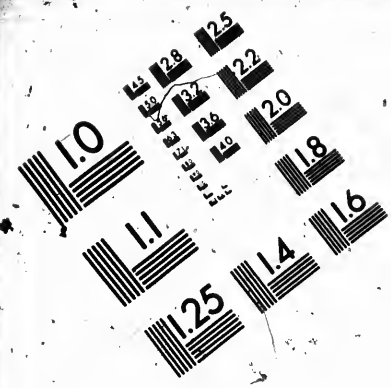

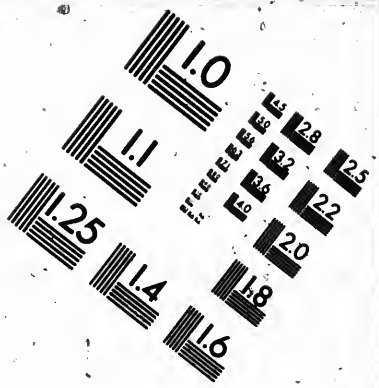

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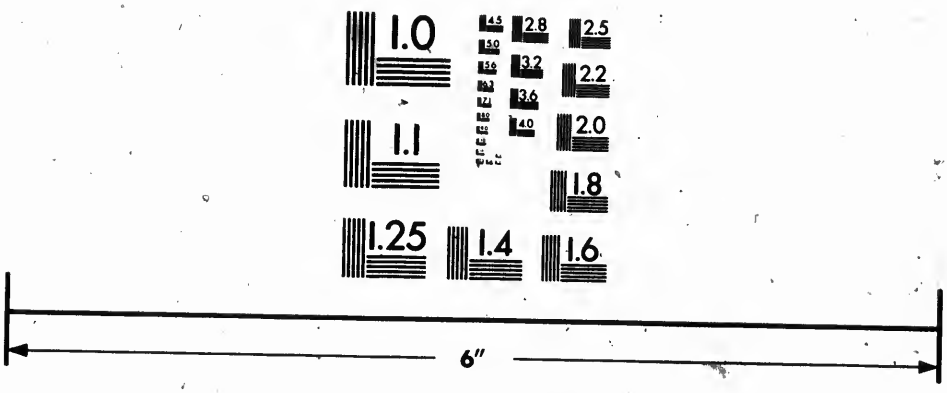

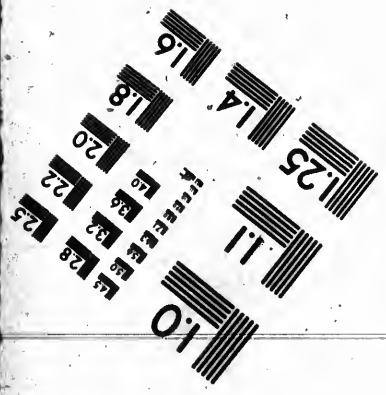

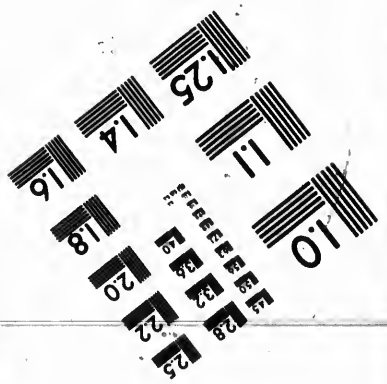

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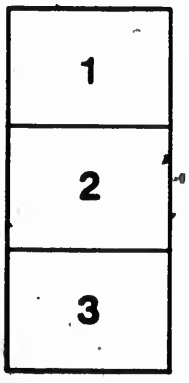

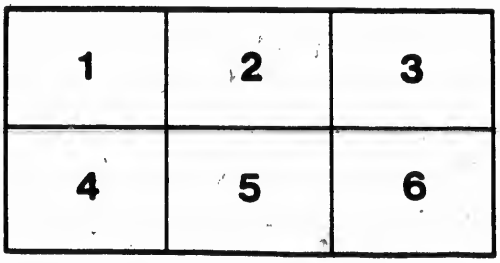

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THE

TACONIC QUESTION

IN

GEOLOGY

BY

THOMAS STERRY HUNT, M.A., LL.D., F.R.S.

PART II.

FROM THE

TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA

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DAWSON BROTHERS, PUBLISHERS.

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VI.—*A Historical Account of the Taconic Question in Geology, with a Discussion of the Relations of the Taconic Series to the Older Crystalline and to the Cambrian Rocks.* By THOMAS STERRY HUNT, LL.D. (Cantab.), F.R.S.

SECOND PART.

(Presented May 21, 1884.)

VIII.—*The Taconic History Reviewed.*—Types of American Cambrian. Recent paleontological studies. Various opinions as to the age of the Lower Taconic rocks. The metamorphic hypothesis considered.
IX.—*Conclusion.*—Summary. Wide distribution of rocks like Taconian. Contents of sections and Note.

VIII.—THE TACONIC HISTORY REVIEWED.

§ 136. In the Transactions of this Society for 1883, (Vol. I, Part IV, pages 217–270), will be found the first part of this account of the Taconic Question. In this second and concluding part, we shall continue the numbering of chapters and of sections begun in the first. It is proposed to notice, in the first place, some of the characteristic differences of the Cambrian or Upper Taconic rocks as seen in different parts of North America, to follow the results of paleontological investigation from the disturbed region in eastern Canada southward into Vermont and New York, and thus to prepare the way for a consideration of the varying and contradictory hypotheses which have been from time to time put forth as to the age of both the Upper and Lower Taconic series.

§ 137. The Cambrian rocks of New York, as originally described by its Geological Survey, were known only in the stable and little disturbed region around the Adirondack Mountains, including the area west of Lake Champlain and the Ottawa basin, where the series is represented by the quartzites and magnesian limestones of the Potsdam and Calciferous subdivisions, which are shallow-water deposits, corresponding, apparently, to small portions only of Cambrian time. The conditions of the Mississippi area are similar to those of the Adirondack region. In Wisconsin, where the Potsdam beds rest in a nearly horizontal position upon highly disturbed strata, often of Kewéenian age, these sandstones and magnesian limestones of the Cambrian, lying in undisturbed succession, have about 1,000 feet in thickness, and are overlaid by the St. Peter sandstone, which divides them from the succeeding Trenton and may itself be regarded as the base of the Ordovician. When, however, we reach the Cordilleras, we find a great augmentation in the thickness of these lower rocks. In the Eureka district of Nevada, according to the late studies of Arnold Hague and Wolcott, the fauna of the so-called Lower and Upper Potsdam ranges through more than 6,000 feet of strata, and is succeeded by that of the Chazy and Trenton subdivisions.

§ 138. A similar great development of these lower rocks exists in north-western Newfoundland, where, from his studies of their organic remains, the late Mr. Billings was led to admit a succession of over 9,000 feet of paleozoic strata below the Trenton horizon.

The subdivisions there recognized by him in ascending order were: 1. Lower Potsdam; 2. Upper Potsdam; 3. Lower Calciferous; 4. Upper Calciferous; 5. Levis; and 6. Phyllograptus beds. The second and third of these were regarded by Billings as the representatives of the Adirondack Potsdam and Calciferous, while the Phyllograptus beds at the summit were considered the equivalent of the Welsh Arenig, which belongs to the base of the Bala group, or the second fauna. It is evident, as Billings declared, that we have, in this great thickness in north-western Newfoundland, a much more complete sequence than in the Adirondack region, where the Upper Potsdam, Calciferous and Chazy subdivisions represent the whole succession from the ancient gneiss up to the Trenton limestone.

§ 139. Keeping in view the great development of the Cambrian alike in the Cordilleras and in Newfoundland, as compared with the Cambrian of the Adirondack and Mississippi areas, we are better prepared to understand the remarkable type assumed by this series in the Appalachian area, on the eastern margin of the American paleozoic basin, from near the Gulf of Mexico north-eastward to the Gulf of St. Lawrence and to Newfoundland, along the western base of the Atlantic or Appalachian belt. These Cambrian rocks throughout this extent, wherever preserved, are characterized by great thickness and considerable diversities in composition, due to the accumulation of mechanical sediments derived from the disintegration and decay of the various groups of pre-Cambrian rocks which made up the adjacent eozoic land. To this, and to repeated movements of the land during and after the Cambrian period, they owe their complex constitution, their great volume their disturbed and faulted condition, and their unconformities. All of these characters serve to distinguish them widely from the horizontal and comparatively thin quartzites and magnesian limestones, their representatives along the northern border of the great basin as seen in the Adirondack and Mississippi areas. It is this Appalachian Cambrian, many thousand feet in thickness, which, as we have already seen, constitutes the First Greywacke of Eaton, the Upper Taconic of Emmons, the Quebec and Potsdam group of Logan, and a large part of the original Hudson River group.

§ 140. That the Levis limestones and Phyllograptus shales, found at the summit of this series, mark the beginnings of the second fauna has already been noticed, as well as the fact that still higher strata, of Ordovician and Silurian ages, are found over portions of this Appalachian Cambrian series, among the strata of which they have sometimes been involved by subsequent movements. It will also be borne in mind, first, that this great mass of 10,000 feet or more of diversified and folded Cambrian strata is soon exchanged to the west for a far more simple type of but a few hundred feet in thickness; and, secondly, that erosion has removed this great series wholly or in part from over large portions of its original area, particularly south of the parallel of 45° north latitude.

§ 141. With these explanations before us, we are now prepared to consider the relations of the Cambrian and Ordovician series, in their two unlike types of the Appalachian and Adirondack areas, to the Lower Taconic limestones. It has already been shown that Emmons, in 1842, in his final Report on the Geology of the Northern District of New York, defined, with the present names, the lower subdivisions of the New York paleozoic system, from the Potsdam to the Oneida, both inclusive, to which he gave the collective appellation of the Champlain division. He at the same time proposed for the granular quartz-rock and the granular lime-rock of Eaton, found in western Massachusetts, the name of the Taconic system, which he followed Eaton in assigning to a lower horizon than

the Potsdam sandstone, and in regarding as entirely distinct from the New York system. The upper limits of this Taconic system, and its relations to the members of the Champlain division on the east side of the Champlain and Hudson valleys, were not at that time clearly defined by Emmons.

§ 142. In 1843 appeared the final Report by Mather upon the Geology of the Southern District of New York, in which he rejected entirely the notion of the Taconic system, and the whole teaching of Eaton, asserting that the Taconic was nothing more than a modified form of the Champlain division of Emmons. The granular quartz-rock of the Taconic he declared to be Potsdam; the granular lime-rock, the Calciferous sand-rock with the succeeding Chazy and Trenton limestones; while the overlying argillites, including the so-called Hudson River group, were the Utica and the Loraine shales. A similar suggestion had been put forth by Messrs. H. D. and W. B. Rogers, in 1841, for the like rocks in New Jersey and Pennsylvania, and was cited by Mather in support of his view. When, later, in 1858, H. D. Rogers published his final Report on the Geology of Pennsylvania, the Lower Taconic rocks of Massachusetts had been by Emmons traced south-westward through the great Appalachian valley, in Pennsylvania, and the adjacent and subordinate Lancaster valley. These rocks, under the names of Primal, Auroral and Matinal, were now described by H. D. Rogers as local modifications of the Champlain series,—the great Auroral limestone being assumed to be the representative of the Calciferous, the Chazy and the so-called Birdseye and Black River subdivisions, while the Matinal slates were supposed to represent the upper part of the Trenton, with the Utica and the Loraine shales. For many extended details with regard to the facts in § 141 and 142, and for other points in the Taconic history, the reader is referred to the author's volume on Azoic Rocks, published as Report E of the Second Geological Survey of Pennsylvania, in 1878.

§ 143. Coupled with this hypothesis of Mather was that of a progressive alteration of these uncrystalline rocks of the Champlain division, supposed to be traced through the Taconic strata into the crystalline schists of western New England, designated by Mather as Metamorphic rocks; between which and the Taconic, it was said by him: "No well-marked line of distinction can be drawn, as they blend into each other by insensible shades of difference." He was at length led to extend this same view to the more massive gneisses and crystalline limestones of southern New York, and to conclude that these also were, wholly or in great part, but altered rocks of the Champlain division,—a notion which has lately found an advocate in Dana, who has also revived Mather's view of the Champlain age of the Taconic quartz-rock and granular limestone, as will be noticed farther on.

§ 144. In Chapters V and VI of this essay we have told the story of the Taconic series as farther studied by Emmons. He soon became aware that the uncrystalline and occasionally fossiliferous series of sandstones, shales and limestones, constituting the the First Graywacke, was not, as maintained by Mather, newer, but older than the Trenton, and coupled these with the original Taconic, under the name of Upper Taconic. This upper division was subsequently clearly recognized by him as a distinct and well defined group, which, as early as 1846, he declared to be the stratigraphical equivalent of the Potsdam and the Calciferous of the Champlain division, while the whole Lower Taconic, including not only the granular quartz-rock and the granular lime-rock, but the immediately succeeding schists and argillites (Transition Argillite of Eaton), was assigned to an horizon below the base of the Champlain division, and consequently older than the Pots-

dam. It was in 1846 that he declared the so-called Red Sand-rock of Vermont to belong to the base of the Champlain series, and to overlie the Lower Taconic, but it was not till 1855 that this Sand-rock, with its succeeding Graywacke series, was described under the name of Upper Taconic.

§ 145. These conclusions as to the age of the Red Sand-rock of Vermont were opposed by C. B. Adams and by W. B. Rogers. The former maintained in 1846, after the announcement of Emmons, the opinion that this sand-rock was newer than the Champlain division, and referred it to "the period of the Medina sandstone and the Clinton group," while W. B. Rogers, in 1851, discussing the same subject, conceived that the reddish limestones which, near Burlington, Vermont, are associated with this sand-rock, were probably "a peculiar development of the upper portion of the Medina group." As regards the relations of this Red Sand-rock and its succeeding limestone to the granular quartz-rock and granular lime-rock of the Lower Taconic, Adams maintained that "the Taconic quartz-rock was probably but a metamorphic equivalent of the Red Sand-rock," and ascribed the change to a supposed "igneous agency." He farther conceived that the granular lime-rock "or Stockbridge limestone of the Taconic system is the equivalent of the calcareous rocks which overlie the Red Sand-rock, rather than that of the lower limestones of the Champlain division, as has been commonly supposed." Allusion is here made by Adams to the views of Mather and the brothers Rogers, who, as already seen, had supposed this same limestone to be the equivalent of the Calciferous, Chazy and Trenton. This opinion of Adams, which, in 1851, was, as we have shown, supported by W. B. Rogers, was again maintained by the latter in 1860, when, after the reading of an essay by C. H. Hitchcock before the Boston Society of Natural History, Rogers cited from his paper of 1851 the conclusions above mentioned, and announced his opinion, "that there is no foundation for what Mr. Emmons called his Taconic system—a mixture of Silurian and Devonian—and that the Dorset limestone (the Stockbridge limestone of the Lower Taconic) is newer than the Lower Silurian, and probably Upper Silurian or Devonian."[1]

§ 146. The explanation of this new opinion as to the horizon of the Lower Taconic limestone is made apparent by reference to the Report on the Geology of Vermont, then in process of publication by the Messrs. Hitchcock. Therein Dr. Edward Hitchcock writes, with regard to the limestone in question, then named by him Eolian limestone, and said to be best displayed in Dorset Mountain: "We have found, mostly in strata from below the middle of the limestones, fossils which, though obscure from metamorphism, are clearly referable to genera characteristic of Devonian rocks, viz: Euomphalus, Stromatopora, Zaphrentis, Chaetetes and encrinal stems." "Nor is it at all improbable, as we shall shortly show, that the Eolian limestone may be as recent as the Carboniferous rocks.[2]" Accompanying this will be found a notice of these organic forms as determined by Prof. James Hall, who declared them to be of Upper Silurian and Devonian types. They are compared by Hitchcock to those found to the east of the Green Mountains, in the valley of Lake Memphramagog, the horizon of which is well known.

§ 147. We have already noticed the occurrence of outliers of Lower Helderberg limestone on St. Helen's Island, near Montreal, and on Belœil Mountain, a few miles farther

[1] Proc. Boston Soc. Nat. History; vii, 238.
[2] Geology of Vermont, 1861; pp. 421 and 418, 419.

east; in the first locality resting unconformably upon Ordovician strata, and in the second, upon a mass of eruptive rock which breaks through similar strata (§ 117). In this connection may be recalled the like occurrence at Becraft's Mountain, near the town of Hudson, on the east side of the Hudson River, long known, and lately re-examined by W. M. Davis. Here, resting upon shales referred to the Hudson River group and, from the locality, probably of Loraine age, there is found, in a small synclinal area, a mass of contorted strata, including 150 feet or more of fossiliferous Lower Helderberg limestones overlaid by as great a thickness of Cauda-galli shales, to which succeed a few feet of cherty limestone regarded as the equivalent of the Corniferous or Upper Helderberg.[3] In all of these localities, as well as at Rondout, also reexamined by Davis, we note the absence, beneath these Silurian strata, of the great mass of mechanical sediments, including the Oneida and Medina sandstones, which, farther west, are so conspicuous in the lower part of the Silurian series, and belong to the Second Graywacke of Eaton.

§ 148. As already mentioned in § 118, Augustus Wing, having detected in Vermont fossiliferous limestones of Trenton age, the locality was examined by Billings. In a section eastward from Crown Point, in New York, the latter found what was described as the Red Sand-rock, with Olenellus, brought up by a fault, on the east side of the Loraine shales, and followed eastward by strata carrying the fauna of the Calciferous sand-rock, succeeded by some forms of the Levis, and then by the Chazy and Trenton; to the east of which another dislocation brings up again a limestone abounding in the typical fauna of the Levis limestone. The close association of the latter with the white marbles quarried in this region, led Billings to refer these to the Levis horizon.[4] It is worthy of notice that it was in the same vicinity, which furnished Billings with Calciferous, Levis, Chazy and Trenton forms, that the organic remains had been found which were referred by Hall to the Niagara and still higher horizons, and which led Edward Hitchcock and W. B. Rogers to conjecture that the marbles of this region might be of Devonian age or younger. So perplexing were these facts to Wing, that we find him led to the conclusion, announced in a letter to J. D. Dana in 1875, and recently cited with approval by the latter,[5] that "The Eolian limestone of the Vermont Geological Report embraced not only the Trenton and the Hudson River beds, but all the formations of the Lower Silurian as well, and even limestones and dolomites of the Red Sand-rock (Potsdam sandstone) series."

§ 149. Another hypothesis touching the age of the Taconic marbles was now offered to the perplexed geologist, and this time by the Geological Survey of Canada. We have already shown that forced by the paleontological evidence (which had previously been urged by Emmons), Logan, in 1860, adopted the views of the latter as regards the horizon of the Upper Taconic, long before traced from New York to below Quebec on the St. Lawrence. This, in accordance with the conclusions of Mather, and the earlier published view of Emmons, had been described by Logan as consisting of the Hudson River group with

[3] Amer. Jour. Science, xxvi, 381 and 389.

[4] Hunt, On Some Points in the Geology of Vermont, 1868, Amer. Jour. Science, xlvi, pp. 222, 229. This paper, from data furnished by Billings, was written while the writer still accepted the untenable view of Logan, from the first opposed by Billings, which assigned the Levis to a position near the base of the Cambrian series, instead of its summit.

[5] Dana, The Age of the Taconic System, Quar. Geol. Jour., xxxviii, 402.

the addition of the Oneida sandstone. The study of its fossils by Billings now led Logan to see that its position was really below and not above the Trenton limestone; but instead of adopting Emmons' name of Upper Taconic, he gave to the series, as seen near Quebec, the name of the Quebec group, then described by Logan as a stratigraphical equivalent of the Calciferous sand-rock. Taking as a type the well-known section there displayed upon the St. Lawrence, he called the apparently superposed sandstone the Sillery, and the underlying fossiliferous limestones and shales (the Sparry lime-rock of Eaton,) the Levis division. This was a reversal of the order described by former observers, and there can be no doubt that the section at Quebec is really an inverted one, the Sillery sandstone being the oldest and not the youngest member of the series as there displayed. This history has already been given at length in Chapter VI of this essay.

§ 150. We have there also explained how Logan's view of the position of the Sillery sandstone was made to support the notion that the crystalline schists which have been found to underlie it were the altered representatives of the sedimentary strata found between the Sillery and the Levis, which he had called the Lauzon division. Following the rocks of his Quebec group southward into Vermont until he met the granular marbles of the Lower Taconic, Logan was led to include these also in the Quebec group, and to regard them as the Levis limestone in an altered condition. This, as already set forth in §§ 115–116, is seen in his large geological map of Canada and the Northern States, published in 1866, after he had spent some time in tracing these rocks through western Vermont and Massachusetts into eastern New York. Therein the Lower Taconic limestone in Massachusetts is represented as an uninterrupted continuation of the Levis limestone from the province of Quebec, brought up along an anticlinal, and having on both sides overlying it, successively, the Lauzon and Sillery divisions,—these, on the west side of the anticlinal, having the ordinary type of the uncrystalline First Greywacke or Upper Taconic, but being represented on the east side by the crystalline schists of the Green Mountain range, their supposed equivalents. Few will now question that Logan was wrong in this latter point, or will doubt the greater antiquity of these crystalline rocks. On the other hand it is to be noted that, in thus asserting the infraposition of the Lower Taconic marbles to the First Graywacke or Upper Taconic series, Logan but confirmed the older observations of Eaton and Emmons, and only erred in having, by a false interpretation of the succession of the latter series near Quebec, assigned the Levis limestone to its base, by which he was led to confound it with the Lower Taconic limestone. In either view, he placed the latter below the series of several thousand feet of sandstones, conglomerates and shales, which constitute the First Graywacke of Eaton and the Upper Taconic of Emmons.

§ 151. We have already seen that Emmons, as early as 1846, had recognized the fossiliferous character of the First Graywacke, which he afterwards called Upper Taconic; that he described and figured, in 1855, trilobitic forms found therein, and did not hesitate, in 1861, to declare that it corresponded with the Primordial zone of Barrande.[6] Thus it happened that Barrande, Marcou, and after him Perry assumed the Taconic system to be the equivalent of the Primordial zone or Cambrian of Great Britain, Bohemia and Spain,—they having failed to recognize the distinction which Emmons had made between the Lower

[6] See, in this connection, Barrande and Marcou on the Primordial Fauna and the Taconic System; Proc. Boston Soc. Nat. Hist., Dec., 1860, vol. vii, pp. 369–382.

or original Taconic, and the Upper Taconic or Cambrian. In 1867, J. B. Perry described the Taconic system of Vermont as composed of three parts: 1. Lower, consisting of quartzites, marbles and talcoid schists, the original or Lower Taconic of Emmons; 2 and 3. Middle and Upper, including the uncrystalline fossiliferous Scranton and Georgia slates, and the overlying Red Sand-rock, which he regarded as the equivalent of Potsdam. The succeeding graywacke, constituting a great part of the Upper Taconic of Emmons, was by Perry supposed to be separated by an unconformity from the Red Sand-rock, and he was disposed to divide it from the Taconic and connect it with the Champlain division.[7]

§ 152. Still more recently Marcou has given us his own latest views of these rocks in Vermont. The true or typical Taconic is, according to him, the Upper Taconic of Emmons, and rests unconformably upon the Lower Taconic. This upper series he divides into four parts, in ascending order, designated the St. Albans, Georgia, Phillipsburg and Scranton groups. In these are found, besides the Primordial fauna, fossils of the second fauna in included limestones, a fact which he explains as indicating centres of creation in which the forms of the second fauna first made their appearance; the whole of these being, according to him, below the horizon of the Red Sand-rock, which he supposes to overlie, unconformably, the Upper Taconic.[8] That the forms of the second fauna, found in portions of this region, belong to a lower horizon than the Potsdam, is in discordance alike with with the facts of paleontology and of stratigraphy, and is opposed to the conclusions of all other observers in that region, including alike Emmons, Logan and Perry. Marcou's conclusions would seem to be based on some of the frequent cases of inversion of strata, or of dislocation and upthrow, to which we have elsewhere alluded, and which led Logan to place the Levis limestone near Quebec at the base of his Quebec group, and to represent the Taconic marbles of southern Vermont as passing below the crystalline schists of the Green Mountain range.

It should, however, here be said, at the same time, that in a disturbed region like eastern Vermont, where areas of the higher rocks of the second fauna exist, and have probably at one time been more widely spread than now, it is not impossible that there may be outliers of a sandstone of Oneida or Medina age, such as in Pennsylvania we have described as overlying unconformably Lower Taconic rocks, and also that such Silurian sandstones may have been confounded with the older Cambrian or Potsdam sandstone, and thus afford a seeming justification for the strange hypothesis advanced by Marcou, that the whole of the Appalachian Cambrian in Vermont is older than the Potsdam sandstone. The absence of these Silurian sandstones at the base of the outliers of Silurian limestones at Montreal, at Hudson and elsewhere, as already noticed in § 147, renders, however, their presence in Vermont less probable.

§ 153. The studies of the last few years have thrown much light on the character of the lower portions of the Cambrian in its development to the east and south-east of the Adirondack area. It has been noticed that the Red Sand-rock, and its accompanying slates and limestones near Burlington, Vermont, referred by Emmons to the Potsdam, but by Adams, and W. B. Rogers to the Medina, and by Logan to the summit of the Hudson River group, were subsequently by Billings called Lower Potsdam, to indicate that the fauna of these rocks belongs to a somewhat lower horizon than the typical Potsdam of the New

[7] The Red Sandrock of Vermont, etc., J. B. Perry; Proc. Bos. Soc. Nat. Hist., 1867, vol. xi.

[8] Marcou, Bull. Soc. Géol. de France, 1880, (3) ix, pp. 18-46.

York system. The subsequent studies of Logan in western Vermont, as given by him in 1863, showed that these ancient rocks are brought up by a north and south dislocation, with upthrow on the east, from beneath rocks of Trenton, of Chazy, or of Levis age, which latter here occupy their natural position at the summit of the Upper Taconic or First Graywacke group.[9] Billings, also in 1868, as already pointed out, had shown that farther southward in Vermont the Red Sand-rock, or Lower Potsdam, is in like manner brought up by a dislocation, so as to overlie on the east the Loraine shales.

§ 154. It now became clear that much of what had been called Hudson River group, to the east of the Hudson Valley, and of Lake Champlain, consisted, not as taught by Mather and his followers, of disturbed and altered strata newer than the Trenton limestone, and of the age of the Loraine shales, but of older rocks, carrying in part, at least, the forms of the first fauna. We have already seen (§ 112) how, in view of these facts, Hall expressed his opinion in 1862, as to the relations of these newer strata to the older ones. In 1877, he returned to the subject and, after retracing the history of investigation, concluded that "we now know approximately the limits between the newer and the older formations, and there is now no longer any question that the newer series, or the rocks above the Trenton limestone, do occupy both sides of the Hudson River for nearly one hundred miles, and continue along the valley for many miles farther towards Lake Champlain. The term, Hudson River group, has, therefore, a definite signification, from absolute knowledge of superposition and fossil remains. The error lay in extending the term to rocks on the eastward, at a time when their fossil contents had not been studied, and were, in fact, unknown, and their geological position had not been determined by critical examination."[10] We have already shown, in §§ 13–14, how Vanuxem had devised this term to include, besides the true Loraine shales, other disturbed and apparently non-fossiliferous rocks of controverted age, which he supposed might be included with the former, and thus introduced much of that confusion which has prevailed in the use of the name of Hudson River group as the equivalent to that of Loraine shales.

§ 155. The eastern limit of the rocks of the second fauna, along the Hudson valley, being defined, as stated by Hall, and as already shown by him for that region on Logan's geological map previously published, it was important to determine the age of the uncrystalline rocks along their eastern border, and to decide whether these were, (as mapped by Logan), portions of the so-called Quebec group, or of the still older Potsdam, which had been found in this position at several points in Vermont. Nothing has contributed more to the solution of this problem than the careful studies of Mr. S. W. Ford, who, in 1871, discovered the existence of fossiliferous rocks of this lower horizon at Troy, New York, and, following up his investigations, showed that these strata, containing an abundant fauna of Lower Potsdam age, (corresponding to the Olenellus slates of Georgia, Vermont, and to the beds at Bic, Quebec, and at the Strait of Belleisle, in Labrador,) are at Troy brought up on the eastern side of a fault, against the Loraine shales.[11] Continuing his studies, Ford has recently traced these Lower Potsdam rocks, under similar conditions, through various parts of Columbia and Duchess Counties, the stratigraphical break and the upthrow of the Cambrian strata on its eastern side being well defined. He does not attempt to estimate

[9] Geology of Canada, chap. xxii, pp. 844–860.
[10] Hall, Proc. Amer. Assoc. Adv. Science, 1877, p. 263.
[11] Amer. Jour. Science, 1873, vi, p. 135.

the thickness of this series of Cambrian sandstones, shales, conglomerates and limestones, but says that it "is manifestly very great in eastern New York."[12]

§ 156. It is hardly necessary to mention that this series of Cambrian fossiliferous rocks, traced by Ford through Rensselaer, Columbia and part of Duchess Counties, along the eastern side of a belt of Loraine shales, is a part of the great Graywacke belt, the age of which was disputed between Emmons and Mather, (the Hudson River group of the latter), and which Logan, after his examination of the region with Hall, in 1863, described and subsequently mapped as Quebec group. These observers, as has been already stated (§ 115), and as may be seen on Logan's map of 1866, then traced a narrow but persistent belt of Loraine shales along the eastern side of the Hudson, from Washington County southward to a point a little above Hyde Park, where they found the boundary between these shales and the older group to cross to the west side of the Hudson. The accuracy of this delineation is confirmed by Ford, who, while remarking that the distribution of the upper rocks might entitle them to be called the Hudson River group, suggests, in view of the perplexities which have attended its use, that it would be better "to discard altogether the designation, and go back to the old term, Loraine shales." Ford farther speaks of the "great dislocation," which, at so many points from western Vermont to the Hudson in Duchess County, brings up the Cambrian rocks against newer strata of Ordovician age. A reference to the sections of Logan and Billings, already cited, will, however, show the existence, not of a single dislocation, but of parallel dislocations, with upthrows on the east side, towards the barrier of older rocks. Of such parallel faults we find, in fact, repeated examples, not only east of the Hudson, but farther southward, along the eastern border of the Appalachian valley, as already shown in § 101.

§ 157. The one continuous break, with an upthrow on the south and east of 7,000 feet, extending from Gaspé to Alabama, imagined by Logan, was required in his structural scheme, because he had assumed the Levis limestone, (which near Quebec is brought to adjoin the Loraine shales,) to occupy a position at the base of his Quebec group, and to have been originally buried 7,000 feet beneath the Loraine shales in a great conformable series. The strata along the west side of these dislocations in Canada and in Vermont are, according to Logan, either Levis, Chazy, Trenton or Loraine, the Lower Potsdam being on the east side. In a section described by Billings, and already noticed (§ 148), where the first dislocation brings up the Lower Potsdam—which is successively overlaid by Calciferous, Levis, Chazy and Trenton—against the Loraine, a second parallel fault, a little farther to the east, brings up the Levis against the Trenton. We see, from the late studies of Ford, that the great belt along the eastern border of the Loraine shales, which Logan described and mapped as Quebec group, is in large part Lower Potsdam. The whole series must now be farther studied in the present light: we must know the real thickness of the Cambrian in the region in question; the interval therein which separates the Lower Potsdam from the Levis fauna; and how much of the Quebec group of Logan is to be included in the Potsdam.

§ 158. As regards the relations of the Cambrian and Ordovician rocks over this area, we have already shown that there is every reason to believe that there exists a stratigraphical break between them, (as is also the case between the Lower Taconic and Cambrian),

[12] Amer. Jour. Science, 1884, xxviii, pp. 35 and 206.

and, farther, that the lower members of the Ordovician series, (the limestones of the Trenton group), thin out and present irregularities to the south and east. Although, according to Hall and Logan, it appeared that the line between the Loraine shales and the inferior series passed from the east to the west bank of the Hudson near Hyde Park in Duchess County, subsequent studies have shown the existence of the higher strata farther southward, on the east bank.[13] Dale, in 1877, found fossils of the Loraine period in shales at Poughkeepsie, and Dwight soon after detected abundant forms of Trenton age in the limestone of the Wappinger valley, a little farther south, as well as at Newburg, on the west bank of the Hudson. These discoveries were soon followed by that of a remarkable fauna of Calciferous age in other limestones in the Wappinger valley, thus showing the presence here, as in Vermont, to the east of the outcrop of the Potsdam, of strata carrying the fossils of the Calciferous, the Trenton and the Loraine subdivisions. These remarkable discoveries by Dwight were made in 1877–1880,[14] and, joined to the observations of Dale, and those of Ford, show the existence, in what has been called Hudson River group and Quebec group, of fossiliferous strata ranging from the Lower Potsdam to the Loraine, both inclusive,—a result identical to that already arrived at in Canada for the area which had been successively mapped as Hudson River group and Quebec group.

§ 159. Having thus recalled the latest results of paleontological research among the so-called Upper Taconic, and shown the association of areas of Ordovician rocks with the predominant Cambrian; we may proceed to notice the views of Prof. J. D. Dana on the Taconic question. He, in 1872 and 1873, published an extended series of papers on the rocks of the Taconic range, as seen in Berkshire County, Massachusetts, and reasoning from the organic forms found in association with similar limestones in Vermont, reached the conclusion that the Stockbridge limestone "is mainly Trenton," the overlying schists being of the Hudson River group.[15] This latter statement, supported by a stratigraphical argument, may be found in a paper on the Geological Age of the Taconic System, in the Quarterly Journal of the Geological Society of London, for August, 1882. Herein, giving a historical introduction to the subject, Dana takes for a definition of the Taconic system the statements made by Emmons in his Geology of the Northern District of New York, published in 1842, while his views were yet vague, and before he had clearly defined, or even studied the relations of the granular quartz-rock, the granular lime-rock, and the interstratified and immediately overlying schists and argillites, together constituting the Lower Taconic, with the great Graywacke series which Eaton, Emmons, Mather and Logan have alike placed above it, and which was subsequently called Upper Taconic by Emmons. This latter series, as we have seen, appears along the western base of the Taconic range, and presents a great mass of faulted and disturbed uncrystalline strata between that range and the narrow band of Loraine shales which extends for a long distance southward along the east bank of the Hudson.

§ 160. In describing, in 1842, the rocks of the Taconic range in western Massachusetts, Emmons notices the occurrence of three parallel belts of limestone, with accompanying shales, the western one of which he designates as the Sparry limestone—the Sparry lime-

[13] Amer. Jour. Science, xvii, 57.
[14] *Ibid.*, xvii. 389; xix, 50; xxi, 78; and xxvii, 249.
[15] *Ibid.*, vi, 274.

rock of Eaton—followed to the east by two other belts, differing from the first in lithological characters, and constituting the Granular lime-rock of Eaton. Emmons then proceeds to inquire whether these three may not be one and the same bed repeated, or, in case there should be two or more distinct beds, which belt is the oldest. "It is," he says, "a question whether these three several belts of limestone may not belong to one bed; it is at least worthy of attentive examination. It is, however, a question that I have often sought to solve, but I have not yet succeeded in a way which is satisfactory to my mind, but I have concluded to regard them as distinct, inasmuch as there are differences of some importance," etc. It had been customary, he tells us, to look upon the most easterly belt as the oldest, and that at the western base of the Taconic range as the newest, notwithstanding the fact that the most westerly belt seems to dip beneath the eastern. At the same time he remarks that, in the absence of fossils, "we must judge of their age by their relative position, or by superposition, and, so long as the most western belt, by this rule, is the inferior one, I can see no necessity in the case to suppose a series of complicated changes, in order to make it coincide with our conjectures." [16]

§ 161. A careful perusal of the page from which these extracts are taken, and, indeed, of the citations themselves, suffices to show that Emmons was at that time—1842—in doubt which of these limestones should be regarded as older and which younger, or, indeed, whether they were not all repetitions of the same belt. These doubts were, however, resolved by him, and those familiar with his subsequent studies and publications are well aware that he soon afterward saw reason to follow Eaton in assigning the Sparry lime-rock of the western belt to the summit of the great Greywacke or Upper Taconic series, which he showed to be fossiliferous and Cambrian in age. The whole history of this is before the world in Emmons' later publications of 1846, 1855 and 1860, but of this, in 1882, Dana tells us nothing, and, after asserting that the Taconic rocks constitute one conformable series—which, so far as regards the Lower Taconic, has never been questioned—refers to the well-known fact that the limestones of the western belt described by Emmons, have since yielded not only a Cambrian, but an Ordovician fauna, and then, falling back on the words of Emmons in 1842, already cited, declares that "if Professor Emmons' view is right with regard to the western and eastern limestones and the intermediate Taconic schists, namely, that the order of superposition is the order of age, then the western is the oldest of the three;" but, "inasmuch as the western limestone is partly of Trenton age, it makes the eastern limestone younger still, or, a part of the Hudson River group." [17] Dana, however, adds that he accepts the alternative conjecture of Emmons in 1842,—which he assumes to be established,—that the eastern and western limestone belts in question are but repetitions of one and the same stratum, and thence argues that the granular marbles of the Taconic range are altered lower paleozoic limestone.

§ 162. The different views with regard to the geological horizon of the Lower Taconic or Stockbridge limestones of Emmons—the Granular lime-rock of Eaton—may be resumed as follows:—

I. That they are pre-Cambrian, and occupy a position below the Potsdam sandstone or Red Sand-rock, and the Quebec group of Logan, which together constitute the First or

[16] Emmons, Geology of the Northern District of New York, p. 147.
[17] Quar. Geol. Journal, xxxviii, 465.

Cambrian Graywacke of Eaton and the Upper Taconic of Emmons, as shown in the table, § 18. (Eaton, Emmons, Perry, Marcou.)

II. That, although lying beneath the greater part of this Graywacke series, they are not distinct therefrom, but are the altered representative of the Levis limestone or Sparry lime-rock, imagined by Logan to lie between the Red Sand-rock below and the chief part of the Quebec group above. (Logan, in his geological map of 1866.)

III. That they are the altered representatives of the whole of the limestones which, in the New York system as seen in the Adirondack area, appear between the Potsdam sandstone and the Utica slate. (Mather, H. D. and W. B. Rogers, J. D. Dana.)

IV. Allied to the last is the view expressed by Wing, in 1875, that they include the representatives of the limestones of the Potsdam and Quebec groups of Logan, together with the Trenton and the Loraine or Hudson River group, or, in other words, the whole of the Champlain division of the New York system, from the Potsdam to the base of the Oneida.

V. That they belong to a horizon above the Champlain division, and are true Silurian and Devonian. (C. B. Adams, Ed. Hitchcock, W. B. Rogers.)

§ 163. We have already briefly set forth the arguments on which these various and contradictory hypotheses have been based. While the fifth supposes the Lower Taconic limestone to hold a position above the Oneida sandstone, and consequently superior to the Second Graywacke, the third was devised at a time before the existence of the First Graywacke, (maintained by Eaton and Emmons, but denied by Mather,) had been again brought into favor by the conversion of Logan to the teaching of Emmons, and by his farther admission that the Lower Taconic limestones in Vermont and Massachusetts are inferior to a great mass of sandstones, conglomerates and shales many thousand feet in thickness, constituting what he called the Lauzon and Sillery divisions of the Quebec group.

§ 164. It was not until after his change of view as to the geological horizon of this great sedimentary or Graywacke series, or in other words, after he had recognized the fact that its place was below and not above the Trenton limestone, that Logan began to examine the Lower Taconic rocks in western New England. Having then, by a misconception, placed the Levis or Sparry lime-rock at the base instead of the summit of the Graywacke, and still holding to the notion of Mather that the crystalline rocks along the eastern border of the great Appalachian valley were but a portion of the paleozoic strata in a so-called metamorphic condition, Logan was led to look upon the Lower Taconic limestone as an altered representative of the Levis limestone, and its underlying quartzite as Potsdam; the immediately overlying schists and the succeeding sandstones, conglomerates and shales of the Graywacke series being referred to the Lauzon and Sillery divisions of his Quebec group. Hence the wide difference between the view of Logan, given under II, and that of Mather and his followers, which we have numbered III. While both would place the Lower Taconic limestones above the Potsdam and below the Oneida, Mather imagined the slates and sandstones overlying them to be Ordovician and Silurian (that is, Utica, Loraine and Oneida) or the Second Graywacke of Eaton. Logan, on the other hand, conceived the same overlying beds, as seen by him in Vermont, Massachusetts and New York, to belong to the Cambrian or First Graywacke. The error of Mather and of H. D. Rogers was that both failed to recognize this great series of sandstones, conglomerates and slates, which are so conspicuous in the Appalachian

valley, and confounded them with the Second Graywacke. This error it was which completely misled the Geological Survey of Canada up to 1860, and continues to obscure the subject in the minds of many American geologists to the present time.

§ 165. It should be remembered that, as already pointed out in Chapters II and III, the overlying Graywacke or Upper Taconic does not include the schistose rocks immediately above the Lower Taconic limestone, but that a considerable amount of crystalline schists and argillites occurs, both interstratified with and overlying this limestone, and forming an integral part of the Lower Taconic series. We have, moreover, set forth in Chapter V, evidences of the distinction between the Upper and the Lower Taconic, and have shown that the latter is not limited to the great Appalachian valley, which confines the former, but is met with in more or less interrupted belts lying upon the crystalline rocks of the Atlantic region, south and east of the great valley, from New Brunswick to Georgia. Thus, in North Carolina, not less than four distinct and separate parallel bands of the Lower Taconic are met with between that of the great valley and the overlying tertiary strata of the coast, while similar narrow bands of the same rocks are found in southern New York and New Jersey, lying upon the ancient gneisses. With none of these Lower Taconic belts outside of the great valley, so far as is known, is the Upper Taconic to be found, its absence being due either to erosion, or more probably, as suggested by Emmons, to the elevation of these areas above the sea during Cambrian time.

§ 166. On the other hand, it has been shown in Chapter VI, that what Mather regarded as a continuation of the great Graywacke series from the east of the Hudson, extends south-westward across Orange County and, according to Horton, there rests, with a high eastern dip, on the north-west side of the gneissic belt of the Highlands. From central Vermont, north-eastward along the great valley, to the St. Lawrence below Quebec, the Lower Taconic is not known, and the Upper Taconic or Graywacke series rests directly upon older crystalline schists, as in Orange County, New York. The same condition of things is again seen in Newfoundland. These facts, already given in detail, serve to show the distinctness and independence of the crystalline Lower Taconic from the uncrystalline Upper Taconic or Cambrian series, which two were probably separated by a considerable interval of time, corresponding to the stratigraphical break, long since pointed out by Eaton, at the base of the First or Transition Graywacke.

§ 167. The student who refers to Dana's paper of 1882, already noticed, on "The Age of the Taconic System," will obtain no light on the question of the Graywacke series, nor indeed any evidence that the author has ever seriously studied the literature of the question, or comprehended its relation to the complex question before us. He will get no notion of the two opposing views as to this series of rocks, or its position as above or below the Trenton limestone, or even of its existence as a great succession of uncrystalline sediments, many thousand feet in thickness and distinct from the Lower Taconic limestones, as maintained alike by Eaton, by Emmons, by Mather, and by Logan, and as set forth in the preceding chapters. We leave it to the reader to seek for an explanation of this incompetent and partial statement of the great geological problem under discussion by one who assumes to be alike an investigator, a teacher, and a critic, and forbear to follow him into the details of his criticisms.

§ 168. The hypothesis of Mather and H. D. Rogers as to the Lower Taconic rocks was

devised at a time when the progress of geology in New York had made known, in the northern district of that state, a great series of nearly horizontal fossiliferous strata resting upon the upturned granitoid gneiss of the Adirondacks and including the now well-known subdivisions of the paleozoic, from the Potsdam sandstone upwards. The relations and succession of these various rocks were simple and evident. To the east and south-east of this region, however, beyond Lake Champlain and the Hudson River, there were found other crystalline rocks unlike the ancient gneiss, and other uncrystalline sediments very different in physical character and in stratigraphical attitude from the paleozoic strata of the northern district of New York. The question then arose as to the correlation of these unlike rocks in the two regions. Amos Eaton, by a grand generalization, had already arrived at a system of classification in which he recognized the existence in the eastern or Appalachian region, of types of Primitive crystalline rocks other than the granitoid gneiss, and of great masses of sedimentary strata to which nothing similar was found in the contemporary series in the Adirondack region.

§ 169. Rejecting the teachings of Eaton, and falling back on the metamorphic doctrine which was then so generally received, Mather maintained, in 1843, that whatever to the east of the Hudson differed lithologically from the ancient gneiss on the one hand, and from the paleozoic rocks of New York system, as seen in the Adirondack region, on the other, could be nothing else than these same paleozoic rocks folded and subjected to successive stages of so-called metamorphism, as seen in the Lower Taconic quartzites and marbles and the crystalline schists which accompany them, as well as those others that succeed them farther to the east. All of these were, according to Mather, nothing but the more or less altered equivalents of the members of the New York system, from the Potsdam sandstone to the Loraine shales, both inclusive; while the great Graywacke belt, extending along the east side of the Hudson from Duchess County northward through Vermont, was not, as maintained by Eaton, older than the Trenton limestone, but newer than the Loraine shales.

§ 170. The considerations which lent probability to this scheme were, first, the general resemblance of this Graywacke series to the Oneida, Clinton, and Medina subdivisions of the New York system, to which it was by Mather referred; and secondly, the fact that the argillites with unctuous schists, granular limestones and granular quartzite, which he agreed with Eaton and Emmons in placing below the adjacent Graywacke, presented a certain resemblance to the Loraine and Utica shales, the Trenton and Chazy limestones, the so-called Calciferous sand-rock, and the underlying Potsdam sandstone. This general parallelism from the top of the Graywacke downward, which suggested to the mind of Eaton only the great law of cycles in sedimentation (since generally recognized), was accepted by H. D. Rogers and by Mather as a proof of identity. In fact the Lower Taconic, as seen along the Appalachian region, in its regular succession of granular quartzites, with granular limestones and intervening and overlying soft schists and argillites, presents, notwithstanding its many mineralogical differences, its crystalline character, and its great thickness, that general parallelism to the Champlain division which is so often remarked in groups of sedimentary strata at very various geological horizons. It is thus, in certain respects, more like the Adirondack Cambrian and Ordovician, with which it has been confounded, than their Appalachian representatives. These resemblances were coupled with the fact that along the base of the South Mountain, in Pennsylvania, this succession

is found lying between the ancient granitoid gneiss beneath, and the Oneida sandstone above, precisely as the Potsdam-Loraine succession in northern New York intervenes between the same gneiss and the same sandstone.

§ 171. It was not, therefore, surprising, that the geologists then engaged in the study of Pennsylvania, New Jersey, and southern New York, should have accepted this plausible and, at first sight, natural explanation of the apparent lithological parallelism presented between these regions and northern New York, or that Mather endeavored to extend it to the rocks east of the Hudson. This attempt led him to assign to the great Graywacke series, which we now know to be of Cambrian age, a position above the Loraine shales, or, in other words, to confound it with the Oneida, Medina and Clinton subdivisions of northern New York and of Pennsylvania, and thus to mistake the First for the Second Graywacke of Eaton, and, in fact, to deny the existence of the former as a great series lying above the Lower Taconic and below the horizon of the Trenton limestone. The brothers Rogers and Mather, forty years since, reasoning from the paleozoic succession as displayed in the Adirondack area, were not prepared to admit that, in a region so near as the great Appalachian valley, the paleozoic sediments beneath the Trenton horizon could assume a type so unlike the well-known Potsdam and Calciferous subdivisions of the northern district of New York, or that these subdivisions could be represented in the Appalachian area by the vast and lithologically unlike series of the First Graywacke, which Eaton had already, ten years before, assigned to its true position below the horizon of the Trenton limestone. Hence came the great mistake in American stratigraphy, the denial by Mather and his followers of the distinctness of the First Graywacke of Eaton, and the assertion of its identity with the Second Graywacke of the same author. So long as this false position was maintained, there was a plausible argument to be made for the original hypothesis of the brothers Rogers and Mather as to the age of the Lower Taconic series; but with the recognition of the correctness of Eaton's view of the First Graywacke, the fallacy of this hypothesis became obvious, and those who would still advocate it can only do so by ignoring alike the results of stratigraphical and paleontological study for the last generation.

§ 172. The absence from the granular quartz-rock, the granular marbles and their intercalated and conformably overlying schists and argillites of the Lower Taconic series, of the organic remains of the various members of the Champlain division, or, indeed, of any organic form save the peculiar Scolithus of the granular quartz-rock already noticed, (§ 23) was explained by those who maintained the paleozoic age of the series by the convenient hypothesis of a chemical change, attended by crystallization or so-called metamorphism, which was supposed to have effaced the original characters of the sediments and obliterated their organic remains. In accordance with this hypothesis, it was believed that great series of strata might, within short distances, assume a new aspect, not through any original differences in the sediments, but from transformations wrought in these after deposition, in virtue of which, fossiliferous and earthy limestones, losing all traces of their organic remains, could be converted into granular limestones containing, instead, only crystalline silicates, while ordinary sandstones and argillites might become micaceous, chloritic, or hornblendic schists, and even gneisses and granite-like rocks.

§ 173. These views, a development of the Huttonian school in geology, were, as is well known to students, accepted a generation since by a large number of geologists, both

in Europe and America, and were carried to an extreme in America. Mather, in his final Report on the Geology of the Southern District of New York, declared that "the Taconic rocks are of the same age with those of the Champlain division, but modified by metamorphic agency and by the intrusion of plutonic rocks." They were, however, designated by him as "imperfectly Metamorphic rocks," while the various crystalline schists of New York and western New England, included by him in his group of proper Metamorphic rocks, were declared to be the same series in a still more highly altered condition (§ 121). Respecting these, he asserted that where the Taconic and Metamorphic rocks come together, "no well-marked line of distinction can be drawn, as they pass into each other by insensible shades of difference." Mather was disposed to admit, in addition to these, an older or so-called Primary series of crystalline rocks in the Highlands of the Hudson, but, in the course of his Report, ended by declaring that the Primary limestones of southern New York and northern New Jersey, with their associated granitic and hornblendic rocks, were nothing more than modifications of the members of the Champlain division. He had been led to believe that the Primary limestones in question "can be easily traced through all the changes from a fossiliferous to a crystalline white limestone, containing crystallized minerals and plumbago." From the interstratification of these crystalline limestones, supposed by him to be paleozoic, with gneissic and hornblendic rocks, he was brought to maintain the paleozoic age of these, and thus to doubt whether a part, at least, of what he had called Primary gneiss was not also paleozoic.

§ 174. Apart from the crystalline rocks of the Highland or South Mountain belt, whose primary character was in part questioned by Mather, the great area of crystalline rocks lying to the south and east of this range in New York, comprising those of Westchester and New York Counties, and embracing Manhattan Island, was by him included, with the adjacent rocks of western New England, in his Metamorphic series, and declared to be "nothing more than the rocks of the Champlain division, modified greatly by metamorphic agencies and by the intrusion of granitic and trappean aggregates."[18] In this area of southern New York he noticed hornblendic rocks, gneiss, mica-schists and crystalline limestones, besides granite, syenite and serpentine, the latter three being regarded by him as intrusive rocks.

§ 175. The doctrine of the Metamorphic school of forty years since, as then resumed and formulated by Mather, was briefly as follows: the different groups of crystalline stratified rocks in south-eastern New York and western New England, (with the doubtful exception of the gneissic belt which he had designated Primary), including the Lower Taconic series, the series of micaceous gneisses and mica-schists, as well as the massive granitoid and hornblendic gneisses with their crystalline limestones, all belong to one and the same geological period, and are contemporaneous in age with the paleozoic rocks of the Champlain division of northern New York, from the Potsdam sandstone to the Loraine shales, both inclusive. These various and unlike, though contiguous groups of crystalline rocks, were, according to Mather, all produced from the same uncrystalline Cambrian and Ordovician sediments, through a mysterious process of transformation, by

[18] For the details of these views see Mather's Geology of the Southern District of New York, 1843, *passim*. A summary of Mather's somewhat diffuse statements will be found in the author's volume on Azoic Rocks, Report E of the Second Geological Survey of Pennsylvania, 1878, pp. 38–42.

what he called "metamorphic agencies," and the intrusion of igneous rocks, in which category he included not only the interbedded serpentines, but apparently, under the name of granites, much of the granitic gneiss, which characterizes large areas of the region, as well as the abundant endogenous granitic veins,—true intrusive or exotic granites being rare in the region. In Mather's cosmogony there was nothing in the geological sequence, at least in north-eastern America, between the New York paleozoic series, as seen in the Adirondack area, and the fundamental Laurentian gneiss which there underlies it. Consequently all crystalline rocks which could not be referred to the latter, were, unless plutonic, the result of some unexplained transformation of the lower part of this paleozoic column, designated by him as the Champlain division.

§ 176. This hypothesis, extravagant as it now seems, was, during the next few years, accepted by many geological students on the authority of Mather and the brothers, H. D. and W. B. Rogers. These latter, in 1846, extended this view of Mather to the White Mountains of New Hampshire, and suggested that the gneissic, hornblendic and micaceous rocks of this series, since named Montalban, instead of belonging, as hitherto believed, to the "so-called Primary periods of geological time," were probably altered paleozoic strata of Silurian age, including the Oneida, Medina and Clinton subdivisions of the New York system. These observers then proceeded to name many species of characteristic organic forms of the Silurian period, which they thought to recognize in certain crystalline aggregates in the mica-schists of the region. In 1847, however, the same observers announced that they no longer considered these forms of organic origin,[19] and, although they did not then formally retract their opinion as to the paleozoic age of the gneisses and mica-schists of the White Mountains, are known, from their subsequent writings, to have abandoned it as unfounded, though it was for some years afterward maintained, with some variations, by Logan, Lesley and the present writer.[20]

§ 177. As regards the ancient crystalline series of the Highlands of the Hudson and of New Jersey, which differs in lithological characters from the last, we find that H. D. Rogers, while he did not accept the notion of Nuttall and of Mather that its gneisses are altered paleozoic sediments, imagined the crystalline limestones, which are really interstratified with them, to be portions of a younger limestone, altered by supposed igneous agencies. In the words of Lesley, Rogers, while maintaining the Primary age of the Highland gneisses, "mistook the crystalline limestone engaged among the Highlands for metamorphosed synclinal outlyers of No. II, as at Franklin," in New Jersey, whereas Cook has since shown that the horizontal strata of this later period overlie the upturned crystalline limestones of Franklin.[21] As a consequence of this, H. D. Rogers was quoted by Mather as supporting the extreme notions of metamorphism maintained by Nuttall in 1824, which Mather himself accepted, and which, as I have elsewhere said, "were adopted by H. D. Rogers, as far as regards the crystalline limestones of the Highlands in New Jersey,"[22] while he soon after applied the same doctrine, in its fullest extent, to the great gneissic series of the White Mountains.

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[19] Amer. Jour. Scien[illegible]2] i, 411, and v, 116.

[20] See, for historical [illegible], Hunt, Amer. Jour. Science, vol. l, 84; also Azoic Rocks, pp. 62, 181, 182, and Trans. Roy. Soc. Canada, vol. i, sec. iv, p. 195.

[21] Lesley, Amer. Jour. Science, 1865, xxxix, 222.

[22] Hunt, Azoic Rocks, p. 41.

§ 178. To sum up in a few words the views of the Metamorphic school forty years since (1840–1846): we find that H. D. and W. B. Rogers then maintained the paleozoic age of the Lower Taconic series, of the White Mountain gneisses and mica-schists, and also of the crystalline limestones found among the gneisses of the New York and New Jersey Highlands, though admitting the primary age of these Highland gneisses. Mather, again, while holding, in like manner, to the paleozoic age of the Lower Taconic, was not acquainted with the White Mountain series, but maintained that the whole of the gneisses, mica-schists and crystalline limestones of south-eastern New York, with the possible exception of the Highland belt, were paleozoic, and of one age with the Taconic series.

It is worthy of note that on the geological map of the State of New York, published in 1842 "by legislative authority," of which the Southern District was prepared by Mather himself, there is no distinction of color between the gneissic rocks of the Highlands and those lying adjacent to them on the south and east, described by him in his final Report, in the following year, as metamorphic paleozoic strata. The serpentine of the region, as seen in Staten Island, is colored on the map like the adjacent intrusive triassic diabase,[23] but no attempt is there made to designate other eruptive rocks than these.

§ 179. In opposition to the views of this Metamorphic school, there were not wanting some, like Emmons and Charles T. Jackson, who maintained the Primitive age of the whole, or a part, of these crystalline rocks of New England, though recognizing, as Eaton had done, their lithological distinctness from the gneiss of the Adirondacks, and of the Highlands of the Hudson. Already, moreover, in 1824, Bigsby had discovered, around Lake Superior and beyond, the existence of two series of crystalline rocks, and distinguished the younger of these as belonging to the Transition series. More than twenty years later the Geological Survey of Canada, while adopting for the crystalline rocks of New England, and their extension into Canada, the hypothesis of their paleozoic age, reexamined these Transition crystalline schists of Bigsby, as seen both on Lakes Superior and Huron, and on the upper Ottawa, and described them as forming a distinct group between the base of the paleozoic series and the ancient gneiss, upon which it was found to rest unconformably. This intermediate series, first described in 1847, was by the present writer designated, in 1855, by the name of Huronian,—the underlying gneissic series having, in 1854, received the name of Laurentian.

§ 180. In 1858 appeared the final Report of H. D. Rogers on the Geology of Pennsylvania, in which we find no recognition of the extreme doctrines of metamorphism maintained by Mather in 1843, and by W. B. Rogers and himself in 1846. Not having come to an understanding of the question of the First Graywacke, H. D. Rogers regarded the Lower Taconic series in Pennsylvania as an altered form of the Champlain division, and considered the granular quartz-rock with Scolithus to be the equivalent of the New York Potsdam sandstone.[24] The characteristic crystalline rocks of western New England and south-eastern New York, described by Mather as altered paleozoic, pass beneath the mesozoic sandstone in New Jersey and reappear in south-eastern Pennsylvania. These rocks were now, in 1858, described by H. D. Rogers as forming two great groups, an older or so-called

[23] See, for details with regard to this and the other serpentines of the region, the present writer on the Geological History of Serpentines, 1883, Trans. Roy. Soc. Canada, vol. i, sec. iv, pages 172–174.

[24] For Lesley's doubts as to the precise equivalence of the Primal quartzite of Pennsylvania and the New York Potsdam, see Amer. Jour. Science, 1865, xxxix, 223.

Hypozoic gneiss system, and a younger one of crystalline schists, which he called Azoic and placed beneath the horizon of the Scolithus sandstone. The views of H. D. Rogers, in 1858, with regard to the crystalline rocks of the Atlantic belt, were thus, as I have elsewhere said, "a return to those held by Eaton and by Emmons, but were in direct opposition to that of Mather, which had been adopted by Logan and the present writer,"[35] and, so far as regards the White Mountains, were maintained by the Messrs. Rogers themselves in 1846.

§ 181. Henry D. Rogers died in 1867, but his venerable brother, William B. Rogers, survived till 1882, and fully shared the views set forth by the former in 1858, as to the pre-paleozoic age of the great groups of crystalline rocks. His careful and extended studies in Virginia during many years had convinced him of the fallacy of the metamorphic hypothesis of Mather. In a sketch of the geology of that state, contributed by him as late as 1878 to Macfarlane's "Geological Railroad Guide," Rogers makes it plain that the crystalline rocks of that region are all pre-paleozoic, and older than what he calls the Primal or Potsdam group. This he describes as lying on the western slope, and in the west-flanking hills of the Blue Ridge, "often by inversion dipping to the south-east, in seeming conformity, beneath the older rocks of the Blue Ridge, but often, also, resting unconformably upon or against them." These older rocks, he tells us, "comprise masses referable probably to Huronian and Laurentian age," and, farther, he informs us that the letters, A, B, C and D, used in his tabular view, "mark four rather distinct groups of Archean rocks found in Virginia, of which the first three may probably be referred to the Laurentian, Huronian and Montalban periods respectively, and the fourth to an intermediate stage,—the Norian or Upper Laurentian."

§ 182. It should here be remarked that this Primal group of the valley of Virginia, also called by Rogers, Lower Cambrian, is no other than the base of the Lower Taconic series, which he continued to regard as in some sense the representative of the Cambrian Potsdam of the Adirondack region. In this connection, as showing the relations of this group to the crystalline rocks, and the apparent inverted succession, I venture to make the following extracts from a letter from W. B. Rogers, written to me in 1877, for publication in my volume on Azoic Rocks, after an examination with him of some forty unpublished transverse sections, made across the Blue Ridge during his geological survey of Virginia. In many of these sections "illustrating the position of the Lower Cambrian, (our Primal conglomerate, etc.,) in their contact with the crystalline and metamorphic rocks of the Blue Ridge in Virginia," "the unconformity of the Cambrian upon and against these crystalline and metamorphic rocks is unmistakable and conspicuous; the lower members of the Primal being seen to rest upon the slope of the Ridge, with north-west undulating dips, on the edges of the steeply southeastward-dipping older rocks. In other cases, the Primal beds, thrown into south-east dips in the hills which flank the Blue Ridge, are made to underlie, with more or less approximation to conformity, the older rocks forming the central mass of the mountain." Here follow details as to localities, for which the reader is referred to the letter as published.[36]

§ 183. While, therefore, the brothers Rogers and others with them held, and still hold,

[35] Hunt, the History of Pre-Cambrian Rocks in America and Europe, 1880, Amer. Jour. Science, xix, p. 272.
[36] Hunt, Azoic Rocks, p. 198.

to the paleozoic age of the Lower Taconic rocks, the view put forward by Mather, that the great region of gneisses and crystalline schists with limestones, lying to the east of these, consists of more highly altered paleozoic strata, had become discredited It was, as we have seen, abandoned by H. D. Rogers for Pennsylvania, in 1858, and by W. B. Rogers for Virginia, where he recognized in the pre-Taconian rocks the same great divisions which I had elsewhere pointed out. The history of the studies of Thomas Macfarlane and my own, which showed conclusively the pre-paleozoic age of the extension of the New England crystalline schists into the Province of Quebec, has already been told elsewhere.[27]

§ 184. It was, therefore, with some surprise that geological students found J. D. Dana, in 1880, attempting to resuscitate, in its completeness, the discarded view of Mather. In an elaborate paper on "The Geological Relations of the Limestone Belts of Westchester County, New York," which appeared that year, Dana, following up the reasoning already noticed (§ 161), by which he sought to sustain the paleozoic age of the Lower Taconic rocks, proceeds to assume that the crystalline marbles enclosed in the gneisses, as well as the gneisses and crystalline schists of the region named, are altered rocks of paleozoic age. To quote his conclusions: "The limestone of Westchester County and of New York Island, and the conformably associated metamorphic rocks, are of Lower Silurian age," and, farther, "the limestone and the conformably associated rocks of the Green Mountain region, from Vermont to New York Island, are of Lower Silurian age."[28] His argument in favor of these assumptions, appears to be briefly this: that the crystalline limestones of the gneissic series, the granular Lower Taconic marbles, and the fossiliferous Cambrian and Ordovician limestones found among the uncrystalline sediments of the Appalachian valley, along the western flank of the crystalline belt north of the Highlands, are but three different conditions of one and the same calcareous series, and, hence, that the great area of crystalline rocks south of the narrow range of the Highlands (of which he admits the eozoic age) consists of paleozoic strata, Cambrian or Ordovician in age.

§ 185. Dana, having announced his conclusions as above, adds: "The evidence which has been adduced, though then but partly discerned, led Professors W. B. and H. D. Rogers, and Professor W. W. Mather, nearly to the results here reached." In support of this assersertion, he refers to Mather's report of 1843, in which, as we have seen, the hypothesis was advanced, and also, under the head of "Professors Rogers," to a paper by them in 1841, in the Proceedings of the American Philosophical Society, as well as to a statement in the American Journal of Science for 1872 (Vol. IV, page 368). This, the reader will find to be nothing more than Dana's assertion that the Messrs. Rogers, in that same paper of 1841, maintained the Champlain age of the Lower Taconic series,—a view which, as we all are aware, one of them, some years later, abandoned for that of its Devonian age. These eminent geologists did, for a time, put forward the view (afterwards relinquished) that the [illegible] series of the White Mountains consists of altered Silurian (Oneida-Clinton [illegible] and Mather, in his argument, made the most of the error of H. D. Rogers, who [illegible], in 1840, certain interstratified crystalline limestones among the Primary gneisses of New Jersey for superincumbent limestones in an altered condition, but Dana fails to show that the Messrs. Rogers ever maintained the paleozoic age of the great series of

[27] Hunt, Azoic Rocks, pp. 182-188, and Amer. Jour. Science, 1880, xix, 272-275.

[28] Amer. Jour. Science, 1880, xx, 455.

crystalline rocks in south-eastern New York, as he would have his readers infer. When, in 1858, H. D. Rogers had occasion, in his final Report on the Geology of Pennsylvania, to describe the continuation of these same rocks into that State, he distinctly assigned them to a horizon below the base of his paleozoic series, proposing, at the same time, a Hypozoic and an Azoic system to include them.

§ 186. The Highland range on the east side of the Hudson traverses Putnam county, and, passing south-westward to the river, occupies but a small area in the north-west corner of Westchester County. Along its south-east base, at Annsville and at Oregon, is met a narrow belt of scarcely crystalline limestone, accompanied by an argillite or talcoid slate, and resting unconformably upon the ancient gneiss. This belt, apparently a Lower Taconic outlier, is regarded by Dana as partially altered Lower Silurian, and "the grade of metamorphism" is declared by him to become more intense to the south and east, giving rise to the whole gneissic area of Westchester and New York Counties. The gneisses and conformably interstratified crystalline limestones of this large area are, as we have seen, supposed by Dana to be metamorphosed Lower Silurian, though they are really undistinguishable from the rocks of the adjacent Highland range, which he admits to be Archean or Primary. In support of his startling proposition, Dana might be expected to point out some distinctions between the rocks of the two areas. He begins by suggesting certain differences as to more or less micaceous or hornblendic gneisses in the two regions in question, but confesses that "there are gradations between the two, in both respects, which make the application of a lithological test very perplexing," and admits that "the lithological evidence of diversity of age is weak,"[29] a criticism which the intelligent reader will conclude is equally applicable to Dana's stratigraphical argument. I am familiar with the rocks of many parts of Westchester County, and since the publication of Dana's paper in 1880 have taken repeated opportunities to examine, in various localities, the rocks called by him Metamorphic Lower Silurian, as at Singsing, Tarrytown, Yonkers, Spuyten Duyvil and Kingsbridge, along the Hudson. I have also studied the same rocks farther to the east, along the River Bronx and the Harlem Railroad to Pleasantvale, as well as between this line and the Hudson, and have crossed eastward to Long Island Sound and examined the exposures on the shore at and near New Rochelle. Being already familiar with the Laurentian rocks throughout Canada, as well as in parts of the Adirondacks, and in the Highlands from Putnam County, New York, through New Jersey and Pennsylvania to the Schuylkill and beyond, I do not hesitate to say that these gneisses and their associated crystalline limestones of Dana's so-called Metamorphic Lower Silurian, in Westchester County, cannot be distinguished from the typical Laurentian. I believe that the judgment of an impartial observer would be that the notion of any difference between the Laurentian gneisses and limestones of the areas mentioned, and the gneisses and their interstratified limestones of Westchester County, has no foundation in fact.

§ 187. Passing now from Westchester County to the adjacent Manhattan Island, the same Laurentian gneiss is seen in its northern portion, between Seventh and Eighth Avenues, especially in a cutting at One Hundred and Forty-fifth Street, and thence in a ridge some distance farther south, the strata being nearly vertical and of grayish horn-

[29] Amer. Jour. Science, 1880, xx, 373.

blendic gneiss, and a band of crystalline limestone appearing a little farther to the east, on Harlem River. A quarter of a mile to the west of this ridge, in Mount St. Vincent, is seen a distinct type of highly micaceous gneiss and mica-schists, and similar rocks are exposed at intervals in the western part of the island, as far south as Fifty-ninth Street. Farther eastward, in the southern part of Central Park, just above Fifty-ninth Street, the numerous rock-exposures are all of similar mica-schists and micaceous gneisses, often at moderate angles. They include endogenous granitic veins, occasionally presenting in their structure a marked bilateral symmetry, and sometimes transverse, but at other times interbedded. Several perched blocks here found are of similar endogenous granite, and are apparently boulders of decomposition, left in the subaerial decay of the rocks of the region. These micaceous rocks are unlike those of Laurentian areas, but, on the contrary, closely resemble those of the White Mountains and of Philadelphia which I have called Montalban, and are like the younger gneissic series of the Alps and the Scottish Highlands. I, therefore, as long ago as 1871,[30] noticed these rocks as belonging to this younger series, and have since expressed the opinion that the Laurentian "of Manhattan Island appears to be overlaid in parts by areas of younger gneisses and mica-schists, the remaining portions of a mantle of Montalban."[31] It is, however, by an error for which I am not responsible, that in Macfarlane's "Geological Railroad Guide," in 1878, the Montalban of Manhattan Island has been represented as extending upward along the Hudson River Railroad by Spuyten Duyvil, Yonkers, Tarrytown and Singsing, as far as Croton, before meeting the Laurentian of the Highlands. There appears to be, however, an outlier of Montalban rocks at Cruger's Station, just above Croton, and there may be others in various parts of Westchester County.

§ 188. It has been deemed necessary to notice thus at length, in this connection, Dana's resuscitation of the ancient views of Mather, for two reasons: first, because therein, both the Lower Taconic rocks and various crystalline rocks just noticed, are supposed by him to be contiguous portions of the same Cambrian and Ordovician (Lower Silurian) sediments in different stages of transformation; and secondly, because the manner in which the names of the brothers Rogers are cited to Dana in conjunction with that of Mather is such as to lead the reader to the false conclusion, that those eminent geologists supported Mather's hypothesis of 1843 as to the Cambrian and Ordovician age of these same crystalline rocks, as well as of the Lower Taconic series; which latter view, as we have shown, W. B. Rogers repudiated a few years later, in 1851 and again in 1860.

§ 189. The rise and fall of the doctrine of regional metamorphism, which is but an extravagant development of the Huttonian hypothesis of the origin of crystalline rocks, forms a curious chapter in the history of geology. I have elsewhere related the early application of this doctrine to the crystalline rocks of Mont Blanc by Bertrand, about 1797, and its subsequent restatement by Keferstein in 1824, until it was taken up and popularized by Lyell, Murchison, and various continental geologists, so that the view became generally accepted that the gneisses and mica-schists of the Alps are but altered secondary and tertiary strata. The story of the refutation of this hypothesis for the Alps by the

[30] President's Address before the Amer. Assoc. Adv. Science, 1871, in Chem. and Geol. Essays, pp. 248 and 197.

[31] Smithsonian Report for 1883, Progress of Geology.

studies of Favre, Pillet, Gastaldi and others has also been told.[32] A similar view was extended to crystalline rocks in other parts of continental Europe, in the British Islands, and in eastern North America, save that for all of these a paleozoic age was generally assigned. The opinions of Mather on this subject were adopted by Logan and others, including the present writer. The brothers Rogers, in 1846, advanced a similar view for the rocks of the White Mountains, but abandoned it before 1858. It was not until 1870 and 1871 that the present writer, rejecting entirely the views of this school, asserted the pre-Cambrian age of all the great areas of crystalline rocks, alike in North America and in Europe. Nearly coinciding in time with this, came the independent action of numerous continental geologists, including those already named, and the result has been such an advance of the views of the new school that, in 1881, Callaway could say that "every case of supposed metamorphic Cambrian and Silurian has been invalidated by recent researches," and in 1883, Bonney, now President of the Geological Society of London, wrote that the hitherto accredited "instances of metamorphism in Wales, and especially in Anglesea, in Cornwall, in Leicestershire, and in Worcestershire, have utterly broken down on careful study,"[33] as had already been the case in the Alps and in North America.

§ 190. The last stronghold of the metamorphic school in the British Islands was in the north-west of Scotland, where Cambrian and Ordovician fossiliferous sandstones, limestones and shales, resting upon the ancient granitoid gneisses to the west, are towards the east overlaid in apparent conformity by a great series of unlike gneisses and mica-schists, which form the Scottish Highlands, and were declared by Murchison and Archibald Geikie, from their studies, to consist of still newer rocks in a so-called metamorphic condition. The structure of this north-western part of Scotland was in fact, according to their teaching, the precise counterpart of that of New England as formerly taught by Mather and his followers, and still supported by Dana. The late Prof. Nicol, however, constantly opposed this view of the structure of the Highlands maintained by Murchison and by Geikie, while the present writer, from his lithological studies of the Highland rocks, declared in 1871 his conviction that the upper gneisses of "the Scottish Highlands will be found . . . . to belong to a period anterior to the deposition of the Cambrian sediments, and will correspond with the newer gneissic series of our Appalachian region,"[34] then described as the White Mountain series,—an opinion which was reiterated, after farther examination of the rocks, in a communication in 1881 to the Geological Society of London, when these Highland gneisses were designated as Montalban.[35]

§ 191. The studies by Hicks of the geology of parts of this region from 1878, and the later and independent ones of Callaway and of Lapworth in other districts, had already, in the beginning of 1883,[36] shown the fallacy of the views maintained by Murchison and Geikie as to the geological structure of the Highlands. The united testimony of these

[32] Amer. Jour. Science, 1872, iii, 9, and Chem. and Geol. Essays, pp. 338-342 and 347, 348. Also farther, Trans. Roy. Soc., Canada, vol. i, sec. iv, pp. 182–196.

[33] Callaway, Geological Magazine, Sept. 1881, p. 423, and Bonney, *ibid.*, Nov., 1883, p. 507.

[34] Hunt, President's Address before the Amer. Assoc. Adv. Science, 1871, and Chem. and Geol. Essays, p. 272

[35] Proc. Geol. Soc., London, in Geological Magazine, 1882, ix, 39.

[36] Hicks, Quar. Geol. Jour., 1878, xxxiv., 816; Geol. Mag., 1880, vi; also Quar. Geol. Jour., 1883 (with appended notes by Bonney), in abstract in Geol. Mag., March, 1883, x, p. 137. Callaway, *ibid.*, x, pp. 139 and 336; and Lapworth, *ibid.*, x, pp. 120, 192, 337; also Callaway on Progressive Metamorphism, *ibid.*, May, 1884; and summaries in accounts of the Progress of Geology in the Reports of the Smithsonian Inst. for 1882 and 1883.

observers made it clear that in the region in question were portions of two gneissic series,—an older or granitoid gneiss, like that of the western coast, and a younger, very distinct in type, which has been variously designated as Upper Pebidian, Grampian and Caledonian, and is that described by me in 1871, and again in 1881, as of the White Mountain or Montalban type. This, the younger gneissic series of Murchison and Giekie, was clearly established to be of great thickness, and older than the fossiliferous Cambrian, which it is brought to overlie by a series of great folds, overturned to the west, and accompanied by parallel faults, with upthrows on the east side, as shown by Hicks in Ross and Inverness shires, as well as by Callaway in Assynt, and by Lapworth in Eriboll.

§ 192. The concordant and independent results of the eminent observers just named having thus demonstrated the fallacy of the views of Murchison and Giekie that the gneiss which in the Highlands overlies the fossiliferous strata, is a still younger paleozoic series in an altered condition, the Geological Survey of Great Britain, of which Giekie is now Director, undertook in 1883 and 1884, a re-examination of the region in question. The result of this has completely disproved the former statements of Murchison and Giekie, and has confirmed those of the new school. The Director of the Geological Survey, in a note very recently published,[37] tells us that he has "found the evidence altogether overwhelming against the upward succession, which Murchison believed to exist in Eriboll, from the base of the Silurian strata into an upper conformable series of schists and gneisses," and adds: "That there is no longer any evidence of a regular conformable passage from fossiliferous Silurian quartzites, shales and limestones upwards into crystalline schists, which were supposed to be metamorphosed Silurian sediments, must be frankly admitted." The same conclusions are also reached by Giekie from the re-examination of the similar sections in Ross-shire, previously described by himself in accordance with the views of Murchison.

The preliminary Report of the surveyors, Messrs Peach and Horne, which is subjoined to the Director's note, shows the same structure as was already described by the late observers, namely, overturned folds and great faults, with lateral thrusts westward, by which the gneisses are made to overlie the fossiliferous strata,—the horizontal displacement of the gneisses to the west, which are superimposed on the Cambrian rocks, being, in some cases, according to Giekie, not less than ten miles.

§ 193. Giekie notices the distinction between the older or granitoid gneiss, portions of which also appear in the Highlands, and the upper gneissic and mica-schists series, the pre-paleozoic age of which was shown by the observations alike of Hicks, and of Callaway and Lapworth. He calls attention to the laminated and schistose structure developed by the great pressure and friction along the lines of movement in gneissic and hornblendic rocks, and also to similar changes produced by the same agency in detrital rocks, such as arkose. Both of these structural alterations are apparently included by Giekie under the head of what he calls a "regional metamorphism,"—a misapplication of the term likely to confuse the reader, since local structural changes, induced by mechanical movements in ancient crystalline rocks, have nothing in common with that mysterious process which has been supposed by the metamorphic school to generate similar crystalline rocks from uncrystalline sediments. As regards the changes wrought by the same agency on detrital

[37] Nature, Nov. 13, 1884, xxxi, 22–35.

masses, it may be repeated that "the resemblance between primitive crystalline rocks and what we know to be detrital rocks compressed, recemented, and often exhibiting interstitial minerals of secondary origin, is too slight and superficial to deceive the critical student in lithology, and disappears under microscopical investigation."[38]

§ 194. We have already elsewhere in this essay (§ 135) referred to the local development of crystalline silicates in sedimentary rocks by infiltration, and have, in another place considered the relation of such a process to the question of the origin of primitive crystalline rocks. These we believe to have been formed anterior to the existence of detrital sediments, and by a process which excludes alike all so-called metamorphic, metasomatic, and plutonic hypotheses of their origin. At the same time we reject the Wernerian or chaotic hypothesis, and its modification by Delabeche and Daubrée, which we have called thermochaotic, in favor of a new aqueous or neptunian hypothesis, which supposes the elements of these rocks to have been dissolved, and brought to the surface from a disintegrated layer of igneous basic rock, the superficial and last-solidified portion of a cooling globe, through the action of circulating waters. The soluble and insoluble products of the subaerial decay, alike of igneous and aqueous rocks, are, however, supposed to have intervened in the process, especially during the period of the later crystalline or Transition rocks. This explanation of their genesis we have elsewhere proposed, and discussed at length in a recent essay on "The Origin of Crystalline Rocks,"[39] and, in allusion to their production through the intervention of springs, have called it the crenitic hypothesis.

IX. Conclusions.

§ 195. The task attempted in the preceding chapters, of discussing the history of the Taconic Question, has involved a review of much of the work done in American geology for more than sixty years, going back to the labors of Eaton, and even to those of Maclure. Of the somewhat extensive literature[40] of the subject I have made use, so far as has seemed of importance in the controversies which have arisen on this question, and have supplemented the researches of various investigators by personal observations extending over a wider field and a greater number of years than those of any of my predecessors. From all of these sources, I have here sought to bring together whatever has appeared to be of value for the elucidation of the important problems before us. In the following sections, the conclusions which have already been set forth at length are summed up.

§ 196. There exists in eastern North America a great group of stratified rocks, consisting of quartzites, limestones, argillites and soft crystalline schists, which have together a thickness of 4,000 feet or more, and are found resting unconformably upon various more ancient crystalline rocks, from the Laurentian to the Montalban inclusive. This series, called

[38] Trans. Roy. Soc. Canada, vol. ii, sec. iii, p. 23.

[39] Trans. Roy. Soc. Canada, vol. ii, sec. iii, pp. 1–67, and in abstract in Nature for July 3, 1884, p. 227, and Amer. Jour. Science, July, 1884, p. 72.

[40] Dana, in the Amer. Jour. Science for 1880, xix, 163, has given "a list of the principal papers" on the Taconic System, in which, while professing to bring together those adverse to the pre-Cambrian age of the Taconian, he omits all reference to the opinions of Adams, of Ed. Hitchcock, and the later conclusions of W. B. Rogers as to the (Upper) Silurian or Devonian age of the Taconian limestones. The list is in other respects very incomplete and calculated to mislead the student.

Transition by Maclure, includes the Primitive Quartz-rock, the Primitive Lime-rock, and the Transition Argillite of Eaton, and is the Lower Taconic of Emmons, and the Itacolumitic group of Lieber. This series, which I have preferred to call Taconian, is essentially one of Transition crystalline rocks. The quartzites, which predominate in the lower portion, contain much detrital matter, and are sometimes conglomerates. They are, however, often vitreous or granular, the latter variety being sometimes flexible and elastic, and constituting what is called elastic sandstone or itacolumite. These quartzites, like the limestones of the series, often contain an indigenous micaceous substance, which is in most cases a hydrous muscovitic mica, related to sericite or to damourite. A similar mineral predominates in certain layers of soft unctuous lustrous schists, which, from their aspect, have been called talcoid or magnesian, and are found intercalated alike with the quartzites and the limestones of the series. The latter, often more or less magnesian, are generally finely granular, and yield marbles for statuary and for architecture. They are often variegated in color or banded with green or gray, constituting cipolins. The mineralogy of the limestones and their associated crystalline schists, has been noticed in §§ 51, 65, 68, 76, 79, and it has been shown that the Taconian is an important ore-bearing horizon, including, besides great deposits of magnetite, others of siderite and of pyrite. Both of the latter species, by epigenesis, give rise to hydrous iron ores, which, throughout the Appalachian region, characterize the outcrops of the series, and are generally imbedded in clays, the result of the subaerial decay of the enclosing schists, which, it may thence be conjectured, include, in many cases, large proportions of a feldspathic mineral. The argillites of the Taconian, often yielding roofing-slates, are interstratified with more or less silicious beds, and occur chiefly in the upper part of the series. The mineralogy of the Taconian has been further discussed in the author's essay on "The Origin of Crystalline Rocks" in the Transactions of the Royal Society of Canada, Vol. II, Sec. III, p. 63.

§ 197. These Taconian rocks are not confined to the Appalachian valley. Extending southward therefrom, they are traced in Pennsylvania along the eastern base of the Blue Ridge into North Carolina, and are found in outliers to the east over the Atlantic belt from Georgia to New Brunswick. To the west of the great valley, they are known to underlie the eastern part of the paleozoic basin, and appear in eroded anticlinals from beneath the coal-measures, alike in Alabama and Pennsylvania, where they are directly overlaid by Ordovician strata. They are seen in similar conditions, lying unconformably beneath the Ordovician limestones of the Ottawa basin, in Hastings County, Ontario, and are believed to be represented by the great series of argillites, quartzites and limestones around Lake Superior, which, in 1873, I called the Animikie series, and which there underlie, unconformably, not only the Cambrian (Potsdam) of the Mississippi area, but, according to Irving, the Keweenian series also. The presence of Lower Taconic rocks was long since asserted by Houghton in the northern peninsula of Michigan, and it is probable that a part of what has since been called Huronian belongs to this Animikie or Taconian series (§ 89, 90). The argillites and quartzites which, in the Black Hills of Dacotah, intervene between the older crystalline rocks and the Cambrian, resemble those of the Taconian.

§ 198. The Taconian series is not destitute of evidences of organic life, but contains, in the granular quartzites near its base, the typical *Scolithus linearis* at many points throughout the Appalachian valley. Similar markings in the silicious beds of the series in Hast-

ings County, Ontario, have been noticed as probably worm-burrows by Sir J. W. Dawson, who has also described the *Eozoon Canadense* found in the associated limestones, while the argillites which I have referred to this series, from the western end of Lake Superior, have afforded the remains of a sponge. The Taconian, as I have suggested, may constitute a link between the older eozoic groups and those of paleozoic time.

§ 199. The Upper Taconic group, the First Graywacke of Eaton, the Potsdam and Quebec groups of Logan, (which include a large part of what was described by Mather and by Logan as Hudson River group,) we have seen to be the Appalachian representative of the Cambrian period. It sometimes overlies the Taconian, but, in the absence of this, rests directly upon the older crystalline groups along the eastern border of the great Appalachian basin. Unlike the Taconian, however, it does not, so far as known, extend eastward of this limit, while to the west, as we recede from this border, it is soon replaced by the Adirondack type of the Cambrian.

This Appalachian Cambrian series is wholly uncrystalline, and is separated from the Taconian by a stratigraphical break, and probably by a great interval of time. From the distribution of the Cambrian and the Ordovician in eastern North America, there was evidently another great stratigraphical break, with erosion, followed by a considerable continental depression, which preceded the deposition of the Ordovician limestones. Similar disturbances seem to have intervened at the beginning of the Silurian period in this eastern region, for we find the Silurian limestones resting directly upon somewhat inclined and eroded Ordovician strata near Montreal, and, apparently, also in the valley of the Hudson, while throughout this eastern border the great mechanical sediments of the Oneida, Medina and Clinton, which to the west of the River Hudson constitute the chief part of the Second Graywacke of Eaton, at the base of these limestones, are apparently absent,—a fact pointing to the emergence of this eastern region during the early part of Silurian time. The local disturbances which at this period prevailed in the eastern part of the great basin, are farther shown in the conglomerate character of these Silurian sandstones in parts of New York and Pennsylvania, though it should be noted that in these regions, as well as in Ontario, there appears to be an unbroken succession from the Loraine shales to the Oneida, Medina and Clinton subdivisions.

§ 200. As a result of all these various movements which affected the eastern border of the Appalachian basin, we find that the Taconian is there in some parts directly overlaid by Cambrian, in others by Ordovician strata, and in parts, it would seem, by limestones belonging to the upper portion of the Silurian, or to Devonian time. The strata of all of these periods are more or less involved with each other, and with still older crystalline groups, by the successive movements of folding and dislocation which continued to affect the Atlantic belt at intervals until after the close of paleozoic time. From the complex stratigraphical relations which have thus resulted, various observers have, during the past forty years, conjectured that the Taconian limestones are strata of Cambrian, of Ordovician, of Silurian, or even of Devonian age, which, by a process of so-called metamorphism, have been changed into granular non-fossiliferous marbles, often holding crystalline silicates.

§ 201. These various conjectures are not only in contradiction with each other, but, as we have seen, are in direct conflict with the facts of stratigraphy, and are, moreover, based upon the unproved and now generally discredited hypothesis of progressive and regional

metamorphism. This hypothesis, as long since maintained by Mather for the rocks of eastern North America, and later by Dana, asserts successive changes,—called by the latter "grades in metamorphism,"—from uncrystalline sediments through the Taconian and other more massive crystalline schists to the granitoid gneisses. These various and dissimilar groups of strata, as I maintained in 1878, and as will to-day be admitted by nearly all geologists, "are not the result of different and unlike changes which one and the same uncrystalline paleozoic series has suffered in different geographical areas, but, on the contrary, belong to successive periods in paleozoic and eozoic time. The great divisions of the latter . . . . present in ascending order a progressive change in mineral character, the nature of which has been shown; . . . . thus constituting a veritable passage in time from the granitoid Ottawa gneiss at the base of the Laurentian, through the intermediate Huronian and Montalban divisions to the less markedly crystalline schists of the Taconian."[41] Such a succession, I have since endeavored to shew, is the necessary result of the secular process by which, from an undifferentiated primeval chaos, the various groups of Primitive and Transition crystalline rocks have been generated, as set forth in the crenitic hypothesis[42] already noticed in § 194 of the present essay.

§ 202. The Taconian crystalline rocks were deposited over a large part of eastern North America upon the eroded surfaces of more ancient eozoic groups, and in their turn suffered greatly from movements of the earth's crust, and from erosion, previous to the beginning of Cambrian time. Over the more depressed portions of the worn surfaces, the uncrystalline sediments of Cambrian, Ordovician, Silurian, and later periods, were next successively laid down, alike on the Taconian and the more ancient crystalline groups, not however without intervening movements of the earth's crust, which along the eastern portion of the great paleozoic basin caused stratigraphical breaks, foldings, and partial erosions of these later groups of sediments. Beyond the limits of this basin, to the south and east, the sparse distribution of areas of paleozoic sediments, and their absence from the higher levels among the crystalline rocks of the Atlantic belt, permit us to suppose that the paleozoic seas did not invade these higher regions; while the deposits made by some of them at lower levels among these same crystalline rocks, have been in great part removed by subsequent agencies. As a final result of this process, we find, within the great basin, the Taconian rocks resting on various older crystalline groups, and themselves overlaid directly by Cambrian, by Ordovician and by Silurian, while outside of the limits of the basin, areas of the same Taconian rocks are in parts overlaid by mesozoic and by tertiary strata.

§ 203. As regards the existence in other lands of a similar series of rocks to the Taconian of North America, we have seen that Lieber, whose independent and careful studies of this series in South Carolina we have resumed in Chapter IV (§ 69-79), supposed them to be the stratigraphical equivalent of the Itacolumite or diamond-bearing series of Brazil,

[41] Hunt, Azoic Rocks, 1878, p. 253; see also *ibid.*, p. 210.

[42] "All physical theories properly so-called are hypotheses, whose eventual recognition as truths depends upon their consistency with themselves, upon their agreement with the canons of logic, upon their congruence with the facts which they serve to connect and explain, upon their conformity with the ascertained order of Nature, upon the extent to which they approve themselves as trustworthy anticipations or previsions of facts verified by subsequent observation or experiment, and finally, upon their simplicity, or rather their reducing power." Stallo in Concepts and Theories of Modern Physics, p. 85.

of the similar rocks of Bundelkhand in India, long since described by Claussen and by Jacquemont, and of those in Russia, where several areas of Itacolumite rocks, diamond-bearing like those of Brazil and India, were discovered in the southern Urals by Helmersen and Hoffman.[43]

These diamond-bearing rocks in Bundelkhand have since been described by the Geological Survey of India as the Lower Vindhyan series.[44] The studies of Hartt, of Gorceix, and of Derby have thrown farther light on the Itacolumite series of Brazil, which, according to the latter, rests unconformably upon the older crystalline rocks, and consists in great part of quartzites, often granular and sometimes flexible, with unctuous talcoid schists containing hydrous micas, chloritic and argillite beds, specular schistose iron-ore (itabirite), and great masses of crystalline limestone. The resemblances, long since noticed by Lieber, between this Brazilian series and the American Taconian were made very evident by a collection of these rocks from the province of Minas Geraes, examined by the writer. This ancient series in Brazil has afforded no organic remains, but being unconformably overlaid by older paleozoic rocks has been by Derby supposed to be altered Cambrian, while others have assigned it to a pre-paleozoic age. The diamonds, (which are also met with in derived rocks,) are found in the province of Diamantina in unctuous banded clays of varying colors, which are derived from the subaerial decay of eastward-dipping schistose beds of the Itacolumite group.[45]

§ 204. A close resemblance between the older rocks of Brazil and those of Guiana has been pointed out by Jannetaz who, as remarked by Crosby, "has recognized in the latter country the itacolumite, with the hydromicaceous and other schists of the former, which have been connected with the Taconian system. The itacolumite of Guiana has also been observed by Schomburgk."[46] Farther to the north-west, beyond the mouth of the Orinoco, we meet a great development of a similar series. Crosby, writing in 1880, says these rocks "constitute the main mass of the great eastern branch of the Andes, or at least that part of it which skirts the Caribbean sea from Caracas eastward, and is known as the Littoral Cordillera of Venezuela." The Cordillera forms the Northern Mountains of Trinidad, which have an altitude of 3,000 feet, and terminates in the neighbouring island of Tobago. These semi-crystalline rocks of the Spanish Main and Trinidad were studied

[43] The following bibliographical references are cited from Lieber: Eschwege, Beitrage zur Gebirgskunde Braziliens, Berlin, 1832, p. 174; Spix and Martius, Reise in Brazilien, II Theil; also Humboldt, Gisement des roches dans les deux hemisphères, pp. 89-92; Jacquemont, Voyage dans les Indes, 1828-32, Sur les grès schisteux de Panna in Bundelkund, etc.; Cotta, Gesteinslehre, 1855, p. 212, and Zerrenner, Gold, Platin und Diamant Waschen, etc., Leipsig, 1851.

[44] Manual of the Geology of India, Medlicott and Blanford, i, pp. xxi. and 69-92.

[45] O. A. Derby, On the Diamond and the Itacolumite Rocks in Brazil, 1881 and 1882, Amer. Jour. Science, xxiii, 7, 178, and xxiv, 34-42; and in abstract, Rep. Smithsonian Inst., 1882, p. 332; also Gorceix, Gisement des Diamants, etc., Bul. Soc. Géol. de France, 1884, xii, 538-545. Derby supposed the Itacolumite group might be altered Cambrian; Gorceix thinks it may be Huronian.

[46] W. O. Crosby, Notes on the Geology of Trinidad, 1878, Proc. Boston Society Natural History, xx, 44-55; also farther, on the Crystalline Formations of Guiana and Brazil, 1880, *ibid.*, xx, 480-497, in which these rocks in Trinidad are described at greater length, and the relations of the Taconian and the more ancient crystalline series in North and South America are well brought out. See, for an analysis of these two papers, Hunt, in Report of Smithsonian Inst. for 1882, pp. 330-333.

some twenty years since by Messrs Wall and Sawkins,[47] by whom they were designated as the Caribbean group, more recently by Mr. R. J. Lechmere Guppy, and in 1878 were examined by Crosby.

§ 205. The structure of the Northern Mountains in Trinidad is monoclinal, high southerly dips being universal. The thickness of the strata exposed is not less than 10,000 feet, included in three divisions: a lower consisting of a quartzite, granular and usually more or less micaceous, followed by and alternating with hydrous micaceous schists and argillites, often lustrous; a middle one of several thousand feet of crystalline limestones in massive beds, varying in colour from white to nearly black, and often somewhat micaceous; and an upper division consisting of several alternations of argillites like those of the first, frequently graphitic, and often passing into hydromicaceous schists, with layers of quartzite, sometimes detrital, and, towards the summit, thin beds of limestone. The whole succession, according to Crosby, strongly resembles the Taconian as seen in western Massachusetts. Overlying unconformably this ancient series, which appears to be unfossiliferous, is a dark-colored compact fossiliferous limestone, with interbedded shales, in which, among many obscure forms, Guppy recognized *Murchisonia Anna* and *M. linearis*, both found in the Calciferous sand-rock in Canada.

§ 206. Subsequent observations of Crosby,[48] in 1882, made in the mountains of eastern Cuba, between Baracoa and the southern coast, show that there exists to the south of the dividing ridge a belt six or eight miles wide of highly inclined strata, having an east and west strike, and consisting of hydromicaceous and chloritic schists with immense beds of white crystalline limestone, often micaceous. This group is entirely distinct from one made up from fissile slates, soft sandstones and impure earthy limestones, found chiefly on the northern slope of the same mountains, and regarded by him as probably equivalent to the cretaceous and tertiary strata of San Domingo and Jamaica. Of the first named group he says: "These rocks bear a strong resemblance to the Taconian system of western New England, and are essentially identical with the great series of semi-crystalline schists and limestones of Trinidad and the Spanish Main, which I have elsewhere correlated with the Taconian." From the published accounts of the geology of San Domingo and Jamaica, Crosby conceives that these islands have a similar structure to that of south-eastern Cuba. Their crystalline schists which, according to him, have been generally confounded with the cretaceous beds, he believes to be like those of Cuba, and of Taconian age. Cleve, in 1870, noticed in Porto Rico, Santa Cruz and the Virgin Islands an unfossiliferous series which he conjectured might be metamorphosed cretaceous. These strata, which are vertical, or have a high northern inclination, consist chiefly of argillites and crystalline limestones like those of Cuba and Trinidad.[49]

§ 207. There exists in the Alps, besides the ancient or central granitoid gneiss (Laurentian), the great *pietre verdi* series proper (Huronian) and the younger gneiss and mica-schist series (Montalban), a fourth great group, very widely distributed, made up in

[47] Wall, Geology of Trinidad, etc., 1860, Quar. Geol. Jour. xvi, 660.

[48] W. O. Crosby on the Probable Occurrence of the Taconian in Cuba; Science, December 7, 1883, p. 740; also in abstract in Report of Smithsonian Inst. for 1883.

[49] P. T. Cleve, Kongl. Svenska Vetenskaps-Akademiens Handlingar; Bandet 9, No. 12. The cretaceous age of the crystalline schists and limestones of San Domingo was maintained by Gabb in his memoir on the Topography and Geology of the Island, etc., in 1873; Trans. Amer. Philos. Soc., vol. xv.

large part of crystalline schists,—the argillo-talcose schists of Favre, the gray lustrous schists of Lory, the sericite-schists and the *glanzschiefer* of others. This schistose series, to which a great thickness is assigned, includes quartzites, dolomites, micaceous limestones, banded and statuary marbles, serpentine, talc, karstenite and gypsum. These rocks, which among other localities, are well displayed on the line of the Mont Cenis tunnel, have been by many Alpine geologists regarded as altered jurassic or triassic. This view was, however, in 1872, combatted by the present writer, who then referred them to primitive or eozoic time; a view which has since been accepted by Favre, who had previously regarded them as mesozoic.[50] Their pre-paleozoic age was afterwards maintained by Gastaldi, by Pillet, and by Jervis. I have since called attention to the fact that these lustrous schists greatly resemble those of the Taconian of North America, to which I have compared this whole Alpine series. In it are included, by Gastaldi and Jervis, the schists of the Apuan Alps, with their crystalline marbles, all of which, as seen in the mountains of Carrara, I have found to resemble the Taconian closely. These marbles, it may be remarked, have, like those of the American Taconian, been referred to very different geological horizons, having been successively called altered cretaceous, liassic, rhætic, infra-carboniferous and pre-paleozoic, to which latter position they were assigned by Gastaldi in 1874.

§ 208. To the same horizon, apparently, belongs the Hercynian Primitive Clay-slate series, which, according to Gümbel, intervenes in Bavaria between the Hercynian mica-schist group and the fossiliferous Cambrian strata, by which it is overlaid. This clay-slate series includes beds of crystalline limestone, sometimes magnesian, attaining in places three hundred and fifty feet in thickness, which contain hornblende and serpentine, and a form of Eozoon, named by Gümbel *E. Bavaricum*. It also includes siderite, which, by epigenesis, gives rise to valuable masses of limonite. The history of the group of lustrous schists in the Alps, and their related rocks, has been recently discussed at some length by the writer in a chapter on the geology of the Alps and the Apennines, contained in an essay on "The Geological History of Serpentines, etc.," to which the reader is referred for details and for authorities.[51]

In some parts of central Norway, the fossiliferous Cambrian, or so-called Primordial zone, is described by Kjerulf as resting directly upon the ancient gneiss, but in other parts it is underlaid by a series which, from the presence therein of detrital beds, is designated as the Sparagmite group, and sometimes attains a thickness of over 2,100 feet, as in Ostdalen. This underlying series, which itself rests upon the gneiss, includes red and grey sandstones and conglomerates, with considerable masses of limestone and of dolomite, besides various fissile rocks described as black argillites, lustrous schists, sometimes talcoid, and schistose quartzites. It is without observed fossils, and has been by Kjerulf compared with the Lower Taconic.[52]

§ 209. The recent studies of Barrois in Spain, published in 1882, appear to throw a further light on the Alpine series which we have compared with the Taconian. The paleozoic rocks, containing at their base an abundant Cambrian fauna, are found in the province of

[50] Hunt, The Geology of the Alps, Amer. Jour. Science, vol. iii, pp. 1–15; also Chem. and Geol. Essays, pp. 336, 347, 348.

[51] Trans. Roy. Soc. Canada, vol. i, sec. iv, pp. 186-196.

[52] Hunt, Azoic Rocks, p. 131, and Kjerulf, Udsigt over det Sydlige Norges Geologi, 1879, pp. 128-138, and the accompanying Atlas, plates xxvi, xxvii.

Toledo resting, according to Cortazar, directly upon the ancient gneissic rocks, but in the Asturias, between these Cambrian strata and the ancient gneisses, there intervenes a volume of not less than 3000 metres of strata, described as argillites and quartzites, with dolomites and limestones, sometimes saccharoidal and cipolin marbles, with beds of specular iron-ore. As there is no apparent stratigraphical break between this younger crystalline series and the strata holding the first fauna of Barrande, the name of Cambrian is applied by Barrois to the whole.[83] The student of American geology, however, recalls the interposition between the Appalachian Cambrian and the ancient gneisses of a similar great series, which suggests that in this region of Spain, as in parts of the Alps and in Norway, we have a pre-Cambrian group that corresponds to the American Taconian.

§ 210. It has been thought well, in concluding this essay on the present state of our knowledge of the Taconian series in North America, thus to bring together, in a condensed form, the principal facts with regard to certain rocks in the West India Islands, in South America, in Hindostan, in Russia, in the Alps, in Bavaria, in Norway and in Spain, which tend to show that in all these various regions there exists a series analogous to the Taconian, alike in mineral and lithological characters and in stratigraphical position. Should further studies confirm this view, it will appear that the Taconian is a great and widespread group of strata which cannot henceforth be overlooked in geognostical history.

Summary of Contents.

PART II.

[83] Barrois, Recherches sur les Terrains Anciens des Asturies et de la Galice; Lille, 1882; 4to, pp. 623.

NOTE.—The late observations of Ford given in § 155, and those of Geikie and his assistants in § 192, 193, have been published since this second part of the present paper was presented in May, 1884.