Mountain).

Table showing the order of succession of the Cambrian faunas in typical areas in America.

		Newfoundland.	Massachusetts.	New York.	Tennessee.	Nevada and Utah.	British Columbia.	Upper Mississippi Valley.	Texas and Arizona.
Cambrian Group.	Upper Cambrian.	Olenus zone.	Unknown.	Dikelocephalus zones.	Present.	Dikelocephalus zones.	Not recognized, but probably present.	Dikelocephalus zones.	Dikelocephalus zones.
	Middle Cambrian.	Paradoxides zones.	Paradoxides zones.	Indicated by other genera than Paradoxides.	Represented by other genera than Paradoxides.	Represented by other genera than Paradoxides.	Represented by other genera than Paradoxides.	Unknown.	Not determined.
	Lower Cambrian.	Olenellus zones.	Olenellus zones.	Olenellus zones.	Olenellus zones.	Olenellus zones.	Olenellus zones.	Unknown.	Unknown.

BASE OF CAMBRIAN.

The statements made in the preceding paragraphs foreshadow the conclusion that over the Interior Continental area the basal beds of the upper division of the group rest unconformably upon pre-Cambrian rocks. This is true also of the lower division of the Atlantic Coast Province, but in the Lake Champlain Valley and the Southern Appalachian Province there is no positive assurance that the conformable series of strata beneath the Olenellus zone do not pass down into some pre-Cambrian group. In Nevada, Utah, Montana, and British Columbia the same conditions exist to a more marked degree, and I have, in the absence of paleontologic proof, referred the conformable pre-Olenellus strata to an Algonkian group. That a considerable portion if not all of the series will be ultimately referred to the Cambrian is probable from the fact that the Olenellus fauna has been traced downward through 1,000 feet of limestone in the Champlain Valley of Vermont and 3,000 feet downward in the Bow River series of British Columbia. The great vertical distribution of the fauna in the limestone leads to the expectation that it will be found to range through a considerable portion of the conformable strata beneath the narrow Olenellus zone of the Southern Appalachian and southern portion of the Rocky Mountain Province. On the map of sections the lower strata are provisionally and doubtfully referred to the Cambrian. This is in opposition to the view advanced in the Tenth Annual Report of the U. S. Geological Survey.

SUMMIT OF CAMBRIAN.

The determination of the top of the Cambrian is beset with more difficulties than its delimitation at the base. At the base there are marked unconformities, and in their absence the presence of a distinctly marked fauna beneath which no other fauna has yet been found. At the summit, however, we meet with a transition both in sedimentation and fauna to the characteristic type of the Silurian (Ordovician). One of the best illustrations of this is in the Eureka district of Central Nevada, where, in the Pogonip limestone, the passage from the Cambrian to the Silurian (Ordovician) is so gradual that it is only by the predominance of the fauna of one or the other of the two great groups that a line of demarkation can be drawn. The transition is such as might be expected where there was no marked physical disturbance to influence the change of faunas resulting from the natural dying out and development of species or the influx of new species from other areas. The sedimentation was very uniform, and no essential change of character occurs between the limestones of the Upper Cambrian and those of the Silurian (Ordovician). On the other hand, the delimitation between the two groups on the northern side of the Adirondacks is clearly and definitely marked by the occurrence of a light-colored, calciferous sandrock, with its distinctive fauna, resting upon a compact, hard quartzite, characterized by the

Dikelocephalus fauna of the Upper Cambrian. Various grades of transition occur between these two extremes, but frequently it is necessary to draw an arbitrary line and define the upper limit of the Cambrian, as terminating where, in any continuous section, the Upper Cambrian fauna gives way, and is superseded by the types of the Silurian (Ordovician) fauna. In Nevada this line would be drawn near the base of the Pogonip limestone; in Tennessee, near the base of the Knox dolomite; in northern New York, north of the Adirondacks, between the Potsdam sandstone and the Calciferous sandrock; on the south side of the Adirondacks, in the limestone between the Potsdam and Calciferous faunas; in the Upper Mississippi Valley, between the upper beds of the St. Croix sandstone and the Lower Magnesian limestone, or in some instances in the lower portion of the Lower Magnesian limestone; in the series of shales opposite Quebec, at Point Levis, beneath the graptolitic-bearing shales and the conglomerate carrying the Dikelocephalus fauna of the Upper Cambrian; and in western Newfoundland, in the limestones between the Upper Cambrian fauna and the base of the Ordovician fauna.

The paleontologic break between the Cambrian and Silurian groups is practically complete where the stratigraphic break is marked. About the Adirondacks the only species I know of that cross the break are the *Lingulepis acuminata* and a species of Ophileta, at Chateaugay Chasm. In Wisconsin some of the species of the Upper Cambrian fauna apparently rise into the lower portion of the Lower Magnesian limestone, and are there associated with forms which are considered to be more typical of the Silurian (Ordovician) fauna. In Nevada, where the sedimentation is of the same character in the Upper Cambrian and the lower portion of the Silurian (Ordovician), there is a slight blending of the faunas, as shown by the occurrence of the genera Asaphus, Dikelocephalus, and Ptychoparia upon the same surface of rock. With our present knowledge, however, the occurrence of the same species in strata that are referred to the Cambrian and the Lower Silurian is so rare that they are the exceptions to the general rule.

It is not, however, by the specific break in the fauna that the two groups are separated; it is the general facies of the fauna referred to the Cambrian and that referred to the Silurian (Ordovician). The distinctness of the Upper Cambrian fauna from the Lower Silurian fauna 100 feet beneath the line of contact of the two groups is such that I think there will be no confusion between the two faunas in America. In England the range of the genus Agnostus has complicated the separateness of the two faunas, but this is not sufficient to combine them as a whole.

SEDIMENTATION OF THE CAMBRIAN GROUP.

The physical and lithologic characters of the strata lead to the conclusion that the sediments were accumulated in relatively shallow seas in the immediate vicinity of the shores of land areas that were being slowly depressed in relation to the surrounding waters. There are some exceptions, as, for instance, the deeper water limestone series of central Nevada, British Columbia, and western Vermont, and perhaps the black shales of the Atlantic Coast Province. The assembled evidence sustains the view that at the beginning of Lower Cambrian time the area of the great Interior Province formed part of a continent, to the eastward and westward of which long ridges of pre-Cambrian rock separated interior seas and straits from the continental area and protected their contained life and sediments from the ravages of the open ocean. As the continent was slowly depressed and the waters advanced upon the land the sediments now forming the rocks of the Lower and Middle Cambrian series were accumulated in the various interior bodies of water to the eastward and westward of the main land area and between it and the outlying ridges. What the contour of the south and southeastern side of the continent was and to what extent the sea advanced upon it from the south during this time is unknown and may never be known, as only the formations that were deposited around the pre-Cambrian islands of Texas and Missouri are now accessible for study. From the evidence afforded by these two localities and that along the eastern front of the Rocky Mountains, and the exposures of Cambrian strata in Wisconsin, Canada, etc., it is very probable that the main portion of the continent north of the thirtieth and south of the fiftieth meridian did not disappear beneath the advancing sea until near the beginning of Upper Cambrian time. The unconformable position of the Upper Cambrian rocks of the Interior Continental Province upon the subjacent Algonkian and Archean rocks sustains this conclusion.

As the sea was transgressing over the surface of the continent on its way northward across the broad interior in late Middle or early Upper Cambrian time it was also working along the base of the border ridges and depositing the sediments derived from them conformably upon those deposited, while the main mass of the continent was above the water. That these deposits were practically contemporaneous with those of the Interior Province is proved by the presence of the same types of animal life, and to a considerable extent of identical species.

Toward the close of Cambrian time a large portion of the continent had disappeared beneath the surface of the sea, and the great limestone-forming period of the Silurian (Ordovician) began. In some areas, as about the Adirondack Mountains of New York, argillaceous and arenaceous sediments were derived from the adjoining coast line, but as a whole mechanical sediments are absent.[1]

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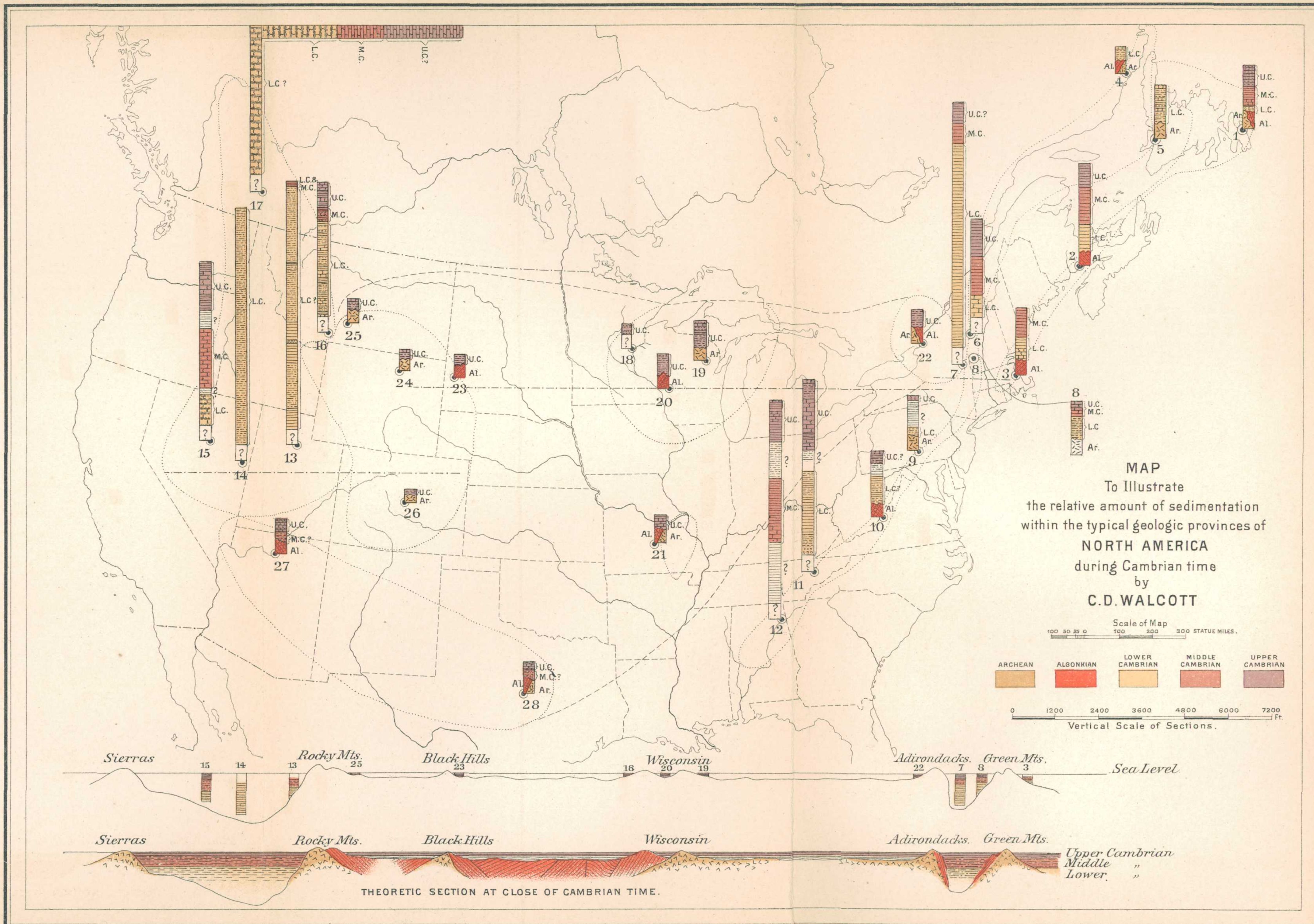
[1] In speaking of the conditions of sedimentation Messrs. Campbell and Ruffner state that "Changes such as these occurred, during a series of geological ages of unknown length, in a great inland sea which was once connected with what is now the Gulf of Mexico, on the south, limited probably by the highlands of Canada on the northeast, having the Archean ledges of the Blue Ridge for its southeastern border, and in all probability separated, in part at least, from the Pacific Ocean by the Rocky Mountain Range. This extensive sea, with Archean rocks for its bottom and shores, was the receptacle of the various materials that now constitute the surface rocks and soils of the Mississippi Valley." (A physical survey extending from Atlanta, Georgia, across Alabama and Mississippi to the Mississippi River, along the line of the Georgia Pacific Railway. New York, 1883, pp. 9, 10.)



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Secular disintegration had prepared an immense amount of material for the advancing sea to assort and rearrange in early Cambrian time. This, with that worn from the solid rocks by the attack upon the coast line, was largely disposed of prior to the opening of the limestone-forming period—an epoch varying in relative time in the various provinces.

I do not think it probable that any considerable amount of sediment accumulated in the southern portion of the Interior Continental area during early Cambrian time. The sections of the Champlain Valley, eastern Tennessee, Utah and Nevada, and of British Columbia prove the accumulation of from 10,000 to 12,000 feet of sediment along the eastern and western flanks of the pre-Cambrian continent before the sea deposited the formations about the Llano Hills of Texas, the Ozark Mountains of Missouri, and other portions of the Interior Continental Province. This evidence leads to the belief that the continent stood at a considerable elevation, and that the great accumulation of sediment during late Algonkian and early Cambrian time resulted from the distribution of material worn from the shore by the waves and brought into the sea by the rivers of the Interior Continental region and the outlying ridges.[1]

DESCRIPTION OF PLATE II.

Map of the central portion of the North American continent, to illustrate the relative thickness of the strata composing the Cambrian group in the various geologic provinces. (The small ring with the dot in the center indicates the geographic location of the base of the section.)

The sections are grouped into the following geologic provinces:

Atlantic Coast Province.
Appalachian Province.
Rocky Mountain Province.
Interior Continental Province.

The latter consists of the Central Interior or Upper Mississippi, the Western or Rocky Mountain, the Southwestern or Arizona and Texas, and the Eastern or Adirondack sub-provinces.

ATLANTIC COAST PROVINCE:

SECTION 1. *Conception Bay, Avalon Peninsula, Newfoundland.*—The Cambrian rocks of the Avalon Peninsula rest unconformably upon strata of Archean and Algonkian age. The section represented is formed by the union of portions of those of Manuel's Brook, Kelly's, Great Bell, and Little Bell Islands.

SECTION 2. *Vicinity of St. John, New Brunswick.*—This section is unconformably superjacent to the Archean, and unites the section at the city of St. John and that of Hanford's Brook.

[1] It is not improbable that the area of the great coastal plain of the Atlantic slope was then an elevated portion of the continent and that much of the sediment deposited during Cambrian and later Paleozoic time was washed from it into the seas immediately to the west. If this be true the source of much of the sediment of the Appalachian series of rocks is accounted for and the absence of the deposits of the eastern coast line is explained by the sinking of the coastal region during, or at the close of Paleozoic time. This view is strengthened by the presence, in the Middle Cambrian fauna of Alabama, of a number of species that are closely allied to if not identical with species of the Middle Cambrian fauna of Newfoundland and Sweden. This fauna is unknown in the Appalachian Province north of Alabama. This leads to the inference that it was distributed along the shore of the Atlantic Coast Province, and that the line of deposits, uniting the Newfoundland and Alabama areas, south of the Massachusetts area, are now buried deep beneath later deposits.

SECTION 3. *Vicinity of North Attleborough and Braintree, Massachusetts.*—In this section the Lower Cambrian series of North Attleborough and the Middle Cambrian of Braintree are united in one generalized section. The basal series is unconformably superjacent to the Archean.

APPALACHIAN PROVINCE:

SECTION 4. *North side of the Straits of Belle Isle, Labrador.*—The base rests unconformably upon the Archean.

SECTION 5. *Central western Newfoundland.*—The base rests unconformably upon the Archean, but the summit of this section is not clearly defined owing to lack of data to determine the range of the fauna.

SECTION 6. *Franklin County, Vermont.*—This represents the "Red sandrock" series, with its superjacent Georgia shales, in the township of Georgia. The base is cut off by a fault line, and the exact limitation at the summit is unknown.

SECTION 7. This represents the great shale and slate section of Washington County, New York. It is cut off at the base by a fault line and the summit is not well defined.

SECTION 8. The shore-line deposits of the Green Mountains or the "Granular Quartz," above which come limestones in which Cambrian fossils have been found. At the base it rests unconformably upon the crystalline pre-Cambrian rocks.

SECTION 9. Typical section in southern Pennsylvania, showing the "Granular Quartz" resting unconformably upon the subjacent crystalline rocks and extending above into the shale series beneath the limestones.

SECTION 10. This section is that of central Virginia, not far away from the shore line. The base rests unconformably upon the pre-Cambrian rocks, and above it passes into the base of the "valley" limestones.

SECTION 11. *Rogersville, East Tennessee.*—The base of this section is cut off by a fault line and above it passes into the Knox dolomite, the lower beds of which carry the Upper Cambrian fauna. The Chilhowee Mountain section comes beneath the Rogersville, and it is so represented in this section. An interrogation point marks the hiatus between the two sections. The data for this section are given by Mr. Bailey Willis, chief of the Appalachian division of geology, U. S. Geological Survey.

SECTION 12. The line of this section extends from Rome, Georgia, westward into Alabama. At the base it is cut off by a fault and above is delimited by the Knox dolomite. The data for it are given by Mr. C. Willard Hayes, of the Appalachian division of the U. S. Geological Survey.

SECTION 13. *Western slope of the Wasatch mountains, Utah.*—In this section the 12,000 feet of quartzite and siliceous slates are tentatively referred to the Cambrian. The fossiliferous zone is confined to the upper 250 feet.

SECTION 14. *Central eastern Nevada.*—This section represents the great quartzite series beneath the fossiliferous Cambrian limestone. The base has been concealed, and the summit has been removed by erosion.

SECTION 15. *Eureka District, Nevada.*—In this section the fossiliferous Lower Cambrian strata rests conformably upon the quartzites, which pass down some 1,500 feet before being concealed. The quartzites may correspond to the upper beds of section 14. The summit of the section passes into the superjacent Pogonip limestone of the Silurian (Ordovician).

SECTION 16. *Gallatin River near Gallatin City, Montana.*—This is essentially the same as the Mount Stephen section of British Columbia (section 17). The subjacent series of quartzites and siliceous slates are tentatively included in the Cambrian.

SECTION 17. Mount Stephen section of British Columbia, in connection with the subjacent Bow River quartzite and siliceous slates. The relations of the section are the same as those of the Eureka section (15) of central Nevada, with the addition of the Bow River quartzite and slates.

ROCKY MOUNTAIN PROVINCE:

Central Interior Continental subprovince:

SECTION 18. The western section of the central Interior Continental Province as it occurs in Minnesota.

SECTION 19. Section of the Upper Cambrian sandstones of eastern Wisconsin.

SECTION 20. Section of southern central Wisconsin, showing the unconformity between the Upper Cambrian and the subjacent Algonkian and Archean rocks. Sections 18, 19, and 20 are all of Upper Cambrian age, and pass conformably above into the superjacent Lower Silurian (Ordovician) or magnesian limestones.

SECTION 21. *Ozark Mountains, southeastern Missouri.*—The relations of the Cambrian and the Archean are the same as those in the Black Hills section (section 23).

Eastern or Adirondack subprovince:

SECTION 22. *The eastern and northern slopes of the Adirondack Mountains of New York.*—In this section the Potsdam sandstone of the Upper Cambrian rests unconformably upon and against the Archean and Algonkian rocks.

Western Interior Continental or Rocky Mountain sub-province:

SECTION 23. *Black Hills, Dakota.*—The Upper Cambrian rests unconformably upon the Archean.

SECTION 24. *Eastern section of Big Horn Mountains of Wyoming.*—It is essentially the same as that of the Black Hills (section 23).

SECTION 25. *Southern Montana.*—This section is very much like that of Wyoming and of the Black Hills.

SECTION 26. *Central Colorado.*—A section representing the sandstones that lie between the subjacent unconformable Archean or Algonkian rocks and the superjacent Lower Silurian (Ordovician).

Southwestern Interior Continental sub-province:

SECTION 27. *Grand Cañon of the Colorado, northern Arizona.*—In this section the Cambrian strata are unconformably superjacent to rocks of Algonkian age.

SECTION 28. *Llano County, Texas.*—This section is similar to that of the Grand Cañon in having an unconformity between the Algonkian and the Cambrian and in representing nearly the same geologic horizon.

Theoretic sections at close of Cambrian time.—The data for these sections are obtained from the associated map. The enormous accumulation of sediment in the Rocky Mountain Basin on the west and the Appalachian Basin or trough on the east are shown, as well as the thin mantle of sediment over the great interior. It serves to illustrate the sedimentation indicated by the vertical columns on the map.

Our knowledge of the sediments of the eastern and western sides of the pre-Cambrian continent is considerable, but of that deposited along the southward-facing front we know nothing. From the fact, however, that the same species of fossils occur in the Lower Cambrian fauna of Labrador, Massachusetts, New York, Vermont, probably Tennessee, Nevada, and British Columbia, I think we may hypothetically assume the continuance of the Lower Cambrian beneath the deposits of the Gulf States and westward through Texas, New Mexico, and Arizona. There is no known line of Lower and Middle Cambrian sedimentation across the continent to the north of this which indicates that the fauna might have been distributed along a more northern shore.

The pre-Cambrian ridges, or protaxis of the present ranges of the northeastern side of the continent, have been outlined by Prof. J. D. Dana from the known exposures of pre-Cambrian rocks.[1] The Paradoxides fauna lived in the depression between two of the eastern ridges of the Atlantic Province in the New Brunswick area, and in the bays

[1] Areas of continental progress in North America and the influence of the condition of these areas on the work carried forward within them. Bull. Geol. Soc. Am., vol. 1, 1890, pp. 36–39.

and protected shores of the seaward slope of the western ridge, where the outer or eastern ridge was absent, as in Massachusetts and Newfoundland. The sediments that accumulated to the eastward of the New Brunswick sea form the supposed Cambrian shales and slates of Nova Scotia. The inner ridges of Maine, New Hampshire, and Massachusetts bounded long, narrow seas, in which the Cambrian faunas are not known to have penetrated. The Lower Cambrian fauna probably passed from the Atlantic along the ancient Labrador shore into the interior Appalachian sea. A few types of the Middle Cambrian fauna followed, and then the passage appears to have been closed, as none of the Upper Cambrian types of the Atlantic fauna have been found in the deposits of the interior seas.

The various views, both theoretical and hypothetical, relating to the pre-Cambrian continent are embodied on the map, Pl. III, and the section at the base of Pl. II.

DESCRIPTION OF PLATE III.

Hypothetical map of the North American Continent at the beginning of and during Lower Cambrian time.

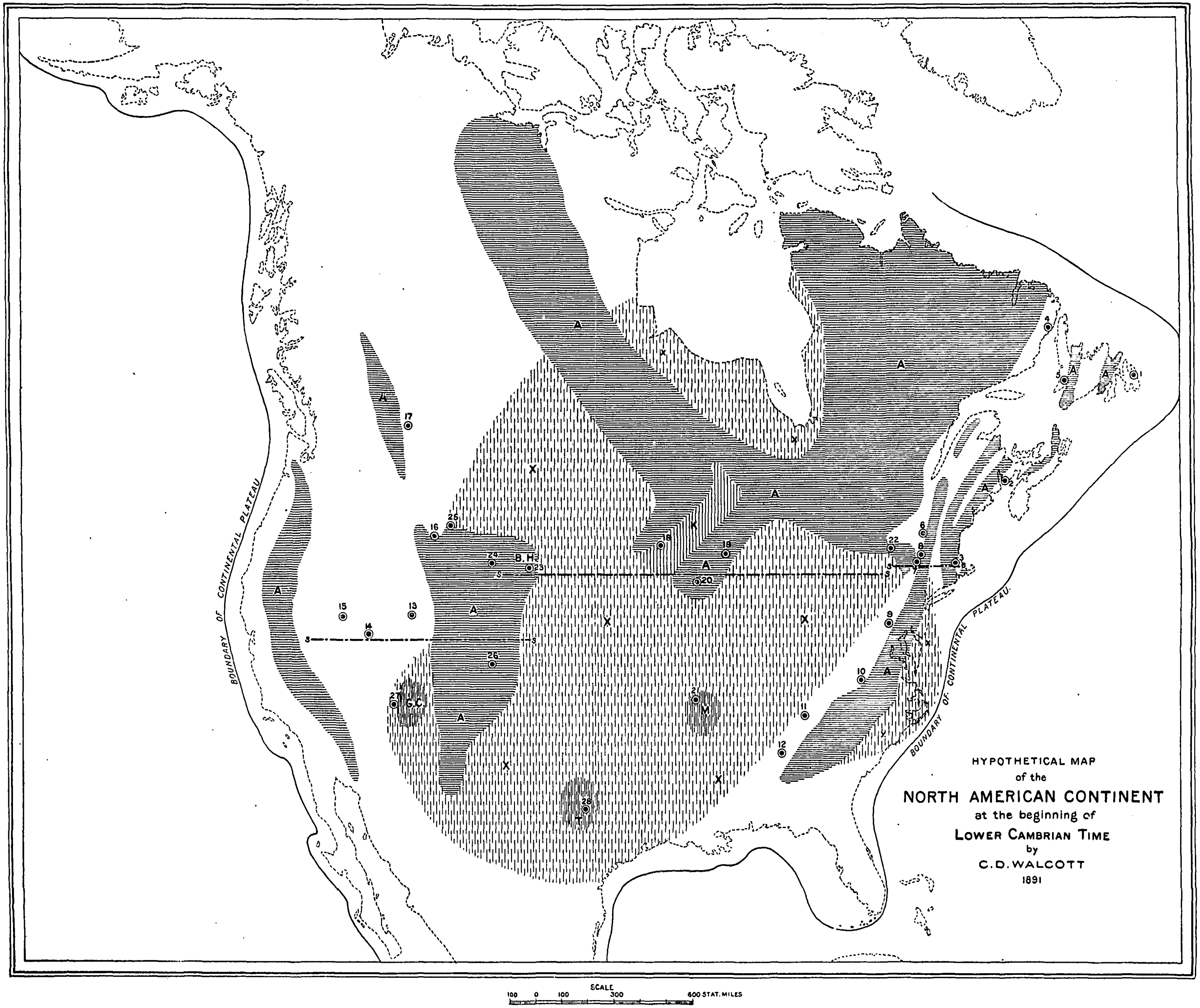
This map is based upon the sections shown on Pl. II, and the theoretic section at the base. The position of the sections on the two maps is indicated by a circle with a corresponding number on each map.

The shaded portions indicate the relative areas that are supposed to have been above the ocean during later Algonkian and Lower Cambrian time. A comparison with Pl. II shows that in the Rocky Mountain and Appalachian areas there was an enormous accumulation of sediment prior to the Upper Cambrian; while over the broad interior there is only the Upper Cambrian which corresponds to the upper portion of the great sections of the Rocky Mountain and Appalachian areas. In the region of the Atlantic Coast Province the continental movement seems to have been less, as the sediments of the Lower and Middle Cambrian are much thinner than those of the corresponding horizon in the Appalachian and Rocky Mountain areas. The conclusion is that the shaded portions and perhaps other unknown areas formed the land during late Algonkian and early Cambrian time, and that about the close of the Middle Cambrian or the beginning of Upper Cambrian time the continental surface was largely depressed beneath the waters of the ocean and the Upper Cambrian sediment accumulated over the entire area where Cambrian rocks are now known to occur. (See distribution on Pl. I.)

On Pl. III, A., Archean; K., Keweenawan; B. H., Black Hills of Dakota; T., Llano area of Texas; M., Ozark uplift of Missouri; C., Grand Cañon area of Arizona. The area marked X, X, X indicates an hypothetical land area of the existence of which we have not at present any absolute proof, as it is now covered by sediments of later age than the Cambrian.

The present shore outlines of the continent are indicated by the dotted line, and the outlines of the continental plateau on the division between the deep sea and the continent by a continuous line.

The descriptive notes of the Cambrian rocks of the various provinces and the résumé following each establishes the fact that in Cambrian time there were geographic areas in which different types of sedimenta-


HYPOTHETICAL MAP
of the
NORTH AMERICAN CONTINENT
at the beginning of
LOWER CAMBRIAN TIME
by
C. D. WALCOTT
1891
BOUNDARY OF CONTINENTAL PLATEAU
BOUNDARY OF CONTINENTAL PLATEAU
B. H.
G. C.
SCALE
100 0 100 300 600 STAT. MILES

tion prevailed, and that great variation existed in what are considered the same geographic provinces. The sediments of the northeastern Atlantic Coast Province are almost entirely shales with a small proportion of sandstone and a trace of limestone. Tracing the long Appalachian Province from the Gulf of St. Lawrence to the southwest and south, we find an immense accumulation of shale with some interbedded sandstone and limestone. This extends to the Lake Champlain region of New York and Vermont, where a great limestone of Lower Cambrian age is subjacent to several thousand feet of shale in which lenticular masses of sandstone and limestone occur at irregular intervals. Farther to the southwest, in southern Vermont and eastern New York, great thicknesses of argillaceous sediment were deposited. These now form the series of shales in which beds of finely laminated roofing slates occur in massive strata. Toward the east, near the pre-Cambrian shore line, the Lower Cambrian sandstones are followed by arenaceous, dolomitic, and purely calcareous limestones of later Cambrian time. This condition of sedimentation continues far to the south, varied more or less by the presence of great thicknesses of shale above the lower quartzite. In the latter case the limestone of the Cambrian forms only a thin belt at the summit.

In the Rocky Mountain Province the siliceous sediments, sandstones, and quartzites are followed by limestone, and nearer the shore line, the sandstones are subjacent to shale. Over the Interior Province the record is sandstone, followed on the west and southwest by alternating limestones and sandstones.

On the map (Pl. II) the thickness and character of the sediment is shown in a general manner for each of the provinces.

The study of the fauna has shown that, while there is a general resemblance in the faunas of the Lower Cambrian in the Atlantic Coast, Appalachian, and Rocky Mountain Provinces, there is sufficient differentiation to mark off distinct faunal areas in the early Cambrian sea.

The fauna of the Upper Cambrian is less specialized over great areas than that of the Lower and Middle zones. The opportunities for communication between the provinces were greater and it is only in the Northeastern or the Atlantic Coast Province that a marked difference is shown.

The Middle Cambrian fauna of the Atlantic Coast Province is so strongly differentiated from that of the Appalachian and Western Rocky Mountain Provinces that it was not until they were found to occupy the same relative stratigraphic position that it was suspected they lived in approximately the same epoch.

The evidence of sedimentation and the evidence of organic remains unite to prove that in Cambrian time the geographic and faunal provinces were differentiated and established over the area of the present North American continent. In fact, the sedimentation of the Cambrian was as varied as that of many of later geologic periods and more so than that of the immediately succeeding Silurian (Ordovician).

SUBDIVISION OF THE CAMBRIAN.

In his admirable report upon the Devonian of North America Prof. H. S. Williams expresses this opinion:

> The subdivision of any great geological system must depend in great measure upon the differences in the faunas or floras contained, and, as I believe, this depends in no small degree upon the geological changes which modified and shifted the geographical conditions under which the animals lived. A sandstone will not contain the same species as a following limestone, and even in arenaceous shales a slight change in the fineness or coarseness or in the amount of argillaceous mud mixed with the sand modifies the composition of the fauna contained in it.[1]

There are not at present sufficient available data from the Cambrian upon which to base comparisons with the same degree of refinement as those made by Prof. Williams. It has been discovered, however, that the predominant types of life of the Cambrian group are to be found in shales, limestones, and sandstones. For instance, the genus Olenellus, characteristic of the Lower Cambrian, is found in the shales, limestones, slates, and sandy shales of the typical section in Northern Vermont. I have found in the quartzites and in the pure limestones of the Potsdam epoch of the Adirondack subprovince the same species of Dikelocephalus, Hyolithes, and Lingulepis. In the dark argillaceous shales of the Middle Cambrian terrane of Newfoundland I found the same species of Paradoxides that occurs in the interbedded limestones of the same series a few miles distant. That Prof. Williams is correct in relation to the great mass of organisms that existed during Paleozoic time there can be very little if any question. As an example the corals of the limestones of the north shore of the Strait of Belle Isle, on the Labrador coast, are unknown, except in an almost identical limestone at Silver Peak, Nevada, in the Rocky Mountain Province. It is in the clearer limestones that the great bulk of the brachiopods, pteropods, and other forms of life are found in the Cambrian; but it is a fact, nevertheless, that the predominant types of the Trilobita, characterizing its three divisions, flourished upon and were imbedded in sediments of widely different character. It is owing to this that they become of so much importance as criteria in the correlation of the three primary divisions of the group.

In the Atlantic Coast Province the fauna of the Lower Cambrian, or Olenellus zone, occurs in arenaceous limestones, pure limestones, and shales. All of these are of a different character from those of the black shales 200 feet above, in which the Paradoxides or Middle Cambrian fauna occurs. The Upper Cambrian fauna is found in dark shales and sandstones several hundred feet, if not a thousand feet, above the Paradoxides zone. The three primary subdivisions of the Cambrian are strongly defined by the sedimentation and faunas. In the St. Lawrence

[1] International Congress of Geologists, American Committee. Report of the subcommittee to the session of the Congress held in London, September 17, 1888. Philadelphia, 1888. Report of the subcommittee on the Upper Paleozoic (Devonic), H. S. Williams, Reporter, p. C 20.

Valley area of the Northern Appalachian Province the Lower Cambrian and Upper Cambrian faunas are found in separate bands of conglomerate limestones and not in situ, the great thickness of shales and sandstones referred to the Cambrian not being characterized by any known fauna. In Vermont the Lower Cambrian fauna occurs throughout the classical "Red sandrock" series and the lower portion of the superjacent Georgia shales, while about 2,000 feet above, the Upper Cambrian fauna is well determined. The Middle Cambrian fauna has not been recognized. In the eastern New York section the Lower Cambrian fauna is strongly differentiated and the base of the Middle Cambrian fauna indicated; but the Upper Cambrian fauna is unknown. Only a few miles distant to the west, however, at the base of the Adirondacks, the Upper Cambrian fauna characterizes sandstones and limestones that occur beneath the base of the Silurian (Ordovician). Farther to the south, in Dutchess County, in the valley of the Hudson, the Lower Cambrian fauna is recognized in the basal quartzite and the superjacent limestone, and also the Middle Cambrian of the Appalachian and Rocky Mountain Provinces, and the Upper Cambrian of all but the Atlantic Coast Province. In Tennessee, in the Southern Appalachian Province, the Lower Cambrian fauna is found in shales, within the quartzite series, and at the summit of the shales the Upper Cambrian fauna occurs. This extends up and into the base of the limestone. In Alabama, in shales apparently occupying the same serial relation, the Middle Cambrian fauna is well developed.

In the Nevada section the Lower Cambrian or Olenellus zone is distinctly defined, and between it and the Upper Cambrian fauna 1,000 feet of limestone is marked by types of the Middle Cambrian fauna. These distinctions of faunas are readily determined wherever two or more of them are present in the same section in the Rocky Mountain Province. In British Columbia the Lower Cambrian and Middle Cambrian faunas have alone been recognized.

I have spoken of the Middle Cambrian fauna of the Atlantic Coast Province and that of the Middle Cambrian of the Appalachian and Rocky Mountain Provinces. This distinction is made because the characteristic types of the Atlantic Coast Middle Cambrian fauna are not found in the Middle Cambrian fauna of the other two provinces. This indicates that a nearly impassable barrier existed during Middle Cambrian time between the sea of the Atlantic Coast Province and those of the interior. This prevented nearly all the species of the former from migrating into the Appalachian and Rocky Mountain Provinces. Within the two latter there is a fauna characterized by similar types in New York, Alabama, Nevada, and British Columbia, and in each section where their stratigraphic position is determined they occupy the same relations to the Lower and Upper Cambrian faunas as does the Middle Cambrian or Paradoxides fauna of the Atlantic Coast Province.

The Lower Cambrian fauna is much more persistent in its character than that of the Middle Cambrian; for all the strata referred to the former horizon have been found to be characterized by essentially the same fauna. This is also true of the much more widely spread Upper Cambrian with the single exception of the Atlantic Coast Province, where the fauna is more of the European or Atlantic Basin type. There is, however, too little known of it at present in Newfoundland to base any final conclusions upon it.

The minor or formation subdivisions of the Cambrian are based largely upon lithologic characters and are relatively of local value only. One exception to this is found in the "Granular Quartz" of New York and Vermont, and the equivalent Chilhowee quartzite series of Tennessee, Alabama, Virginia, Pennsylvania, etc. Another is in the widely spread shore-line deposits, called the Potsdam sandstone in New York, the St. Croix sandstone in the Upper Mississippi Valley, the supposed equivalent deposits of the Black Hills of Dakota, the sandstones of the eastern flanks of the Rocky Mountains and of the Llano area of Texas. These two formations furnish illustrations of the accumulation of similar sediments over very extended areas. Their minor value in classification, when not supported by paleontologic evidence, is shown by the fact that the Lower Cambrian "Granular Quartz" or Chilhowee sandstone has been correlated by nearly all geologists who have referred to it with the Potsdam sandstone about the Adirondacks of New York and the St. Croix sandstone of the Upper Mississippi Valley, thus bringing together formations separated in the stratigraphic column by a long time interval and several thousand feet of sediment. Other sandstones of pre-Cambrian and post-Cambrian age have also been correlated with the Potsdam sandstone of New York.

With our present knowledge of the faunas and sediments it is impossible in all instances to differentiate the primary divisions of Upper, Middle, and Lower Cambrian in America.

Extending our views across to the eastern side of the Atlantic Ocean, we find an extensive development of Cambrian rocks in North and South Wales, where the three great divisions of the North American Cambrian are to be recognized. The Lower, in the roofing-slate series of North Wales and the Cærfai group of South Wales; the Middle, in the Solva and Menevian formations, and the Upper, in the Lingula flags series. These divisions are also recognized in Sweden and North Wales, although in greatly diminished force. The Lower division has been recognized in western Russia, and the central belt of the celebrated "Zone Primordiale" of Bohemia represents the Middle Cambrian series.

In lithologic, stratigraphic, and paleontologic characters the Cambrian series on the opposite sides of the Atlantic are such that there is no hesitancy in considering them as belonging to one geologic group and as part of one geologic basin.

There is a great variation in the sedimentation and faunas of the various formations referred to the Cambrian in North America and Europe; they all fall within the limits of the group and, united, constitute a great geologic division of equal taxonomic value with Silurian (Ordovician), Silurian, Devonian, etc.

COMPARISON WITH THE CAMBRIAN ROCKS OF OTHER COUNTRIES.

EUROPE.

Dr. Henry Hicks expresses the view that the sediments of the Cambrian and Silurian were largely deposited on the western side of the European continent.[1] In Spain and Wales the sediments accumulated to a great thickness, while to the eastward, in Bohemia, Scandinavia, and Russia, the sections show less than one-fifth of the thickness of those in Wales. In central Russia the Cambrian strata entirely disappear and the Silurian (Ordovician) rests unconformably and directly upon the Archean. These observations lead to the conclusions (*a*) that the Cambrian sediments were deposited upon a gradually sinking coast line; (*b*) that the greatest depression was on the western margin of the continent; (*c*) that the movement which depressed the North American continent during pre-Cambrian time also affected the western side of the European continent, with a gradually diminishing force, from the Atlantic coast to the Ural Mountains.[2]

A comparison of the Atlantic Coast Cambrian series of America with the Atlantic Coast series of Europe, as exhibited in Wales, shows a marked similarity between the sedimentation of the opposite sides of the Atlantic. The basal Cambrian in South Wales, named the Caerfai group, by Dr. Henry Hicks, consists of 1,570 feet of strata, as follows: 520 feet of conglomerates and greenish sandstones subjacent to a bed of red shales and schists, 50 feet in thickness, above which 1,000 feet of purple sandstones occur. Dr. Hicks correlates the roofing slates of North Wales as found at Llanberris, Bethesda, and Penrhyn with this lower division of the Cambrian, on stratigraphic evidence, as the few fossils found are not sufficiently characteristic to correlate the two series with each other or with the American Lower Cambrian. A comparison of the sections with that of the southeastern coast of Newfoundland shows in each the presence of a basal conglomerate subjacent to a series of purple and green shales or slates. It is also to be noted that the Lower Cambrian of New Brunswick and eastern Massachusetts is made up of shales of a somewhat similar character to those of the Caerfai group. It is a curious coincidence that the section of the Lower Cambrian of North Wales is almost identical in the physical character of its slates, including color and texture, to the Lower Cambrian roofing slate belt of southern Vermont and eastern New York.

[1] On the deposition of the Cambrian and Lower Silurian rocks. Quart. Jour. Geol. Soc., London, vol. 31, 1875, Pl. 27, op. p. 558.

[2] Walcott, C. D.: The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rep. U. S. Geol. Surv., 1890, pp. 563, 564.

The Solva group of South Wales consists of 150 feet of yellowish grits beneath 1,500 feet of gray, purple, and red rocks, above which 150 feet of gray rocks occur. All three divisions are characterized by the presence of the genus Paradoxides. The superior division of the Menevian group consists of 750 feet of slates and sandstones, and, with the Solva formation, constitutes the Paradoxides zone corresponding to the Middle Cambrian of the American section. This division is represented in Massachusetts by the Paradoxides beds of Braintree, in New Brunswick by the Paradoxides shales of the St. John Basin, and in Newfoundland by the Paradoxides shales of the Avalon Peninsula. The faunas of this division are largely identical on the opposite sides of the Atlantic, and form the great connecting link that binds the sections together and permits of almost positive correlation between them.

The North American Upper Cambrian is represented in Wales by the Lingula flags and Lower Tremadoc series, formed of over 5,500 feet of bluish and black slates and flags with bands of gray flags and sandstones. The faunal and stratigraphic equivalent of this series has been distinctly recognized in New Brunswick, on Cape Breton Island, and on the Avalon Peninsula of Newfoundland.

Most English geologists have included the Tremadoc slates in the Cambrian; but from an examination of the list of their contained fauna it appears to me that the line of demarcation between the Cambrian and Silurian, if based upon the general facies of the fauna, should be drawn in the Tremadoc series between the upper and lower divisions. The fauna of the lower division is essentially that of the Cambrian, with a few genera and species more characteristic of the Lower Silurian (Ordovician), while the fauna of the upper division is largely of the Lower Silurian (Ordovician) type, with a few forms of the Cambrian intermingled with it.

The problem of the line of demarcation between the two groups in England is essentially of the same character as that presented in Nevada, where there is no clearly drawn stratigraphic or faunal break in the Pogonip series of limestones.

That there is a strongly marked resemblance between the Cambrian series of the Atlantic Coast Province of America and that of the western Atlantic Coast Province of Wales there is no question. We are able to compare the three main subdivisions and assume that they belong practically to one province. In fact, there is no more difference between the faunas and sediments on the opposite side of the Atlantic than there is in different portions of the Appalachian Province, and not as much as between different provinces on the North American Continent.

In explaining the strong similarity of the faunas and sediments of the Cambrian rocks of the opposite side of the Atlantic, Dr. Henry Hicks says:

The home of the earliest forms of life seems to have been somewhere towards the southwest, and possibly not far from the equator; and it is from here that the various forms seem to have migrated to the areas in which they were subsequently entombed. The migrations seem to have taken place towards the North American continent very much about the same time as towards the European; and the sea encroachments along that continent seem to have been in a direction from southeast to northwest, so that the line indicating the two depressions would meet in mid-Atlantic. This accounts for the great similarity in the two faunas and for the general resemblance offered by the order of succession of these early rocks in the two continents. The higher lands in America would be to the west and northwest, and the higher lands in Europe to the east and northeast, so that the last lands submerged would approach each other and occupy the same region of the globe.[1]

The Scandinavian Cambrian series is not over 200 feet in thickness, and represents the entire British series.[2] It is divisible into the Lower Cambrian or Olenellus zone, the Middle Cambrian or Paradoxides zone, and the Upper Cambrian or Olenus zone.

On the opposite side of the Baltic, in eastern Estoria, the Lower Cambrian zone alone is recognized by the presence of its characteristic fauna. The Middle and Upper Cambrian faunas probably existed in this region, but they have not as yet been discovered.

Beneath the Paradoxides zone of central Bohemia there is a considerable thickness of shales, grits, schists, conglomerates, and quartzites that may represent the Lower Cambrian. The Upper Cambrian, if it has not been removed by pre-Silurian ero sion, does not appear to have been clearly differentiated from the Middle Cambrian or Paradoxides zone.[3]

The Cambrian rocks of the north of France are correlated with the Cambrian of St. David's, Wales, by authors, but they are not sufficiently well defined by faunas to compare them with American formations. In the province of Hérault, in the south of France, the presence of Paradoxides correlates the rocks with the Cambrian of Bohemia.[4]

On the island of Sardinia there is a mixture of Middle and Lower Cambrian faunas, which may arise from the confused state of the strata, or it is not impossible that the faunas are really mingled in the same beds. In the absence of more definite data it is not practicable to compare them with the American sections.

The contrast between the American and European Cambrian, with the exception of the sections of Bohemia and Sardinia, are not as great as those between the Atlantic Coast Province and the Appalachian Province, or as between the Atlantic Coast and Rocky Mountain Prov-

[1] On the deposition of the Cambrian and Lower Silurian rocks. Quart. Jour. Geol. Soc., London, vol. 31, 1875, p. 556.

[2] See Prof. Charles Lapworth's comparative table of the Cambrian rocks of Britain and Scandinavia. "Materials for the Correlation of the Lower Paleozoic Rocks of Britain and Scandinavia." Geol. Mag., new series, dec. II, vol. 8, 1881, pp. 320, 321.

[3] Mr. J. E. Marr correlates the basal beds of Barrande's Étage D (d 1a) in which *Lingula feistmanteli* occurs in abundance, with the Lingula flags of Britain. Quart. Jour. Geol. Soc., London, vol. 36, 1880, p. 602.

[4] Bergeron, Jules: Note sur la présence de la Faune primordiale (Paradoxidien) dans les environs de Ferrals-les-Montagnes. Bull. Soc. géol. France, 3e sér., vol. 16, 1888, pp. 282-285.

inces. In point of fact the Atlantic Coast Province of America is practically a portion of the Atlantic Province of which the sections of western Europe are on the eastern side. The Bohemian area and that represented by the deposits on the island of Sardinia partake, in part, of the character of the Atlantic Basin deposits, in the presence of the Paradoxides fauna, but not in other details.

The essential difference between the English and the American classification is in drawing the line between the Cambrian and Silurian (Ordovician). The English geologists have included the Upper Tremadoc slates, with their strongly marked Ordovician fauna, in the Cambrian, because a local stratigraphic break occurs at their summit and between it and the subjacent Arenig series. By the definition adopted in this paper for distinguishing the great geologic groups, the Upper Tremadoc slates, with their fauna, would be included in the Silurian (Ordovician), and the line of delimitation between the Cambrian and the Silurian (Ordovician) be drawn at the base of the upper Tremadoc slates, thus referring the Lower Tremadoc and the Lingula flag series to the Upper Cambrian, and the Upper Tremadoc to the base of Silurian (Ordovician).

In conclusion: (*a*) The relations between the Cambrian rocks of the eastern or Atlantic coast of North America and those of Wales are of a genetic character, and point to their having been deposited in the same time interval; (*b*) the Scandinavian Cambrian represents the same interval, but with a greatly diminished bulk of sediments; (*c*) the French and Spanish sections are too incomplete for close comparison, although representing the coast of Wales series; (*d*) the Bohemian and Sardinian areas point to local conditions that may have affected their connection with the typical Atlantic Basin sediments and faunas.

SCOTLAND.

The occurrence of Cambrian rocks in Scotland has not yet been fully proved, but it is quite probable that the Torridon sandstones of northwestern Scotland may be referred to the Lower Cambrian. Prof. Archibald Geikie, in summing up the notice of the Cambrian rocks in Scotland in his Text Book of Geology, says:

> In the northwest of Scotland a mass of reddish brown and chocolate-colored sandstone and conglomerate (at least 4,000 feet thick in the Loch Torridon district) lies unconformably upon the Archean gneiss in nearly horizontal or gently inclined beds. * * * The denudation must have been considerable even in early Silurian times, for the sandstones are unconformably overlaid by quartzites and limestones containing Lower Silurian fossils, and these younger strata even in the same district rest directly on the Archean gneiss. * * * No trace of organic remains of any kind has been found in the red sandstones themselves, unless certain track-like impressions, observed on the west side of Loch Maree, can be regarded as having been imprinted by crustacea or other organisms.[1]

[1] Text Book of Geology, 1885, p. 653.

IRELAND.

The supposed representative of the Welch Cambrian series in the southeast of Ireland is described by Prof. Geikie as follows:

In the southeast of Ireland, masses of purplish, red, and green shales, slates, grits, quartzites, and schists occupy a considerable area and attain a depth of 14,000 feet without revealing their base, while their top is covered by unconformable formations (Lower Silurian and Lower Carboniferous). They have yielded *Oldhamia*, also numerous burrows and trails of annelides (*Histioderma hibernicum*, *Arenicolites didymus*, *A. sparsus*, *Haughtonia pœcila*.) No Upper Cambrian forms have been met with in the Irish rocks, which are therefore placed with the Lower Cambrian, the unconformability at their top being regarded as equivalent to the interval required for the deposition of the intervening formations up to the time of the Llandeilo rocks, as in the northwest of Scotland.[1]

A very full description of the Cambrian rocks of Ireland, especially as they occur at Bray Head, Wicklow, is given by Prof. William Hellier Baily in 1865. A diagrammatic section accompanies the paper, and the author also describes the supposed organic remains that have been found in the rocks.[2]

CHINA.

Our knowledge of the Cambrian rocks of China results from the investigations of Baron Richthofen in the province of Liau-tung in northeastern China, near the Corean frontier. He found a series of limestone containing the "Primordial" fauna in the sections of Sai-maki and Tai-tsze-ho.[3] The limestones are superjacent to a series of sandstones and quartzites that correspond in stratigraphic position to the Lower Cambrian of North America.

The collections of fossils were studied by Dr. Wilhelm Dames, who came to the conclusion that two horizons were represented—the Andrarum limestone or Paradoxides horizon of Sweden, and the Quebec horizon of North America.[4] At the time Dr. Dames wrote *Dikelocephalus gothicus* and *D. quadriceps*, which he referred to the genus Doropyge, were cited as from the Quebec group; and it was on the comparison between the *Doropyge richthofeni* and these two species that he considered that the Quebec horizon was represented. The two species mentioned are now referred to the genus Olenoides of the Middle Cambrian fauna, which is not known to occur in the Upper Cambrian or in the Calciferous-Chazy fauna corresponding to the Quebec. A study of the species illustrated by Dr. Dames leads me to think that the Middle Cambrian fauna only is present, although it is not impossible that some Upper Cambrian species may have been collected. The sections of Baron Richthofen, however, indicate a considerable thickness of con-

[1] Text Book of Geology, 1885, p. 654.

[2] The Cambrian rocks of the British Islands, with especial reference to the occurrence of this formation and its fossils in Ireland. Geological Magazine, vol. 2, 1865, pp. 385–400.

[3] Richthofen, F. F. von: China. Ergebnisse eigener Reisen und darauf gegründeter Studien. Vol. 2 (das nördliche China) fig. 21, p. 94; fig. 29, p. 101, 1882.

[4] Cambrische Trilobiten von Liau-tung. China; by F. F. von Richthofen, vol. 4, 1883, p. 33.

formable strata beneath the Middle Cambrian zone in which the Lower Cambrian or Olenellus fauna should be sought for, and there are beds above in which the Upper Cambrian fauna may possibly be discovered. The geologic section is to be compared to that of the Rocky Mountain Province, and the presence of the same peculiar Middle Cambrian fauna, unmarked by the genus Paradoxides, also strengthens the comparison.

INDIA.

In a note on the discovery of trilobites by Dr. H. Warth in the Neobolus beds of the Salt Range, by Mr. Will King, director of the Geological Survey of India,[1] it is stated that the trilobites were discovered in the Neobolus beds of the Salt Range. The stratigraphic succession, from the summit downward, beneath the Carboniferous limestone, is as follows:[2]

Magnesian sandstone group.	7. Red shaly zone (Salt-pseudomorph zone). 6. Magnesian sandstone. 5. Dark shaly zone (Neobolus beds).
Purple sandstone group.	4. Upper purple sandstone (purple sandstone). 3. Rock salt and red gypsum group. 2. Gray gypsum group. 1. Lower purple sandstone.

There had been previously discovered in the Neobolus beds by Dr. Warth and Dr. Waagen a number of brachiopods, which were described by Dr. Waagen as follows: *Discinolepis granulata* (p. 750), *Schizopholis rugosa* (p. 753), *Neobolus warthi* (p. 758), *N. wynnei* (p. 759), *Davidsonella linguloides* (p. 764), *D. squama* (p. 766), *Lingula kiurensis* (p. 768) and *L. warthi* (p. 769).[3]

It is stated that the trilobites were sent to Dr. Waagen, who identified one of the two determinable species as a Conocephalites, very nearly related to *Conocephalites formosus* Hartt, from the St. John group, and the other as probably an Olenus.

> The beds in which such forms occur can not be anything but Cambrian, and they must probably be classed as referable to the upper region of the Lower Cambrian.[4]

In the table the probable equivalent elsewhere of this formation is the Sinic formation of Richthofen, in China.[5]

AUSTRALIA.

The Cambrian rocks of Australia appear to be confined to the southeastern portion of South Australia and the northern portion of Tasmania. In the "Papers and Proceedings of the Royal Society of Tasmania for 1882," Mr. R. Etheridge, jr., described a species of Conocephalites which he named *Conocephalites ? stephensi* (p. 153), and the tail of a trilobite which is named *Dikelocephalus tasmanicus* (p. 155).

[1] Records of the Geological Survey of India, vol. 22, 1889, pp. 153–157.
[2] Op. cit., p. 157.
[3] Memoirs of Geol. Surv., India. Palæontologia Indica, ser. xiii, vol. 1, 1887, pp. 750–770.
[4] Records of the Geological Survey of India, vol. 22, 1889, p. 154.
[5] Op. cit., p. 157.

Another pygidium is identified as belonging to the genus Asaphus, and small univalves which have the appearance of the genus Ophileta, of Vanuxem.[1]

The trilobites and the gasteropods are correlated with the Upper Cambrian fauna of America and Great Britain, to the Potsdam sandstone in America and the Lingula flags of Wales.

In 1884 Dr. Henry Woodward described some trilobites from the Parara limestone of the Yorke Peninsula, South Australia, *Conocephalites australis* and *Dolichometopus tatei*.[2] He concludes that the trilobites are clearly of Lower Silurian age, being equivalent to the Swedish, Bohemian, Tasmanian, and North American beds with similar fossils.

A recent paper by Mr. R. Etheridge, jr., on some Australian species of the family Archæocyathinæ describes the presence of several species of that family in association with trilobitic remains at Ardrassan, Yorke Peninsula, South Australia. The species described are *Ethmophyllum hindei*, *Protopharetra ? scoulari* and *Coscinocyathus tatei*.[3]

The strata containing the fossils are correlated with the Potsdam horizon sandstone of America or the Lingula flags of Wales. From the stratigraphic position of the American forms of Ethmophyllum and Coscinocyathus it is quite probable that the Australian species belong to the Lower Cambrian fauna and not to the Upper, as identified by Mr. Etheridge.

SOUTH AMERICA.

In 1876 Dr. Emanuel Kayser described a small collection of Primordial fossils made in the northern portion of the Argentine Republic, in the provinces of Salta and Jujuy, by Prof. Lorentz and Dr. Hyeronimus, of Cordova. The fossils occur in a micaceous sandstone, and include the genera Lingula, Obolus, Orthis, Hyolithes, Arionellus, Agnostus and Olenus.[4] Dr. Kayser compares the fauna with that of the north of Europe and North America, and concludes that it belongs to the upper zone of the Primordial. He calls attention to the fact that the genus Paradoxides is wanting and that Olenus appears in great numbers. "This fact seems to indicate that our fauna belongs to the upper Primordial zone or the Olenus stage."[5]

A glance at Pl. I, of Dr. Kayser's memoir proves that he is correct in the reference and that the fauna is of the type of the Upper Cambrian. From the geographical position and character of the fauna it is quite probable that Cambrian formations will be found on the eastern slope of the Andes, as well as the Cordillera of Central America and Mexico, if not concealed by later deposits.

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[1] Papers and Proc. Royal Soc. Tasmania for 1882, 1883, pp. 151–158.

[2] Note on the remains of trilobites from South Australia. Geol. Mag., new series, dec. III, vol. 1, 1884, pp. 342–344.

[3] On some Australian species of the family Archæocyathinæ. Trans. Roy. Soc. South Australia, vol. 13, 1890, pp. 10–22, Pls. II and III.

[4] Beiträge zur Geologie und Palaeontologie der Argentinischen Republik; II. Palaeontologische Theil.; von Dr. Emanuel Kayser, Cassel, 1876, pp. 28.

[5] Op. cit., p. 29.

CHAPTER V.

PROBLEMS FOR INVESTIGATION AND SETTLEMENT.

I.—Local problems within the subdivision of each province.
II.—Problems affecting our knowledge of the Cambrian group as a whole or in large parts.
III.—Problems of nomenclature and classification.

LOCAL PROBLEMS.

There are many local problems that are not mentioned in the following notes. With the settlement of the more important questions they will assume prominence, and some of them may prove to be equal to if not of more import than those now suggested for investigation.

Newfoundland.—The prominent questions are:

(1) The determination of the relation of the Cambrian rocks of St. Mary's and Trinity Bays to the basal conglomerate in the Manuel's Brook section, to ascertain if a series of Cambrian strata occurs between the lowest recognized Cambrian on Conception Bay and Manuel's Brook and the pre-Cambrian rocks of Trinity and St. Mary's Bay, as thought by the Newfoundland geologists. If such a series be found its fauna should be carefully collected and studied with reference to its being basal Cambrian or pre-Cambrian.

(2) The discovery of an unbroken stratigraphic section to prove the assumed relations of the Paradoxides fauna to the Upper Cambrian fauna. This will probably be found in the vicinity of or on the shores of the peninsula west of St. Mary's Bay and the shores of Placentia Bay.

(3) The determination on the west and northwest sides of the island of the relations of the Olenellus bearing strata to the subjacent and superjacent beds and the character of the section from its base to the limestone carrying the Calciferous fauna of the Silurian (Ordovician).

(4) The study of the geographic distribution and detailed sections of the strata on the southwestern and northeastern coasts.

(5) The relations of the Cambrian strata to the superjacent beds of the Silurian (Ordovician) wherever they can be found in the same section.

Nova Scotia.—The important question in Nova Scotia, as in Maine and New Hampshire, is the determination of the geological age of the slates referred provisionally to the Cambrian. After this come the local details of the sedimentation and paleontology of the Cambrian terrane. Until the first is decided very little except conjecture can be used in the correlation of the slates with the Cambrian or other groups.

New Brunswick.—Through the efforts of Mr. G. F. Matthew many of the problems relating to the Cambrian system in New Brunswick have been successfully solved. More information is needed for—

(1) The clearer identification of the Lower Cambrian or Olenellus zone and its exact stratigraphic relations to the Paradoxides zone.

(2) A clearer determination of the Upper Cambrian fauna and its relations to the Paradoxides zone.

(3) It is desirable that more data should be obtained upon the zoologic relations of the different faunas to each other.

Maine and New Hampshire.—The problem presented in Maine and New Hampshire is essentially of the same character as that presented in Nova Scotia. It is the determination of the presence of rocks of Cambrian age by paleontologic evidence. Until this is done the other problems of stratigraphic succession and geographic distribution of the strata and faunas can not be considered.

Eastern Massachusetts.—In eastern Massachusetts it is desirable to ascertain—

(1) The stratigraphic relations of the strata carrying the Olenellus fauna and Paradoxides fauna and decide whether the Upper Cambrian is represented in the region.

(2) To obtain more paleontologic data in order to correlate the various outcrops that have been referred to the Lower and Middle Cambrian in different portions of the Boston Basin and to the south-southwest toward the Rhode Island line.

(3) To identify and map the Cambrian rocks in detail.

New York.—In New York it is desirable to ascertain—

(1) The exact relation of the strata carrying the Olenellus fauna to those carrying the Upper Cambrian or Potsdam fauna about the Adirondacks.

(2) The stratigraphic succession and thickness of the strata carrying the Olenellus fauna in Rensselaer and Washington Counties, and whether the Middle and Upper Cambrian can be recognized either by the faunal or lithologic characters.

(3) The geographic distribution of the Cambrian rocks in the Hudson Valley south of Rensselaer County.

Adirondack subprovince.—The most important problem in connection with this subprovince is the tracing of the transition from the sandstone of the Potsdam about the Adirondacks to the off-shore deposit represented by the shales and slates now found beneath the limestone of the marble belt of western Vermont and eastern New York. More extensive collections of fossils are also desirable for the purpose of instituting closer correlations between the faunal zones of the typical Potsdam section of the Adirondacks with that of the correlated sandstone of the Mississippi Valley and elsewhere.

Vermont.—In Vermont the problems presented for study in connection with the Cambrian rocks are somewhat of the same type as those of New York. They differ in the northern portion, owing to the varying character of the sediment. Some of the questions are—

(1) The relation of the lower band of limestone ("Red sandrock"), bearing the Olenellus fauna, to subjacent rocks.

(2) The relation of the shore deposits, forming the "Granular Quartz" on the western slope of the Green Mountains, to the off-shore deposits, forming the limestones ("Red Sandrock") and shales (Georgia, etc.) carrying the Lower and Upper Cambrian faunas, in northern Vermont.

(3) The change in character of the sedimentation of the Cambrian rocks from the northern to the southern part of the State and their transition into the shale and slate series of New York.

(4) The determination of the extent of the range of the Cambrian fauna in the limestones of the "marble belt" in southern Vermont and the relations of these beds to the subjacent Cambrian strata on the western side of the "marble belt." The latter involves the question of the relation of the slates and shales carrying the Olenellus fauna and, in part, the base of what may be a portion of the Middle Cambrian fauna to the limestones. The working out of the complicated structural geology and the identification and mapping of all the formations will be required in the solution of these problems.

(5) The determination of the absence or presence of paleontologic data sufficient to differentiate the three primary divisions of the Cambrian group.

(6) The detailed geographic distribution of the formations referred to the Cambrian throughout the State.

Canadian extension.—The Cambrian group on the line of the Canadian extension north of Vermont, in the vicinity of Quebec and down the St. Lawrence River, requires detailed study in all its parts, both to determine the stratigraphic succession and character of the beds and the relation of the strata to the subjacent and superjacent series. One of the important problems presented is the determination of the origin of the limestone bowlders in the Point Levis conglomerate that carry the Upper Cambrian fauna, and those of the Sillery shale that carry the Lower Cambrian or Olenellus fauna. In fact, the entire Cambrian group of this portion of Canada requires full investigation.

New Jersey.—In New Jersey it is desirable to ascertain:

(1) The relation of the quartzite that has been referred to the Potsdam, to the subjacent Green Pond Mountain rocks.

(2) The representatives in New Jersey of the Pennsylvania Primal slates of Prof. Rogers.

Pennsylvania.—In the State of Pennsylvania attention should be given:

(1) To determining, by paleontological evidence, the exact age of the quartzite which has been referred to the Potsdam sandstone by all authors.

(2) To a careful study of the upper Primal slate, for the purpose of determining the line of demarcation between the Cambrian and Silu-

rian (Ordovician) rocks. This, apparently, will have to be based upon the paleontological evidence, as the stratigraphic series is unbroken and there is a gradual gradation between the schists or slates and the limestone by the intercalation of calcareous beds in the shales until the latter predominate and form the limestone series. This investigation can probably be best carried on in York and Adams Counties and the western portion of Lancaster County.

(3) The relation of the quartzite to the subjacent rocks also requires careful investigation all along the line of contact of the two terranes.

(4) Another problem that requires investigation is whether the Primal slates and schists graduate into limestones to the east and northeast of Lancaster County, or whether there is a line of unconformity, by non-deposition, between the quartzite and limestone in Chester, Berks, Bucks, Lehigh, and Northampton Counties. In other words, whether the portion of the Cambrian section as found in York and Adams Counties is absent in the counties to the northeast, or if it be represented by the lower portion of the limestone series.

Virginia.—The knowledge of the stratigraphic position of the rocks referred to the Cambrian, in Virginia, is in a much more satisfactory condition than that of Pennsylvania. It is desirable, however, that attention be given to:

(1) The changes in the character of the sedimentation from the Tennessee line north to the Potomac, and also the changes in the character of the sediment between the shore deposits of sand and conglomerate and the off-shore deposits of shale and calcareous matter.

(2) The paleontologic evidence of the geologic age of the strata referred to the Cambrian, is very defective, and investigation in this line should be made throughout the State.

North Carolina.—The problems to be considered in North Carolina are:

(1) The section along the French Broad, so as to determine the age of the strata and, if Cambrian, ascertain the stratigraphic position of the limestones, shales, sandstones, and quartzite to each other and to the sections of eastern Tennessee.

(2) About the same problem is presented in the rocks on the line of the Hiwassee section, in the southwestern portion of the State.

Tennessee.—The questions requiring investigation in Tennessee are:

(1) The stratigraphic relations of the Chilhowee formation to the Knox sandstone and Shale series.

(2) The relations of the eastern shore deposits to the off-shore deposits westward of the pre-Cambrian rocks.

(3) The collection and the study of the faunas of the Chilhowee and Knox shale formations.

(4) The geographic distribution of the strata and the vertical range of the faunas.

Georgia and Alabama.—The entire Cambrian section of Georgia and Alabama needs to be worked out stratigraphically, especially the relation of the Coosa Valley shales to the quartzites referred to the Chilhowee formation of Tennessee. The fauna of the shales is large and varied, and should be studied in connection with that of the Cambrian section of Tennessee and New York.

Utah and Nevada.—The problems awaiting solution in the study of the Cambrian rocks of Nevada and Utah are of an unusually interesting character. Those that suggest themselves are:

(1) The study of the basal beds of the Cambrian, and the possible extension of the Olenellus fauna down into the quartzite series beneath what is now recognized as the Olenellus zone. From all that is known to me of the rocks in Nevada and Utah, I think that in western central Nevada the best opportunity will be found for the discovery of the faunas preceding the present recognized base of the Cambrian. During later Algonkian time there appears to have been a great accumulation of arenaceous and siliceous sediments along the line of the Wasatch and extending westward into central Nevada. In western Nevada they are more shaly and calcareous, and it is possible that the conditions under which they were deposited were more favorable for the presence and preservation of the life of that period.

(2) The careful and detailed study of the great Cambrian section of central Nevada for the purpose of determining the full sequence of life throughout. Our present knowledge of it is very incomplete, and there are many gaps that can probably be filled in by detailed work and the careful collection of the fauna in connection with the study of stratigraphy and sedimentation.

(3) The study of the sections from the Wasatch westward to western Nevada for the purpose of determining the change of sedimentation and life from east to west.

(4) Another important subject of investigation is the transition between the Upper Cambrian and Ordovician faunas. This has been partially worked out in the Eureka district section, but there still remains much to be learned by careful detailed study of the sediments and faunas in the field.

(5) One of the unsolved problems of Utah is the question of the geological age of the quartzite beneath the Carboniferous limestone surrounding the main quartzite series of the Uinta Mountains. It is probable that there is a series of Cambrian rocks beneath the limestone and above the quartzite as in the Big Cottonwood Cañon section of the Wasatch Range; but it will remain an open question until paleontologic evidence is obtained.

Colorado.—Investigation in Colorado should be directed toward discovering fossils in the strata referred to the Upper Cambrian zone, and to verifying the exact stratigraphic position of the beds carrying Dikelocephalus at Quandary Peak.

Rocky Mountains.—In the eastern district of the Rocky Mountain Province it is desirable that close study should be made of the various sections of the eastern ranges of Colorado, Wyoming, and Montana, for the purpose of detecting the presence and character of the fauna as a means of correlating the strata with those of the Black Hills and the upper Mississippi Valley. On the western side, in southeastern Idaho, the Gallatin River section needs special investigation in order to correlate it with the sections of Nevada. Reference to what is required in Utah, Nevada, and Colorado has already been made.

Arizona.—It is desirable that larger collections should be made from the lower sandstone of the Cambrian section in the Grand Cañon area, and that the geographic distribution of the Cambrian in western Arizona be determined.

Upper Mississippi Valley.—Through the work of the Wisconsin and Minnesota surveys our knowledge of the Upper Cambrian sandstone is unusually complete. It is desirable that more information should be obtained in relation to the distribution of the fauna in the section and to ascertain whether the Middle Cambrian fauna accompanied the invasion of the sea that deposited the lowest beds of the terrane.

To determine the age of the sandstones on the south shore of Lake Superior it is still necessary to obtain paleontologic evidence to enable the geologist to state positively that the sandstones are the geologic equivalent of the fossiliferous sandstone of the central area of Wisconsin. It is also desirable to trace the continuation of the recognized fossiliferous Upper Cambrian sandstone directly west of Green Bay, Wisconsin, with that occurring on the south shore of Lake Superior. The definite settlement of these two problems will remove what has long been the source of contention among geologists.

Missouri.—It is desirable that the exact line of demarcation between the Upper Cambrian and Silurian (Ordovician) zones should be determined and more positive paleontologic data be obtained of the relative stratigraphic position of the beds with those of other areas that are now referred to the Cambrian.

Texas.—The information in relation to the Cambrian area of central Texas, in Llano County, is sufficient for most geologic purposes, although more detailed information as to the horizontal distribution of the fauna and the presence or absence of the Middle Cambrian fauna is desirable. The principal question, however, is the investigation of the supposed Cambrian in the vicinity of El Paso and the southwestern portion of the State.

PROBLEMS AFFECTING OUR KNOWLEDGE OF THE CAMBRIAN GROUP AS A WHOLE OR IN LARGE PARTS.

A glance at the map delineating the distribution of the Cambrian strata as shown by outcrops in North America, Pl. I, reveals at once the fact that we are dealing almost entirely with a marginal or coast series of sediments that are largely covered, over great areas, by later deposits. It is only here and there that a deep-seated disturbance has brought up the sediment that accumulated at some distance from the shore line. In Vermont and Nevada, especially in the latter, the calcareous sediments forming the limestone have been brought to the surface. In the great interior area of Wisconsin, Missouri, Texas, and the eastern front of the Rocky Mountains and the northern line between Canada and New York nothing is known of the deeper water deposits, if any such existed.

We know something of the sediments that accumulated along the western shore line of the Appalachian protaxis; but what was deposited over the area of which Ohio, Indiana, Kentucky, Tennessee, northwestern Alabama, Mississippi, northern Texas, Indian Territory, Kansas, and Nebraska forms a part we know nothing.

From the fact that in Texas, Missouri, the Upper Mississippi Valley, along the eastern front of the Rocky Mountains, and in New York and Canada west of the Adirondacks the deposits are such as would accumulate in a shallow sea not far distant from the shore line it has been assumed that the Cambrian ocean of this great area was relatively shallow. I think that during Lower and Middle Cambrian times the entire interior continental area was above the sea level. These opinions are based on the character of the deposits and the absence of the sediments of the Lower and Middle Cambrian. The great problem in this connection, however, is to determine how far the pre-Cambrian continent extended to the south and east and what its relations were to the offshore ridges of the eastern and western margins, along which we now find deposits of Lower and Middle Cambrian age.

A careful study of the sections in Pennsylvania, Virginia, Tennessee, Georgia, and Alabama may throw some light upon the question on the southeastern side. Over the remaining portions of the great central area no natural outcrops are known, and there seems to be no way of obtaining information except by very deep borings.

The question of the relations of the Middle Cambrian fauna of the Atlantic Coast Province to that of the Appalachian and Rocky Mountain Provinces is one that can be settled only by a close and careful study of the faunas, based on large collections methodically made throughout the entire areas of the three provinces. That the Middle Cambrian or Paradoxides fauna of the Atlantic Coast Province is represented by a very different fauna in the Rocky Mountain Province there is not, I think, any question. It is also well proved that the latter fauna is present to a less extent in the Appalachian Province.

Throughout the Rocky Mountain Province, except in British Columbia, the Olenellus or Lower Cambrian fauna is confined to a very narrow zone, while in Vermont it ranges through 1,000 feet of limestone and up into the superjacent shales. In New York it has a range through a great thickness of shales, slates, interbedded limestones, and sandstones; and one of the problems requiring investigation is the downward extension of this fauna in the series of shales, slates, and sandstones beneath the now known Olenellus horizon of the western Rocky Mountain Province. The lower series of slates and quartzites have been tentatively referred to the Algonkian, but it is quite probable that they will be found to carry the Olenellus fauna to a considerable depth, and a pre-Olenellus fauna may yet be discovered.

The problem of the downward extension of the Cambrian faunas also requires investigation in the Appalachian Province, especially in the southern portion—in Tennessee, Georgia, and Alabama. The basal limit of the Cambrian is now drawn at the Olenellus zone, but in the absence of any subjacent fauna there still remain the problems of the downward extension of the Cambrian fauna and of the existence of a pre-Cambrian fauna that may have lived in the Appalachian seas.

A local question of interest may be here introduced, as it affects a considerable area and involves conditions of sedimentation unknown elsewhere in the Cambrian. It is the question of the place of derivation and mode of transportation of the bowlders of the limestone conglomerates that carry in the lower zone, the Lower Cambrian, and in the upper zone the Upper Cambrian fauna found along the southern shore of the St. Lawrence River from Quebec to Gaspé.

One of the problems partially solved, and one that still requires investigation, is the relation of the pre-Cambrian topography to the sediments deposited upon it, to determine the source of sediments and the habitat of the faunas.

Along the Atlantic coast the presence of the pre-Cambrian shore line with a varied coast topography is clearly distinguishable, and it is evident that the Cambrian strata now occupy the same relative position to the pre-Cambrian as the sediments did when they were deposited. The same is true of the shore-line deposits along the western margin of the Appalachian, pre-Cambrian protaxis, and the sediments about the Adirondack area. Between the Adirondacks and the Green Mountains a great thickness of Cambrian rocks appears to have been deposited in a deep, relatively narrow sea; but what the conditions were to the westward of the long line of the eastern boundary of the Appalachian Province is one of the questions requiring solution. The same is true of the western limits of the sediments now exposed in the great uplifts of central Nevada and British Columbia.

The questions arising from the study and comparison of the various provinces all require a more thorough investigation of the sections of the western Rocky Mountain, Appalachian and Atlantic Coast Provinces. They bear upon the nomenclature and classification to be adopted for the Cambrian group; and not until we have a more thorough knowledge of the sections of northern Vermont, New York, Tennesse, British Columbia, and Nevada can the classification be considered more than a provisional one.

PROBLEMS OF NOMENCLATURE AND CLASSIFICATION.

The name.—It is still a debatable question with a few geologists, whether we shall follow the present general usage and use the name Cambrian group, with the area of Cambrian in Wales as its type and the descriptions of Prof. Adam Sedgwick as the classical description of the group, or, in opposition to this, adopt the name Taconic, proposed by Dr. Ebenezer Emmons, with the area of Berkshire, Rensselaer, and Washington Counties, east of the Hudson River, in New York, as the type, and the papers of 1842 and 1844 of Dr. Emmons as the classical description of the group.

While recognizing the fact that the name Taconic has certain claims upon the sentiment of Americans, I have stated elsewhere that I think the interests of geology are best served by adopting the term Cambrian, as has been done by the great majority of geologists.

The limit of the group.—The delimitation of the upper limit of the group by geologists who recognize it as distinct from the superjacent Silurian (Ordovician) has varied to the extent of placing the arenaceous deposits of the shore line, or the strata referred to the Potsdam sandstone, in the Silurian, or including the superjacent Calciferous formation in the Cambrian. To a large extent this difference of opinion is based upon the evidence of the local physical conditions of sedimentation, and not upon the included faunas. If we adopt as the principle of classification that the delimitation of the great geological groups must rest upon the broad zoological characters of their included faunas and not on local stratigraphic breaks between certain series of rocks, or on local differences of sedimentation, the line of demarkation between the Cambrian and Silurian (Ordovician) is to be drawn where the marked characters of the Cambrian fauna give way to those of the Ordovician. That this principle is the only sound one upon which to base the delimitation of a group is proved by the fact that there is no other relatively constant character upon which to rely in geologic classification. That it is often arbitrary is known to all working geologists.

The line of demarcation along the northern and eastern sides of the Adirondacks is between the upper beds of the Potsdam sandstone and the calcareous layers of the Calciferous formation. On the south side, in Saratoga County, it is drawn in a series of limestones, where the characteristic Upper Cambrian fauna disappears and the types of the Silurian (Ordovician) fauna appear. In western Vermont, 20 miles from where the division is made between the Potsdam and Calciferous formations, the line is drawn in a series of black argillaceous shales, somewhere between a horizon carrying characteristic Upper Cambrian fossils and another horizon some distance above, in which characteristic Calciferous fossils are found. In the Southern Appalachian Province, in East Tennessee, the line of demarcation is not at the base of the limestone series, but at a point in the lower portion of it, where the characteristic Upper Cambrian fauna disappears and the Silurian (Ordovician) fauna begins to predominate. This same principle of demarcation is followed in the limestone series of central Nevada, while over the interior continental area it is largely drawn at the summit of the sandstone carrying the Upper Cambrian fauna and at the base of the limestone in which the Calciferous fauna occurs. In some instances, however, the Upper Cambrian fauna extends up into the Calciferous beds, and in such the line of demarcation occurs in the Calciferous zone.

It is not always possible to delineate on the map such close lines of demarcation within a formation, and for the sake of convenience it may be well to map the formation by their lithologic characteristics and describe in the text the line of delimitation between the groups. When, however, the line between two groups occurs in a limestone, as in the Pogonip limestone of the Eureka district, Nevada, and there is sufficient paleontologic evidence to demonstrate it, the line should be drawn on the map at the point indicated by the faunas.

The problems in connection with the delimitation of the summit of the Cambrian group remain to be studied in nearly all portions of the various provinces. In some they are fairly well settled, but there still remains much to be done in the way of collecting the faunas and studying their vertical distribution in the strata.

Is the basal line of the Cambrian group at the lowest limit at which the Olenellus fauna is found? Where this lowest limit occurs at the base of a conformable series resting unconformably upon pre-Cambrian rocks there is no difficulty in answering the question. But where it occurs in the midst of a conformable series and there remain thousands of feet of sediments beneath the Olenellus zone, as in Nevada and Utah, it still remains a problem for consideration. On the general proposition that I would not refer to the Cambrian any rocks beneath the Olenellus zone, the subjacent strata of the western Rocky Mountain area were referred to the Algonkian in the paper reviewing the Lower Cambrian or Olenellus fauna published in the tenth annual report of the U. S. Geological Survey. I think, however, it is a question for discussion and research, as the Olenellus fauna has a great vertical and time range in the Northern Appalachian Province, while in the Southern Rocky Mountain Province it is limited to the very narrow band of strata at the summit of the siliceous series of slates and quartzites.

That the question of how the Cambrian shall be divided in America still requires investigation, with special relation to the classification to be applied in the various provinces, is well known. The three primary divisions of the Cambrian (Lower, Middle, and Upper) are readily recognized in Newfoundland, and that one or the other of these divisions can be distinctly recognized in the other provinces has been proved.

In the Interior Continental Province only the Upper Cambrian, with its distinct sedimentation and fauna, is known, and no other appears to have been deposited. In the Appalachian Province, in Vermont, the Lower Cambrian is readily separated by organic remains and sedimentation; but with our present knowledge it is impossible clearly to distinguish between the Middle and Upper Cambrian. The same is true throughout the Appalachian region, except in the Adirondack subprovince, where the Upper Cambrian is well developed. In the Rocky Mountain Province the Lower Cambrian is distinctly developed, but the Middle and Upper merge more or less into each other. The problems in this connection requiring investigation are clearer delimitations of the Middle and Upper Cambrian in the Appalachian and Rocky Mountain Provinces, both by the careful study and comparison of the sections and the collecting and differentiation of the faunas.

It is not anticipated that uniformity will be found to exist in each of the primary subdivisions; the sedimentation of the various provinces is too unlike. The three divisions will have to be used, if at all, in a somewhat arbitrary manner in some of the areas, just as the greater division of the Cambrian is arbitrarily separated from the Silurian (Ordovician) where no physical line of division is apparent. We recognize the Cambrian group as a convenient means of classification, but its subdivisions must be controlled by the needs of the local geologist and not used unless distinctly recognized.

CHAPTER VI.

THE CRITERIA AND PRINCIPLES USED BY AUTHORS IN THE CORRELATION OF THE VARIOUS PARTS COMPOSING THE GROUP, WITH OBSERVATIONS ON SOME METHODS OF CORRELATION.

HISTORICAL NOTES.

The earlier American geologists took their first views of classification and principles of correlation mainly from European authors. Among the latter Dr. John Woodward said early in the eighteenth century in his "Natural History of the Earth":

That the stone and other terrestrial matter in France, Flanders, Holland, Spain, Italy, Germany, Russia, and Sweden were distinguished in *strata* or *layers* as it is in England; that these strata were divided by parallel layers; that there were inclosed in the stone and all the other denser kinds of terrestrial matter great numbers of the shells and other productions of the sea in the same manner as in that of this island.[1]

This is one of the earliest correlations of stratified and fossiliferous rocks. It is crude and indefinite as compared with modern correlation, but the general method of comparing stratified fossiliferous rocks because they are stratified and fossiliferous was inaugurated.

Dr. Abraham Werner, in Germany, gave systematic form to descriptive geology in the latter part of the eighteenth century; while about the same time Prof. William Smith, in England, applied organic remains in geologic investigation, and correlated formations in various parts of the British islands by their contained fossils. A little later Baron George Cuvier was establishing in France the great principles of the succession of varying organic remains in the strata and their differentiation from living forms.

AMERICA.

Maclure.—In America Mr. William Maclure was among the first to take advantage of the principles of classification enunciated by Dr. Werner, and we find the correlations made by him in preparing his geological maps were based entirely upon lithologic and stratigraphic evidence. This is stated in the first paragraph of the introduction to his paper:[2]

Necessity dictates the adoption of some system. So far as respects the classification and arrangement of names the Wernerian appears to be the most suitable, first, because it is the most perfect and extensive in its general outlines, and secondly,

[1] An Essay towards a Natural History of the Earth and Terrestrial Bodies. London, 3d ed., 1723.

[2] Observations on the Geology of the United States explanatory of a geological map. Am. Phil. Soc. Trans., vol. 6, 1809, pp. 411, 412.

the nature and relative situation of the minerals in the United States, while they are certainly the most extensive of any field yet examined, may perhaps be found to be the most correct elucidation of the general exactitude of that theory as respects the relative position of the different series of rocks.

On the map four great classes of rocks are recognized: Class I, Primitive rocks; II, Transition rocks; III, Secondary rocks; IV, Alluvial rocks. The presence of rock salt in the southern Appalachian is recognized by a separate color.

In the text[1] the Primitive rocks are divided into fourteen varieties, the Transition into five varieties, the Secondary into twelve, and the Alluvial into seven. In traversing the country Mr. Maclure noticed the presence of any one of these rocks at their various outcrops, and thus correlated the geological formations that presented similar characters. In the second edition of his work[2] two methods of examining and correlating the rocks are given:

The first, the accurate investigation of a small portion of the surface, describing exactly the different rocks with their immense variety of arrangement and position of their component parts, detailing the changes, accidental or natural, constantly occurring in their relative situation, and endeavoring to reduce the whole to some regular series of arrangement. This method necessitates the reunion of a great number of those portions before any correct general idea can be formed.

The second, beginning with the great outline, traces the limits which divide the principal classes of rocks and their relative situation and extent. Mr. Maclure favors the second, stating:

In tracing the outlines of the different formations in most countries there is less confusion and embarrassing description necessary; the limits once ascertained, a few pages define the boundaries and explain the relative situations to the comprehension of every reader.[3]

Eaton.—After Mr. Maclure, Prof. Amos Eaton was the most important factor in the shaping of the methods of geologic work in America. By his various publications and his influence as a teacher he outlined the methods and formulated the general principles upon which geologic investigation was carried forward for nearly two decades. The correlations made in his earlier works were based entirely upon the lithologic characters of the rocks. Believing in the Mosaic cosmogony, he explained the phenomena he observed in the structural relations of the rocks by the giving way of the foundation of the Old World prior to the flood. He says:[4]

While this tremendous crash of nature was going on, scales of various thicknesses from the various strata were shot up, detached, and broken, which gave formation to our surrounding hills, the ragged cliffs of the Catskill, and the bleak brow of the

[1] Op. cit., p. 412.

[2] Observations on the Geology of the United States; with remarks on the probable effects that may be produced by the decomposition of the different classes of rocks on the nature and fertility of soils. Am. Phil. Soc. Trans., vol. 1, new ser., 1817, pp. 1-91.

[3] Op. cit., p. 9.

[4] An index to the Geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, pp. 48, 49.

Andes. Some were formed at the bottom of the sea by volcanic fires, others have arisen from various causes since the great deep retired.

During the deluged state of the earth many species of animals were probably destroyed. For we continually find the petrified remains of species of animals now totally extinct.

From the latter observation it is quite evident that at that time he did not consider fossils to be of any value in the correlation of the rocks. In the next edition of the Index [1] his theories of the origin and first condition of the surface and position of the rocks are omitted, and a more thorough description is given of the various rock masses, the classification of which was lithologic and based on the views of Dr. Werner. His more extensive work of 1824[2] shows that the correlations made between the rocks of the Hudson and those west of the Hudson, along the line of the Erie Canal, were based mainly upon their lithologic characters. For instance, the Calciferous sandrock of the Mohawk Valley, in the vicinity of Little Falls, New York, was traced westward in the vicinity of Utica and eastward down the Mohawk Valley to the vicinity of Schenectady, and then correlated with a Calciferous sandrock on the east side of the Hudson. This correlation was made upon the lithologic character and the stratigraphic succession of the rock masses. Its defective character is shown by the fact that the Calciferous sandrock east of the Hudson is of Lower Cambrian age and that west of the Hudson is of Silurian (Ordovician) age.

Classification and correlation on the basis of lithologic character and stratigraphic succession was continued by Prof. Eaton in his work of 1828 [3] and again in his text-book of 1830.[4] On the map accompanying the latter all the quartzose formations are colored yellow, all the calcareous formations blue, the variegated sandstones red, and the subordinate rocks green. By this the primitive limestones of the Adirondacks (Algonkian), the Lower Cambrian limestones of Washington County, the Calciferous-Chazy-Trenton limestones of the central portions of the State, and the Lower Devonian limestones of the Upper Helderberg are all placed under one color.

In 1832[5] he introduced a new heading into his Text Book, as follows: "Organized remains as auxiliaries in the determination of rock strata." Under this he says:

The remains of similar species of animals and plants are found embraced in similar series of rocks; and these occurrences are so uniform that rocky and earthy strata may be determined by them.[6]

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[1]An Index to the Geology of the Northern States, 2d ed., 1820, pp. 286.

[2]A geological and agricultural survey of the district adjoining the Erie Canal, 1824, pp. 163.

[3]Geological nomenclature, exhibited in a synopsis of North American rocks and detritus. Am. Jour. Sci., vol. 14, 1828, oppo. p. 144, pp. 145–149, 359–368.

[4] Geological text-book, prepared for popular lectures on North American geology; with applications to agriculture and the arts. Albany, 1830, pp. 64.

[5] Geological text-book for aiding the study of North American Geology; being a systematic arrangement of facts, collected by the author and his pupils, under the patronage of the Hon. Stephen Van Rensselaer. 2d ed. Albany, 1832.

[6] Op. cit., p. 25.

In connection with the discussion of the presence of organic remains in the rocks the following passage occurs:

The geological deposits of this country (and probably those of the eastern continent) exhibit grounds for conjecture if not absolute demonstration that the surface of the earth has undergone five general modifications, which no animals survived. Four of these modifications were followed by as many new creations of animals. Also that two new creations of animals succeeded the final depositions of all regular strata. In the whole, there appears to have been five creations of animals at least (perhaps ten) since the primitive mass of the earth was formed, and a long interval succeeded each creation.[1]

It is also said that the "remains or impressions of plants are limited to coal and coal formations whose relative position is indicated by their rocky associates; the determination of rocks by their animal relics serves as an index to the position of coal measures or beds. In this concise selection of the most essential relics animals alone will be noted which have no backbone nor brains" [invertebrates].[2]

Under the title of "Geological Equivalents" Prof. Eaton mentions that relative position and mineral constituents were deemed sufficient by Werner for determining geological equivalents. As relative position is the basis of the science, all other circumstances have always been received as auxiliaries only so far as classification is concerned.[3] He reasoned that as rocks can be traced more or less continuously throughout New York and Pennsylvania the data used by Werner are of value; but—

From a consideration of the cases here referred to, intrinsic characters more definite than any left us by Werner seem to be essential to the progress of the science. The enumeration of mineral constituents of rocks can never be satisfactorily applied. Unorganized matter presents but few characteristics. Naturalists find it a more difficult task to describe by external characters about two hundred and seventy species of minerals than fifty thousand species of plants and a still larger number of animals.

It is a subject of high congratulation to students in geology of our day that the illustrious Cuvier, aided by the Brongniarts and their coadjutors, have extended the science of organic nature to the science of geology. We are no longer limited to the enumeration of mineral constituents. We find the same organized remains associated with equivalent strata in every part of the earth, though they often extend into several adjoining strata, which are probably contemporaneous or nearly so.[4]

He then proceeds to classify the strata as known to geologists of both continents by means of some of their organic associations in North America.[5]

A few months later he published a paper on "Four cardinal points in stratigraphical geology established by organic remains," saying:

If the identity of the *Granular*, the *Metalliferous*, and the *Oolitic calcareous rocks*, and of the *Tertiary marls* are established on both continents all intervening strata may be ascertained with great facility. I think that a reference to the following facts will be sufficient to establish their equivalent characters at least.[6]

[1] Op. cit., p. 48.

[2] Op cit., p. 25.

[3] Geological equivalents. Am. Jour. Sci., vol. 21, 1832, pp. 132–138.

[4] Op. cit., p. 134.

[5] Op. cit., pp. 136–138.

[6] Four cardinal points in stratigraphical geology established by organic remains. Am. Jour. Sci., vol. 21, 1832, p. 199.

The first cardinal point is the Granular limerock "the only limerock which is always destitute of organic remains." The second cardinal point is the Metalliferous, Mountain or Carboniferous limerock. Under this heading he correlates the limestone at Trenton Falls and most of the limestones of New York. The third cardinal point embraces the Oolitic series or Calcareous rocks, and the fourth the Tertiary marls. These correlations of Eaton were crude, but when refined by the geologists of the New York State survey the first three formed the basis for the correlation of the lower and middle Paleozoic rocks of the continent.

Bigsby.—The earlier work of Dr. J. J. Bigsby was apparently unknown to Eaton. The former used organic remains in a very general manner to correlate the strata of England and America, but also depended upon the lithologic characters and stratigraphic succession. In an article entitled "A list of minerals and organic remains occurring in the Canadas" he remarks upon the extent and relations of the limestones and sandstones of the eastern and western parts of Canada. Of the limestones he says:

Their relation to the subjacent rocks and uniform similarity in structure and contents, mineral as well as organic, seem to indicate that the beds of limestone, extending with few or no interruptions from Cape Tourment, below Quebec, to near the Falls of St. Mary, are the effects of a contemporaneous deposition; and further, that they are the representatives of the Mountain or Carboniferous limestone of England.

I make these statements with extreme diffidence, being in some degree aware of the difficulties of the discussion, of the existence of contradictory facts, few but weighty, and of the defective state of our information respecting the vast calcareous formations of North America.[1]

The reference to the secondary limestone of the St. Lawrence and the lake region is as follows:

The limestone now described abuts on one of the older rocks directly, or with the interposition of another horizontal stratum, and by far the most commonly on gneiss, which I have strong grounds for believing to be of the same age and general characters throughout the whole of the districts under consideration. It is incumbent directly on gneiss in the bed of the river St. Anne, near its upper falls, in the seigniory of St. Feriole, Lower Canada; at Montmorenci, not far from "the natural steps," but only seen in time of low water; at and near Point Henry, close to Kingston, Upper Canada; and in many places on the north coast of Lake Huron. In the last-named locality it rests directly, in several instances, on a beautiful snow-white transition quartz, which occupies the main shore in steep hills, 400 and 500 feet high, from near the French River to the River Le Serpent (70–80 miles). The immediately subjacent rock at La Cloche and on the isles north of the Manitoulines, in the same lake, is sometimes a highly inclined greenstone. Near Montreal it overlies directly crystalline trap, containing augite, zeolite, mica, feldspar, etc.

But ordinarily a sandstone, graywacke, or a conglomerate of quartzose or calcareous materials is interposed; also in horizontal layers. It is to be remarked (en passant) that much the greater part of the graywacke of Lower Canada does not belong to this deposition, but is conformable to the mica-slate, gneiss, etc., ranging along the north shore of the St. Lawrence, between Quebec and the river Saguenay. * * *

[1] A list of mineral and organic remains occurring in the Canadas. Am. Jour. Sci., vol. 8, 1824, pp. 76, 77.

The sandstone, which is beneath the limestone from near Kingston, Upper Canada, to St. Anne's, 26 miles northwest of Montreal (174 miles), is white, but with ferruginous spots and clouds, hard, fine grained, without cement, and contains thick layers of large and small nodules of crystalline quartz, disposed in horizonal lines. It forms cliffs an hundred feet high in the Lake of the Thousand Islands, which rest on the very small-grained gneiss (often a granite) which abounds so in the north and northeast and passes largely and frequently into primitive white quartz rock, thus disclosing a possible source of the sandstone and quartz nodules. Where clay is the cement an argillaceous sandstone or graywacke is furnished. The former of these I have never seen in contact with the inclined rocks. It occurs very distinctly in the chasm of the Niagara, the lower strata of which (and particularly those on which Queenston stands) are almost ferruginous clay. The nearest primitive is on the north shore of Lake Simcoe, 90 miles off. From the nature of the organic remains and other contents of the limestones covering this sandstone, I am inclined to believe the latter to be the old red, which is often thus intermixed with argillaceous matters. At Dunkirk, on the south side of Lake Erie, Mr. Hulbert has bored through these rocks to the depth of 682 feet (117 feet below the surface of the Atlantic) and without meeting with salt. The above observations apply to the fine sections in the bed of the Genesee River; but I have not sufficiently examined the fossils in the limestone of that locality. Its sandstone has large but indistinct casts of what I suppose to be encrinites, but which may be vegetable, but in either case resembling the Old Red sandstone. It may be added that it is on the same level with and not very far from the sandstone of the vicinity of Kingston; but similarity in level taken by itself is not an unerring test of similarity in age. In one part of a district or lake granite, gneiss, etc., may attain a given elevation and be there covered with graywacke only; while in another and not very distant place these rocks may not rise to within some thousand feet of that height, and be buried under all the succeeding strata up to the Crag above the London clay.[1]

A conglomerate wholly calcareous occurs in situ near the foot of the Long Sault of the river Ottawa, and at the Coteau du lac, 3 miles below Lake St. Francis, composed of angular and rolled masses, sometimes very large, of fine granular limestone light brown and blue, imbedded in a dark brown paste. A similar rock occurs with the limestone about Poughkeepsie, in the State of New York, and at Aubigny, opposite Quebec, interleaved with clay slate and graywacke, highly inclined, and having a southwest direction.[2]

The elements of correlation suggested in the preceding quotations include lithologic resemblance, similarity of level in a given area, stratigraphic succession, and the presence of organic remains.

At a later date Dr. Bigsby noticed in the conglomerates on the south side of the St. Lawrence, opposite Quebec, the presence of trilobites, encrinites, corrallites, and other fossils, and, on this account, considers the formation the equivalent of the Carboniferous limestone of the English geologists.[3]

James.—One of the earliest extended correlations in America is that of Dr. Edwin James.[4] In his remarks on the sandstone of the western part of the valley of the Mississippi he first describes in detail the red sandstone.[5] He states that this rock is the lowest of the horizontal or

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[1] Op. cit., pp. 78-80.

[2] Op. cit., p. 81.

[3] On the geology of Quebec and vicinity. Proc. Geol. Soc. London, vol. 1, 1827, p. 38.

[4] Remarks on the sandstone and Floetz trap formations of the western part of the valley of the Mississippi. Am. Phil. Soc. Trans., vol. 2, new ser., 1821, pp. 191-215.

[5] Op. cit., p. 204.

secondary rocks met with and is very abundant in all that part of the plain immediately adjacent to the Rocky Mountains which he had examined. A similar rock is met with in the eastern part of the State of New York. Specimens from many parts of the strata on the Canadian River are entirely similar to those quarried in New Jersey and used in great quantities in the cities of New York, Albany, etc., for building.

"Whether this sandstone is in all respects similar to the 'Old Red sandstone' of Werner, which makes so conspicuous a figure in the systems of certain geologists, we are not able to say. It, however, certainly occupies a place similar to the one which has been assigned to that rock." In a foot-note referring to this statement it is said that—

This red sandstone is first found on the waters of the lakes on the strait between Lake Huron and Lake Superior, and forms the fall called the Sault de Ste. Maria.[2]

It also occurs in the Catskill Mountains and in the Salt District in the western part of the State of New York, having a similar relation to the secondary rocks in that quarter. * * * The red sandrock now under consideration appears at one place with every character requisite to place it among the rocks of transition, at another it is manifestly secondary; yet its continuity may be traced through minute shades of gradation or by a sudden transition from one of these points to the other.[2]

A review of the preceding remarks indicates that Dr. James supposed the Jura-Trias sandstone of the eastern foothills of the Rocky Mountains, the red sandstone of the Lake Superior region (Algonkian), the eastern New York sandstone (Upper Cambrian), and the New Jersey Triassic sandstone were of the same relative geologic age as shown by their lithologic characters and supposed stratigraphic position.

Bakewell.—The publication of the American edition of Mr. Robert Bakewell's Geology in 1829 was an important contribution to American geologic literature. It presents an account of the geological distribution of organic remains as then understood and the general principles of geology as known to English geologists.

In regard to correlation by fossils Mr. Bakewell says:

With respect to fossil conchology he is inclined to believe that the attempt to identify the strata of distant countries by the isolated occurrence of any particular species of shell has been carried further than a sound induction from facts or analogy would warrant. His opinion on this subject, given in the second edition of this work, he will here insert: "It may be doubted whether the occurrence of similar organic remains is sufficient to identify strata in distant parts of the globe; for could we admit that strata are universal formations and extended from the frozen to the torrid zone, it seems more than probable that the animals that lived on any one particular stratum would be of very different species in different latitudes." * * *

In strata belonging to one formation and in adjacent districts, the existence of certain shells, whether we regard them as distinct species or as varieties, may be of use in identifying any particular bed; and in distant countries where we find the same remarkable species of shell associated with any other remarkable species in considerable numbers it may serve to identify a particular rock formation, where the mineral character of the rock may be very different from that in which the observer has

[1] Op. cit., p. 205. [2] Op. cit., p. 206.

been accustomed to meet with them. The occurrence of a considerable number of gryphеæ, the *Gryphea arcuata* in a bed of blue clay in the mountains around the Lake of Annecy in Savoy, served the author as a key to discover to what formation the calcareous strata belonged, when their mineral characters would have indicated a more ancient series.[1]

De la Beche.—In 1832 an edition of the Geological Manual[2] of De la Beche was published in Philadelphia. In the section upon the classification of rocks we find the following remarks upon classifiation by organic remains:

To propose in the present state of geological science any classification of rocks which should pretend to more than temporary utility would be to assume a more intimate acquaintance with the earth's crust than we possess. Our knowledge of this structure is far from extensive, and principally confined to certain portions of Europe. Still, however, a mass of information has gradually been collected, particularly as respects this quarter of the world, tending to certain general and important conclusions, among which the principal are, that rocks may be divided into two great classes, the stratified and the unstratified; that of the former some contain organic remains and others do not; and that the nonfossiliferous stratified rocks, as a mass, occupy an inferior place to the fossiliferous[3] strata, also taken as a mass. The next important conclusion is, that among the stratified fossiliferous rocks there is a certain order of superposition, apparently marked by peculiar general accumulations of organic remains, though the mineralogical character varies materially. It has even been supposed that in the divisions termed formations there are found certain species of shells, etc., characteristic of each. Of this supposition extended observation can alone prove the truth; but it must not be supposed, as some now do, that in any accumulation of ten or twenty beds, characterized by the presence of distinct fossils in a given district, the organic remains will be found equally characteristic of the same part of the series at remote distances.

To suppose that all the formations into which it has been thought advisable to divide European rocks can be detected by the same organic remains in various distant points of the globe is to assume that the vegetables and animals distributed over the surface of the world were always the same at the same time, and that they were all destroyed at the same moment, to be replaced by a new creation, differing specifically, if not generically, from that which immediately preceded it. From this theory it would also be inferred that the whole surface of the world possessed an uniform temperature at the same given epoch.

It has been considered, but has not yet been sufficiently proved, that the lowest rocks in which organic remains are found entombed show a general uniformity in their organic contents at points on the surface considerably distant from each other, and that this general uniformity gradually disappeared, until animal and vegetable life became as different in different latitudes, and even under various meridians, as it now is. How far this opinion may or may not be correct can only be seen when geological facts shall have been sufficiently multiplied; but it is one which demands considerable attention, as the classification of fossiliferous rocks greatly depends upon it. Should it eventually be found to a certain degree correct it would not be at variance with the theory of a central heat, which having diminished permitted solar heat and light gradually to acquire an influence on the earth's surface.[4]

Numerous other European works soon came into the hands of the American geologists, among them the earlier editions of Bakewell,

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[1] Introduction to Geology, Robt. Bakewell, 1st American edition, New Haven, 1829, pp. 32, 33.

[2] Geological Manual, Philadelphia, 1832.

[3] The term *fossiliferous* is here confined to organic remains.

[4] Op. cit., pp. 33, 34.

Lyell, Mantell, and various French and German authors. Their influence is shown by the rapid development of stratigraphic geology based upon the principles established in Europe. Of the means of correlation available to Prof. Amos Eaton in his earlier work he says, in 1839:

Eaton.—When I commenced my geological surveys the application of organized remains for demonstrating strata was not studied in America. I had become acquainted with no method for determining the character of such strata but that of tracing them separately through a vast extent of country and then comparing their general characters. For this purpose I traveled some thousand miles at my own expense and with the liberal aid of students of Williams College, with Prof. Dewey at their head, where I was employed more than a score of years since by the authorities of the college to introduce the natural sciences. Afterwards I traveled more than 17,000 miles on geologizing tours at the expense of the Hon. Stephen Van Rensslaer, and I was always aided by several assistants and competent students. Had the application of paleontology been then as well understood as it now is I could have settled the characters of most rocks as well in my closet by the aid of specimens. But it is a true remark in your last journal that strata must have been first settled according to the method to which I was compelled by ignorance to submit, before the service of organized remains could be successfully employed. In this country no material progress had then been made in the study of organized relics, and even now we have very few good paleontologists.[1]

NEW YORK SURVEY.

The geologists of the New York State survey systematized the work of the geologists who preceded them and established a standard section of the lower and middle Paleozoic formations of New York. On this account it is desirable to examine the principles of correlation mentioned by Messrs. Conrad, Hall, and Emmons and to notice the extension of the nomenclature of the formations of the New York section to various portions of the continent.

Conrad.—As paleontologist of the survey Mr. T. A. Conrad made the following comments upon the use of fossils in the correlation of strata:[2]

There is a strange misunderstanding of the method of applying organic remains in the division of series of strata into formations and the identification of widely separated rocks by the zoological characters of each. In the January number of the New York Review the opinion is advanced that the "Calymene blumenbachii ought to be carefully sought for in the rocks which are said to correspond to the Dudley period. Unless it is found, or some other consideration is introduced, can it be believed that fossils are a satisfactory evidence of the age and place of rocks?" The line of demarcation between rocks of different age has never yet been drawn with any accuracy by the aid of paleontology, except by the consideration of groups of species, one or even a few species having no weight whatever in the determination. Thus the shell termed *Terebratula Schlotheimii* dates its existence with the Trenton limestone, and reappears in three of the latter formations of the Silurian system. *Orthis testudinaria,* Dalm., is peculiarly characteristic of the Trenton limestone, by its almost invariable presence and extreme abundance, and yet it is also found in the limestone of the Helderberg, a formation of a far more recent origin. But, although a few species may have been continued through a succession of geological eras, the

[1] Cherty limerock or Corniferous limerock, proposed as the line of reference for State geologists of New York and Pennsylvania. Am. Jour. Sci., vol. 36, 1839, p. 67.

[2] Second annual report of the paleontological department of the survey. Third annual report of the geological survey of New York, 1839, p. 58. Albany.

groups are widely distinct, and their value in determining the comparative age and identity of formations can never again be called in question by a geologist who deserves the name.

Attention is called to the fact that no observer has yet drawn the line of distinction between the Trenton and the newer limestone superimposed upon it in Ohio and Kentucky, because the similarity in mineral character and color is so perfect, and both formations thin out into mere seams and layers. It is also stated that the catalogues of organic remains of the Silurian system hitherto published in Europe are calculated only to mislead and confound the geological inquirer, as they are far too vague.[1]

In 1840 Mr. Conrad instituted a series of comparisons of formations of the New York section with those of England, based upon the fossils contained in their respectative formations. He compares the Caradoc sandstone with the limestone of Trenton Falls, and the Wenlock shale with the Rochester shale, and the Wenlock limestone with a limestone developed in the Helderberg Mountains.[2]

In the fifth annual report on the paleontology of New York we find the following remarks applied to correlation of the rocks of the State:[3]

The horizontally and undisturbed condition of the strata have enabled us to trace their sequence or order of superposition with comparative ease and greater accuracy than can always be obtained in regions where the formations have been much inclined or distorted. These divisions or series are usually composed of various layers, as compact limestone associated with friable shale, sandstone alternating with argillaceous shale, etc., and these modifications of their mineral constituents are generally accompanied by some variation of the organic contents; new species have been introduced, or more ancient ones have disappeared. But it is only at the junction of two formations that each *group* of organic remains is not perfectly distinct and characteristic, a mixture of species sometimes occurring which proves a gradual transition from one era to another, and gives rise to some uncertainty where the exact line of demarcation should be drawn. This fact opposes the idea sometimes indulged by speculative geologists, that sudden convulsions of the earth's surface have been the cause of exterminating forms of life, and the introduction of others to supply their place. The change seems rather due to alteration of temperature in the water, whatever new physical conditions of the earth resulted at the same time. Such phenomena, however, do not interfere with the general distinctive characters of the stratigraphical divisions adopted in this work. It is now, I believe, an undisputed point in geology that certain groups of organic remains belong exclusively to certain formations, and that these strata, in a general way, may be known and compared by the same groups of genera, if not species, in every region of the earth. It is also established, that whilst some genera and many species are restricted to a single formation, others have originated at an early period and continued to exist throughout a large portion of the time occupied in the deposition of a system or series of formations. * * *

The color and even mineral character of a formation usually varies greatly over an extended region, but it may be recognized by its fossil contents; for example, the black slate of the Mohawk, characterized by a peculiar trilobite, Triarthrus, which

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[1] Op. cit., p. 59.

[2] On the Silurian System, with a table of the strata and characteristic fossils. Am. Jour. Sci., vol. 38 1840 pp. 87-91.

[3] Fifth annual report on the paleontology of New York. Fifth Annual Report of the Geological Survey of New York, 1841, pp. 25-27. Albany.

has never been known to occur in any other geological position, is represented by a drab-colored shale in the vicinity of Cincinnati, Ohio. There also the equivalent or continuation of the black limestone of Trenton Falls is of a gray or pale hue, and could be known as the same rock only by its organic reliquiæ. The Caradoc sandstone series of Wales is represented in New York by limestone and slate in proportion equal to the arenaceous strata.

Hall.—The desirability of naming formations from typical exposures to serve as standards of comparison for the purpose of correlation was enunciated by Prof. James Hall very clearly in 1839, as follows:

Everyone who has studied rocks even partially is aware of the insufficiency of mineral or lithological characters for giving nomenclature, and the many errors into which he may be led, whether in his own researches or by the mistakes of others. So likewise in the present state of our knowledge we are unable in all cases to give names from fossil characters; for, though without doubt every group embraces its peculiar fossils, yet in all localities these may not be so marked as to excite attention, and in some may possibly be absent. It thus becomes a desideratum to distinguish rocks by names which can not be traduced, and which, when the attendant circumstances are fully understood, will never prove fallacious. The basis of this nomenclature is derived from localities, and the rock or group will receive its name from the place where it is best developed.[1]

He then proceeds to name the "Rochester shale" from Rochester, New York, and the Lockport limestone from Lockport, New York.

In 1843, after stating the general results of an examination of a section southwest from Cleveland to the Mississippi River, he wrote:[2]

From the facts here stated the conclusion seems unavoidable, that the character of fossils is, or may be, as variable as lithological characters; in fact, that the species depend in some degree upon the nature of the material among which they lived. Fossil characters therefore become of parallel importance to the lithological; and, in order to arrive at just conclusions, both must be studied in connection, and localities of proximity examined. In the case of the Hudson River group of shales and sandstones, in passing from New York to Ohio, the lithological character is almost entirely changed; and at the same time also the most prominent and abundant fossils are unlike those of the group in New York. More careful examination, however, reveals the fossils which characterize this group at the East, and also at the same time some obscurely similar lithological characters. Similar lithological changes, accompanied by like changes in fossils, occur in more limited districts within the State of New York.

The most marked and important changes, however, appear to be in the higher rocks of the New York system. The Hamilton group and Marcellus shale, which in New York have a thickness of 1,000 feet, have diminished to 100 where last examined; and from being the group most prolific in fossils, as it is in New York, it has become entirely barren of them. The rocks forming the Portage and Chemung groups, which in their greatest development in New York are scarcely less than 3,000 feet in thickness, and in Pennsylvania much more, have in Indiana diminished to as many hundred. The upper of these groups, from being extremely fossiliferous, has become almost destitute of these characters, so that, at the farthest extreme examined, they furnish but an equivocal guide. In these groups lithological character is more persistent than fossils, and it requires a knowledge of the superposition to identify them satisfactorily. The greater thickness of these sedimentary deposits, and the greater

[1] Third Annual Report of the 4th Geological district of New York. Third Annual Report of the Geological Survey of New York. Albany, 1839, pp. 288, 289.

[2] Notes explanatory of a section from Cleveland, Ohio, to the Mississippi River, in a southwest direction; with remarks upon the identity of the western formations with those of New York. Assoc. Am. Geol. Trans., 1843, pp. 289–291.

development of fossils occurring at the same point, proves the organic forms to have flourished in a littoral position; and beyond these points, where the thinning of the strata indicates a greater distance from the shore the fossils diminish, and at the more distant and deeper points are not found at all. There is no evidence of denudation in these instances, and if there had been the parts left would have retained the same fossils, had it ever contained them, as they do farther east.

Throughout that part of the ancient ocean now occupied by Ohio, Indiana, Michigan, Illinois, and even to the west of the Mississippi, there appears to have been comparatively a small number of living forms existing from the period of the final deposition of the Helderberg limestones to the commencement of the Carboniferous period; while in New York, during the same period, there were a greater number of forms and individuals than in all the preceding periods. Without desiring to diminish the value of fossil characters as means of identifying strata, it must still be acknowledged that similar conditions in the bed of the ocean, and apparently similar depth of water, are required to give existence or continuation to a uniform fauna; and when we pass beyond the points where these conditions existed in the ancient ocean, we lose in the same degree the evidences of identity founded upon fossils. Some species, it is true, have lived onward through successive depositions, often of very different nature; yet, at the same time, these may not have had a very wide geographical range. In the case before us, some species have lived during the deposition of all the rocks from the Hamilton through the Chemung groups, and yet they have never extended themselves as far westward as Ohio and Indiana, although the nature of the deposits there was as favorable to their existence as in New York.

For the distance of 100 or 200 miles from the shores of the present continents the forms may be similar—we know not but they are—still who can say what changes may occur, or whether any exist in the depths 1,000 miles from land? From the nature of sedimentary deposits it can be only the finer parts that ever reach to great distances from their origin; and, reasoning thus, the fauna of the deep and distant parts of the ocean, if any exist, would be uniform, not being liable to destruction or change of condition from the rapid invasion of variable deposits like those near the shore. The deposition of a coarse sandstone or conglomerate succeeding to a shaly mass would in all probability destroy the greater number of living forms as far as it extended. But at the same time, the finer materials produced by the same cause would extend far beyond the limits of the coarser, and thus approximating in some degree to the lower mass, the fossils might be continued long after they were destroyed at another point.

One of the most interesting changes in the products on going westward is the great increase of carbonate of lime and the diminution of shaly and sandy matter, indicating a deeper ocean or greater distance from land. The source of the calcareous deposits is thus shown to have been in that direction, or in the southwest, while the sands and clays had their origin in the east, southeast, and northeast, producing a turbid condition in the waters of these parts during long intervals, which was unfavorable to the production of calcareous matter and the formation of chemical deposits. In New York we are evidently upon the margin of this primeval ocean, as indicated in the character of the deposits as well as organic remains; the southwest unfolds to us that portion where greater depth and more quiet condition prevailed.

At a later date he said:

I have met with no essay upon the geographical distribution of fossils in the older rocks; and the few facts here and there gleaned serve rather to stimulate than to satisfy curiosity. It has been a favorite opinion of many, and frequently advanced, that the condition of this ancient ocean was uniform and its depth *moderate*, and that the uniformity of organic products affords proof of the same. Without pretending to refute any theories or to establish general conclusions for the whole continent or for the whole globe, I shall merely offer a few facts which have fallen under my own observation, and this with the hope of calling the attention of other observers to the subject and aid in deciding the true cause and amount of variation in paleozoic characters when examined over wide districts. We shall doubtless be led eventually to see in all these changes the influences of *depths of water, distance from or proximity to land*, and *the influence of the nature of that deposit* which formed the bed of the ocean, on which the animals lived. Every one of these causes, and perhaps other minor ones, have influenced the present character and condition of our older fossiliferous deposits. All these circumstances influence the organic productions of our present ocean, whatever may be the climate; and we have every proof that the same causes operated in this ancient sea, where, although depth and temperature may have been more uniform, yet these could not have been paramount to all other influences.[1]

He then proceeds to correlate the strata of the Mississippi Basin with those of the New York section by means of the contained fossils, and where possible the order of stratigraphic succession.

Emmons.—In a geological report of the midland counties of North Carolina, Dr. E. Emmons, in 1856, speaks of the classification of the sediments and says in this connection:

Superposition is, however, the highest proof of age, the oldest occupying the inferior position.

The bearing which fossils have to any scheme of classification which has been proposed can be understood only by a knowledge of the following laws: (1) *That species or kinds have had a limited duration;* (2) *that there has been a succession of species;* and (3) *that the species of one period, and which have become extinct, have never lived in any future period.* The utility of the knowledge of fossils is based on these three laws. This knowledge is particularly useful in comparing rocks which are widely separated from each other, or in those cases where direct superposition can not be observed. If, for example, certain rocks in Canada furnish a group of fossils similar to those of a given series in Tennessee, the inference would be that they belonged to the same period and hence occupy the same geological position; or, if we compare the fossils of the coal formation of England and America it will be found that they are almost identical; and it is proved also that the position relatively is the same in both countries, though separated from each other 3,000 miles.[2]

The extension of the New York section to the south along the line of the Appalachian Mountains was principally the work of the Rogers Brothers and Prof. Safford.

Rogers.—As geologists Messrs. H. D. and W. B. Rogers traced the the formations by stratigraphic continuity, lithologic characters, serial relation, and the presence of similar fossils as in the Trenton limestone, etc. I have not met with a statement of their views of geologic correlation except in incidental remarks. In a reply made to Prof. James Hall, who had congratulated the Profs. Rogers that they had borne such able evidence to the value of organic remains in determining the age of rock, Prof. W. B. Rogers said:[3]

That they had not been understood on this point; they had followed out the intricate structural geology of Pennsylvania and Virginia, relying chiefly on lithological characters, and had found to their great gratification that they had been working in parallel planes to the New York geologists, whose labors among the regular and

[1] Nature of the strata and geographical distribution of the organic remains in the older formations of the United States. Boston Jour. Nat. Hist., vol. 5, 1845, pp. 2, 3.

[2] Geological report of the midland counties of North Carolina. New York and Raleigh, 1856, p. 24.

[3] A system of classification and nomenclature of the paleozoic rocks of the United States, with an account of their distribution, more particularly in the Appalachian Mountain Chain. Am. Jour. Sci., vol. 47, 1844, p. 112.

horizontal strata of that State, relying on the evidence of fossil remains, had brought out results in the main quite consistent with the determinations of the Virginia and Pennsylvania strata.

In an address before the Association of American Geologists and Naturalists, Prof. Henry D. Rogers, in speaking of the tracks in the sandstone of the Connecticut Valley, says:

Of the organic remains, through an investigation of which alone we can hope to establish the position of these strata in the scale of time, or reach definite conclusions respecting the physical conditions under which they were produced, the most instructive are the remarkable bird tracks, brought to light by Prof. Hitchcock, in Connecticut and Massachusetts.

Guided by mere lithological resemblance, Maclure imagined this stratum to be the equivalent of the Old Red Sandstone of England.[1]

These passages imply that Prof. Henry D. Rogers considered paleontological evidence of the highest value in correlation, although in his work in Virginia he relied largely upon stratigraphic relations and lithology for the correlation of the Virginia with the Pennsylvania formations.

The correlation of the sandstone beneath the Trenton and Magnesian limestones of Pennsylvania, by Prof. H. D. Rogers and those that succeeded him, was based upon the stratigraphic position of the sandstone and the presence of *Scolithus linearis*, a fossil believed to be common to the Potsdam sandstone of New York and the lower sandstone of Pennsylvania.

The evidence of the identity of the sandstone with that of the Potsdam sandstone of New York, on the stratigraphic succession and position, is as follows:

(1) The formation is beneath a series of limestones, a portion of which is identified with the Trenton limestone by the contained fossils.

(2) The sandstone rests unconformably upon the crystalline gneisses forming the basal rocks of the Paleozoic period of Pennsylvania.

(3) The lithologic characters of the sandstone formation corresponded to that of the Potsdam sandstone of New York.

The paleontologic evidence is the presence of the annelid borings called *Scolithus linearis* in the sandstone of New York and Pennsylvania.

When once established this correlation was adopted and used by the first survey of Pennsylvania and also the second, but not altogether without protest by some of the workers in the latter. Mr. d'Invilliers[2] calls attention to this correlation of the Potsdam in the following words:

It would be safer to name this formation the *Reading sandstone*, but in the descriptions of its outcrops along the Little Lehigh, the Lehigh, and the Delaware Rivers, in Vol. I of this report, it has been called *Potsdam sandstone*, taking for granted that any sand formation underneath the Magnesian limestones of the Great Valley must be the same sand formation which in northern New York underlies the Corniferous [Calciferous?], Chazy, and other limestones of the Mohawk Valley.

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[1] On American geology and present condition of geological research in the United States. Am. Jour. Sci., vol. 47, 1844, p. 248.

[2] The geology of the South Mountain Belt of Berks County. Second Geol. Surv. of Penn., D3, vol. 2, 1883, p. 99.

On the map of Adams County, based upon the results of geological work of Dr. Persifor Frazer, the quartzite resting upon Azoic is identified as Potsdam, with a question mark.

Safford.—In his first report upon the geology of Tennessee, Prof. J. M. Safford describes the method of the grouping of the strata into formations. He says:[1]

We often meet with a series of adjacent strata similar in many respects, so much so that they can conveniently be thrown together in a single *group* or *formation*, as such a series is often termed.

He says further:

For example, the *sandstone, slates,* and *coal* which form the upper part of the Cumberland Table-land, are grouped in a *formation*, called the *Coal Measures*, with the following among other common characters: *First*, coal is found at intervals throughout the series; *secondly*, there is very little limestone or calcareous matter in the series; *thirdly*, the strata are parallel, and appear to have been formed in succession, under similar circumstances; *fourthly*, the same *fossils*, such as different species of petrified shells, leaves, branches, and trunks of trees, etc., occur imbedded in the rocks throughout the length and breadth of the series. *Characters* similar to these unite the strata of all the formations.

The character last mentioned we must refer to more particularly, on account of its great importance in designating with precision the group to which local and isolated beds of rock belong.

In defining the use of fossils it is stated that each formation has, in great part, its own fossils.

Most of those found in one do not occur in any other. Upon this fact depends their great utility. They furnish, when known well enough to be recognized, unmistakable evidence of the geological position, and hence the general character of the formation in which they are found.

From these observations of Prof. Safford we postulate the principles of correlation which he used, as follows:

I. Stratigraphic position.
II. The occurrence of similar fossils.
III. Lithologic characters.

CANADA.

The New York series was traced into Canada by Sir Wm. E. Logan and his associates and correlations made by direct stratigraphic connection, and in the absence of that, paleontologic data, stratigraphic relations, and lithologic characters.

Logan.—In speaking of the stratigraphic succession of the New York and Canadian sections Sir W. E. Logan makes the following reference to the fossiliferous limestone above the Calciferous sandrock, or the Trenton limestone:

The lowest of the fossiliferous strata is a sandstone of variable quality, more purely siliceous towards the bottom, and calciferous towards the top, which gives support to a thick and remarkably persistent deposit of limestone, strongly distinguished by its organic remains. This limestone thus becomes an admirable means of tracing

[1] A geological reconnaissance of Tennessee; first biennial report, Nashville, 1856, pp. 130, 131.

out the perimeter of the great western area under consideration. From the northwest border of North Carolina it sweeps in a broad belt across Virginia to the junction of the Shenandoah and Potomac. Thence traversing Maryland, it passes through Pennsylvania by Harrisburg, on the Susquehanna, and Belvidere, on the Delaware, accompanied up to this point by the underlying sandstone. Diminished in its thickness, it thence crosses New Jersey, and reaching Poughkeepsie it passes up the valley of the Hudson and Champlain, keeping to the east of the river and the lake, and attains the neighborhood of Missisquoi Bay. Entering Canada, it proceeds towards Quebec, and it reaches the vicinity of that fortress; but I am not yet aware of the precise spots at which it is visible in its course thither, farther than that I have been informed a stratified limestone answering its condition is quarried and burned in the Seignory of St. Hyacinthe, east of the Yamaska River.[1]

He states that the city of Quebec does not stand on this limestone, but it is found below the city on the north shore of Beauport and farther down the river to Cape Tourment. Following up the valley of the St. Lawrence, it is found to run along the foot of a range of syenitic hills, and it leaves the river in the vicinity of Montreal and again appears in the Ottawa Basin. He then describes its extension south along the valley of Lake Champlain, and west through the valley of the Mohawk and Black River and north of Lakes Ontario, Huron, and Michigan, to Wisconsin, following thus the correlation made by Hall.

NEWFOUNDLAND.

The extension of the Canadian nomenclature to Newfoundland was the work of Messrs. Logan and Billings. In tracing the Paleozoic formations down the St. Lawrence River from Montreal, Logan found that a series of sandstones occurs beneath the Calciferous sandrock, which was well recognized beneath the Trenton limestone. The sandstones rested unconformably upon the subjacent Archean. A long interval exists between these exposures and those on the north side of the Straits of Belle Isle, where sandstones and limestones are superjacent to the Archean. In his first expression of opinion he calls the sandstones the Potsdam, from their stratigraphic position and lithologic character. When the fossils which were obtained from the associated limestones were examined by Mr. Billings and found to be identical with those that he had referred to the Lower Potsdam in Vermont, the strata on the north side of the Straits of Belle Isle were referred without reserve to the Potsdam horizon, and those occupying a similiar position on the west of Newfoundland were also similarly referred.[2]

When correlating the Lower Cambrian sandstones and slates of northern Vermont with the limestones and sandstones of the north shore of the Straits of Belle Isle, upon the lithologic and paleontologic similarities between the two deposits, Mr. E. Billings states that although 860 miles distant from each other there can be little doubt that they are of the same age.

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[1] [Account of general structure of an extended area in North America.] Geol. Survey Canada, Report of Progress for 1843, 1845, p. 8.

[2] Geological Survey of Canada; Report of Progress from its commencement to 1863, pp. 97, 288, 289, 864, 865. Montreal, 1863.

The occurrence of *Scolithus linearis* and the general aspect of the fossils also show that these rocks must be very nearly, if not exactly, in the same geological horizon with the Upper Primal sandstones and slates of Pennsylvania.[1]

The Lower Paleozoic rocks of Newfoundland were correlated with those of Canada by Sir W. E. Logan upon the evidence of the fossils and their stratigraphic position. The fossils were identified by Mr. Billings, and the stratigraphic geology was studied by Messrs. Richardson, Murray, and Howley.

Dana.—Prof. J. D. Dana availed himself of the correlations made by the New York, Canadian, and other surveys in the preparation of the earlier editions of his Manual of Geology. The Manual is a masterly compilation of the available data upon broad principles of correlation, and as it went at once into the hands of all American geologists and students its influence has been widespread. The principles of correlation mentioned are outlined in the following paragraphs:

But the question may arise whether a geological age is not, after all, strongly marked off in the rocks. Rocks are but the moving sands or the accumulations of dead relics of the age they represent, and are local phenomena, as already explained. Each continent has its special history as regards rock-making, and it is only through the fossils in the rocks that the special histories are combined into a general system. Movements have in all ages disturbed one hemisphere without affecting the other, causing breaks in the succession of rocks in one continent or part of a continent that have no representatives in another.

When an age can be proved, through careful study, to have been closed by a catastrophe or a transition which was universal in its effects, the event is accepted as a grand and striking one in geological history. But the proof should be obtained before the universality is assumed. Hence the conclusion:

Fourthly. The grander subdivisions or ages in geological history based on organic progress should be laid down independently of the rocks. They are universal ideas for the globe. The rocks are to be divided off as nearly as practicable in accordance with them.

Each continent, under these ages, then becomes a special study, and its history has its periods and epochs which may or may not correspond in their limits with those of the other continents. Every transition in the strata, as from limestone to sandstone, clay beds or conglomerate, or from either one to the other, and especially where there is also a striking change in the organic remains, indicates a transition in the era from one set of circumstances to another; it may be a change from one level to another in the continents, a submergence or emergence or some other kind of catastrophe. All such transitions mark great events in the history of the continent, and thus divide the era into periods, and periods into epochs, and epochs, it may be, into subepochs. Hence—

Fifthly. Through the ages each continent had its special history; and the periods and epochs in that history are indicated by changes or transitions in the rock formations and their fossils.

It is greatly to the assistance of research that some of the revolutions of the globe have probably been nearly or quite universal. The one preceding the Mammalian age appears to be an example; although, even with regard to this, further investigation is required before its actual universality can be regarded as established. But the periods and epochs of America and Europe are not in general the same in their

[1] Paleozoic fossils. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. Vol. 1, 1860-1865, p. 2. Montreal, 1865. First printed in 1861 in a bulletin issued by the Geological Survey of Canada.

limits. A near contemporaneity in rocks may be proved, but not in the transitions from one rock to another. For example, the Devonian age has a very different series of periods and epochs in North America from what it has in Europe, and there is even considerable diversity between the epochs of New York and the Atlantic slope and those of the Mississippi Valley. The Carboniferous, Reptilian, and Mammalian ages also have their American epochs and their European, differing from one another; and the differences between the continents increase as we come down to more modern times. There are Tertiary and Cretaceous rocks in America as well as Europe, but there is little reason for the assumption that the transitions from one set of Tertiary or Cretaceous strata to another were, in the two, contemporaneous. The point should be proved, not assumed. We add, therefore,

Sixthly. It is an important object in geology to ascertain as nearly as possible the parallelism between the periods and epochs marked off on each continent, and study out the precise *equivalents* of the rocks, each for each, that all the special histories may read as parts of one general history, and thus contribute to the perfection of one geological system.[1]

MISSISSIPPI VALLEY.

The Lower Paleozoic rocks of this region were correlated with those of New York by Messrs. Owen, Locke, Hall, and others, usually without stating the data except by implication (e. g., speaking of the Trenton limestone of New York as a limestone carrying certain fossils and superjacent to a marked formation, the Calciferous sandrock of New York or the Lower Magnesian limestone of Wisconsin, etc.). Thus the correlation is based upon stratigraphic position, presence of similar fossils, and lithologic characters.

Hall.—The following observations by Prof. Hall are a good illustration of the method by which the Potsdam sandstone of New York was correlated with the lower sandstone of the Mississippi Valley section:[2]

In comparing the older rocks of New York and of the East generally with those of the West it should not be forgotten that there is a long interval on the line of the northern outcrop of these ancient strata between the St. Lawrence and the western limit of Michigan on the Menomonee River, where we can expect little aid from paleontology. The fossiliferous beds of these ancient formations in Wisconsin lie to the west of what appears to have been a great promontory at the time of their deposition, stretching southward from the region of Lake Superior far into the ancient sea. The disconnection caused by this promontory between the East and the West would of itself prepare us to expect a fauna differing in a great degree from beds of corresponding age on the opposite sides.

It has been shown by the investigations of the Canadian Survey that not only the Potsdam sandstone but all the fossiliferous beds below the Birdseye and Black River limestones are absent from Kingston, on Lake Ontario, to Lacloche, on lake Huron. From Lacloche to Lake Superior there is a sandstone coming in below the Birdseye limestone, which, from its position, may be considered as of the age of the Chazy[3] for-

[1] Manual of Geology, 1st ed., New Haven, 1863, pp. 126-128.

[2] Preliminary notice of the fauna of the Potsdam sandstone, with remarks on the previously known species of fossils and descriptions of some new ones from the sandstone of the Upper Mississippi Valley. 16th Ann. Rep. Reg. State Cab., Nat. Hist. N. Y., 1863, pp. 211-213.

[3] The 'Chazy formation' of the Canadian Geological Survey, in its eastern localities includes a sandstone which comes in below the greater part of the limestone, leaving from 10 to 20 feet of shale and limestone beneath (Geology of Canada, 1863, p. 123). It is apparently this sandstone of the Chazy formation, having in Canada a thickness of 50 feet, which has become augmented in its western extension while the calcareous part of the formation has partially or entirely disappeared.

mation and equivalent to the St. Peters sandstone of Wisconsin and Minnesota, and it is this sandstone, doubtless, which has been taken for the Potsdam sandstone in some localities along that line.

The succeeding Birdseye and Black River formation from Lacloche to Lake Superior has become a buff-colored magnesian limestone, or weathering externally to this color, but still holding the characteristic fossils.

In New York a sandstone (the Potsdam) lies immediately beneath a magnesian limestone (the "Calciferous sandrock"); this deposit is succeeded by a calcareous formation (the Chazy), including a sandstone and surmounted by the Birdseye, Black River, and Trenton limestones.

In Wisconsin, Iowa, and Minnesota we have undoubted Trenton limestone, and below it a buff-colored magnesian limestone containing so many of the characteristic fossils of the Birdseye and Black River limestones as to leave no doubt of the parallelism of these beds with those of New York. Below this magnesian limestone we have the St. Peters sandstone, corresponding, as already shown, with the Chazy formation, and beneath this a magnesian limestone, which, in its position and lithological character, corresponds in all respects with the "*Calciferous sandrock*" of New York.

It is from all these facts that the lower sandstone of the Upper Mississippi Valley has been placed in parallelism with the sandstone of New York known as the "Potsdam."

Notwithstanding, however, that this sequence is precisely like that observed in New York it may not yet be regarded as proved that the sandstone from which I have described these fossils is in all respects the equivalent of the Potsdam sandstone of New York, Vermont, and Canada. It may represent more or it may represent less than that formation. The *lower* accessible beds of the Mississippi Valley may represent the Potsdam of 150 or 200 feet in thickness in the typical localities in New York, while the middle and upper beds of the West may be of epochs not represented in that part of the series studied in New York; and in some other places, as in the regions just mentioned, the same epochs may be represented by a shaly or semi-calcareous deposition, or may be included in the commencement of the Calciferous epoch. It should not therefore be regarded as decided that the Potsdam sandstone, as developed in New York, occupies the entire interval from the base of the oldest sedimentary formation of the Paleozoic era to the Calciferous sandstone. From what we know of the Primordial fauna in other localities we are prepared to find beds above or below, or both above and below, the epoch represented (so far as now known) by the Potsdam sandstone of New York, and which may still be of the same period.

Winchell.—It is stated by Prof. N. H. Winchell that—

It has been abundantly proved that the red sandstones of Lake Superior, however disturbed and changed locally, or however much increased in thickness by the agency of volcanic outbursts, are the exact equivalents of the New York *Potsdam*. They occupy the first position over the metamorphic slates of the *Huronian* rocks on which they lie unconformably, and from which they differ in being but slightly and only locally metamorphosed. They retain usually their evidently sedimentary characters, and have not well preserved fossil remains.[1]

He also publishes a table showing the number of species common to various Silurian formations of the Lake Superior district and New York State, and calls attention to the fact that three species only are found in the Lake Superior sandstone and the typical Potsdam sandstone of New York.

[1] General sketch of the geology of Minnesota. Geol. and Nat. Hist. Survey, Minnesota, 1st Ann. Rep. for 1872, 1873, p. 68.

The correlation by Prof. N. H. Winchell of the "Granular Quartz" and the "Red sandrock" of Vermont with the "Potsdam" sandstone of the Upper Mississippi Valley and the "Primordial" quartzite of the Northwest appears to be based upon the fact that the "Granular Quartz" of Vermont and Massachusetts rests unconformably upon the Archean, and that a similar quartzite is superjacent to Archean rocks in the Mississippi Valley. This same principle of correlation appears in his statement that the stratigraphic relations of the "Granular Quartz" and the Potsdam of New York are the same. He says: "In the first place, they are seen to lie unconformably upon the older granite."[1]

Messrs. N. H. Winchell and H. V. Winchell correlated the Winooski marble series of Vermont with the Stockbridge limestone or marble belt of the southwestern portions of the State.[2]

This correlation is based upon (*a*) the assumed Primordial age of the iron-bearing limestones and shales of the Penokee-Gogebic range of Wisconsin and the Mesabi range of Minnesota, and their assumed stratigraphic identity with the limestones and shales of western Vermont, which correspond to the Stockbridge limestones and iron ores of western New England; (*b*) the known Cambrian age of the Winooski marble series.

Meek.—As paleontologist of the Hayden and other surveys of the interior and western continental area, Mr. F. B. Meek's influence upon the correlation of fossiliferous strata was important. His views upon correlation by paleontologic evidence are given in a report on the Paleontology of eastern Nebraska, as follows:[3]

> There are probably few well informed geologists who will at the present time maintain that the occurrence of a very similar or even the same group of fossils at widely separated localities necessarily proves the rocks in which they are found to be of exactly contemporaneous origin. The most that is now generally maintained in this regard is that such identity or correspondence of types at very distantly separated parts of the world indicates that the strata in which they are imbedded were formed during the prevalence of identical or similar physical conditions at some time during the same great geological epoch, and that they hold the same or nearly the same *relative* position in the geological column of their respective districts. For instance, although a stratum in the Rocky Mountains, containing the remains of very nearly the same fauna as some particular subdivision of the Devonian system of Europe, might, for aught we know, be hundreds of years older or newer than that particular division, we would have little or no room for doubting that it belonged to the great Devonian series, or possibly even to some definite, known horizon in that series. We could moreover very positively assert in such a case that it would be, according to all past experience, useless to seek there at any lower geological horizon for workable beds of coal, or to expect to find Silurian rocks or any of their pe-

[1] The crystalline rocks of Minnesota. General report of progress made in the study of their field relations. Statement of problems yet to be solved. Geol. and Nat. Hist. Survey of Minn., 17th Ann. Rep. for 1888, 1889, p. 49.

[2] The Taconic Iron Ores of Minnesota and Western New England. Am. Geologist, vol. 6, 1890, pp. 263-274.

[3] Report on the Paleontology of eastern Nebraska, in Final Rep. of U. S. Geol. Surv. of Nebraska, Washington, 1872, p. 83.

culiar products above, supposing there had been no overturning of the strata at the particular localities.

Hence, although paleontology does not enable us to ascertain the exact *actual* ages of rocks, when applied with due caution and skill in connection with a careful observance of their stratigraphical arrangement and lithological and other physical characters, it does afford the means of fixing their *relative* ages, as well as of identifying the same beds at different localities, within given fields of observation, with very considerable precision. It is therefore not merely *one* of the more important aids to the geologist in his investigations, but in the present state of geological science it is the only sure guide in classifying and determining the order of succession of rocks where this can not be done by their actual continuity or obvious superposition. For these reasons it is now the universal practice in all geological surveys conducted upon sound scientific principles to devote especial attention to this department.

ROCKY MOUNTAINS.

Whitney.—In speaking of the occurrence of the Primordial fauna in Nevada Prof. J. D. Whitney calls attention to the fact that the fossils are of Potsdam age, and that similar trilobites and brachiopods occur in Bohemia in argillaceous shales; throughout the United States, from New York to the Rocky Mountains, in the "Potsdam sandstone, or in the shales or slates;" in Texas and in Nevada, in limestone. He says:

> This discovery will also indicate the necessity of caution in theorizing on the geological structure and age of regions which have only been hastily examined. It will not do to put down every red-sandstone group below the Trias in the far west as "Potsdam," for that subdivision may be much lower down, hiding itself as a modest limestone of a very neutral tint of color.[1]

Although not stated, it is evidênt that the principle of correlation used is purely biologic, or the occurrence of similar fossil remains.

Bradley.—When describing the strata upon the western base of the Wasatch range, near Ogden, Utah, Prof. F. H. Bradley refers the quartzite, some 1,500 feet in thickness, to the Potsdam, and the gray and calcareous shales and limestones above to the Upper and Lower Silurian.[2] A reference to the Upper Silurian was on the assumption that the limestone was the same limestone as that found 25 miles to the north, in which the characteristic Niagara coral *Halysites catenulata* was obtained by Dr. Hayden in 1871. The data upon which the other correlations are made are not given. It is probable and almost certain that the presence of a quartzite beneath the limestone, supposed to be of Silurian age, was considered to be sufficient for the reference to the Potsdam sandstone. He correlates the glauconite sandstone beneath the limestone of the Teton range section, which carries Conocoryphe and Dikelocephalus, with the Knox sandstone of Safford, in Tennessee. Beneath them, and often present when they are absent, he found from 50 to 75 feet of a very compact ferruginous quartzite "which must represent the Potsdam."[3]

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[1] Note on the occurrence of the "Primordial Fauna" in Nevada. Am. Jour. Sci., 3d ser., vol. 3, 1872, p. 85.

[2] Report of Frank H. Bradley, geologist of the Snake River Division. U. S. Geol. Sur. of the Terr., 6th Ann. Rep. 1873, p. 194.

[3] Op. cit., p. 216.

It is evident that Prof. Bradley had in mind the Tennessee section, with which he was familiar, and on finding a quartzite, corresponding to the Chilhowee quartzite, and then a sandstone and shale corresponding in position to those of the Knox section, he correlated the two upon the evidence of serial relation of similar deposits and the presence of certain fossils in the limestone superjacent to the sandstone.

Fortieth parallel survey.—The correlations made by the fortieth parallel survey of the Paleozoic rocks of Utah and Nevada with those of the eastern part of the continent, especially the New York section, are based almost entirely upon the paleontologic evidence as determined by Messrs. Hall and Whitfield. Within the area of the survey correlations were made both on the stratigraphic succession of beds of different lithologic character, and the presence of similar organic remains. A correlation based on the "likeness of two great masses of rock to each other that occur beneath a known horizon" is made by Mr. Clarence King as follows:

> Comparing the quartzites and argillites with those of the Cambrian section in Wales, the likeness is too great to pass unnoticed, and in view of the enormous developments of these low-lying rocks as compared with the Silurian lying above the Primordial horizon, I have determined to draw a line at the upper limits of the Primordial period to include the uppermost members of the Potsdam epoch, and to consider the whole underlying conformable series as Cambrian down to the point of their nonconformity with the Archean.[1]

Explorations and surveys west of the one hundredth meridian.—The correlations made in the publications of this survey on the Lower Paleozoic rocks are mainly by Mr. G. K. Gilbert in his report on the geology of portions of Nevada, Utah, California, and Arizona.[2] The data used for correlation are, the stratigraphic position, lithologic characters, and the presence of fossils of previously determined range. No attempt is made to correlate by a study of the minor details of the faunas and strata except in the correlation of the Tonto of the Grand Cañon district with the Primordial formations of the East. From the known position of the genus Cruziana he argues that the beds containing it are Lower Silurian or Primordial. Mr. F. B. Meek compares the species of Olenellus found in central Nevada with *O. thompsoni* and *O. vermontana* of Vermont and thus indirectly correlates the faunas.[3]

Geological surveys of the Territories.—The correlations made by the various writers of the Powell and Hayden surveys were principally based upon the paleontologic determinations of Mr. F. B. Meek and Dr. C. A. White outside the territory of the survey, and within its territory on stratigraphic positions, lithologic character, and fossils when present. In most instances the data for correlation are not given, the identification of the formations following that of previous workers in the same territory. An example of this is found in the "Geology of the

[1] Paleozoic subdivisions on the 40th Parallel. Am. Jour. Sci., 3d ser., vol. 11, 1876, p. 476.
[2] Expl. and Surv. West of 100th Merid., vol. 3, 1875, pp. 156–171.
[3] Op. cit., pp. 182, 183.

Black Hills of Dakota," where a sandstone characterized by Upper Cambrian fossils is identified without comment as the Potsdam sandstone.

U. S. Geological Survey.—In the consolidation of the various Government surveys and their reorganization under one head in 1879 the opportunity for broad comparisons and studies was increased, and the opportunities were still further increased in 1881, when the survey was extended to include the entire area of the United States. In the Rocky Mountain Province the correlations of the fortieth parallel survey were accepted, and extended in the abstract of the report on the geology of the Eureka district of Nevada.[1] In the report on the paleontology of the district the paleontologic data upon which the correlations were made are assembled and described.[2] In this it is shown that while correlations between the great groups may be extended between the Appalachian Province and the Rocky Mountain area, it is impossible to correlate the minor divisions of the groups.

In 1886 an extended correlation of the rocks and fossils from the Lower Cambrian, then called Middle Cambrian, was published in Bulletin No. 30 of the U. S. Geological Survey.[3] Typical sections are given of the Cambrian rocks of the Atlantic Coast, Appalachian, and Rocky Mountain Provinces, with the names of the species of fossils occurring in the various zones, and on page 44 the various sections are correlated and grouped in a table to show their relative range. The principles of correlation are not enunciated, but those used, as shown by the text, are the stratigraphic position of the faunas in relation to each other in the same province and a comparison of the faunas in one area with those of another.

In a more recent work[4] the correlations are made between the various horizons of the Cambrian of the United States on the stratigraphic position of the strata and the occurrence of similar groupings of organic remains. It is observed that the presence of the Olenellus fauna is regarded as the strongest factor in the correlation of the Lower Cambrian, and it is assumed that the presence of this fauna indicates the same geologic horizon. It is not implied that the formations characterized by the Olenellus fauna are strictly contemporaneous wherever it has been found. On the contrary, its presence in such widely separated localities as England, France, Spain, Nevada, and British Columbia is considered as prima facie evidence that the deposits are not strictly contemporaneous. That they were contemporaneous in a geologic sense or that they occupy the same relative position in the geologic series is accepted throughout the paper.

[1] Third Ann. Rept. U. S. Geol. Survey, 1883, pp. 248-272.

[2] Mong. U. S. Geol. Survey, vol. 8, 1884.

[3] Walcott, C. D.: Second contribution to the studies of the Cambrian faunas of North America. 1886.

[4] Walcott, C. D.: The fauna of the Lower Cambrian or Olenellus zone. Tenth Ann. Rept. U. S. Geol. Survey, 1890, pp. 509-763.

In his extended and valuable essays upon the history of the names Cambrian and Silurian in geology and the Taconic question in geology, and numerous other minor papers, Dr. T. S. Hunt[1] clearly sets forth the description of the various strata referred to the Cambrian and Silurian in America and Europe, and shows by testimony of different writers the relations the various formations sustain to each other, both stratigraphically and in their geographic distribution. Nearly all, if not all, the original correlations made by him are based upon lithologic data, as he believes in a uniform development and sequence of lithologic forms from earlier Archean time to the deposition of the fossiliferous sedimentary rocks. The correlations within the latter are largely made upon their stratigraphic, lithologic, and paleontologic characters as mentioned by authors.

CORRELATIONS WITH EUROPEAN FORMATIONS.

Numerous correlations were made between the strata of the formations of America and those of Europe by Messrs. Conrad, Owen, Rogers, Troost, Jackson, and others; but it was not until the investigation of M. Edward de Verneuil, in 1847, that correlations were made by one who had personally investigated the formations and fossils, both in Europe and America.[2]

De Verneuil.—He began his comparisons with the view that superposition was the foundation of paleontology; that the only comparisons that could be made between continents separated by a sea was by a study, in each of them, of a series of beds confined between two zones at well determined points; that their fossils must be compared, and the identical species picked out to see if the species are distributed according to the same laws. He concluded that, if it happens in the two countries that a certain number of systems, characterized by the same fossils, are superimposed in the same order, whatever may be otherwise their thickness and the number of physical groups of which they are composed, it is philosophical to consider these systems as parallel and synchronous. Comparisons were made between the strata in the two countries that occur beneath the coal-bearing or Carboniferous rocks. He noted that the Potsdam sandstone with Lingula is probably analogous to the sandstone with Obolus, of Russia, and the lower sandstones of Scandinavia. "These are in the two continents the most ancient pre-Carboniferous rocks."

The *siliceous* limestones, those of Black River and of Trenton, are the equivalents of a great part of the Lower Silurian stage of Europe, and they occupy the same posi-

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[1] History of the names Cambrian and Silurian in Geology. Canadian Nat., new ser., vol. 6, 1872, pp. 281-312, 417-448. The Taconic Question in Geology. Mineral Physiology and Physiography. A second series of Chemical and Geological Essays. 1886, pp. 517-686.

[2] Note sur le parallélisme des roches des dépôts paléozoïques de l'Amérique Septentrionale avec ceux de l'Europe, suivie d'un tableau des espèces fossiles communes aux deux continents, avec l'indication des étages où elles se rencontrent, et terminée par un examen critique de chacune de ces espèces. Soc. géol. France, Bull., 2e sér., vol. 4, pp. 646-709, 1847. Translated and condensed by Prof. James Hall, Am. Jour. Sci., 2d ser., vol. 5, 1848, pp. 176-183, 359-370; vol. 7, 1849, pp. 45-51, 218-231.

tion as the bituminous schists and the Orthoceratite limestones of Sweden and Russia. The Utica slate and the Hudson River group, with the Graptolites at their base, represent the Graptolite slates which in Sweden succeed to the red Orthoceratite limestone. They are also the same as those of Bain in France.[1]

Of the Upper Silurian rocks the Niagara group is considered the exact equivalent of the limestones and slates of Wenlock and of Gothland. The Clinton group, with *Pentamerus oblongus*, represents the extreme upper part of the Caradoc sandstone, or a stage intermediate between the Wenlock and Caradoc beds; while the five inferior groups of the Helderberg division represent the rocks of Ludlow. The correlation is then extended to the Devonian, and lists are given of identical species of fossils on the two continents.

Hall.—The essay of M. de Verneuil was followed in 1851 by a paper on the "Parallelism of the Paleozoic deposit of the United States and Europe," by Prof. James Hall. In discussing the criteria of correlation he says:[2]

The simplest principles of elementary geology teach us that sedimentary beds, having the same thickness and the same lithological characters, can not have spread over an area so wide as that now included between the European and American continents. All sedimentary deposits must vary in character at remote points, as the physical conditions of the ocean can not be presumed to have remained the same over a wide extent of surface. Under such circumstances absolute parallelism is not to be sought for or expected. Calcareous deposits, as would naturally be supposed, have been found to be more persistent and more uniform in the character of their fossil contents; but these, over some portion of their extent, have often been invaded by argillaceous and arenaceous sediments, and the fauna is found to be in a greater or less degree influenced by such circumstances. In distant and disconnected localities we are compelled to base our opinions of the equivalency of beds upon the organic remains which they contain; and when we reflect that the nature of the sediment may in a great degree influence the character of the fossils we shall not fail to recognize the necessity of keeping the character of these lithological changes in view. * * *

Besides the changes which take place in the nature of the sediment deposited upon the bed of the ocean, we are to look to other important conditions which may affect the fauna, and consequently our conclusions regarding the equivalency of formations. Among the most important of these is the depth of the ocean in which the animals lived, since we know that certain species are confined within certain zones, depending on the depth of the water.

There are other conditions which sensibly affect the distribution of organic life, such as temperature, pressure, and light. * * * In investigating the fauna of past ages we see nothing to lead us to believe that the same great laws which regulate the distribution of species did not then operate with as great effect as at the present time.

In speaking of the attempted correlation between the European and American rocks Prof. Hall remarks:

All the attempts to show that the parallelism of American and European paleozoic deposits have been with a view to find a correspondence with the European standard where the series is confessedly incomplete, and where it has suffered during its deposition, or subsequent to it, many disturbances.[3]

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[1] Op. cit., p. 361.

[2] Report on the Geology of the Lake Superior Land District, by J. W. Foster and J. D. Whitney; Part II, 1851, pp. 286, 287.

[3] Op. cit., p. 294.

The author agrees with M. de Verneuil that the Potsdam sandstone is represented in Russia by the beds containing Obolus and Lingula, and in Scandinavia by the sandstones which rest unconformably upon the gneissoid and schistose rocks composing the Azoic system. Of the Chazy, Birdseye and Black River limestones of New York he says:

They are not very clearly recognized in Europe. It is probable that some part of the Orthoceratite limestone of Sweden is the equivalent of the Black River mass; but we have no evidence, from fossils or otherwise, that there are any representatives of the two lower rocks. * * *

The Trenton limestone, the Utica slate, and the Hudson River group are represented in northern Europe by the Orthoceratite limestone of Sweden and Russia and by the shales with Graptolites, which succeed to that limestone. In Great Britain the Llandeilo flags and Caradoc sandstone are clearly the equivalent of these groups. It is here that we first find a number of species identical with European ones, and which enable us to institute a comparison. It will be found, however, that the species in the Hudson River group correspond most nearly with the European forms, and that it may be doubtful if the base of the Trenton limestone has been reached in Great Britain.[1]

The Clinton group, with its beds of *Pentamerus oblongus*, represents what in England is regarded as the upper part of the Caradoc sandstone; but we find it not only above this well marked horizon, which we have already indicated, but associated with numerous species of fossils, some of which are known as upper Silurian forms in Europe, and others pass into forms characteristic of the Niagara group in this country.

The Niagara group, with its shale and limestone, would seem, at first view, to be the exact equivalent of the shale and limestone of Wenlock and Dudley in England, and of Gothland in Sweden, so numerous are the identical species in these groups; but on examination we find that there are numerous species included in these rocks in Europe which occur only in the lower Helderberg limestones, and which are separated from the Niagara by the enormous deposit of the Onondaga salt group. It is clear, therefore, that in the Wenlock formation of England and its representatives in northern Europe are included parts at least of two distinct groups in the order of time—distinct both in their physical and zoological features; and we can not institute a proper comparison between the rocks of our own country and those of Europe while we regard that as one group. The condition, both in England and on the continent, is doubtless similar to what we find in Tennessee and Virginia, where, from the absence of the intermediate groups not only the Niagara and lower Helderberg are united together, but even the upper Helderberg limestones are superadded.[2]

Barrande.—A correlation based upon paleontologic data was made by Mons. J. Barrande, in 1853, between the formations characterized by the first, second, and third faunas of Europe and those included in the Silurian of America. In commenting upon the identification of the Russian *Obolus apollinis* Eichwald, by Owen, with the Potsdam sandstone species of the Upper Mississippi Valley, he says:

In fact I am inclined to think that science has passed out of the epoch when it was thought necessary to have identical species in order to recognize equivalence of geologic horizons, even at great distances on the earth's surface. The distribution of our present fauna teaches us that this means can not be altogether relied on to prove strata contemporaneous.[3]

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[1] Op. cit., pp. 295, 296. [2] Op. cit., p. 299.

[3] Barrande, J: (Silur-fauna in Wisconsin und in New York.) Neues Jahrbuch für Miner., 1853, p. 338.

The fact that the Paleozoic formations of America during the appearance and disappearance of three successive faunas, which despite some common species are on the whole well distinct, teaches us that the extinction and appearance of beings on the earth's surface are by no means determined exclusively by the physical revolutions of the crust, but are ordered and regulated by the laws of animal creation itself. Still, it is not my intention to follow out this consideration, as it would lead me too far. I merely wished to mention this, in passing, as a subject for further study, and to point out to investigators that paleontology leads to the establishment of a geologic chronology, independently of the more or less local revolutions which the fossiliferous strata have undergone since their deposition.[1]

From a study of the faunas of the two countries he considered that the first, second, and third faunas of Bohemia are to be identified in America; that there exist manifold relations in all classes of animals of the Upper Silurian division of the United States and Bohemia; that, in the first volume of Hall's Paleontology of New York, on the Lower Silurian division, from the Potsdam sandstone to the Hudson River group inclusive, he recognizes the First Silurian fauna of Bohemia, Sweden, and England; that the presence of the long-missed first fauna of Bohemia in America has been demonstrated in a very satisfactory manner by Owen in his discoveries in the northwestern United States; and that the occurrence of this fauna in the State of Georgia is indicated by a Conocephalus brought to England. In conclusion, he says:

Hence I am now perfectly convinced that the Silurian formations of North America, as well as those of the old continent, contain a succession of three different faunas, which, on being separately compared with the latter, are seen to consist of the same geologic elements and to follow each other in the same order. When I say that they consist of the same geologic elements you know already that I am far from wishing to maintain identity of species. I rely on other more general analogies which to me are not less convincing. This is not the place to explain this more in detail, as that would lead me too far; but you will find here and there in my work some passages which express my view of the matter. In admitting and recognizing in all Silurian regions of the two continents three general faunas corresponding and equivalent to each other, I am induced by the facts to pronounce a further result of my investigations, namely, that the local divisions of strata containing these great faunas, though greatly differing from each other in each region of a certain extent, are not equal to each other in the various countries, especially when the countries are far apart, geographically. This truth seems to me solidly established by a multitude of facts which are tabulated and compared in my geologic sketch, and is confirmed in a very satisfactory manner by the facts mentioned in volume 2 of J. Hall's Paleontology of New York.[2]

Rogers.—In a paper read before the British Association for the Advancement of Science in 1856, on the correlation of the North American and British Paleozoic strata, Prof. Henry D. Rogers described the Paleozoic section of the Appalachian region and that of England, and instituted comparisons between them, to show the parallelism of the North American and European Paleozoic rocks.[3] He says:

In attempting this correlation it should be remembered that nature represents no true or literal equivalency of strata, nor anything closer than a mere approximate

[1] Op. cit., p. 339. [2] Op. cit., p. 345.

[3] On the correlation of the North American and British Paleozoic strata. British Assoc. Adv. Sci., vol. 26, 1857. Trans. Sec., p. 184.

relationship where the deposits compared belong to independent basins, or even to the remote sides of the same great receptacle. The most we can hope to establish is a general agreement in time, with possibly a stricter synchronism of the few chief paroxysmal movements which agitated the bed of the ancient ocean. Partially *representative* formations are discoverable, but *equivalent* ones are not to be looked for upon any philosophical view, since the distribution of organic beings is essentially partial or geographical. The life horizons of the globe are no more universal than are its horizons of sedimentation. With these reservations we turn to the degrees of affinity, linking the American and European Paleozoic groups of fossils.

As the result of his correlation he concludes:

(*a*) The Appalachian Primal series is obviously nearly on the horizon of Barrande's Primordial zone and the lowest rocks of Russia and Scandinavia.

(*b*) The Appalachian Auroral strata may possibly be approximately contemporaneous with the Swedish Orthoceratite limestone. The Auroral series includes the Calciferous, Chazy, and Black River groups.

(*c*) The Matinal series of the Trenton and Hudson River groups, from the testimony of the fossils, are represented in Britain by the Llandeilo flags and Caradoc sandstone, or more generally by Sedgwick's Bala or Upper Cambrian group. He also finds a near equivalent in the Orthoceratite limestone of Sweden and Russia and in the Graptolite shales. The authority of Prof. Hall is cited to show the paleontologic similarity of the English and American formations.

(*d*) The Levant or Medina group does not appear to be represented in Europe.

(*e*) The Surgent and Scalent series, or Clinton and Niagara, are compared with the British Wenlock strata.

(*f*) The Pre-meridian series or Lower Helderberg. He quotes Mr. Hall as saying that he agrees with Mr. Sharpe and regards the Lower Helderberg strata as representing the Wenlock formation of England, while M. de Verneuil considers them as equivalent to the Ludlow. He then proceeds to correlate the Devonian formations with those of Europe.

His final conclusion is:

From all the foregoing facts and statements we arrive at this general inference, that upon both paleontological and physical evidence there is no well marked Silurian-Devonian break discernible in the North American basin, no proof of an epoch or general interruption in the life-stream, with wide crust disturbance in the middle Paleozoic ages, such as that which in earlier times, in the morning of the Paleozoic day, at the Cambro-Silurian transition, revolutionized alike the entire extent of the American and European areas, both in their inhabitants and in their physical geography.[1]

Bigsby.—A most elaborate comparison and correlation between the Paleozoic section of New York and that of Wales was made by Dr. J. J. Bigsby in 1859. He observes that "both these geological areas appear to have been constructed on the same great comprehensive principles and nearly of the same material, two most important considera-

[1] Op. cit., p. 186.

tions. One very great distinction between them, however, is that they have received different dynamic treatment, in the frequency of plutonic disturbance in Wales and its comparative absence in New York, such dynamic treatment involving, it must be kept in mind, both gradual and sudden changes of population. While the strata of these areas are formed of much the same mineral substances, the conditions of these, their order, and quantities are very varied."[1]

He sums up the points of zoological similarity under the following heads:

(1) The organic remains of both basins belong to the same orders and genera, unmixed with those of other sedimentary systems, as Permian, Jurassic, etc.

(2) Vertebrate animals were introduced at nearly the same date.

(3) The organic remains approximate closely in general facies.

(4) They affect strata of the same mineral character in both, the majority preferring the calcareous, the others the arenaceous form of deposit.

(5) The great majority exhibit the same order in their introduction and distribution. This is seen in Orthis, Pentamerus, Spirifer, and other Brachiopoda, and in Endoceras, Graptolites, Trilobites, etc., the more highly organized being often prominent in the early stages.

(6) The law of divergency into several matrices is the same, or nearly so, in the two basins, the number of instances being fewer in New York.

(7) The great majority of animals typical or recurrent in one basin are so in the other.

(8) The great majority of the recurrent fossils in both occupy the same number of epochs, many or few.

(9) The great majority observe the same process or law of increment and decrement. This takes place in nineteen out of twenty-four orders and genera.

(10) The two basins have 108 organic forms in common, including most of the genera.

(11) The same orders and genera are rich and poor in species.

(12) There is the same limited admission of Silurian forms into the Devonian system in New York and in Europe.

(13) The plants of both are typical, with one or two exceptions.

Such are some of the great points of similarity. Now as to dissimilarity. Those which arise out of the mineral character are partly owing to physical disturbances and to a certain amount of metamorphism undergone by the Welsh strata. The paleontological differences are many, but small, often merely individual, and they seldom affect principles. They are due to the varying sea depths and other well known conditions.

The facts just recorded certainly indicate a close connection in nature and mode of formation between the basins of New York and Wales. They seem to be quasi-equivalents—the same, but other, to use a short, but convenient phrase in common use.[2]

Agassiz.—When commenting upon correlations made between the Paradoxides zone of Newfoundland, Massachusetts, and Scandinavia, Prof. Louis Agassiz said:

That there may be synchronism of deposit without identity of fossils must be evident if we glance at the present distribution of animals. If at the present epoch the fauna of America and Australia should become fossilized there would not be the slightest resemblance between the representative species of the two continents. The

[1] Quart. Jour. Geol. Soc., London, vol. 15, 1859, p. 292. [2] Op. cit., pp. 292, 293.

paleontologist must be ready to admit that very different fossil faunæ may be contemporaneous, and that their difference does not necessarily imply a distinct zoological age.[1]

When discussing the typical forms and the distribution of the rocks of the Cambrian, Mr. J. J. Bigsby presents a table showing the order of succession of the Cambrian rocks in various countries.[2] In this he includes the Upper Cambrian sandstones of Texas and Nebraska, and they are referred to the upper or Primordial division of the Cambrian.

Matthew.—During the progress of his extended researches in the faunas and rocks of the Cambrian system in New Brunswick, Mr. G. F. Matthew has had frequent occasion to compare the stratigraphic succession and the faunas of the Cambrian of New Brunswick with that of Europe.

In a paper read before the British Association for the Advancement of Science in 1884, he correlates the fauna of the St. John group of New Brunswick with that of the Cambrian of Wales, and concludes that it shows closer relations with the Solva group than with the Menevian.[3]

Near the close of the same year he stated in a paper read before the Natural History Society of New Brunswick that the discovery of a higher fauna enabled him to correlate the beds containing it with the Menevian group of Wales.[4]

In an essay on the classification of the Cambrian rocks in Acadia,[5] Mr. Matthew considers that the Potsdam sandstone is equivalent to the Ceratopyge limestone, or the Tremadoc group, and represents the upper part of the Tremadoc, as the Georgian series probably does the lower. This correlation is made upon the interpretation of the characters of the genera of trilobites in the American and European rocks.

A second paper on the classification of the Cambrian rocks in Acadia appeared in 1889, in which a comparison of sections in Sweden and New Brunswick with the characteristic sections of Cambrian rocks in Europe and in North America is made.[6] In the comparison of sections of Sweden and New Brunswick the base of the Paradoxides beds is taken as the datum point and it is shown that the pre-Paradoxides horizon is present both in Sweden and New Brunswick, and that the Upper Cambrian or Olenus horizon is represented in New Brunswick by Stage 2 of the St. John County section and by the same stage in Sweden. In the second table of the sections of the Cambrian rocks in Europe and in North America, the correlations made between the sections of Sweden and New Brunswick are accurate and valuable; but those between the

[1] On the difference between faunas of zoological and geological periods. Boston Soc. Nat. Hist., Proc., vol. 8, 1862, p. 58.

[2] On the Cambrian and Huronian formations. Geol. Soc. Quart. Jour., London, vol. 19, 1863, p. 44.

[3] The geological age of the Acadian fauna. Brit. Ass. Adv. Sci., Rep. 54th meeting, 1884, pp. 742, 743.

[4] An outline of recent discoveries in the St. John group. Nat. Hist. Soc. N. B., Bull., No. 4, 1885, p. 101.

[5] Canad. Rec. Sci., vol. 3, 1888, pp. 79, 80.

[6] Canad. Rec. Sci., vol. 3, 1889, pp. 308–311.

western North American sections of the Wasatch, Nevada, Highland Range, and Eureka are more or less defective, owing to the imperfect interpretation of the paleontologic data.

The next essay upon the correlation and comparison of the European formations with those of America by Mr. Matthew is entitled: "How is the Cambrian divided?—A plea for the classification of Salter and Hicks."[1] He institutes comparisons of the strata in Wales, Newfoundland, and Norway, and of the characteristic trilobitic genera of each horizon. From the results obtained by these comparisons he considers that the Cambrian is to be divided into the Upper and Lower, and that the method proposed by Mr. C. D. Walcott, of separating the Olenellus or Lower Cambrian from the Paradoxides or Upper Cambrian, is not justified by the evidence afforded by the American and European sections.

METHODS OF CORRELATION.

I. Superposition.
II. Organic Remains.
III. Lithologic Characters.
IV. Unconformity.
V. Miscellaneous.

I. SUPERPOSITION.

(*a*) The order of superposition of strata is the foundation of geologic chronology. By its aid the stratigraphic succession and serial relations of the fossil faunas are first determined. Undisturbed superposition within a section is an absolute test of relative age of the parts of that section; it is not positive evidence of the age of the various beds in relation to beds sustaining the same serial relations in some disconnected section without other tests to support it, even though they occur in the same geologic province: e. g., a band of sandstone beneath a limestone and above a shale may be identified in one portion of a geologic province; but the occurrence of a band of sandstone beneath a limestone and above a shale, in a distant portion of the same province, is not positive evidence that the two bands of sandstone are synchronous or portions of one continuous formation, unless their continuity can be traced.

(*b*) Superposition is not a test of identity of formation except in a limited basin, where the geologist has evidence to show that the formation is practically continuous in its stratigraphic relations. In widely separated portions of the same basin, or of different basins, the order of superposition must be sustained by other tests before it can be asserted positively that the formations thus correlated are identical.

(*c*) In the same geographic or geologic province, fresh-water and marine deposits are not to be correlated with each other, even if they

[1] Am. Geologist, vol. 4, 1889, pp. 139-148.

have the same order of superposition, as the conditions under which they were accumulated are entirely dissimilar, and the proof of the contemporaneity of deposition is not available. An exception to this may occur where a stream passes through a lake and carries the fauna and flora to the sea, where it is mingled with the marine fauna.

II. ORGANIC REMAINS.

There are several considerations always to be borne in mind in correlating a formation on the evidence of its contained organic remains:

(*a*) There can be no scientific or systematic paleontology without a stratigraphical basis.[1]

(*b*) The method of correlation by the comparison of fossils; or, as it has been called, "matching," is the one that affords the best results. It includes the comparison of species, genera, families, and the general facies of a fauna. It is the basis of paleontologic correlation and geologic classification of the sedimentary rocks, with the exception of the stratigraphic and lithologic correlation of local formations.

(*c*) In nearly every section of strata there are considerable thicknesses of beds, in which, no fossils are to be found. These beds occur in nearly every formation. The record of life, during these nonfossiliferous periods of sedimentation, is broken.

(*d*) Many fossils have a great vertical range; and the occurrence of a few species of this character without the presence of species of known limited range can not be taken for the identification of any particular formation. If the laws of constancy and variation of the wide-ranging and long-enduring species are known, it may be possible to use them in the correlation of minor formations, and thus create an exception to the general rule.

(*e*) All paleontologic reasoning is based upon known data. By the discovery of a new grouping of fossils, or a different range of known species, the identification of horizons may be materially modified.

(*f*) In correlating a formation it is necessary to exercise caution before deciding that the contained fossils belong to any specified zone of the fauna characterizing a terrane or group of formations, and thus locating the exact stratigraphic horizon of the formation. A fauna may vary in its constituent parts and afford different groupings of species in localities not far distant.

(*g*) All correlations between widely separated provinces are based upon the general and not upon the specific character of the fauna; i. e., it is the general assemblage of a fauna in one basin that is compared with that in another basin.

Within limited areas the comparison of species and the grouping of species suffice to determine some particular horizon or formation. In widely separated parts of the same area or province there will

[1] Hall, James. On the Primordial fauna and Point Levi fossils. Am. Jour. Sci., 2d ser., vol. 31, 1861, p. 224.

be a greater difference in the species, and the general or the specific grouping of the genera will have to be taken as the data for comparison. In separate provinces the species may be the same in some instances; but it is by the comparison of representative species and genera that the correlations are to be made. In provinces separated by great distances, or upon two continents, the general assemblage of the characters of the two faunas are to be compared. It may be accepted as a general rule that the more detailed the comparisons are the more restricted is the area in which specific results are of value. The results, however, may be of the highest value in strengthening a correlation based upon representative types. The exception to this is the occurrence of similar life zones in widely separated regions.

(*h*) Zoologic provinces have been more or less limited in area from the beginning of Paleozoic time. This is shown by the character and distribution of the earlier Cambrian fauna. The provinces were as distinctly marked then as at any time during the deposition of the Paleozoic.

(*i*) Many of the earlier zoologists and paleontologists prior to the period of Darwin studied the strata and the contained fauna with the view that each group of species had a greater or less distribution and were then suddenly exterminated, a newly created fauna taking its place. This enabled them to correlate their formations with great accuracy, and to differentiate them upon the evidence offered by the occurence of a very few species.

(*j*) The environment or condition under which the faunas lived and were deposited is also to be noted. Whether they were littoral or pelagic, whether they lived in cold or warm water, upon a sandy or a muddy bottom, in salt or in fresh water, are all considerations which must be taken into account in discussing their value as factors in correlation.

(*k*) The presence of recurrent faunas in strata lithologically similar may give rise to imperfect and erroneous correlations. This is not liable to occur except in a limited geologic basin, where the conditions of sedimentation were uniform over large areas, and the environment of the fauna such that it continued, under favorable conditions, in some portions of the basin, and occupied other portions intermittently, as the varying phases of sedimentation were favorable or inimical to its distribution.

(*l*) The relative age, serial relation, or homotaxis of sedimentary formations is best determined by the marine faunas, as the conditions under which they lived and were deposited were much more uniform than those surrounding the terrestrial fauna and flora.

The evidence furnished by paleobotany is fragmentary, and its sequence is so interrupted by nondeposition and nonpreservation that no comparisons of great value have been established by its aid. What is true of paleobotany is also true, to a less extent, of terrestrial faunas.

It is only by accident and through peculiarly favorable conditions that land faunas have been preserved. With the marine faunas on the contrary the opportunities for the preservation of the fauna of each epoch were far greater, and the conditions of environment were more favorable for the uniform advancement and evolution of life over extended areas.

Life-zones.—The proof of the presence of life-zones in the geologic series is one of great importance in correlation. The subject has been so ably presented by Prof. H. A. Nicholson that I will quote it in full in preference to giving a synopsis of it or to presenting my own views, which accord essentially with those of the author. He says:

While each geological rock-system is characterized by a general assemblage of distinctive types of animals and plants, the minor subdivisions of each system are likewise distinguished by the prevalence of particular forms of life. There are no doubt cases in which an extensive series of successive strata may appear to be characterized throughout by essentially the same organic types, there being apparently no restriction of special fossils to special horizons in the series. In so far as such cases have any real existence, they may be explained as instances in which a great series of sediments has been accumulated with such rapidity that there has been no time for marked biological changes, resulting in the dying out of old species and the introduction of new forms. In many cases, however, the apparent diffusion of the same kinds of fossils from the base to the summit of a series of beds perhaps two or three thousand feet in thickness is due simply to the fact that the organic remains met with in the formation have not been sufficiently investigated and that the exact horizon at which each occurs in the series has not been accurately determined. The determination of the horizons of particular life-forms is a work of time and demands both great stratigraphical knowledge and also a wide and accurate acquaintance with the characters of the fossils themselves, two requirements rarely fulfilled in the same individual.

In a considerable number of cases, however, it has now been shown that the fossils of a given formation may be divided into two principal groups. In the one group is comprised a series of common forms of life, which may be regarded as characterizing the formation *as a whole*. In the other group are included certain special fossils confined to particular parts of the formation and characteristic of certain definite *horizons* or *zones*, within the limits of the formation. All the great formations are to some extent capable of being broken up into minor rock-groups, characterized by special life-forms. Some of the differences in the kinds of fossils found in different parts of the same formation must, of course, be simply set down to the fact that different kinds of sediment imply changed conditions in the sea, and hence changes in the marine fauna. If, for example, part of a formation consisted of limestone and part of sandstone, we should expect, beforehand, to find that each of these rock-groups would have some fossils not found in the other, since the two would have been formed under different conditions. Apart, however, from differences arising from causes of this nature, we meet with cases in which a formation, even if essentially homogeneous in its mineral nature, can be divided into *zones*, each of which is characterized by the possession of special groups of fossils. Organisms belonging to any class of animals may serve in this way as test forms ("Leit-Fossilien") for special horizons in a series of stratified formations, but there are particular groups of fossils which have been found to be preeminently available for this purpose. Among the older rocks of the earth's crust, the forms which have proved specially valuable for the determination of particular "zones" are the Graptolites, the Trilobites, and the Brachiopods, while the Cephalopods have been found to afford the most satisfactory tests in the case of the Secondary rocks. A well known instance of this subdivision of a system of strata by means of special types of fossils is that afforded by the Ordovician and Silurian rocks of Europe, in which paleontologists, following Professor Lapworth, have recognized numerous well marked "life-zones," characterized for the most part by the possession of particular types of Graptolites, though, in some cases, the distinctive fossils belong to other groups Another well known example of the same phenomenon is afforded by the Jurassic deposits. These have been shown to contain a number of well marked zones, each of which is characterized by the possession of some special fossils, and particularly by some special Ammonite. These zones are extremely constant in any particular region, and they enable the observer to effect a division of the formation into special horizons, which have no stratigraphical existence and are not separated by any physical break, but are of the utmost paleontological importance and can be rendered readily available in working out the stratigraphy of any given area.

Certain life-zones appear to have nothing more than a local development and importance, but in other cases they have proved to be astonishingly constant even over very large areas. Perhaps the most remarkable known instance of the extension of particular life-forms over a vast area is that afforded by the Arenig rocks (a subdivision of the Ordovician system), which have been recognized as occurring in Europe, in Canada, and in Australia, and contain in all these widely remote areas the same peculiar types of Graptolites.

The principal difficulty that we have to confront in dealing with these "zones" is to produce any plausible explanation accounting for the destruction of the special life-forms of the one zone and the appearance of those of the next zone. For the most part, these zones are of very limited vertical extent, and they succeed each other in such a manner as totally to preclude the idea that the dying out of the old forms can have been in any way caused by a physical disturbance of the area. Perhaps the most probable view to adopt in the meanwhile is that the formations in which distinct and limited life-zones can be recognized were deposited with extreme slowness, whereas those which show an essentially compact and homogeneous fauna from base to summit were deposited with comparative rapidity. Upon this view, a formation like the Lias is one formed by a process of very slow and intermittent sedimentation, the life-zones being separated by intervals during which sedimentation must have been at a standstill, but which were long enough to allow more or less considerable biological changes, some forms dying out or becoming modified while other new ones came in. Upon this view, further, a formation like the Lias, though of comparatively small vertical extent, may represent as long a period of time as the whole of such a great formation as the Lower Carboniferous, which appears to have been formed under conditions of comparatively rapid sedimentation.[1]

Life-zones have been determined in the Middle Cambrian or Paradoxides terrane of Sweden, Wales, New Brunswick, and Newfoundland or the Atlantic Basin Province. In a broader range the genera Olenellus, Paradoxides, and Dikelocephalus are considered typical of the three primary zones or divisions of the Cambrian group. They are of unequal value and decrease in precision from the older to the later faunas. The genus Olenellus has a wide distribution in western Europe and North America, while Paradoxides is more limited in America, and the true Dikelocephalus probably has a still smaller geographic range.

Stage of evolution.—The evolution of organic life is a factor in correlation that has been assuming some importance within the last few years. To be of practical use the paleontologist must have a thorough

[1] General Introduction, Manual of Paleontology, by H. A. Nicholson and R. Lydekker, vol. 1, 1889, pp. 58–60.

accurate knowledge of the species and their life history, including that of the genus and family to which they belong. Types of restricted range and short duration are of little importance, except as expressing the stage of development of their genus. The persistent, long-enduring types, that range from formation to formation and even from group to group, may be of service if their study and analysis have revealed characters by which their relative stratigraphic position, in a given area, may be determined. The evolution of genera is of greater value, and the analyses of the development of specific types within them may be used in the identification of horizons.

Extended to groups of genera, families, or orders, correlation by the known evolution of the faunas may be used in a general way. In the presence of other reliable data it is of relatively small value. Only in instances where there are no other data that can be made available will it be really of practical service to the geologist.

Even under the best conditions and circumstances great care must be used, owing to the varying conditions caused by environment and the unequal evolution of organisms in different geographic areas or basins. I do not wish to imply that this method of correlation should be entirely overlooked or dismissed in the presence of more reliable data. It can be used in connection with other methods in correlating any formation or group of formations, but only in extreme cases should it be considered the only factor. When used, the result obtained can be considered as little more than provisional.

Life history.—A careful study of the life history of the various elements of the faunas promises to yield data that may be important in correlation. An illustration of this is afforded by Prof. H. S. Williams's study of *Spirifera lævis.*[1] This is a type that is represented by various forms from the Niagara limestone of the Silurian to the summit of the Devonian, that are evidently descended one from the other, although they have been described under several specific names. At each horizon the variation from the initial form serves to locate its stratigraphic horizon and thus its relative age and position in space and time. The tracing of the migration of forms from one area to another and the changes produced upon them during this migration are to be taken into consideration. The theory of Prof. Alpheus Hyatt,[2] that there is a cycle of forms in the geologic series and a corresponding cycle of variation in the species of that series and in the individuals of any one species, may lead to practical results. He finds it to prevail very extensively in the Cephalopoda, and it will undoubtedly be found to apply to all the other zoologic groups. The conclusions obtained will be more or less marred by the imperfections of the geologic and life record, but I look forward to the time in the future when minute biologic studies

[1] The Life History of Spirifer lævis, Hall. Ann. N. Y. Acad. Sciences, vol. 2, 1881, pp. 140-160, pl. xiv.

[2] Genera of Fossil Cephalopods. Proc. Boston Soc. Nat. Hist., vol. 22, 1883, pp. 253-265. Also, many other papers by Professor Hyatt, referring to and describing the Cephalopoda.

of the faunas, in connection with a careful study of the sedimentation and stratigraphy, will make our present methods appear to have been lacking in scientific precision.

Contemporaneity and Homotaxis.—When it was once established that a certain order of succession of fossils occurred in Europe, it was concluded that identical or similar assemblages of organisms would be found to prevail elsewhere over the earth; and that the geographic distribution of each successive fauna was world-wide, each fauna being a new creation. The present view is, that the chronologic succession of the fauna is local, as proved by the existence of zoologic provinces, and that each fauna is descendant from some preexisting fauna. This result is modified for each province by the migration of faunas and portions of faunas from province to province. Notwithstanding the various elements that influenced the evolution of the faunas, it is found that the general succession of species and faunas is in the aggregate the same all over the world, however much it may have been broken, advanced, or retarded in certain areas in ancient or relatively recent geologic time.

Prof. Huxley, when introducing the term "Homotaxis," said:

Edward Forbes was in the habit of asserting that the similarity of the organic contents of distant formations was prima facie evidence, not of their similarity, but of their difference of age; and holding as he did the doctrine of single specific centers, the conclusion was as legitimate as any other; for the two districts must have been occupied by migration from one of the two, or from an intermediate spot, and the chances against exact coincidence of migration and of imbedding are infinite.

In point of fact, however, whether the hypothesis of single or of multiple specific centers be adopted, similarity of organic contents can not possibly afford any proof of the synchrony of the deposits which contain them; on the contrary, it is demonstrably compatible with the lapse of the most prodigious intervals of time, and with interposition of vast changes in the organic and inorganic worlds, between the epochs in which such deposits were formed.[1] * * *

There seems, then, no escape from the admission that neither physical geology nor paleontology possesses any method by which the absolute synchronism of two strata can be demonstrated. All that geology can prove is local order of succession. It is mathematically certain that, in any given vertical linear section of an undisturbed series of sedimentary deposits, the bed which lies lowest is the oldest. In any other vertical linear section of the same series, of course, corresponding beds will occur in a similar order; but however great may be the probability, no man can say with absolute certainty that the beds in the two sections were synchronously deposited. For areas of moderate extent, it is doubtless true that no practical evil is likely to result from assuming the corresponding beds to be synchronous or strictly contemporaneous; and there are multitudes of accessory circumstances which may fully justify the assumption of such synchrony. But the moment the geologist has to deal with large areas or with completely separated deposits, then the mischief of confounding that "Homotaxis" or "similarity of arrangement," which *can* be demonstrated, with "synchrony" or "identity of date," for which there is not a shadow of proof, under the one common term of "contemporaneity" becomes incalculable, and proves the constant source of gratuitous speculations.[2]

[1] Quart. Jour. Geol. Soc., London, vol. 18, 1862, p. xlv.
[2] Op. cit., p. xlvi.

In this connection the student should read Mr. J. E. Marr's paper on Homotaxis.[1]

Percentage of species.—This method of paleontologic correlation was employed by Sir Charles Lyell. He found a certain percentage of species identical with living forms in one horizon, the Eocene; a larger percentage in the Miocene, and a still larger one in the Pliocene. He then concluded the Eocene represented the oldest and the Pliocene the latest deposit. He thus classified the formations and gave an indirect method for their correlation in different areas. It is not capable of application where all the members of a fauna are extinct.

III. LITHOLOGIC CHARACTER.

Lithologic character has very little value in establishing correlations, when comparing formations outside of limited areas. The constituents of a rock may differ in their chemical and mechanical condition in a stratum that is proved by other evidences to be continuous. In some instances lithologic characters may be of value, especially in areas where the stratigraphic sequence of the beds is known and paleontologic evidence is lacking. Dr. R. D. Irving used the method successfully among the pre-Cambrian rocks of the Lake Superior region, and says of it:

> Its value in tracing formations from point to point can hardly be overestimated, being as great as that of paleontological evidence and, in my judgment, of much the same nature. As we trace formations and their minor subdivisions from place to place we must of course constantly check lithological evidence by stratigraphy. As we pass from one extremity of the field to the other, changes in lithological characters of course come in, and these changes might lead to unsafe conclusions were we to compare stratal successions too distantly removed from one another; but when we work from point to point such changes are detected as they gradually appear, and are provided for.[2]

An illustration of the value of the method is shown by the correlations made by the brothers Roger's[3] in Virginia and Pennsylvania, where they correlated the quartzites, shales, and limestones by their lithologic characters along an extent of several hundred miles. When, however, they came to carry this correlation without that area of sedimentation, the inadequacy of the method is shown by the fact they correlated the Lower Cambrian quartzite with the Upper Cambrian quartzite about the Adirondacks of New York. A still more striking illustration of erroneous correlation by this method is that made by Prof. N. H. Winchell[4] in correlating, as members of one formation, the

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[1] Proc. Cambridge Phil. Soc., vol. 6, 1887, pp. 74-82.

[2] Seventh Ann. Rep. U. S. Geol. Survey, 1885-'86, 1888, pp. 378, 379.

[3] A system of classification and nomenclature of the Paleozoic rocks of the United States, with an account of their distribution, more particularly in the Appalachian mountain chain. Am. Jour. Sci., vol. 47, 1844, p. 112.

[4] The crystalline rocks of Minnesota. General report of progress made in the study of their field relations. Statement of problems yet to be solved. Geol. and Nat. Hist. Survey of Minn., 17th Ann. Rep. for 1888, 1889, p. 49.

Lower Cambrian quartzite of the western slopes of the Green Mountains, the Upper Cambrian Potsdam sandstone of New York, the pre-Cambrian Sioux quartzites of Minnesota, the pre-Cambrian Baraboo quartzite of Wisconsin, and the pre-Cambrian quartzite of the Keweenawan series of Lake Superior.

Lithologic character is often of great value within limited areas and where the formation can be practically traced from place to place. As this can rarely be done, it is best to seek other data and to combine with the lithologic, the stratigraphic and paleontologic evidence, if it is possible to obtain any.

IV. UNCONFORMITY.

Of all the data of correlation that of unconformity of the formation correlated, with its superjacent or subjacent formation, would appear at first sight to be the most unreliable. In most instances it is, but where combined with other data it has a certain value. We find it used in the earliest correlations made of the Potsdam sandstone of New York, with the basal sandstone all along the Appalachian Range south through New Jersey, Pennsylvania, Maryland, Virginia, Tennessee, Georgia, and Alabama. It is also used in the correlations made between the Potsdam sandstone of New York and the sandstone of the south shore of Lake Superior, and the fossiliferous sandstones of Wisconsin, Iowa, and Minnesota, that were correlated with the Potsdam sandstone by Messrs. Owen, Hall, and later observers. In fact, it is implied in nearly all the references of strata to the Potsdam horizon in other localties than that of the typical area about the Adirondack Mountains of New York. It was not, however, until the appearance of Prof. R. D. Irving's essay on the classification of the earlier Cambrian and pre-Cambrian formations[1] that full significance was given to the value of unconformities in correlation.

The problem is presented by Dr. Irving as follows:

> (1) To determine upon the grander divisions (groups) to be made in classifying the rocks independently of their relations to the general geological column; (2) to extend these divisions to other portions of the same geological basins; and (3) to correlate these divisions with those of different and distant geological regions. This is the problem which presents itself in the Lake Superior region, at the base of the Grand Cañon of the Colorado, in central Texas, Newfoundland, and in other portions of North America.
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> In any attempt to solve such a problem we can make use of one or more of three kinds of characteristics in the formations involved, viz: (1) their paleontological characteristics, (2) their lithological characteristics, and (3) their mutual structural relations.[2]

Under the third title, "their mutual structural relations," he considers unconformity as a basis for classification[3] discussing the general nature and significance of conformities and the distinguishing characters of true unconformities. A description is given of the Potsdam-

[1] Seventh Ann. Rep. U. S. Geol. Surv., 1885-'86, 1888.
[2] Op. cit., p. 371. [3] Op. cit., p. 390.

Huronian unconformity on the north shore of Lake Huron, the Potsdam-Keweenaw unconformity, the Laurentian-Huronian unconformity and others of the Lake Superior region. This is followed by a section on the use of unconformities in classification.[1] In this the use of unconformities in defining the grander groups of strata and in correlating the formations of a single geologic basin are discussed. Under the first, he says:

Returning to our problem as originally stated, we have next to consider how far unconformaties may be made use of in defining the grander groups of strata in a region in which the succession of these strata has been determined. Further argument than that already given in discussing the nature and kinds of unconformity is hardly necessary to show that genuine unconformities, indicative of great lapses of time between the periods in which the strata on either side of the break in each case were respectively made, are of prime value and importance in determining the limits of the grander groups of the geological formations, whatever use we may make of paleontological and lithological characters in determining subordinate divisions. Such structures as the greater ones of the true unconformities, above considered, indicate lapses of time great enough to cover extended periods of mountain-making, always a slow process, and also great periods of denudation or exposure to the atmospheric agencies. It is hardly possible for us to compare such time gaps with the time necessary for the formation of definite thicknesses of strata, but the thicknesses of strata corresponding to such breaks must surely always be very great.

If we take for instance the gap indicated by the relations of the Potsdam sandstone to the ancient gneissic formation of the northwest, as above illustrated by a number of examples, we find that it was long enough to cover not merely one period of rock alteration, orographic movement, and land surface exposure, but three such periods, between which were times long enough for the accumulation of thicknesses of strata aggregating over 60,000 feet, a thickness exceeding that of the entire Paleozoic series in its greatest development in the Appalachian region. It is true that a portion of this 60,000 feet is made up of volcanic materials, chiefly lava flows. The accumulation of such materials may, it is true, have been more rapid than is the case with ordinary fragmental deposits; but the accumulation of such a mass of eruptive material must have occupied at least a considerable lapse of time; while more than one-half of the 60,000 feet, or an amount approximating the maximum Paleozoic accumulations in the Appalachian region, is made up of genuine detrital deposits. When we consider that in addition to the time necessary for the accumulation of this mass of sediment there intervened between the Potsdam and the gneisses three periods of rock alteration, mountain-making, and complete mountain removal, it becomes plain that the time gap indicated by this unconformity must have exceeded the entire Paleozoic era. More probably, indeed, it equalled all later geological time. Each one of the three unconformities mentioned must of course have required a shorter period than this greater gap, but in each case the relations of the several formations are such as to indicate periods of time only comparable to the periods necessary for the accumulation of one of the great geological groups.[2]

The use of unconformities in correlating the formations of a single geologic basin, where the exposures of the formations are not continuous, is illustrated by a tabulation showing the general succession of formations in various districts from the northern end of Lake Huron to Dakota and from central Wisconsin to the north shore of Lake Superior. This table shows that in various localities there is a great unconformity

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[1] Op. cit., p. 438.

[2] Op. cit., pp. 438, 439.

between the Laurentian and the Huronian, between the Huronian and the Keweenawan, where the two series of rocks are present, and between the Keweenawan and the Cambrian if these two occur in the same area.

He next takes up the use of unconformities in establishing general relations. Under this heading we quote as follows:

Having established the general order of succession and the grander groups of the strata for a given geological province, the question which arises next in order is how to correlate these divisions with those of other geological provinces, and more particularly with the established divisions of the general geological column.

It will take but little consideration of the causes which have been at work in the production of such unconformities as have been above cited to make us realize that such breaks as these must be widespread in their influence. Great unconformities, in which the strata below the unconformity have been subjected to folding, mark periods of orographic movements which will, in general, have been extensive somewhat in proportion to the intensity of the folding process.[1]

It is well known, indeed, that some of the greater physical breaks in the strata of one continent may have their parallels among the strata of another continent. The interruption between the Paleozoic and the Mesozoic is intercontinental, if not world wide. Equally extensive is the great break between the Mesozoic and the Cenozoic. Each of these physical breaks corresponds to an immense change in life conditions. But, if we may judge from structural relations, from the amount of intervening denudation, and from the rank already attained by the life of the lowest of the fossiliferous Cambrian formations, neither of these great breaks corresponds in length of time interval to the break between the lowest of the distinctly fossiliferous formations and the youngest of those beneath it.[2]

The great structural breaks furnish, at times at least, a more trustworthy guide. If, for instance, we make a comparison of the succession of Cambrian and pre-Cambrian strata in the Lake Superior region with the succession revealed in the depths of the Grand Cañon of the Colorado, we find some singular correspondences between the structural breaks of the two successions. In each one of these regions the Potsdam sandstone is strongly characterized by its well known fauna. In each region the sandstone traverses the edges of a gently bowed but deeply denuded formation composed of a great thickness of detrital and eruptive materials. Below these formations in each region, and separated from them in each case by one of the strongest of unconformities, is a great quartzitic series, while below this series again in the Lake Superior region, and separated from it by still another of the most notable of unconformities, is the great Laurentian gneissic series. That this series also exists in the base of the Grand Cañon we have good reason to believe.

Such a striking similarity in succession as this certainly most strongly suggests the conclusions that the physical breaks of the two regions were coincident in point of time (that is, that the mountain-making movement which preceded the deposition of the Potsdam sandstone of the Lake Superior country corresponded with that which preceded the Tonto sandstone of the Grand Cañon region); that the mountain-making periods preceding the deposition of the Grand Cañon series of the Grand Cañon district and of the Keweenaw series of the Lake Superior region were equally synchronous; and, finally, that the Grand Cañon series is, in general, the equivalent of the Keweenaw series, while the pre-Grand Cañon rocks are the equivalent of the Lake Superior Huronian.

Of course such correlations as these should be made, for the present at least, somewhat provisionally; but, on the other hand, they must be taken as of much greater value than correlations between distant formations established on feeble fossil evidence.[3]

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[1] Op. cit., p. 443. [2] Op. cit., p. 444. [3] Op. cit., p. 445.

The question is asked, is the term Cambrian to stop at the first unconformity below the Potsdam sandstone? Is it to extend to the second of those uncomformities, or to the third? Or is it to include, finally, the lowest of the formations of the region?

He makes the following reply to these questions:

All these usages of the term have been made. In taxonomical value the term Cambrian is designed, of course, to correspond to the terms Upper Silurian, Lower Silurian, Devonian, Carboniferous, etc., which terms are based primarily upon the general continuity for each one of the periods to which they correspond of similar life conditions. In no case, however, has one of these terms been allowed to span any such unconformable break as the least of those beneath the Potsdam sandstone of the Lake Superior region. Minor breaks in the succession have been included within a single one of these geological groups because—although in every case of a physical break, even the smallest, a corresponding break in life-succession is found—there have been found on both sides of the break fully developed faunas of general similarity in characters; but no great break in the succession such as those with which we are now concerned has ever yet been found to be spanned by a continuity of forms. The conclusion, therefore, seems inevitable that we should not extend the term Cambrian over any such break, at least until there shall have been found closely corresponding faunas on opposite sides of the interval. Were such faunas to be discovered the greatness of the unrecorded interval would still remain, and we should have indicated only a singularly long continuance of similar life-conditions. Even then the question might arise as to whether continuity of life-conditions should outweigh the great lapse of time indicated by the physical hiatus.[1]

Finally Dr. Irving states that

The structural breaks called unconformities are properly used in classification—

(1) *To mark the boundaries of the rock groups of a given region.*

(2) *To aid in establishing correlations between the formations of different parts of a single geological basin.*

(3) *To aid in the establishment of correlations between the groups of regions distantly removed from one another; but* caution is needed in attempting such correlations in proportion as the distances between the regions compared grow greater.

They are improperly ignored:

(1) *When the evidence they offer as to separateness is allowed to be overborne by anything but* the most complete and weighty of paleontological evidence.[2]

V. MISCELLANEOUS.

Homogeny.—A method of correlation that has frequently been used has recently been named by Mr. W J McGee "Homogeny" or correlation by community of genesis.[3] Mr. McGee defines it as follows:

The method of correlation devised to systematize the structure of the Coastal Plain combines the desirable features of the older methods, and adds thereto the interpretation of the products of the several physical processes operating upon the earth's exterior.[4]

The older methods mentioned are those of stratigraphic continuity, lithologic correlation or correlation by petrography, and paleontologic

[1] Op. cit., p. 446.
[2] Op. cit., p. 448.
[3] Am. Jour. Sci., 3d ser., vol. 40, 1890, pp. 36–41.
[4] Op. cit., p. 36.

correlation. He considers that "the method involves a yet broader conspectus of phenomena and principles than the paleontologic method; for in its application it is necessary mentally to restore the various physical and biotic conditions of the past, just as paleontology vivifies the fossils of past ages." Again:[4]

In discriminating the general and local genetic conditions it is necessary to ascertain the relations between each formation and its newer and older neighbors, and to interpret the record of each unconformity in terms of continent growth. By this means the different parts of a formation may be found to represent not only general community of genesis but community of beginning and ending; in short, entire community of structural relation. Each part of the formation then records in similar terms the same episode in continent building and world growth.

So, when a coastal plain formation is found to represent general community of genesis and structural relation in its various parts it is considered homogenic, and accepted as a record of an episode in geologic history. The parts may or may not be homotaxial; one part may be slightly older than another part; but in a general way it is contemporaneous throughout. Homogeny implies not only equivalence but synchrony.

The principles of homogenic correlation have long been used in the correlations of formations by geologists. An illustration of this is the correlations that have been made of the Potsdam sandstones of New York with those of the Mississippi Valley, the eastern slope of the Rocky Mountains, the islands of Texas and Missouri, and the valley of the St. Lawrence. In these correlations to subjacent and superjacent formations, stratigraphic continuity, lithologic or petrographic resemblance, and similarity of organic remains have all been used.

Under the definition of homogeny, that is, correlation by community of genesis, decided errors must necessarily occur unless checked by paleontologic data. An illustration of this is the correlation of the Potsdam sandstone of the Adirondack Mountains of New York with the "Granular Quartz" of western New England and southeastern Pennsylvania, and the Chilhowee sandstone of Tennessee. These sandstones are lithologically alike, they were accumulated along a coast line, their petrographic characters are the same, and the action of the waves upon and the distribution by tidal currents of the sediments originating from similar crystalline rocks all point to a community of origin; in fact, they did originate in the same manner. They have been correlated upon the characters mentioned for upwards of 40 years, but the study of the fossil remains shows they are not equivalent or synchronous. One represents the basal beds of the Cambrian system and the other the Potsdam sandstone or the closing deposits of Cambrian time in the same area. I think that after we have fully proven to our satisfaction the similarity of origin or the community of genesis we must still rely upon paleontologic data for the final determination of geologic equivalence. For the determination of synchrony, except in a limited area, there is little hope for satisfactory conclusions by any method yet devised.

[4] Op. cit., pp. 38, 39.

Topographic features in correlation.—Topographic features may indicate relative geologic age in the discussion of the later formations; but in dealing with the Lower Paleozoic it has thus far been found to be impossible to obtain the evidence of newer or older topographic features that are of value. Mr. G. K. Gilbert has used it successfully in discussing the age of the Equus fauna of Lakes Mono and Lahonton of California and Nevada.[1]

[1] U. S. Geol. Survey, Monograph, vol. 1, 1890, pp. 393-402.

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