Address delivered at the meeting of the Association of American Geologists and Naturalists, held in Washington, May, 1844 / By Henry D. Rogers.

Richard Taylor F.G.S. &c.
Charter House Square
London.

AN

ADDRESS

from the Author

ON THE

RECENT PROGRESS OF GEOLOGICAL RESEARCH

IN THE

UNITED STATES.

DELIVERED AT THE FIFTH ANNUAL MEETING

OF THE

ASSOCIATION OF AMERICAN GEOLOGISTS AND NATURALISTS,

HELD AT WASHINGTON CITY,

MAY 1844.

BY HENRY D. ROGERS,

PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF PENNSYLVANIA—FOREIGN MEMBER OF THE GEOLOGICAL SOCIETY OF LONDON.

PHILADELPHIA:

PRINTED BY C. SHERMAN.

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ADDRESS.

GENTLEMEN OF THE ASSOCIATION,

HAVING been kindly invited by you to preside at the last annual meeting of the Society, it devolves upon me, in accordance with our rules, to bring before you on this occasion a brief history of the recent labours of American geologists, and to take a rapid survey of the present condition of geological research in the United States. In attempting to discharge this acceptable but by no means easy duty, I am well aware that my sketch will exhibit many defects and omissions, incident in part, to the dispersed state of my materials, but attributable in greater part, I fear, to my own imperfect fitness for the task. Those deficiencies in this short review of American geology, which you cannot but impute to myself, your generosity will, I feel assured, indulgently pardon, but those others, which you must ascribe to the hitherto insufficient concentration of scientific effort in our country, I would not have you so lightly overlook.

On the other hand, I would here invite your attention to the difficulties, which though much abated, still beset any one who attempts either to gather into shape the scattered materials of American geology, or to prosecute extensively a connected train of research. It was in full view of these difficulties and in the hope of lessening them, that our Association was organized. And let us here congratulate each other on the success which has attended our efforts. Scattered over a country of great extent and kept asunder by distance and the claims of professional duties, the American geologists were labouring amid all the inconveniences of solitude, each hewing his lonely path through the mighty wilderness of our rocks, isolated in the worst sense of the term,—in the only sense really repulsive to the genuine student of nature,—I mean, isolated from the sympathy, the counsel, the instruction, of those engaged in the same glorious enterprise. Though fellow-labourers we were not companions, for we seldom met, knew imperfectly each others' performances, and were still less acquainted with each others' social and scientific worth. Many of you, by your published researches had made your labours to be valued, and had won the sincere respect of the rest,

but how different was that respect, when from the author we came to know the man, when with opportunities of personal intercourse we learned *how* the work had been accomplished, what impediments from deficiency in books had been surmounted, and what physical hardships had been braved, but especially when we learned the spirit of the explorer, his intrepid zeal, his untiring patience, and his devotion to the cause of truth.

If we contrast our recent imperfect knowledge of each others' discoveries, with the present ample survey which we are now able to take of the geology of three fourths of the vast region between the Atlantic and the Mississippi, if we are conscious how much more intimately we now comprehend each others' published descriptions and theoretical views, and feel how much more justly we can now estimate the relative accuracy and value of each others' researches, and consider how much of all this change has been brought about by our annual meetings, we shall indeed see reason to congratulate ourselves on our success. To labour unostentatiously for the advancement of American geology and the collateral branches of natural science, by cultivating a spirit of mutual fellowship and generous co-operation, was the intention, has been the course, and should ever be the pride of this Association. Our ranks, it is true are thin, for grievous obstacles, especially distance and want of time, restrain many from joining us who share our tastes, yet has our zeal never been daunted, and at every meeting we number among our associates some from the remotest corners of the country. The long and arduous journeys which some of you annually perform to reach our place of meeting, are a sufficient proof of the utility and attractiveness of our proceedings, and should it be asked what are the scientific and other fruits of these annual assemblages, I would point not boastfully, yet with a just pride, on the one hand, to both our printed and unpublished papers, and on the other, to the excellent spirit and the friendly intercourse which have invariably marked our proceedings.

Our youthful Association, though it would not presume to invite a comparison between its labours and those of the similar societies of Europe, is yet conscious of being moved by a kindred impulse, and of seeking through accordant means, the same praiseworthy objects. Those illustrious assemblages, which in England, Germany, Italy and Switzerland, have in the last ten years done so much to quicken the march of science, so much to call out from solitude and obscurity modest learning and genius, so much to win for the student of nature the once withheld respect

of literary scholars, statesmen and governments, and best of all so much to make science and letters what they are yet far from fully being, a true republic, all were the results of the same necessities, the same intellectual and social wants, and the same high aspirations, which drew the geologists of America, a small but an enthusiastic band, together.

It is proper, before entering upon topics of purely scientific interest, that we pause to pay a tribute to the memory of our esteemed and lamented associates, Prof. Hall and Mr. Nicollet, both of whom at the inexorable mandate of death, have lately left this scene of their scientific usefulness.

Prof. Frederick Hall possessed great ardor in the pursuit of knowledge, and was one of the earliest cultivators in this country of geology and mineralogy. He was educated at Dartmouth College, became professor of natural philosophy and chemistry in Middlebury College, and afterwards president of Mount Hope College in Maryland, and at the time of his death (which took place at Peoria, Ill.) was professor of chemistry in the medical department of Columbia College, Washington. Of a generous and enthusiastic nature, he manifested the sincerity of his zeal for science and the cause of education, by the very handsome contribution in money and a rich cabinet, which he made a few years ago in aid of the establishment of a new professorship in the respected institution from which he imbibed his strong love for learning. Though not a practical geologist, he was a successful teacher of the science, evinced a lively interest in its advancement, and earnestly encouraged this our present effort to promote its progress in our country.

Mr. Nicollet was born in Savoy between Geneva and Mont Blanc. Repairing to Paris about the age of twenty, he applied himself with great enthusiasm to improve, through the resources of that capital, the defects of his early education, and gifted with a fine mathematical ability, and enjoying the lessons and friendship of Laplace, he soon rose to distinction as a mathematician and astronomer. In his assiduous devotion to his favourite branches, he became the author of several works of merit, and of many papers and memoirs which procured him a well-deserved reputation in the scientific world. He was a member of the *Bureau des Longitudes*, and one of the principal examiners in the French navy.

About ten years ago, Mr. Nicollet came to the United States, and impressed with the abundance of the scientific harvest which he saw spread out before him, he entered forthwith upon the rich field of his subsequent labours. With extraordinary ardor, he applied himself to the study of the physical geography of the great valley of the Mississippi. By a

widely-planned series of astronomical and barometrical observations, he collected in a few years, data for exhibiting with an accuracy never before attempted, the features and the physical relief of that enormous basin. To these researches, he united an extensive system of observations upon terrestrial magnetism, and though not a trained geologist, he was successfully gathering a body of very instructive facts respecting the stratification and organic remains of the region of the Missouri and upper Mississippi. Exploring, in solitude and with indomitable courage, the vast and inhospitable wilderness of the far west, with none to bear testimony to his hardships and earnest zeal, but the equally isolated and fervent Indian missionary, or the wild aboriginal, whose profound veneration and affection he enlisted by his commanding powers, kind manners and humane and gentle character, he came among us after the lapse of a few years, somewhat broken in health, but loaded with scientific treasures.

He was then engaged by the war department, directed by Mr. Poinsett, to revisit the far west and to embody his observations in a general report and map for the use of the government. Of that portion of his labours, which relates to the region traversed by the head waters of the Mississippi and extending to the Missouri, this Association has already had a glimpse through the interesting verbal communications of Mr. Nicollet himself, made at our two last meetings. His beautiful and elaborate map, seen by us at Albany is finished, but exhaustion, sickness and death, the result of over toil arrested the completion of his report. As he had given much attention to the customs, polity and vocabularies of our Indian tribes, and had gathered a diversified mass of valuable materials, it is greatly to be lamented, that for the cause of science, he was not spared to give his work to the public. All those whose privilege it was to listen to his clear, ingenious and eloquent descriptions of the majestic country, the scene of his researches, must be conscious how much American science has lost in the premature departure of our gifted associate.

RECENT PUBLICATIONS ON THE GEOLOGY OF THE UNITED STATES.

In attempting to trace the progress thus far made in developing the geology of the United States, I shall first present a concise sketch of the publications embodying original researches made during the last two or three years. You have already been furnished by my predecessors in the chair, Prof. Hitchcock and Prof. Silliman, with a clear and instructive history of the contributions to American geology, from

the first valuable labours of Maclure in 1809, to the period of 1841. In the interval which has since elapsed, a copious mass of publications has appeared, enlarging prodigiously our acquaintance with the exact geographical distribution of our strata, with their relationship to each other, and to the rocks of Europe, and with their organic remains, and their other contents. Many of these embody the results of years of previous systematic research, prosecuted in obedience to legislative enactment in several of our states, while others are the fruits of individual investigations, conducted by members of our Association, and others again, the contributions of distinguished foreign geologists, liberally assisted with materials by our own explorers.

These publications consist chiefly of the printed volume of Transactions of this Society, published about a year ago the five large quarto volumes on the Geology and Mineralogy of the state of New York issued by that state at intervals during the last two years; also the first Report on the Geological Survey of Connecticut, and those papers read at our last annual meeting, which have appeared in the American Journal of Science and Arts, together with memoirs submitted to the Geological Society of London, by Owen, Lyell and Logan.

By these reports and memoirs, our knowledge has been greatly enlarged in relation to almost every class of our rocks and every period in our geological chronology. Respecting the primary crystalline masses, we have received most valuable additions to the details previously in print through the minute description of Connecticut by Dr. Percival, the interesting and instructive account of the district between the St. Lawrence and Lake Champlain, by Prof. Emmons, and that of the southern counties of New York by Prof. Mather. We have also been presented with an interesting article on Tin veins in New Hampshire by Dr. C. T. Jackson.

Concerning the *Palæozoic* strata of the United States, the publications have been of an interest commensurate with the magnitude and grandeur of the formations. Besides the accounts already given of the range of these rocks in New England, principally by Hitchcock and Jackson; a thorough and minute analysis of them as developed throughout the wide state of New York, has been furnished by Emmons, Hall, Mather and Vanuxem in their respective reports on the survey of that state. The identity of some of the western strata with those of New York, is well set forth in a memoir by Mr. Hall published in our volume of Transactions, while a valuable contribution has been made to the geology of the Western States by Dr. Owen in a paper on that subject, read

to the Geological Society of London. The extension of some of the New York strata through the western part of Upper Canada and the adjacent districts of Michigan and Ohio, was briefly sketched in a paper laid before the American Philosophical Society in 1842, by my brother and myself; while to Dr. Troost's last Annual Report on Tennessee, published in 1841, we are indebted for some interesting additions to our knowledge of the palæozoic rocks in that state. A short communication made by Dr. Clapp of New Albany in Indiana, to the Academy of Natural Sciences of Philadelphia, has also contributed to assist in the identification of the western with the eastern strata.

The Appalachian coal strata of Pennsylvania, Ohio, Maryland, Virginia, Kentucky and Tennessee, bituminous and anthracitic, have been compared and traced, and a theory of their origin ventured upon in a paper by myself, submitted to this Association; and my brother and myself have also presented a memoir on the Physical Structure of the Appalachian chain.

The areas occupied by the palæozoic strata have been already carefully delineated in geological maps, for a large portion of the United States, this side of the Mississippi. Thus we are in possession of an excellent map of the state of New York by the state geologists, and one on a small scale of Ohio, Indiana, Illinois and Kentucky by Lawrence. A map of the last named states, including also middle and western Tennessee, has likewise been carefully compiled, principally from personal observation, by Dr. Owen, and gives us the most exact picture we yet possess of the distribution in that region of the several groups of our palæozoic strata under their western types. The information conveyed by it has been freely imparted, though the map has not, I believe, been yet published. The palæozoic formations of New Jersey and Pennsylvania have been mapped by myself and my assistants, those of Maryland by Dr. Ducatel, and Prof. W. B. Rogers and myself, while those of Virginia have been minutely delineated by my brother and his corps, in the survey of that state. But the geological maps of Pennsylvania, Maryland and Virginia have not yet been published. To Mr. Conrad we owe the approximate tracing of the southern border of these formations in Alabama. At our last meeting a valuable paper was read by Mr. James Hall, on the geographical distribution of the fossils of the palæozoic rocks of the United States, and another on the geological and geographical distribution of the Crinoideæ of the older rocks of New York.

Our knowledge of the *Mesozoic* strata of the United States has been

considerably advanced by publications issued during the two or three past years. Thus Dr. Percival in his report on Connecticut, has described and mapped the mesozoic red sandstone of that state in detail, affording much minute local information concerning the numerous trap dykes which intersect it. Prof. Mather has, in like manner, in his report on New York shown its boundaries and structure in Rockland county. To Prof. Hitchcock we are indebted for a paper printed in our Transactions, describing five new and interesting species of ancient bird-tracks in the same formation in the Connecticut valley, together with several obscure fossil plants, and to Mr. William C. Redfield the thanks of the Association are due, for a communication made last year at Albany on the fishes and bird-tracks discovered by him in the same formation at Pompton, New Jersey. From Prof. William B. Rogers we have learned the existence of the *Posidonia Keuperi* in this rock in Virginia, a fact almost decisive of the European affinity of the formation. He has also in a paper printed in our Transactions settled with considerable exactitude the age of the interesting coal rocks of eastern Virginia. The limits of the mesozoic red sandstone (new red) in North Carolina have been described and mapped by Prof. Elisha Mitchell of that state.

Mr. Lyell will no doubt soon enlarge our knowledge of the foreign affinities of the *Cretaceous* strata of New Jersey, the Carolinas and Georgia, by a comparison of the fossils procured by him in this country with those of the cretaceous groups of Europe. Dr. Morton to whose patient and skilful investigation of the cretaceous fossils of this country we are indebted for the chief part of our facts respecting this interesting division of our Palæontology, has recently laid us under new obligations by figuring some striking forms collected by the lamented Nicollet in the remote and vast cretaceous region of the Missouri; and at the last meeting of the association Mr. Nicollet himself read an interesting sketch of the cretaceous beds examined by him on the Missouri river.

Our acquaintance with the *Cainozoic* or tertiary strata of the United States has also been materially advanced in the interval under consideration. Mr. Conrad in a communication to the National Institute, made in 1841, has presented a clear and interesting synopsis of his researches among the tertiary beds of some parts of Maryland, and of the Southern States, and Mr. Lyell in two papers to the Geological Society, has contributed various useful facts concerning the same strata in the Carolinas and Georgia and in Martha's Vineyard. Mr. Hodge has also given the Association his observations on some parts of the southern tertiary

and cretaceous strata. The list of miocene fossils of Virginia has been considerably enlarged by Mr. Henry Lea, of Philadelphia, in a paper read to the American Philosophical Society, describing a number of minute species; and Mr. Conrad has figured some interesting species collected by Mr. Hodge in North Carolina and by himself in Maryland. Prof. William B. Rogers has, during the last two years, traced extensively the tertiary infusorial stratum of Virginia, while Profs. Bailey and Ehrenberg have discerned in this material a great multitude of curious microscopic forms. Mr. J. Hamilton Couper of Georgia has written on the bones of certain fossil mammalia in that state; and Mr. Lyell has published a paper (Proceedings of the Geological Society of London) on the position of the Mastodon giganteum and its associated fossils in Kentucky and elsewhere.

Several papers on topics in geological dynamics and in chemical geology have also appeared. Thus the complicated and interesting question of the origin of the vast drift formation of this continent, has been discussed by Dewey, Emmons, Hall, Hitchcock, Jackson, Mather, Vanuxem, and W. B. Rogers and myself, so that it may be said that we are now in possession of the observations and theoretical views of most of the investigators of this curious deposit. The laws of earthquake motion, the explanation they offer of the origin of anticlinal flexures and folds in strata, and the elevation of mountain chains, and the aid which the same views afford in accounting for the facts connected with our coal strata, with the drift and other formations, have been in several shapes submitted to the geological world by my brother and myself. Mr. J. D. Dana has read at our last meeting a paper containing a theory of the metamorphism of rocks, attributing their schistose structure to crystallization, and ascribing their alteration by heat to "the heated waters of a surrounding ocean." Two papers were read on the same occasion, by Prof. Lewis C. Beck, one "on certain phenomena of igneous action chiefly observed in the state of New York," in which the author arrives at the interesting conclusion that certain rocks have been subjected to a high temperature subsequent to the formation of the minerals in them, by which these were softened and deranged in shape. The other paper was on the ancient climates of the globe. Our volume of Transactions contains a paper, by Mr. Vanuxem, on the origin of mineral springs, and one by Prof. William B. Rogers on the connexion of the thermal springs of Virginia with anticlinal flexures and faults. To Prof. Bailey we were indebted last year, for a paper on the crystals formed in the tissues of dicotyledonous plants, and

a valuable report was submitted to the Association at the same meeting, by Mr. John L. Hayes, on the transportation of detrital matter, by icebergs, affording useful facts connected with the theory of drift. At the preceding meeting Mr. Couthouy it will be remembered read an interesting paper, descriptive of some of the phenomena of icebergs as witnessed by himself at various times. This paper, published in our proceedings, contains important statements in relation to the partial rotation of icebergs when aground.

Among the chemico-geological communications recently made to the Association is one by Prof. Lewis C. Beck on the bituminous matter in several of the limestones and sandstones of New York, and another by Dr. Charles T. Jackson, on the organic matters of soils.

PRESENT STATE OF OUR KNOWLEDGE OF THE FORMATIONS OF THE UNITED STATES.

I shall now review as briefly as practicable, the geology of this country, and show the developement which it has reached through the researches above cited, through those of earlier date and those not yet in print. In taking such a survey we shall find that, while the materials already gathered, form a valuable accession to the positive geology of our times, some of the conclusions arrived at, and many of the questions presented, bear upon some of the most fundamental generalizations of the science.

Let us inquire in the first place, what we know touching our *palæozoic strata*, the sediments of that enormous sea, which, filling once the whole interior of our continent, has its history, despite of all catastrophes, beautifully recorded in the vast sheets of matter, which from beyond the lakes to Alabama, and from the Atlantic slope to the far Missouri, tell of its depths and changes, its earthquakes, its intervals of long repose, and the structure and mode of life of its inhabitants. As the most expanded, and by far the most complicated in its outcrops of all the systems of strata this side of the Mississippi, it may be well to ascertain over how wide an area we have succeeded in tracing and mapping its numerous subordinate formations, and as the repository of a host of organic relics, leading us back to the extreme dawn of animal and vegetable life, and forward through a long series of successive creations, it becomes of the highest interest to learn how far we have advanced in exploring its fossils, and in framing in accordance with their distribution a classification of the formations which shall be widely applicable.

The outcrops then, of these vast formations, commencing at the northeast in Vermont, have been traced through the western border of Massachusetts by Hitchcock, and westward through New York by Emmons, Hall, Mather and Vanuxem; through Ohio by Briggs, Lawrence, Locke and Owen; through Upper Canada, north of Lake Erie, by W. B. Rogers and myself; through Michigan by Houghton and his corps; through Indiana, Illinois and part of Wisconsin by Owen and Locke; through Kentucky and Middle Tennessee by Owen and Troost, and southward along the broad Appalachian chain and the coal fields west of it in New Jersey and Pennsylvania, by myself and corps; in Maryland by Prof. Ducatel, W. B. Rogers and myself; in Virginia by W. B. Rogers and his corps, and in east Tennessee to Alabama, by my brother and myself. From Lake Champlain therefore, westward to the mouth of the Wisconsin river, a distance of at least eleven hundred miles, and southward to Alabama over a still larger and very complicated tract, and throughout the entire triangular area included between these limits, the boundaries of each of our Palæozoic Appalachian formations have been determined, and with very considerable precision. To a result so practically useful, so fraught with scientific benefit, so creditable to our young country, the numerous geological surveys by state authority, either completed or begun, have principally contributed.

Although but seven or eight years have elapsed since most of the surveys of the wide region before us were instituted, so diligent have those engaged upon them been, that we are now almost ready to unite the whole of our lines, into one comprehensive and huge map of the entire Appalachian basin. If there were a general map of the United States, or a series of state maps upon a common scale, it might even now be practicable, combining the published data with the yet unpublished materials for Pennsylvania, Maryland, Virginia and east Tennessee, in the possession of my brother and myself, to produce a geological picture of the wide surface mentioned, upon which should appear each special formation in all its separate belts or outcrops. The real condition of topographical geology, is indeed already such, that our treasures are beyond the size of the caskets which should contain them; and much that has been deciphered, the most beautiful structural features, it is feared must go unwritten, not for want of *scribes* certainly, but because of the narrowness of our *tablets*, because of the insurmountable impediments from bad geographical maps. A tolerably correct and clear delineation of the limits of the strata is practicable enough, with perfect maps, where the rocks are clearly horizontal, and their

outcrops are wide and not tortuous, and, therefore, from the Mohawk westward, the formations are depicted with sufficient precision in the geological map of New York, and in the unpublished one of the states farther west, compiled by Dr. Owen; but when, as in the long and complicated Appalachian chain, almost innumerable anticlinal flexures of various lengths and forms throw the strata into nearly countless belts, some of them of extreme narrowness, which wind about in strictest conformity to the topography, their delineation is much more difficult, and an accurate and ample map basis, on which to lay them down, becomes of the first importance. Impressed with this conviction, and reluctant to see the errors and distortions of the existing map of Pennsylvania falsify the more accurately drawn lines of the strata, furnished by a seven years' laborious survey, I have with the aid of my assistants, especially Messrs. Jackson, Henderson, Lesley, McKinley and Whelpley, constructed a more accurate general map of the Appalachian mountains of the state on a scale of two miles to the inch, upon which I am able to depict every outcrop and every axis of importance. Though far from possessing the precision of a thorough map, it is the only approximately exact picture we yet have of any part of our great mountain chain, so peculiar in the symmetry of its structure, so instructive as to the close dependence of topographical features upon the hardness, thickness and dip of the strata, and so interesting in a yet more scientific light, as revealing the nature of the grand and wonderful movements through which the great floor of an ancient sea, rose and became wrinkled into this stupendous zone of long parallel mountain crests.

Availing ourselves of some of the abundant materials for a detailed geological map of the United States, Prof. W. B. Rogers and myself have constructed for our own convenience a general map of the strata, fourteen feet by twelve feet, painted on canvass by Russell Smith. It aims not at minute accuracy, nor does it embrace all the narrow belts of the Appalachian formations in their southeastern outcrops, each of the great natural groups of the strata only being represented in this part of the map.

While we thus see how much has been done towards tracing the limits of each formation, we must remember that an accurate mensuration of the strata has also, for most districts, been carefully attended to. Having at an early stage of their researches, ascertained the order of superposition of the stratified masses, and analyzed them, at least approximately, into groups and formations by aid of their organic remains, and their well-marked lithological limits, the geologists in charge

of the various surveys have, while tracing the boundaries of each stratum, been patiently estimating its variations of thickness and its changes of aspect, texture and composition. The labors of Emmons, Hall, Mather, and Vanuxem, in New York, and of Hall, Locke, and Owen, especially of the latter, in the Western States, have taught us many curious facts concerning the modifications which the more persistent strata undergo in this westward range from the Hudson to the Mississippi. The changes which the same mineral deposits experience in their long course from the Hudson to Alabama, have been examined by my brother and myself, and have already exposed to us some beautiful general laws of variation which we believe will throw light on the character of the physical conditions and movements that accompanied the diffusion of these ancient sediments. As the strata generally reascend to the surface several times across a wide belt in the mountain chain, especially in Pennsylvania and Virginia, it is practicable to study the variations of type, not in one direction merely, as from N. E. to S. W., but also from S. E. to N. W., or *seawards* as respects the coast of the ancient Appalachian ocean. In so many places, both in the mountains and the great plains of the Western States are the shore and the deep sea deposits of that ancient ocean lifted to the surface by anticlinal flexures, so entirely in each of its many successive floors with the whole of the once living tribes that they supported, brought into contact with our hands for exact measurement, within reach of our closest vision for minute inspection, or even microscopic analysis, that the systematic and patient study of its contents, its sediments and organic fossils, now in progress, cannot fail to reward us with a full disclosure of all that was striking in its history.

Let us now turn to the progress recently made in developing the palæontology of this great Appalachian basin, in classifying and naming the formations, and in determining the relationship in age between these and the palæozoic strata of Europe. By the researches of Mr. Conrad, Prof. Emmons, and Mr. Hall, in New York, and of Hall, Owen, Troost, Locke, and Clapp, in the Western States, we are already made familiar with the forms and the positions in the strata of perhaps five hundred well-characterized marine fossils, embraced in numerous genera of trilobites, testacea, and corals. The labors of Hall and Conrad, in bringing to light the chief part of these remains, have been especially valuable. As Mr. Hall is devoting himself with great zeal and signal success to the fascinating study of the organic remains of New York, and as the geologists of other states are availing themselves of its clearly defined specimens for those comparisons, without

which little real progress can be achieved in the more refined inquiries connected with our palæontology, we may anticipate the speedy developement of highly curious generalizations, in relation to the limits of these extinct races and the conditions which have controlled their distribution.

Guided by the ascertained boundaries of the principal groups of fossils, and also influenced by the great natural lithological horizons, the geologists in the different quarters of the wide Appalachian field have sedulously aimed at making such an analysis and classification of the strata as would best accord with the special type which they present in their respective district. Seeking at first for a classification founded on local and not general characteristics, the subdivisions hitherto instituted only admit of extension to districts beyond those for which they were framed, in so far as the strata retain with more than usual constancy these local features. Hence a general scheme of grouping, applicable, if possible, to the whole region occupied by the strata, and expressed in terms significant of general and not local and restricted relations, is yet to be supplied.

The most elaborate classification of our Appalachian palæozoic strata, hitherto published, is that of the New York geological survey. From the very considerable amount of palæontological research connected with this survey, from the diversity of formations in the State, and the clear typical characters which some of them possess, this classification merits much attention. It embraces under the title of the New York system, the entire body of strata from the bottom of the lowest fossiliferous rocks, to the base of the red sandstone of the Catskill Mountains, the whole having in their maximum expansion a thickness of about six thousand feet. This large mineral mass has been subdivided by the gentlemen of the New York survey in conformity, chiefly, to the horizons established by organic remains, into *twenty-eight* special formations, or subordinate masses, and these twenty-eight are thrown into four series or divisions named from the districts where they are best developed. Observing the ascending order, these are the Champlain division, the Ontario division, the Helderberg division, and the Erie division. Referring you to the ample and well illustrated volumes on the geology of New York, for the views which have induced the geologists of that survey to adopt the above classification and nomenclature of the rocks, and for many valuable details connected with the organic remains, I will embrace this opportunity to bring to your attention some points of general interest to American geology, which the perusal of these works has suggested.

In geological, as in all archæological research, the earliest periods

seem most to enlist our attention. Ascending the stream of time, the structures we *first* meet with have too much the features of the present day deeply to move our minds; but far towards its sources, on the very confines of the great desert of the forgotten past, monuments are found, that, by their strange outlines and dim inscriptions, calling conjecture to the aid of thought, stir in us a curiosity which belongs to the profoundest part of our intellectual and moral nature. The whole history of geology is the record of a series of successive incursions into remoter and still remoter provinces of time. Pushing research to its limits, we seem nearly to have reached the bounds of the accessible past, in the diminution, and at last the total disappearance of fossils in the earlier strata. Our science has reached the point just attained by geography. No conjectural continent is left for a geological Columbus to discover —no great region remains unvisited, and no principal boundary undrawn. The business of the present and future generations of geologists is to establish with all the precision admissible by science, the exact limits which divide the many districts of ancient time into which they have penetrated; to define the position, so to speak, of each known coast, and to bring to light such lesser districts as may yet lie undiscovered within their more conspicuous borders. This work, more difficult by far than that of mere first discovery, since it demands a very thorough knowledge both of palæontology and of structural geology, is advancing at this time with extraordinary speed in Europe, in the hands especially of Phillips and De la Beche, Murchison and Sedgwick, De Beaumont and D'Orbigny.

Let us inquire how far we in the United States have proceeded in the same labour of firmly establishing some of the more important limits between the several portions of geological time, as recorded by our strata and their organic remains. And first, let us examine the conclusions reached regarding the commencement or dawn of the whole fossiliferous period. The fixing of a base for the palæozoic rocks of the United States is a problem scarcely less difficult than that of determining the lower limit of the corresponding system in England, to which the admirable sagacity of Sedgwick has been so usefully directed. Do we possess in the so called *Taconic system* of rocks lying to the southeast of the unequivocally fossiliferous strata at the base of the New York or Appalachian system, an independent mass of formations, of an unquestionably earlier date, or are they on the other hand but well known lower Appalachian strata, disguised by some change of mineral type, and by igneous metamorphosis. These Taconic rocks under the form they assume along the eastern boundary of New York and the western

side of Vermont and Massachusetts, have been carefully studied by Emmons, Hitchcock and Mather, all of whom appear to have arrived at different conclusions concerning them. Since the same or a very analogous group of strata ranges at intervals, holding the same relative position the whole distance from Vermont to Georgia, the question of their age, while it has a wide bearing on any general classification of our formations, ought certainly to admit, sooner or later, of settlement, when so many and such noble transverse sections are opened to inspection by the river gorges which cut the Blue Ridge.

Prof. Emmons considers the granular quartz, slate and limestone of the Taconic hills and the Stockbridge valley as constituting a distinct group of strata, neither appertaining to the true gneissoid or mica schist system on the east, nor to the palæozoic fossiliferous rocks of the Champlain and Hudson valley on the west, but holding an intermediate place in the scale of time. His principal argument in defence of this view, is that the order of succession of the component members of the group, is essentially different from that witnessed in the sandstone, limestone and slate of the Champlain division, and he denies that the theory of plication of the beds, advanced originally by myself and my brother, and applied to this very region, can reconcile the seeming want of agreement. Now it is true that the *apparent* order of superposition in the Taconic belt, is in discrepancy with the well-known succession of the Champlain formations, but this is precisely what should arise from the introduction of those complete folds or doublings together of the strata which we have conceived to exist; and I would add that the sections furnished by Prof. Emmons and Prof. Mather in their reports, if resolved by the introduction of the flexures supposed by us to prevail, will all of them display, for their western portions at least, the normal order of superposition of the Champlain rocks. This identity of the so named Taconic system, with the formations of the Hudson and Champlain valley, was announced by W. B. Rogers and myself, in the beginning of 1841, to the American Philosophical Society. By aid of a section from Stockbridge towards the Hudson river, we showed the existence of numerous close anticlinal and synclinal folds, and thus explained the apparent inversion of the dip, which other geologists had ascribed to one general overturning of the whole series. The plication was shown to be greatest along the Berkshire valley and the ridges east, the granular Berkshire marble was identified with the blue limestone of the Hudson valley, but metamorphosed by heat, and the associated micaceous, talcose, and other schists were referred in the language of the communication, to the slates of the lowest formation of the Appalachian

system, while the semivitrified quartz rock of the western part of the Hoosac mountains was stated to be nothing else than the white sandstone (Potsdam Sandstone) of the same series slightly altered.* I am gratified to find from Prof. Mather's report, that these views of identity are embraced by him, as they now are, if I mistake not, by Prof. Hitchcock. Prof. Mather indeed says that he has traced the slate (Hudson slate) through all its gradations into talco-argillaceous and talcy slate, and into graphic and plumbaginous slate, the limestone from compact sandy and slaty, to sparry, slaty talcose, and crystalline limestone, within short distances, and the Potsdam Sandstone, to a hard compact and granular quartz rock. It is true, Prof. Emmons has presented in his report a series of sections of the strata exhibiting an unconformity at the passage of his Taconic into the rocks of the Champlain division, but I must take the liberty of expressing my disbelief of the existence of any such unconformity, and of observing that in the prolongation southwestward of this altered and plicated belt as far as the termination of the Blue Ridge in Georgia, a distance of one thousand miles, no interruption of the general conformity of the strata has ever met the observations of either my brother or myself.

It would appear thus that the Potsdam Sandstone forms the base of the palæozoic strata in the latitude of Lake Champlain, or at least in the region of the lake and of the Mohawk river. Is this formation then the lowest limit of our Appalachian palæozoic masses generally, or is it the system expanded downwards in other districts, by the introduction beneath of other conformable sedimentary rocks? From the Susquehanna River southwestward, a much more complex series of strata comes in below the bottom of the lowest limestone, than is any where seen northeast of the Schuylkill. In some portions of the Blue Ridge belt there are at least four independent and often very thick deposits, constituting one general group, in which the Potsdam, or White sandstone, is the second in descending order. The uppermost of these is an arenaceous and ferriferous slate, many hundred feet thick, in which the only fossil is a peculiar fucoid. Beneath this lies the Potsdam Sandstone, and under this again a mass of coarse sandy slates and flaggy sandstones, amounting sometimes to six hundred or seven hundred feet, below which occurs in Virginia and east Tennessee a series of heterogeneous conglomerates. Neither of the two lowest of these masses, has yet rewarded research with a single fossil, and therefore the white or Potsdam Sandstone is yet

* See Proceedings of American Philosophical Society, Jan. 1, 1841.

the most ancient depository of organic life hitherto discovered in our strata. Adjoining this great mass of arenaceous strata towards the southeast, we find throughout much of the broad belt of the Blue Ridge, especially in its prolongation southwestward from the Potomac, a wide expansion of metamorphic strata intersected by innumerable veins and dykes of greenstone and other igneous materials, and displaying almost every grade and variety of alteration in texture and mineral contents. These after long and careful observation, we have been led to consider as a group of sedimentary beds still older than the preceding; but forming a part of one and the same unbroken series. Thus then, in the great group of strata at the base of our lowest fossiliferous series, we are presented with perhaps more striking results of igneous modifying powers than even in that portion of the Champlain system whose metamorphosed beds constitute the Taconic group. Although no relics of either vegetable or animal life have hitherto been met with in this group, we cannot confidently infer their entire absence, since from the effects of cleavage and chemical change their remains could not fail to be greatly obscured and for the most part quite obliterated. It is most probable, however, that the same barrenness of fossils remarked in the slates and sandstones immediately beneath the Potsdam Sandstone, prevails throughout the whole of the continuous series of subjacent strata.

Respecting the phenomena presented in the long belt of rocks here referred to, the question suggests itself whether the so-called Taconic system, instead of belonging exclusively to the Champlain division, may not, along the western border of Vermont and Massachusetts, include also some of the sandy and slaty strata here spoken of as lying beneath the Potsdam Sandstone.

Applying for the present the term palæozoic only to the strata commencing in the ascending order with the conglomerates at the base of the group, including the Potsdam Sandstone, since below this there is little probability of our finding traces of organic beings, the next inquiry of general interest relates to the natural divisions, groups and formations, into which we should arrange the whole enormous body of sedimentary deposits, between this horizon and the top of the Coal rocks. Throughout this great mass of strata, whose aggregate thickness exceeds in some districts Thirty Thousand feet, made up of an extraordinary number of distinct formations, characterized by peculiar organic remains and composition, and marking a long series of events and a vast lapse of time, we behold one uninterrupted succession of deposits, closely linked by an equally unbroken sequence of animal and vegetable remains.

We are therefore constrained to view the whole as constituting a single system, the entire record of one immense continuous period, the collected gatherings of one prodigious sea. To deduce from a study of the organic remains of the different portions of this mass, aided by considerations of mineral type, a classification which shall be in harmony with the natural relationships of the different members throughout the entire basin, as respects time and circumstances of origin, one which, in other words, shall express the various epochs and changes in their relative importance, and to clothe this classification in language which shall be at once suggestive of their relationships and generally applicable, furnishes a complex problem of much difficulty, but one perhaps which at the present time has strong claims to the attention of American geologists.

As the necessity for a general nomenclature for these rocks, founded on a wide survey of their fossils, is getting to be recognized, as many and grave objections exist to the adoption of all local and partial classifications, and as it is believed that through the diligence of our geologists, we are already prepared with a sufficiently ample body of data for the construction of a system which shall unite the chief requisites here mentioned, I venture, craving the indulgence of the Association, to present the outlines of a scheme of grouping and naming our Palæozoic strata, which my brother Prof. W. B. Rogers and myself, have been carefully maturing during the last three years.

We propose to distribute the whole great body of strata from the base already designated to the top of the coal measures into *nine* distinct *series*, the products of as many great successive *periods*, and resorting to the analogy between these periods and the nine natural intervals into which the *day* is conveniently divided, we have named them in ascending order, the *Primal*, *Matinal*, *Levant*, *Premedidial*, *Medidial*, *Postmedidial*, *Ponent*, *Vespertine*, and *Seral* series, the deposits of the Dawn, Morning, Sunrise, Forenoon, Afternoon, Sunset, Evening and Twilight periods of the great Appalachian Palæozoic day. Subdividing each *series* in obedience to natural and obvious relations of the organic remains and mineral boundaries, we have named each ultimate subdivision a *formation*, calling the time during which each formation was produced an *epoch*, and between the series and formations, we have constructed *groups* in all cases where the natural affinities of the formations require that two or more of these latter shall be united into sets subordinate to the series.

Our *Primal series* embraces the four great rocks between the base

of the Palæozoic strata and the base of the first limestone, the Calciferous Sandstone of New York. Of these the Primal White Sandstone would seem to be the only formation existing in New York, or according to Owen, on the northwestern margin of the basin in the Western States.

The *Matinal series* includes all the strata from the horizon of the base of the Calciferous Sandstone, to that which marks the top of the Hudson River slate in New York, and the top of the blue limestone of the Western States. This series, in southwestern Virginia and East Tennessee, embraces a thick and important middle group consisting of three formations, not extending northeast of the New River, and only imperfectly represented in some portions of the Western States.

The *Levant series* includes all the formations between the horizon terminating the Matinal rocks and one running through the top of the Water Lime formation of New York, the top of the non-fossiliferous "pitted rock" of Lake Huron, and through a plain low in the Cliff limestone of the Western States. It takes in, therefore, the Medina, Clinton, Niagara and Onondaga salt, groups, and Water Lime of the New York survey.

The *Premedidial series* embraces the strata between the top of the Water Lime and the top of the Oriskany sandstone of New York, and includes, therefore, the Pentamerus and Catskill shaly limestones of that State as its oldest formation, and the Oriskany Sandstone as its newest; and besides these, a middle formation not there seen but well developed in Pennsylvania, with characteristic fossils.

The *Medidial series* ranks in it all the strata between the top of the Oriskany or Premedidial sandstone and the Marcellus Black slate of New York, or the Black bituminous slate of Ohio, Indiana, Kentucky and Middle Tennessee. It, therefore, includes the Scoharie grit and Onondaga and Corniferous limestones of New York, and the upper division of the Cliff limestone of the west.

The *Postmedidial series* embraces that very natural assemblage of formations commencing with the black slate just named, and ceasing with the horizon which marks the base of the Catskill red sandstone. It contains, therefore, for New York the Marcellus slates, the Hamilton group, the Tully limestone, the Genesee slate, the Portage group and the Chemung group, and for the west all the strata between the top of the Cliff limestone and the bottom of the Carboniferous limestone.

The *Ponent series* includes all the rocks between the base of the

Catskill red sandstone and the top of the overlying conglomerate. (Formation X. of the Pennsylvania and Virginia annual Reports.) It usually embraces but two formations, the Ponent Red Sandstone and the Ponent Conglomerate, though the former of these requires for some districts a triple subdivision.

The *Vespertine series* comprehends the interesting formations above the horizon of the Ponent Conglomerate, and below that at the base of the great conglomerate under the coal measures. In Pennsylvania it is composed of the thick Red shale deposit of the coal regions, and in Virginia of a much more complex set of strata, including a lower red shale or variegated marl, next a great thickness of carboniferous limestone, and then an upper set of shales with alternating sandstones. In the Western States, on the other hand, it consists almost exclusively of the Carboniferous limestone and its subordinate chert.

The *Seral series* embraces our vast and multiform body of coal strata, the thickness of which in Western Pennsylvania and Virginia exceeds three thousand feet, being in the anthracite basins probably still greater. The lowest or oldest subdivision of this series is the Seral conglomerate, and the true coal formation overlying this is divided into four distinct members—the *older coal measures*, *older shales*, *new coal measures* and *new shales;* these last terminating the entire succession of our thick and wide-spread Appalachian strata.

The whole body of rocks here grouped into nine series, contains upon the most careful analysis which we have been able thus far to institute, about Forty-Eight formations, few if any of which are co-extensive with the present limits of the great Palæozoic basin in which they lie, or even with that part of it included between the Blue Ridge chain, the Mississippi River, and the great Lakes. Those which were most widely deposited are the Matinal magnesian limestone, the Levant older (or Niagara) limestone, the Vespertine (or carboniferous) limestone, and the Older Coal measures. Others occupy a relatively circumscribed area, yet none are called formations which are not the products of distinct formative actions operating during epochs characterized by distinct groups of races.

My brief limits will not allow me to present here even the general scheme of names by which we propose to designate the divisions of this extensive system of strata; but I will explain succinctly the principles upon which the names are chosen. The title given to any formation is composed first, of the name of the *period* to which it appertains, and secondly, of a word or words descriptive of the *ruling mineral*

character of the rock; and to these is appended, when we wish to specify the type under which the formation is referred to, the name of the district or place where it is so developed. Let me exemplify this by one or two instances. The well characterized formation called in the New York survey the Marcellus shales, is named by us the *Postmedidial older black slate*, while the Genesee slate is called *Postmedidial newer black slate*, and a member of the Clinton group of New York, occurring there as a thin bed of brown and ponderous sandstone, (seen on the Sequoit,) but expanded in Pennsylvania and Virginia into an important mass having characteristic fossils and a maximum thickness of two hundred feet, we propose to call the *Levant iron sandstone*.

The *nomenclature* here employed for the designation of the strata, is recommended we conceive by several features of obvious utility. Being a nomenclature based on considerations of geological time, it suggests at once in the names themselves, the relative *ages* of the different strata, thus defining the fundamental relationship of *succession in time*, the only relationship between rocks which never varies. It has thus the advantages of a numerical or ordinal designation, combined with the descriptiveness which that has not. While it conveys the fixed relations of time, it expresses the accidental or local character of each formation, and what is of much more importance, it signifies under what particular type any special stratum is referred to, by introducing into the name that of the district where the rock assumes the phasis treated of. Thus by the mere name assigned to each formation we are reminded of all its most essential attributes, its *age*, its *region*, and its *mineral composition;* or in other words, what place among the other strata it occupies—in what district we are describing it, and what its composition is under its normal or typical developement. One of the most obvious defects in any nomenclature is a want to ready adaptability to new or abnormal relations and conditions of the objects named, and in this unfortunate rigidity in the terminology of some of the sciences we may discern a most influential barrier to their progress. In devising the system proposed, we have aimed at uniting the power of representing the fundamental or permanent relations of the objects named, and of pliantly expressing their special deviations and gradations. In the phenomena of mineral and Palæontological deviations of type lie concealed, we should remember, the very *arcana* of our science, secrets which interpreted will give us the only insight we can hope ever to procure into the actual state of our earth's surface in periods long remote. In the above system we try to give to geological language the

capacity of expressing those facts and laws of gradations in strata which are so constantly appearing.

As an illustration of the necessity for some such general applicable scheme for our Palæozoic rocks, it may be mentioned, that while some of these are remarkable for adherence to their typical characters, others are conspicuous for their protean variations. The value of our particular mode of designation, may be seen in the instance of the group of formations we have called the Matinal series. Being remarkably well separated by great natural features from the Primal series below, and from the Levant series above, from both of which it is insulated as well by clear mineral characters as by dissimilarity of organic remains, it yet exhibits within itself, when widely traced, several important modifications of type, which no geographical or other artificial nomenclature can possible indicate or express. Thus it consists in New York of five rather well defined formations the Calciferous Sandstone, Black River limestone, Trenton limestone, Utica slate and Hudson river group, each possessing an easily distinguishable mineral aspect, and its own organic remains with little intermixture. But how different is the condition of the whole mass in Ohio and Kentucky, and again how different in Southwestern Virginia and East Tennessee. In the anticlinal district of Cincinnati and Lexington, where the series bears the name of the Blue limestone, not one of the special subdivisions or formations, so easily recognized on the Mohawk, can be distinguished, but the whole displays a fusion or blending of the different portions, and also of the mineral materials, which baffles every attempt at tracing an exact equivalency between any of its parts and the New York formations. It is true the investigations of Prof. Locke, Dr. Owen and other geologists, show that certain species observe certain horizons, but it should be observed that these horizons in many cases, do not bear to each other the same relations which those of the same fossils do on the Mohawk. In place of the five rather clearly marked masses of New York, the whole exposed portion in Ohio, about one thousand feet in thickness, is composed of alternating calcareous shales and thin layers of limestone.

Turning to Virginia and East Tennessee, we have a still different state of things; the Mohawk type, with no very important modifications, continues from New York through New Jersey, Pennsylvania, and Maryland, extending into Virginia as far as the north branch of the Shenandoah, some seventy or eighty miles southwest of the Potomac. The principal change in this distance is in the Black River Limestone, which expands greatly in thickness, becomes more

highly magnesian, and acquires some fossils not seen to the northeast. But beyond the neighbourhood of New Market in Virginia, the changes are much more important; for with the magnesian limestone is associated a vast body of chert, and the Utica slate as a stratum disappears, the place of that rock and the Trenton limestone and Hudson River slate, being occupied somewhat as in Ohio, with a blended calcareo-argillaceous mass, in which neither formation is distinctly recognized, and where the fossils of each are to a considerable extent intermingled; the *Lingula rectilateris*, for example, deemed characteristic of the Utica slate in New York, being found throughout all the middle and southwestern region of Virginia associated with the Cypricardiæ, so distinctive of the Hudson River group, and always very high in the series. Entering East Tennessee, but especially in the region of Knoxville, the middle part of the series represented by the Trenton limestone and Utica slate of New York and Pennsylvania, and by the simple alternation of layers of limestone and slate containing Trenton, Utica, and some Hudson slate fossils at Cincinnati and in the interior of Virginia, becomes a complex group of several distinct formations no where developed farther north.

Thus the entire Matinal series in East Tennessee embraces in the ascending order, 1st, a great magnesian limestone between two thousand and three thousand feet thick, with beds of chert, often oolitic, and layers of white and even red sandstone; 2d, a knotty argillaceous limestone containing Maclurea, Isotelus, and a great profusion of Calamapora polymorpha, and other corals, seven hundred feet thick; 3d, a white encrinal sparry limestone, five hundred feet; 4th, yellowish calcareous slate, several hundred feet; 5th, sandy gray limestone very ferruginous, three hundred feet? 6th, yellowish or buff slates, several hundred feet; 7th, red and greenish coralline and encrinal marble, four hundred? feet; 8th, calcareous gray and yellowish slates several hundred feet.

Upon comparing these Matinal rocks of East Tennessee, with those of the northeastern portions of the basin, the difficulty of establishing an equivalency in the ordinary sense of the term, will be found to be insuperable; for while the Tennessee strata in the middle part of the column, possess a number of well-known Trenton limestone fossils, the mingling of these with Hudson slate species, the total disappearance of others, and the introduction of new forms, preclude every attempt at *identification*.

In a case of this kind a nomenclature on the plan here proposed, will

be found to obviate all confusion. When speaking of the strata, as they exist in New York, we would call the Trenton limestone and Utica slate, for example, the Matinal newer limestone, and Matinal older slate, but when these become blended, as in Virginia, the portion of the series which they occupy, the Matinal argillaceous limestone group, or Matinal middle group, while the strata on the same general horizon in East Tennessee, would be called the Matinal encrinal limestone, or Matinal coral marble, as the case might be, appending when necessary to each such name, that of the district in which the rock or group attains its fullest developement. In those instances where any thing short of a minute analysis of local application, is impracticable, as is the case perhaps of the Cincinnati Blue limestone, the general term *Matinal series* will be most appropriate. If that mass should in any district acquire a binary or ternary subdivision, the respective parts may be called the Matinal older limestone, &c., of Ohio, a mode of naming which is amply descriptive as respects each requisite of time or place in the series, of composition and locality, and which furthermore takes nothing for granted.

Before leaving this important but difficult subject of classification and nomenclature, permit me very briefly to indicate why I conceive that the prevailing method of naming rocks without regard to their relationships of age, but solely by titles drawn from the spots or districts where they occur, must seriously retard our science. If the names be derived from a single district, even an extensive one like New York, however rich in strata and however ably these may be explored, only a portion of the names, generally a small part of them, will really be assigned to formations which are there fully or typically developed, for we well know, that no single corner of a vast basin can ever contain but a few of its deposits in a condition of maximum expansion and richness in organic remains. If geographical terms are to be employed it would be more appropriate to select those belonging to districts any where in the basin where the formations are found to be most amply represented. On this plan the names would be found to possess a wider significance, than when all are chosen from one region, yet as geographical names, they would lack suggestiveness when applied to any other district. If on the other hand, the rocks are to receive different local titles in the different territories explored, then will our descriptive geology be rendered almost unintelligible, by a crowd of synonyms, and every attempt at extensive comparison, every effort to read in this ample page of nature's great history, some of her higher laws, will be rendered doubly arduous.

MESOZOIC PERIOD.

Let us now take a brief survey of the state of our knowledge of the mesozoic formations of this country, or those produced during what may be termed the middle ages of geological history. The vast interval between the remote epoch of our coal and the dawn of the existing marine species in the eocene tertiary, is much more imperfectly represented in North America than either the earlier or later periods. With the exception of its last or cretaceous age, this great interval, which, in the eastern continent, is so rich in beautiful monuments of extinguished life, so abundant in striking records of the physical revolutions of our globe, seems to have left on this side of the Atlantic only a few fragmentary memorials of its races or its events. Like some of the obscurer periods in human mediœval history, these, the dark ages of American geological time, have been explored of late with a zeal and skill awakened by the very difficulties of the research, and which have already produced some very instructive results.

Referring the isolated formations of this country, whose dates are intermediate between the coal and the tertiary, to the more full and continuous scale of the European strata, as a present standard of comparison, we are now acquainted with deposits belonging to three distinct mesozoic epochs, the equivalents severally of the upper new red sandstone or Triassic rocks, of the lower oolitic deposits, and of the cretaceous strata. Thus we are destitute, so far as this continent has yet been explored, in products of the newer palæozoic period, or, in other words, in any representatives of the Zechstein or magnesian limestone group of Europe, and likewise in equivalents of several of the middle and upper oolitic formations of the old world.

A concise exhibition of some of the facts bearing upon the determination of the age and origin of the three known mesozoic formations of the United States may not be unsuitable on this occasion.

The older of these groups of strata, which I shall call the *Mesozoic red sandstone*, occupies two long and narrow and probably shallow troughs, extending along the eastern side of the great Blue Ridge chain and its northeastern prolongation in New Jersey, New York and New England. The larger of the two troughs ranges continuously from beneath the trap of the Palisadoes of the Hudson southwestward in a diminishing belt to the interior of Virginia, and beyond this point the deposit occurs in narrow detached tracts as far as the southern side of North Carolina. Throughout all this course, the strata dip towards the

north and northwest at angles from fifteen to twenty five degrees. The smaller trough fills the valley of the Connecticut river through the whole breadth of Connecticut and Massachusetts, and in this belt the beds dip at an angle of ten or fifteen degrees to the east and southeast and northeast. The materials of both basins are red shale and argillaceous sandstone, with some detached beds of conglomerate.

Of the organic remains, through an investigation of which alone we can hope to establish the position of these strata in the scale of time, or reach definite conclusions respecting the physical conditions under which they were produced, the most instructive are the remarkable bird-tracks brought to light by Professor Hitchcock in Connecticut and Massachusetts, the fishes of the genera Palæoniscus and Catopterus, discovered by the Messrs. Redfield in New Jersey and elsewhere, and one or two small but most expressive testacea detected by my brother in the formation in Virginia. Through the discovery by Mr. Redfield of some of the same fishes and even bird-tracks in the two distinct belts described, these deposits are identified in age and origin; but what exact epoch should be assigned to the formation, was not until lately susceptible of that rigorous demonstration which the present advanced state of our science calls for.

Guided by mere lithological resemblance, Maclure imagined this stratum to be the equivalent of the old red sandstone of England; but Prof. Hitchcock and Mr. Redfield, chiefly by their investigations into the character of the fishes, have shown conclusively that the date of the deposit is somewhere in the great period of the European new red sandstone, an opinion several years ago expressed by Prof. Hitchcock. But while the low degree of heterocercal structure in the tails of the fishes indicated that these strata could not be newer than the new red sandstone, and the same feature and the bird-tracks both proved them newer than the coal, it was still not settled which of the epochs between the oolitic and the carboniferous ones should claim them. The more favorite supposition was, if I mistake not, that the deposit belonged to the age of the older new red sandstone, and highly instructive as both the fishes and the bird-tracks are, as respects the general date, and above all as regards the nature of the waters, the climate and the surface, still there being among them no one species identifiable with any European relic, some further evidence was required in order to establish the exact epoch. In this stage of research, my brother was fortunate enough, about two years ago, to discover in the formation in Virginia, two or three small shells, and to recognize, in the most abundant of these species, the *Po-*

sidonia Keuperi, a well known and characteristic species of the Trias, or upper new red sandstone of Europe. With this positive link, supported by the strong analogies already mentioned, the most skeptical can no longer hesitate to refer our red sandstone formation to some part of the Triassic or earliest mesozoic period. The conjecture recently expressed by Mr. Murchison, therefore, that the Connecticut deposit is of the age of the magnesian limestone group, or the Permian system of this able geologist, resting as it does chiefly on the occurrence of the genus Palæoniscus, but not on an identity of species, cannot be considered as consistent with the other more conclusive evidence which we now possess of a difference of date; and should it hereafter appear, as seems to be suspected by Mr. Redfield, that the American fishes referred to Palæoniscus, constitute truly a new though allied genus, even the present supposed generic relationships of the formations will vanish. The fact mentioned by Mr. Redfield, that "the scales and apparently the vertebræ in the American species are prolonged to a more limited extent into the upper lobe of the tail than in the European species," while it supports his surmise that they may not be true Palæonisci, must be regarded as in itself an indication of a somewhat more modern period. It will be seen, therefore, that the affinities of this formation forbid our yet assuming that any birds coexisted with the last races of primeval or palæozoic life. But the existence of creatures thus high in the scale of animal organization, in times so remote as the earliest mesozoic epoch, is a fact full of interest, and it is gratifying to the American geologist to perceive that the views so early and candidly submitted in the face of skepticism by Prof. Hitchcock, of the true origin of the bird-tracks, are now universally admitted. That to him alone is due the merit of being the original scientific discoverer of the nature of these impressions, all who are familiar with the history of his labors must acknowledge. Others before him had found specimens of the foot-marks, and had shrewdly suggested that they may have been produced by birds, that opinion having been entertained by a few persons even early in this century, and Dr. James Deane, in drawing the attention of Prof. Hitchcock to some specimens, distinctly intimated the same belief as to their origin. But conjecture in science is not discovery; and if the principle be a sound one, which awards the high title of "minister and interpreter" of nature to him only who, by extended, laborious and systematic observation and inductive reasoning, turns conjecture into demonstration, and from a few isolated phenomena casually presented to him, developes to the view of all after generations an eternal truth, then as-

suredly must Prof. Hitchcock be regarded as the only scientific discoverer of the origin of these curious and instructive foot-prints. The conscientious wish to acknowledge the claim of Dr. Deane as a suggester of the ornithichnite character of these impressions, has led some of those who have lately reviewed this subject, to do, I think, an unintentional injustice to the well-earned and far more ample claims of Prof. Hitchcock.

In speculating upon the circumstances connected with the deposition of the red sandstone, Prof. Hitchcock supposes the Connecticut formation to be the sediment of an extensive tidal estuary, upon the low and muddy beach of which the various birds whose footsteps he has described, were in the habit of walking and wading at low tide in pursuit of their prey—their foot-prints being covered with a thin layer of silt, probably at each reflux of the waters. Some of these birds, rivaling in size the recently extinct gigantic Dinornis of New Zealand, whose height is computed by Prof. Owen to have been more than ten feet, and frequenting in numerous flocks those lonely shores of the great Connecticut bay, must have imparted a strange aspect to the landscape.

Prof. Mather conceives that in this early mesozoic age, the Blue Ridge and Green Mountain chains having been previously elevated, and much of the country to the eastward being still submerged, "the current which we call the Gulf Stream must have flowed along the eastern coast of this part of the continent where the red sandstone formation now extends;" and to this, and to a supposed polar current from the northeast, he ascribes its deposition, attributing the present dip of the beds to the overlapping of the one current upon the other. To sustain this hypothesis, it would be necessary to show that it is not at variance with the inferences to be drawn from the bird-tracks and other data, which I cannot but consider to indicate, not an open sea, but the existence of two confined tidal estuaries.

The strata which constitute the next link in our broken succession of mesozoic formations, are the coal rocks of Eastern Virginia. The portion of these productive in coal, occupies a basin in the vicinity of Richmond, about thirty miles long, and eight miles wide in its centre, extending from the Appomattox across the James river to near Chickahominy. Another rather higher and unproductive mass is spread irregularly in a narrow belt east of the former, from the Potomac to the James river.

Both of these deposits repose immediately on gneissoid and granitic rocks, and consist for the most part of coarse grits composed of the

materials of those underlying crystalline aggregates. North of the James river, the coal lies in two, and in some places in three distinct seams, and is confined to the lowest hundred and fifty feet of the series; but south of that river, it forms one huge stratum, which though very variable, is frequently from twenty to forty feet thick,* and what is remarkable, the principal bed is separated by only a few feet, and sometimes by not more than a few inches, of carbonaceous shale from the granitic floor. By Maclure this formation was referred to the period of the old red sandstone, and more recently Mr. Richard C. Taylor assigned it to the so called "transition carboniferous deposits;" but my brother having during the last three years investigated its fossil vegetation, finds not only a general agreement, but a specific identity between some of its forms and those of the oolite coal of Europe; and he has therefore in a paper in our Transactions, stated that he feels "no hesitation in referring the formation to a place in the oolite system on the same general parallel with the carbonaceous beds of Whitby and Brora, that is, in the lower part of the great oolite group." The most abundant of the coal plants are the *Equisetum columnare*, a large species of *Zamites*, a beautiful fern, *Tæniopteris magnifolia*, and *Tæniopteris scitaminea;* and the remains of these four species, occurring interlaminated with the coal and immediately upon it in great profusion, appear to have furnished the materials of the stratum. No traces of the *Stigmaria ficoides*, so universally associated with the older or palæozoic coal, can be discovered in the soft slates in contact with the coal of this formation. Of *animal remains*, the most interesting is a small fish four or five inches long, referred by Mr. W. C. Redfield to the genus *Catopterus*.

It is perhaps worthy of remark that this genus *Catopterus* of Mr. Redfield, Jr. contains three other species which characterize the mesozoic red sandstone deposits of both Connecticut and New Jersey, and that therefore while there remains some doubt as to the existence of true *Palæonisci* in our American red sandstone, and consequently as to any generic link between it and the Permian strata of Europe, of which the genus Palæoniscus is so definitive, this red sandstone *is* related by such a link in the genus Catopterus to a formation of the oolitic epoch. Thus even as respects its ichthyolite remains, the affinities of the red sandstone are obviously rather to the mesozoic than the palæozoic rocks.

Cretaceous Period.—But if the memorials are scanty of the early and middle mesozoic periods, those of the last or cretaceous age are

* See Reports Geol. Survey of Virginia; also, Memoir in Trans. of Geol. Society of Pennsylvania, by Mr. R. C. Taylor.

full and satisfactory. Perhaps no one group of rocks in North America covers so many square miles, or more abounds in various, expressive and beautifully preserved remains of former life, than our greensands and cretaceous limestones. Commencing on the northeast at the Raritan Bay, these deposits range in a contracting belt along the Atlantic plain through New Jersey into Delaware. There they disappear beneath the tertiary, and though not visible in Maryland, Virginia or North Carolina north of Cape Hatteras, they probably form the floor of the tertiary in all this space; for in North Carolina they emerge again, and hold the same relations to the older and newer systems of strata which they observe in New Jersey. From the Cape Fear river these cretaceous deposits spread southwestward, occupying the seaboard of South Carolina, much of the southern half of Georgia, a large part of Florida, the southern half of Alabama, and the chief part of Mississippi; and west of the great river of that name, they expand so as to underlie the surface of a great portion of the enormous interior basin of the continent from Louisiana and Texas northward to the upper Missouri, and westward probably to the Rocky Mountains. Throughout all the southern tracts, they support detached local patches of interesting tertiary formations, principally eocene.

This whole cretaceous group of the United States is viewed by Dr. Morton and Mr. Conrad, after a careful investigation of the fossils, to consist of three great divisions, called the upper, middle and lower.* The *upper division* includes the nummulite limestone, familiarly called the "rotten limestone" of southern Alabama and the contiguous southern states. The *middle division* consists of a thin but very fossiliferous straw-colored limestone, capping in small patches the greensand beds of New Jersey, and this is supposed by Dr. Morton to be contemporaneous with the European white chalk. The *lower division* embraces the expanded greensand deposits of the Atlantic states and the Missouri basin, and this is considered by Dr. Morton and others to have been formed contemporaneously with the strata which in Europe lie between the chalk and the oolites.

Above the *middle* division or thin limestone of New Jersey, there occur in that state two strata not mentioned in Dr. Morton's classification, the lowest a yellow ferruginous sand with fossils, and the uppermost a coarse brown ferruginous sandstone. As many of the fossils of

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* See a tabular view of organic remains of the cretaceous strata, by Dr. Morton, in the Journal of the Acad. Nat. Scien. of Phila., vol. viii, part 2.

the yellow sand are species common in the lower or greensand division, *Ostrea falcata* being one, may not some doubt exist, I would suggest, as to the expediency of placing the intermediate straw-colored limestone so definitely on the parallel of the chalk of Europe? Influenced by the fact just mentioned, and the still more weighty consideration that the American strata in a list of about one hundred and sixty organic forms contain probably not more than six or eight species in common with the cretaceous rocks of Europe, I may be allowed to repeat a suggestion made in my Report on the geology of New Jersey, that a further comparison of the organic remains is required, before we can determine more than approximately the degree of affinity between the several divisions of the cretaceous series of the two continents. Mr. Lyell, who when in this country collected, with Mr. Conrad's assistance, a somewhat extensive group of fossils from the straw-colored limestone of New Jersey, will probably soon give us a more ample insight into the exact degree of affinity subsisting between this stratum and the chalk.

According to Dr. Morton, the shells hitherto ascertained to be common to the cretaceous deposits of Europe and America, are four: *Trigonia alæformis*, *Pecten quinquicostatus*, *Ostrea falcata* and *Gryphea vomer;* and to these links he adds about four species of fishes, and that strange gigantic oceanic lizard, the *Mososaurus*. To these points of agreement we must add those of mere analogy in the remarkable *generic* affinity of the fossils of the two distinct cretaceous basins. But even in some of the more positive links above named, we recognize in the discrepancies of their position in the two series of deposits, the difficulty of establishing an exact equivalency between the strata of basins originally unconnected. Thus, while the *Pecten quinquicostatus* of our greensand or lower cretaceous group is absent from the middle and upper divisions, which have been placed on the same horizon of time with the chalk of Europe, it occurs on that side of the Atlantic in *all* the strata of the series; and again, the *Ostrea falcata*, restricted I believe in Europe to the limits of the chalk or upper cretaceous group, abounds in this country chiefly in the lowest and disappears in the middle. In these instances we see exemplified a general and important law concerning the distribution of fossils, which is, that those species whose geographical distribution is the widest, possess likewise the greatest *vertical* range, or, adapted to a greater variety of localities and physical conditions, they have been suited to withstand a greater series of vicissitude, and to endure therefore a longer time. Such, though usually styled the *characteristic* fossils, are in reality the least characteristic of all; for, while

they are invaluable in establishing approximate identity of age between large groups of strata, separated in all other respects from each other, they fail entirely to fix the equivalency of particular members or formations, and from their obtuseness to ordinary changes they are the least instructive of all the species in respect to the special events and conditions of their epoch.

CAINOZOIC OR TERTIARY PERIOD.

Our knowledge of the tertiary strata of the Atlantic seaboard has been considerably advanced during the last three years, through the researches of Mr. Conrad, Mr. Lyell, Prof. W. B. Rogers, Prof. Bailey, Prof. Booth, and Mr. Henry Lea, while Prof. Emmons has made us acquainted with the contents of the modern tertiary of Lake Champlain. We may confidently anticipate further contributions to this very interesting portion of American geology from Mr. Conrad and Mr. Tuomey, who are engaged I believe at present in exploring some portions of the southern strata. The plan which I have assigned to myself in this address will require me to confine myself to the principal results arrived at.

Mr. Conrad, to whom this branch of our geology is so largely indebted, has, in a neat and instructive synopsis of his own labors, printed in the second bulletin of the National Institute, renewed a statement formerly made by him, that our older tertiary is linked to the newest secondary or cretaceous strata by the possession in common of three species of organic remains. Every fact which would tend to restore any part of that lost leaf in the earth's chronology, the absence of which marks the abrupt transition from the secondary to the tertiary periods, would be hailed with general interest; for, although the interruption in the succession of species at the close of the cretaceous epoch is hardly greater than prevails in other portions of geological time; and though the discoveries of Ehrenberg have partially bridged the chasm, yet the very *wide extent* of this horizon of discontinuity throughout Europe and America, lends it much importance. It was therefore a principal object with Mr. Lyell, in his visit to the tertiary strata of the Carolinas and Georgia in 1842, to investigate the evidence for the alleged passage of certain cretaceous species into the lower eocene strata. Having done so, he mentions that he was "unable to find any beds containing an intermixture of cretaceous and tertiary fossils," and he affirms that "the facts at present ascertained will not bear out the conclusion that any beds of passage exist in the southern states."* It is to be observed, how-

* See Proceed. Geol. Soc. London, No. 89.

ever, that the districts which have led Mr. Conrad to an opposite conclusion, viz. the vicinity of Claiborne in Alabama, and of Upper Marlborough in Maryland, were not visited by Mr. Lyell, and it is possible that, had he inspected the whole ground, he might have somewhat modified his opinion. Nevertheless, the evidence presented by Mr. Conrad does not seem entirely convincing, since his account of the conditions under which the *Gryphea vomer* occurs in Maryland and the *Plagiostoma dumosum* was found at Claiborne, do permit the inference that they were swept by currents into the eocene waters from an adjacent upraised cretaceous deposit. Even if it should be proved that these fossils lived associated with the earlier tertiary races, so preponderating are the true eocene forms, both as respects variety and abundance, that it would still seem inexpedient to class the stratum containing the mixture as a transition bed between the secondary and tertiary. Would it not be more philosophical indeed to suppose that the two or three intruding races had escaped the general catastrophe which cut off all the rest of the larger cretaceous species?

Mr. Lyell, I am gratified to perceive, fully sanctions the application of the terms eocene, miocene and pleiocene, to the respective divisions of our Atlantic tertiary, as made by me in 1834, from data derived chiefly from the palæontological determinations of Mr. Conrad, and this latter gentleman now lends the weight of his valuable authority to the correctness of the generalization.

The proportion of living to extinct species in our *eocene* strata appears to be as minute as in the corresponding beds of Europe, amounting probably to not more than one or two per cent., there being about two hundred and fifty species definitely ascertained. The average ratio in our *miocene* is about that in the Faluns of Touraine, Mr. Conrad having identified as living species thirty eight in a list of two hundred and thirty eight at present known to him.

The interesting exhibition of tertiary strata at Gay Head in Martha's Vineyard, referred by Prof. Hitchcock to the eocene period, and by some conjectured to contain fossils washed from a cretaceous formation, has been examined by Mr. Lyell, and is pronounced by him to appertain to the miocene age. It has yielded him some interesting organic remains, none of which are of eocene genera, while several of them are identical with species characteristic of the miocene beds of Maryland and Virginia.

In alluding to the more interesting general determinations connected with the tertiary strata of the United States, I ought not to pass over the

discovery made in the wonder field of microscopic life. The remarkable infusorial stratum originally detected by my brother on the Rappahannock, and at Richmond, Virginia, he has since traced from the Meherrin river near the southern boundary of that state, to the vicinity of Piscataway, a few miles south of Washington. The great thickness of the stratum, amounting at Petersburg to thirty feet, and consisting almost exclusively of the siliceous cases of minute infusoriæ, but especially the variety and beauty of the many new species brought to light through the skill of Prof. Bailey and Prof. Ehrenberg, invest this deposit with a high interest. Respecting its geological relations, I would here observe that it is not, as intimated by Mr. Lyell, of eocene epoch, but lies, according to the investigations of my brother and Mr. Tuomey, within and near the bottom of the miocene strata, being underlaid by unequivocal miocene, both at the Stratford cliffs on the Potomac and at Petersburg. The former suspects, indeed, that the infusorial deposit occupies more than one horizon in the miocene. The following short extract from a recent memoir by Ehrenberg, an interesting notice of which has just appeared in Silliman's Journal, exhibits the palæontological affinities of this stratum to the infusorial deposits of other regions and other geological times.

After ascribing the discovery of eleven of the species to Prof. Bailey, Ehrenberg proceeds to say, that up to this time he has observed fifty two forms, among which are about forty six infusoria belonging to twenty genera, which genera are all European with the exception of two, *Goniothecium* and *Rhizosolenia*, which have not been observed at any other locality. Of the species, ten, or almost *one fifth*, are new and peculiar. "Many of the forms occurring in the deposit are, as Prof. Bailey quite correctly concluded from his smaller number of observations, similar to those of Oran, but many of these forms also do *not* occur at Oran." Thus "of the eleven species of the genus *Coscinodiscus*, five occur at Oran which are also found at Richmond, five are found at Richmond alone, and one at Oran alone."

"As a considerable number of the species of animals belonging to the chalk formation of Sicily still exist and consequently cannot be wanting in the tertiary formations, it is evident that no conclusion as to the geological age of these formations, can be drawn from the similarity or dissimilarity of these forms." He goes on to say, that "This group of American forms is of peculiar interest and scientific importance, because the strata at Richmond are decidedly of marine origin and consequently give at once a general view of the marine microscopic

animals of the North American ocean; for probably the greater number of species are still living there, as they have already been found abundantly on the German coast of the North Sea. The geological position of the strata must be determined by the order of superposition, the larger included organic remains, &c., as it cannot be decided by means of the infusoria."

In the same memoir, Ehrenberg acknowledges in terms of just praise, the value of the careful researches of Prof. Bailey, gives lists of the fossil infusoria from two deposits discovered by Dr. Charles T. Jackson in Maine, and states that the knowledge of the microscopic organisms of Massachusetts has been much extended by Prof. Hitchcock through the discovery of several deposits there, during his geological survey. All of these deposits are referred, I believe, by their discoverers, to the most modern epoch.

POST PLEIOCENE PERIOD.

The later tertiary strata of this country, though existing in but circumscribed patches, possess much interest on account of the questions suggested by their organic remains, concerning the changes which this portion of the globe has undergone in the level of its surface, and in its temperature during the epochs next antecedent to the introduction of the human race. Of these post pleiocene, or pleistocene deposits as they have been called, several small areas have been described by Mr. Conrad. The principal ones are in St. Mary's County, Maryland, and on the Neuse River below Newbern in North Carolina. To the same period he also refers the numerous small beds of *Ostrea Virginiana*, which skirt the low margins of the islets and rivers in Delaware, Maryland, and Virginia, and by many people attributed to the agency of the aborigines. The deposit on the Potomac in St. Mary's County, is especially interesting for containing several southern species, one in particular, an estuary shell, the *Gnathodon cuneatus*, now restricted to the warmer waters of the Gulf of Mexico. Mr. Conrad infers that the association of the *Gnathodon*, *Mytilus hamatus*, and *Arca ponderosa*, with species now inhabiting our coast as far north as Massachusetts, indicates a climate at the period of the formation, equivalent to that of Florida; perhaps we should say, an aquatic climate. The cause of the change of temperature which banished these shells from the waters of our middle and southern Atlantic bays, connected as it is with some of the widest questions in our science, will, I doubt not, receive hereafter from American geologists and naturalists, the atten-

tion which it deserves. Was it the recession of the tepid waters of the Gulf Stream driven eastward by a partial elevation, possibly of the Florida peninsula, or was it connected with the incursion southward of a vast body of icy waters from the north, the same which in the opinion of some was concerned in the dispersion of the drift, or was it the result of some more inscrutable agency?

The post pleiocene deposit on the Neuse River, has been described by Mr. Conrad* as consisting of a shallow stratum, in which the shells with two exceptions, are such as now exist on our southern Atlantic coast and in the Gulf of Mexico, the *Gnathodon cuneatus* being one of the species. Mixed with these shells are the bones and teeth of extinct land animals, such as those of an *elephant*, a species of *horse*, and the *Mastodon giganteum.*

Another small tract of this modern tertiary has recently been described by Mr. J. Hamilton Couper,† as occupying a part of the seacoast of Georgia between the Altamaha and Turtle Rivers. Associated with shells belonging to species now inhabiting the neighboring coast, are the remains of the *Megatherium*, *Mastodon giganteum*, *elephant*, *hippopotamus*, *horse*, and *bison*, all of the four latter belonging it is believed to extinct species.

Mr. Lyell in an instructive paper on the *Mastodon giganteum* and other mammalian fossil remains found at several localities in the United States,‡ mentions the occurrence in Georgia of that curious Proboscidean described by Owen, the *Mylodon.* He also informs us that Mr. Darwin found the mastodon, horse, megatherium, megalonyx, and mylodon, in Patagonia and contiguous districts of South America, and occupying a more recent horizon than certain post pleiocene strata; and some of these extinct animals Mr. Darwin ascertained to be more modern than the drift of Patagonia. It may be remembered that several years ago, in a report to the British Association, he announced the fact, that the mastodon remains in this country lie invariably above the diluvian, a position equivalent, it would seem, to that which they occupy in South America, and I draw from this the inference, that they were not overwhelmed by any sudden catastrophe, but disappeared gradually, being probably overtaken by a progressive chilling of the climate. It is correctly urged by Mr. Lyell, that having lived after the deposition of the northern drift, their extinction cannot have proceeded from any coldness of temperature such as he conceives coin-

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* Bulletin of National Institute.

† Proceedings Geol. Soc. London, No. 92. ‡ Ibid.

cided in date with that formation, and this confirms, I think, my view of their gradual disappearance. But it has been clearly shown that contemporaneously with these very fossils, existed the *Gnathodon* and other shells of the Mexican Gulf, indicative of a warm climate in the so called post pleiocene period. Does this not suggest the conclusion, that the expulsion southward of the *Gnathodon* and its tropical associates, was unconnected with the northern drift and its assumed cold, and occurred in all probability contemporaneously with the extinction of the mastodon, at an era subsequent to that which witnessed the strewing of the northern erratics. Whether the other cause I have proposed, viz. the withdrawal from our immediate coast of the Gulf Stream, that great tepid river in the ocean, could produce a sufficient cooling of the climate of the adjacent continent and its coast, to effect at length the extinction of the higher animals and the disappearance of the more susceptible testacea, is a suggestion which those will best be able to weigh, who have studied the influences which that warm current, remote as it is, even now exerts in controlling the climate of the United States.*

POST PLEIOCENE OF THE NORTH.

Turning to the northern districts of the United States, we meet with another formation referable to the post pleiocene period, which is much more widely dispersed than that containing the Gnathodon, and which also sheds additional light on the epoch of the drift. This is the great blue clay deposit which fringes so many of the rivers and lakes from the coast of Maine to Michigan, and from the parallel of the mouth of the

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* Since this address was read, some very instructive facts connected with the subject of the climate of the post pleiocene period, have been presented to the Association by Dr. Amos Binney, as part of a valuable report on the land shells of North America. From this report, it appears that in Indiana and some of the adjacent western states, there exists a shallow deposit of clay, first noticed by Dr. Owen, which abounds in fossil land shells. Among them a southern species of Helecina, now rare in the middle latitudes, occurs in the greatest profusion, being as far as the evidence of a single species can reach, an indication of a somewhat warmer temperature. But the value of this discovery is much enhanced by the fact, that the same land mollusks underlie the remains of the mastodon and other large mammalia at Big Bone Lick in Kentucky. Later than the deposition of the drift which they overlie, and earlier than the epoch of the extinction of the mastodon, these fossilized land shells promise when more fully investigated, to furnish a record of an intermediate period, when according to the view of Dr. Binney, a series of shallow lakes existed in the West, and when, as we may conjecture, the temperature of the region was at least as high as during the immediately succeeding era of the mastodon.

Hudson to the lower St. Lawrence. It has been examined by Prof. Emmons and Dr. Jackson in Maine, by Capt. Bayfield, Mr. Lyell and Mr. Logan in the valley of the St. Lawrence, by Profs. Hitchcock and Mather and Emmons in the valley of the Hudson and Lake Champlain, by Mr. Vanuxem on the Mohawk, by Mr. Hall in western New York, and by Prof. Mather on the upper lakes; and the inferences arrived at by some of these gentlemen respecting the physical conditions under which the formation was produced, are not a little remarkable.

Among the most instructive exhibitions of the deposit are those of Lake Champlain and the St. Lawrence, where in certain places some very interesting fossils are met with. According to Prof. Emmons the mass on the borders of Lake Champlain, consists of a stiff blue clay overlaid by yellowish brown clay and this in turn by a yellowish brown sand, and Prof. Mather mentions that in many parts of the Hudson valley these are surmounted by gravel. More than twenty species of marine shells have been procured by Prof. Emmons from the blue clay on the St. Lawrence and Lake Champlain, the two most generally diffused being the *Saxicava rugosa* and *Tellina Grœnlandica.* The greater part if not all of these species, it is stated by our conchologists, now live either on the coast of Massachusetts, or in the Gulf of St. Lawrence, and they therefore imply a climate at the period of the clay deposit, as cold at least, as that which the same region now possesses. Although in the Hudson valley and throughout still wider limits, the blue clay is destitute of fossils, its identity with the stratum of Lake Champlain is not doubted by Profs. Mather and Emmons. The formation though generally thin, attains at certain points on Lake Champlain a thickness of one hundred feet, and Prof. Mather states the whole depth at the town of Hudson, to be one hundred and eighty four feet. It is worthy of remark that the upper surface of the deposit rises in some places in the Champlain valley, to an elevation of between two hundred and three hundred feet above the lake, or more than four hundred feet above the tide, and this agrees with its highest level in the valley of the Hudson.* At Montreal the same stratum has an elevation above the tide of between six hundred and seven hundred feet. These facts have been considered as indicating that a wide tract of the continent, as far south at least as latitude 42°, stood depressed during this recent tertiary epoch below its present level, to the extent of four hundred or five hundred feet, and

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* For the above and other facts, consult Reports on New York survey by Emmons and Mather.

Profs. Emmons, Mather and Hall, and Mr. Vanuxem, rest some interesting speculative views concerning the physical geography of the region in the period of the drift, upon this conclusion.

Here I may be permitted to suggest a caution. We are not I believe yet assured that the clay deposit in all districts belongs to one formation, or is the product of a single epoch, and especially we are destitute of proofs that the stratum which occurs on the great lakes, excepting that on lake Ontario, is of oceanic origin. The clay on the Detroit river is fossiliferous, but whether the shells are lacustrine or marine has not, I believe, been ascertained. Should they prove to be identical or nearly so with those of the St. Lawrence, then the whole amount of depression of the land required to let in the ocean to the present basins of the Upper Lakes, as supposed by Prof. Mather, must be conceded; but for the determination of this identity further observation is required.*

As it has been shown by Mr. Lyell and others, that several of the fossils found in this deposit at Port Kent on Lake Champlain and at Beauport on the St. Lawrence, are identical with species found by him at Uddevalla, and elsewhere in Sweden, and known to frequent the colder latitudes at the present day, he and other geologists conceive that they behold in these facts, proofs of an arctic climate, and this inference has been made to bear on the hypothesis of the origin of the drift. But since nearly all of these shells are stated to exist at present in the Gulf of St. Lawrence and on the coast of New England, they do not necessarily imply a decidedly colder temperature in the waters than may now prevail in certain parts of the great Labrador current.

In addition to the proofs afforded by this post pleiocene formation, of the former lower level of the land and of the nature of the climate, it leads to some important inferences connected with the epoch of the still more extensive drift formation of the same region. It has, I think, been satisfactorily established by Profs. Hitchcock, Mather and Emmons, that the blue fossiliferous clay is newer than that period of erosive action which witnessed the scratching and polishing of the rocky floor throughout the northern part of the continent, for not only does the deposit rest on that striated surface, but there often intervenes, according to Prof. Mather, a bed of gravel and bowlders, which he views as a part of the drift itself, though from this conclusion Prof. Emmons and Mr. Hall seem, if I

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* Since this address was written I have been informed by Prof. Mather that he has examined the fossils of the clay of the Detroit river and found them to appertain exclusively to *fresh-water species*.

understand them correctly, to dissent. At the same time it would appear that in the Hudson and Champlain valleys and elsewhere, the tertiary clay is covered with another stratum of drift "composed of coarse gravel pebbles and bowlders," lying on its trenched and denuded surface, and this latest drift, from the magnitude of its erratics, seems not less indicative than the first, of the extent and energy of the transporting agency, whatever that may have been.

Produced in the interval of comparative tranquillity between the two epochs of more vehement disturbance, what let us inquire, is the relative antiquity of this northern tertiary clay compared with the post pleiocene beds of the south, containing the *Gnathodon cuneatus*. These, as we have seen, were contemporaneous with the *Mastodon giganteum* and other large mammalia, and there can be little doubt that the mastodon was posterior to the latest drift of the country, since no erratic deposit covers its remains any where in the region of the drift. The northern post pleiocene, is therefore older in all probability than the southern, by at least the intervening period which produced the later drift.

Reviewing now all the facts respecting the newer tertiary ages, we are led to the following conclusions. That the whole period of the drift was a prolonged one; that the active dispersion of the far transported matter was interrupted by an interval of comparative repose, when a part of the northern country was lower than it now is by at least five hundred feet, and low enough to admit the sea into its valleys; that in this interval the northern waters of this region were quite as cold as they are at present in the same latitude; that after the close of the drift period there was a condition of temperature compatible with the general distribution of the mastodon on the land and with the existence in the waters, as far northward as Maryland at least, of certain shells of the Gulf of Mexico, and that subsequently to this there was an expulsion southward of these southern shells, a slight uplift of the Atlantic coast and an extinction of the gigantic mammalia. Whether these deductions afford any countenance to the hypothesis of some eminent geologists, that the age of the drift was a period of great cold throughout the northern temperate zone, or whether we may not account for all the vicissitudes here recorded, by the simple theory of local modifications of climate by changes in the oceanic currents, I will not here further discuss. Prof. Mather in his report on the geology of New York, has with much ingenuity treated of the possible conditions of the great oceanic currents at the formation of some of our earlier strata and during the epoch of the drift, and although I cannot assent to certain portions of his reason-

ing respecting the origin of the supposed ancient currents, nor acquiesce in his views of an almost general submergence of the land at the deposition of the drift, yet there is a value in his speculations respecting especially the Gulf Stream, and a general consistency in the whole hypothesis, which claim for his treatise a careful consideration.

GEOLOGICAL DYNAMICS.

Drift—Earthquake Theory—Elevation of Mountain Chains.—The attention of this society has been zealously directed during the last three years, to questions of *geological dynamics*. The phenomena and origin of our anticlinal axis, the nature of the forces concerned in the elevation of mountain chains, and the cause, character and consequences of earthquake motion, have been investigated by my brother, Prof. W. B. Rogers and myself, but the subject which has enlisted the greatest number of pens and called forth the most general discussion, has been among the American geologists as among the European, the interesting and complicated problem of the origin of the superficial bowlder stratum, the great sheet of diluvium or drift. With the phenomena as they exist in New England, a region where they are particularly striking, we have been made familiar through the extended researches of Prof. Hitchcock, Dr. C. T. Jackson and other geologists. At an early day, 1826, a clear account was given through the pages of the American Journal of Science, by Mr. Peter Dobson of Connecticut, of the worn and striated aspect of bowlders in that state, and very soon after this Mr. Nathan Appleton of Boston, to whom this society is under large obligations, first called attention to the universality of the smoothed and grooved surfaces of the rocks wherever they had been protected from atmospheric action. It is due to Prof. Hitchcock to state that early in the history of the geological survey of Massachusetts, being guided by his own observations, he investigated with much minuteness and care the phenomena of smoothed and striated rocks and transported bowlders. Profs. Mather, Emmons, Hall and Dewey, and Mr. Vanuxem, have described the features connected with the drift of New York, and the former geologist embracing a wide survey has examined the phenomena from New England to the Upper Lakes and to the sources of the Mississippi. In the western states the drift deposit has been described also by Drake, Hildreth, Houghton, Lapham, Locke, Owen, Tappan and others.

Bearing upon the same general subject some interesting communications have been submitted to this Association, descriptive of icebergs and

their probable influence in dispersing bowlder matter, by Mr. Couthouy and Mr. John L. Hayes. In addition to the valuable facts and views thus imparted, the animated discussions at some of our meetings have elicited from many of the gentlemen mentioned, and from others, much important information.

To embark upon a full view of all that has been done of late in field investigation and discussion connected with this multifarious subject, would lead me quite beyond my limits, and I shall therefore content myself with as brief a statement as possible of the chief generalizations and theoretical conclusions to which the geologists of this country have arrived. And here let me advert to the truly favorable field which North America, with its wide expanse and its peculiar surface, affords us, for testing some of the leading theories of drift now advocated in Europe and this country.

The most important facts connected with the great detrital stratum, are of four classes; those which relate to the grooves or scratches on the rocky surface beneath the drift; those which refer to the distribution of the bowlder material; those which indicate the condition of level of the land at the period of the formation; and those which imply the epoch and duration of the action. The principal phenomena in relation to the surface on which the drift rests are these.

1st, The smoothed and furrowed surface is coextensive or nearly so with the drift stratum, and it occurs at all altitudes, from the summits of the loftiest mountains of New England and New York, to the beds of the valleys, and over the whole broad plain of the lakes and the western states. In the mountainous and hilly tracts, the northern and northwestern brow and flank of each eminence, are much more smoothed and striated than the opposite. The scratches do not radiate from the high mountain summits, but in the vast plains and prairies of the west, among the confused hills of New England, or on the transverse mountain crests of northern Pennsylvania, and western Vermont and Massachusetts, they maintain invariably in all the higher levels a general southeasterly direction. In lower situations, however, on the slopes of the great drainage valleys, their course is diverted to conform more nearly and sometimes with exact parallelism to the direction of the natural barriers and channels. They exhibit a remarkable *general* parallelism among themselves, yet do we seldom meet with a striated surface of any extent which does not disclose more than one set of furrows; the more recent and distinct crossing the fainter one at various small angles. Nor are the scratches truly *straight* over any considerable length, except where

the surface containing them is remarkably homogeneous, even and horizontal. On the other hand wherever it consists of harder and softer parts, and where the rock contains imbedded pebbles, or where it has an irregular outline, we may invariably detect a bending, and as it were a free conforming to every inequality on the part of the largest furrows and the minutest striæ. Lastly, where there is much disparity in the hardness of the different parts of the eroded surface, there will be observed a little ridge of the softer portion lying to the southeast or on the lee side of each harder knot or pebble, round which the striæ sweep and meet upon the ridge or tail, precisely as water parts at the prow of a ship and coalesces beyond the stern.

2d. Respecting the drift itself, the following appear to be the principal phenomena:

Throughout all the northern tracts of the United States and the adjoining districts of the British provinces, the surface is covered with a loose stratum composed of sand, clay, gravel and bowlders of all sizes, variously mingled and *locally stratified.*

The stratification is characterized by plains of inclined and confused deposition, denoting turbulent currents.

The materials invariably belong to formations lying north or northwest of their present positions, and great spaces occupied by broad plains, wide belts of hills and even mountains, deep valleys, and vast sheets of water, intervene. The bowlders have evidently not radiated from any local centres of dispersion.

The southern margin of the continuous drift stratum reaches in the east to Long Island and northern Pennsylvania, and in the west to the Ohio river; but its gravel extends along the immediate valleys of the Delaware, Susquehanna and Mississippi, to points much further south.

The direction of the transport of the drift is in each district coincident with that of the scratches.

The size of the rolled fragments progressively declines as we recede from the parent rock southward or southeastward, and though solitary blocks of large dimensions lie in and upon the general stratum, where the imbedding matter has only the coarseness of gravel or sand, yet even there these bowlders obey the general law of a rapid diminution of size towards the south.

In wide and level districts, the bowlders are often strewed uniformly over great spaces of country. In other places, more especially at the base of plateaus or terraces, and opposite to gorges and prominent crests in the hills and mountains, they frequently form long narrow belts, the margins of which sometimes maintain a remarkable parallelism.

The course of the drift and bowlders, like that of the scratches, is obliquely across the crests of most of our mountain ridges; but lower on their slopes, and in the beds of the deeper longitudinal valleys, it conforms partially or entirely to the directions of what would be the great natural channels of drainage, if the whole surface were temporarily or permanently under water.

It should be observed that the bowlders of all sizes are themselves smoothed and striated, and in many cases in such manner as to indicate that this effect has been produced by the fragments rushing past each other.

Lastly, blocks of considerable size have been transported from lower to higher elevations, being seen in New England, New York and northern Pennsylvania, on mountain ridges a thousand or fifteen hundred feet above the level of their parent rocks; and this fact, as Prof. Hitchcock has justly remarked, is one of great importance in the history of our drift.

3d. The third class of facts connected with the drift, relate to the proofs of a lower level in the land at the epoch of its production. In describing the post pleiocene blue clay of Lake Champlain and other northern valleys, I have already cited the proofs that at one period at least in the general era of the drift, the surface of the country in the region of New York and the St. Lawrence was lower in level than it now is by as much as perhaps five hundred feet. It is obvious too that the whole of New England was at the same time somewhat depressed, though there is no satisfactory indication that it was throughout as much submerged as the region of Lake Champlain. It is moreover highly probable that the country of the upper lakes was lower and more overflowed than at present, though it has not yet been established that the depression was sufficient to let in the sea. That the waters of the ocean flowed freely at this particular middle period of the drift through the long and narrow valleys of the St. Lawrence, Lake Champlain, the Hudson and the Mohawk, and ascended those of the principal rivers of New England, and even gained admission to the basin of Lake Ontario, there cannot be a doubt; but that our whole northern region was, as Prof. Mather and Mr. Hall suppose, lower than it now is by fifteen hundred or two thousand feet, and the greater part of New England and New York and the vast area of the western states all at that era beneath the sea, appears to me I confess entirely unsustained by that kind of demonstration which so important an inference demands. Indeed the absence of any marine deposit identifiable with the Lake

Champlain clays, from levels higher than the beds of the valleys enumerated, seems a conclusive proof that the only part of the land submersed was in those narrow channels. Thus New England and the mountain region of the Adirondack, were islands separated from the main continent by merely shallow and confined straits.

This conclusion has reference, however, only to the condition of the land during the tranquil interval between the epochs of vehement action denoted by the earlier and later drift deposits; and the main question still remains unanswered, as to what was the degree of submergence of the continent at those periods of commotion. Was "the whole surface" at present overspread with the detrital matter then "permanently covered by water," as some of our geologists suppose, and the depression therefore greater even than in the quiet epoch which intervened; or do we in reality possess one satisfactory monument to record that any part of the surface, at either bowlder period, was below the general level of the ocean. If the presence of marine fossils in the post pleiocene clays is accepted as a convincing argument that the tracts to which they belong were at the time of their deposition beneath the waters of the sea, certainly the universal *absence* in all other districts of any analogous remains, is no less conclusive that the submerged condition which would have infallibly produced them did not exist. To this reasoning it cannot be objected that the sediments of the supposed waters may have been removed by the same currents which brought in the drift; for the waters of the later and perhaps most disturbed of the two drift periods, were manifestly unable to obliterate the limited post pleiocene clays which they overspread and could only partially denude.

4th. Respecting the *age* of the drift deposits of this continent, I have already presented the chief facts hitherto discovered which seem connected with the inquiry. That the whole belongs to a later age than that of the miocene tertiary, is evident from the superposition to beds of that date in Martha's Vineyard; and there can be little hazard in assigning it to an epoch in that relatively recent though vaguely defined period of the tertiary, denominated by Lyell and other geologists the post pleiocene. Commencing before the era of the Champlain fossiliferous clays, the same energetic and wide dispersion of detrital matter was repeated after its close, and yet the whole was apparently terminated before the epoch of the mastodon and megatherium. Of the *time* occupied in the formation of the drift, we have not data even for conjecture. It must have been immense indeed, if icebergs were the prin-

cipal agents of dispersion; nor could it have been brief, even if produced by a succession of paroxysmal disturbances. Yet the whole period constitutes, as it were, but a *single beat* of that slow-swinging pendulum which has counted the innumerable successive stages in the geological history of our globe.

The principal hypotheses proposed for explaining the detrital phenomena, are—

First, the theory which attributes the scratches on the rocky floor of the drift, and the dispersion of the far-carried fragmentary materials, to the agency of ice, creeping forward with a slow velocity but an enormous momentum, like the glaciers of the Alps, grinding down and finely grooving the jagged asperities of the surface, and bearing on its back the collected rubbish in the mountain slopes, and strewing this still further by a rapid thaw:

Secondly, the theory which imputes the whole to icebergs, loaded with detrital matter, and floating southward until stranded on the surface of the submerged land, which the ice-fields are conceived to have smoothed and scored through the agency of innumerable fragments frozen into their lower surfaces:

Thirdly, the theory which supposes no general permanent submersion of the land, but imagines one or more paroxysmal movements of the earth's crust in the higher northern latitudes to have sent a portion of the contents of the Arctic seas—water, ice, and fragmentary rock—in a succession of tremendous deluges southward across the continent.

Other explanations, consisting in the main either of an union or of modifications of the chief features of these hypotheses, have also been suggested and find advocates. Which of these doctrines is to be deemed most in accordance with the phenomena of the drift on this continent, is a point which still causes considerable diversity of opinion, and discussion is still busy in relation to each branch of the problem, that is to say, the origin of the smoothed surfaces and striæ, the cause of the wide dispersion of the erratics, the source of the currents, and the condition of level of the land. Upon the question of the origin of the polished and grooved surface of the whole rocky base on which the drift reposes, many of our geologists conceive that ice was essential to the production of this phenomenon; but some, sharing the caution of Prof. Hitchcock, refrain from "attempting to decide whether it has been ice in one vast sheet acting by mere expansion," or the same in the form of stranded icebergs. Others, among whom is Prof. Mather, think that "there can be no doubt that the scratches on the rocks are

due to the movements of floating ice, containing masses of rock frozen in, and grinding upon the bottom." Prof. Emmons, on the contrary, conceives that "the phenomena in the main are independent of the action of icebergs," which he believes "to be very poorly adapted to polish, groove and score rocks," and he urges that their motion when they are grounded is rotatory, and therefore not such as to produce striæ deviating so little from a prevailing direction as those which we behold. He thinks the grooved surfaces have been overflowed by wide shallow rivers, which have smoothed and scored the rocks by pushing along gravel, sand and ice; and confining his view to New York, he supposes that these rivers communicated with the Atlantic on the south through the Champlain, Hudson and Mohawk valleys, and that they bore along ice loaded with sand and pebbles, which scratched and grooved the surfaces of the rocks. He thinks that the erosion occurred before the true bowlder epoch.

Mr. Hall suggests several objections to its production by angular fragments set in the bottom of icebergs or icefloes. He mentions the divergence of many furrows from their regular course as indicative of a freedom of motion in the grooving body, and he calls attention to the minuteness of the striæ as implying that they were probably caused by sand and gravel moved by some superincumbent even surface, "not unlike the polishing of marble when the motion is all in one direction." Both Mr. Hall and Prof. Emmons suggest moreover, that the bottom of the ocean would be necessarily covered with detrital matter, which would protect the rocky floor from the direct graving action of icebergs.

My brother and myself entertaining very similar objections to the explanation of the phenomena by icebergs, have ventured farther, and perceiving no necessity for supposing that the cutting fragments and particles were ever pressed upon by ice, have appealed to the enormous erosive power which a thick and ponderous sheet of angular fragmentary rock would possess, if driven forward at a high velocity under the waters of a deep and general inundation, excited and kept in motion by an energetic upheaval and undulation of the earth's crust during an era of earthquake commotion.

Respecting the agencies concerned in the strewing of the detrital matter, a considerable diversity of theoretical opinion prevails among those geologists who have recently written upon our drift. Nevertheless, the doctrine which ascribes the transportation of the bowlder matter to icebergs driven by currents over a permanently submerged surface, finds evidently the greatest number of advocates. Some geol-

ogists however, believing this hypothesis insufficient to explain the phenomena, appeal to the theory which supposes a series of inundations of the land engendered by a violent paroxysmal movement of all the northern latitudes. Permit me to examine briefly some of the principal features in these doctrines, and the leading arguments connected with them.

An extensive submergence of all the northern tracts of the continent is of course implied in the supposition, that the detrital matter has been floated to where it now rests by icebergs. Thus Prof. Hitchcock, who thinks that the greater part of the phenomena must be explained by icebergs, conceives that nearly the entire surface of the land must have been beneath the level of the sea, and against the opinion that diluvial currents could have rushed across the continent while it stood at nearly its present elevation, he objects that the assigned causes for such, are insufficient to send an ocean to the summit of our mountains, five or six thousand feet above its proper horizon.

Mr. Hall in like manner, urges that no explanation of the mode of transport of the bowlders reconcilable with their present situation, can be offered, which does not assume that the whole surface was permanently covered with water,* and he thinks that a depression below the present level of as much as two thousand feet, is required for the transport and deposition of the bowlders forming the later drift of southern New York. He is led to the conclusion, that they were "not moved by any powerful flood." He supposes that the "mountain chains of New England and New York formed long ranges of islands rising from the ocean to two or three thousand feet above its level, their sides covered with perpetual snow and glaciers, and their bays terminated by cliffs of ice from which detached masses floated off, bearing with them bowlders and fragments of rocks," and he thinks, "that it can be demonstrated that this dispersion of the bowlders and fragments continued for a long period, while the land was rising from the ocean." "After the land had risen to within eight hundred or one thousand feet of its present elevation, the great valley of Lake Ontario would form a broad bay communicating with the ocean through the valleys of the Mohawk and Susquehanna, the communication by the valley of the Mississippi becoming closed." At this stage of partial conversion to dry land, both Prof. Mather and Mr. Hall conceive, if I do not mistake their views, that the tertiary clays of Lake Champlain and the adjoining valleys

* See page 336 of Mr. Hall's Rep. Geol. New York.

were deposited. Mr. Hall, adverting to the position of the post pleiocene clays of Lake Champlain in relation to the drift, believes that "the facts clearly establish distinct and widely distant periods between the formation of the great body of the drift in western New York and the erratic blocks or bowlders," and he conceives "that the scouring and polishing of the rocks has taken place at a period long anterior to the transportation of these northern bowlders, and that their passage over the surface has had little or no connection with this phenomenon."

Very similar views as to the physical condition of the region now covered with drift, appear to be entertained by Prof. Mather. Describing the phenomena throughout an extensive area, and assuming about the same amount of submergence, this geologist has entered into an elaborate and ingenious enquiry respecting the character and direction of the great systematic currents which should prevail under the supposed distribution of land and ocean. Conceiving that the configuration of the continent at the drift period was in the main the same as at present, he shows that the great polar or Labrador current and the Gulf Stream being the results of this configuration and the laws of aqueous motion, connected with the rotation of the earth, and its belts of different temperatures, these currents must have existed then equally as at the present day. The Labrador or polar current possessing necessarily a *westward* travel, he supposes to have flowed over the northern parts of the United States, bringing ice loaded with detritus. The Gulf Stream, deriving from the rotation of the earth an *eastward* tendency, he supposes to have been parted by the mountain chain then having the form of a great peninsula or island, and one portion to have flowed up the wide plain or valley of the Mississippi, melting by its warmth the ice of the Labrador stream, and causing its freights of rocky matter to be deposited over the country north of the Ohio and Missouri rivers. The tendency of the southern current to set eastward would, Prof. Mather thinks, convert the westward direction of the ice-bearing current into a southeasterly one, and he thus explains the southeasterly course which the detritus has evidently taken.

Prof. Emmons, in his view of the condition which attended the dispersion of the drift, conceives that the first detrital stratum and the erosion of the rocky floor, were produced by currents of the nature of broad shallow rivers, and that subsequently the land subsided and continued beneath the ocean long enough for the deposition of the Cham-

plain tertiary, upon which the icebergs at the same time brought bowlders from the north to form the upper or later drift.*

The hypothesis of a general depression of the surface at the detrital epoch is objected to by Mr. Vanuxem, who has himself been a careful explorer of the phenomenon of the drift in New York, on the ground that "the absence of all marine productions whatever, excepting those which form a part of the materials of the alluvium, (meaning the post pleiocene clays,) is in opposition to any but a very transient submersion." This argument, as I have already intimated, appears to me conclusive. The whole method of geological reasoning requires, that we should find a marine deposit before we can assume the presence of the ocean, while analogies derived from every other geological period show that in the supposed condition of general submergence, the great, steady currents which floated those fleets of icebergs must also have wafted in *some* sedimentary matter and left *continuous strata*, however thin, of clay, fine sand, or marl, if not every where, at least in the more tranquil tracts of that extensive sea. Yet not even outside of the drift, along its southern border, do we find a trace of any such deposit. This total deficiency of all proofs of a permanent overflowing of the land, must, I think, be viewed as fatal to the iceberg theory. During the progress of the limited post pleiocene marine deposit, it is quite conceivable that ice from the neighboring lands did play some part, dropping bowlders from time to time on the bed of those inlets of the sea which occupied the present valleys of the St. Lawrence and Lake Champlain; but these very bowlders I would trace to the adjacent earlier drift. Such icefloes belong in reality less to the epoch of either drift, than to an intermediate one in which the physical circumtances were more nearly those of the present time.

But if we admit, for the sake of concession, that the wide-furrowed floor of the drift was permanently beneath the water, the explanations given will be found to be still at variance with several incontrovertible considerations. The idea that the icebergs may have come from the coasts of mountain islands, such as, on one hypothesis, the Adirondack region and the White mountains were, is contradicted by the important fact, made known by Prof. Hitchcock and Prof. Emmons, that those

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* Since this address was read, Prof. Emmons has sent to the Association a brief paper, containing, I believe, some essential modifications in his views respecting the origin of the earlier drift. He now attributes it, if I understand him correctly, to a general and rapid movement of waters from the north, the explanation advocated for the last three years by my brother and myself.

high tracts have not been centres of dispersion, but like every other spot, have been invaded by the drift from the north. But there is also another opposing consideration. The extent of the drift throughout the northern regions of this continent is immense ; yet by this theory nearly the whole of it and of northern Europe was depressed below the sea at that period, and I confess I look over that vast imagined ocean of the north in vain for the conditions of physical geography, compatible with the arctic winter supposed. The conceived state of things, an enormous expanse of waters, with here and there an island, in place of a broad continent in the higher latitudes, is the very converse of that distribution which is compatible with great cold and with islands and fields of ice.

In reference to the generalizations of Prof. Mather regarding the direction and agency of oceanic currents at the period of this assumed depression, I cannot refrain from expressing my belief that the hypothesis of an ancient Gulf Stream, not flowing however up the valley of the Mississippi, but, during certain periods at least, along the line of our great Atlantic tertiary belt, is sufficiently in accordance with the probable ancient configuration of the land and with geological memorials, to promise important aid in certain speculative questions in our geology. I encounter, however, some difficulty in understanding how the two great currents, the polar and the southern one, would produce a resultant movement which would strew the drift in the direction which it obviously took. The general course of the furrows in the rocky surface, and of the trains of detrital matter, is from about north northwest to south southeast, and I cannot conceive how a current setting to the southwest could be turned by one setting in the opposite direction into a southeasterly course, or how a single direction could, by such a conflict, be imparted to such a vast area of waters, as wide in latitude and longitude as the region now occupied by the drift ; or how, if it could be thus deflected, it should be able to retain the high velocity which it must have held in order to distribute the bowlders in their long narrow trains, to round the angles of the hills, and score and gutter the very hardest rocks.

Let us now give our attention for a moment to the paroxysmal theory, which I cannot but think will be found, on careful examination, to be more in agreement with the admitted laws of physical dynamics than either of the more popular hypotheses of the day. This doctrine, appealing to the proofs which our science furnishes of the sudden disturbances of the level of the different tracts of the earth's surface, at all

periods of geological time, merely supposes that at the epoch of the drift, the polar half of the northern hemisphere was the theatre of violent and perhaps frequently repeated movements of the earth's crust, each particular disturbance emanating probably from a different local region. These disturbances, which are conceived by Van Buch, De Beaumont, Hopkins, De la Beche, Sedgwick, Phillips, and other distinguished geologists, to have been of the nature of simple *paroxysmal elevations*, and by my brother and myself to have consisted in an energetic and extensive *undulation* of the crust of the earth accompanying each sudden rise, are deemed sufficient to have caused a rush of the northern waters over all the higher latitudes of Europe and North America, covering the surface with an almost continuous sheet of gravel and bowlders, and polishing and scoring the whole rocky floor.

The chief cause of hesitation with many minds in embracing a theory so much in harmony with the general physical history of our globe, has arisen from their not recognizing a force sufficient to dislodge and sweep onward blocks of the huge size which we sometimes encounter, or to drive the detrital matter up and over the high mountain barriers, across which, by some process, it had travelled. So long as no definite estimate has been made of the velocity of the current which would result from a given amount of paroxysmal elevation, such a distrust of the energy of diluvial waters was natural and prudent; but we are in possession of facts and generalizations calculated greatly to exalt our conceptions of this power.

It has been shown by Mr. Hopkins, of Cambridge, reasoning from the experimental deductions of Mr. Scott Russell upon the properties of waves, that "there is no difficulty in accounting for a current twenty five or thirty miles an hour, if we allow of *paroxysmal elevation* of from one hundred to two hundred feet;" and he further proves that a current of twenty miles an hour ought to move a block of three hundred and twenty tons, and since the force of the current increases in the ratio of the square of the velocity, a very moderate addition to this speed is compatible with the transportation of the very largest erratics any where to be met with, either in America or Europe.

Holding in view these demonstrable conclusions, let us consider the far *more* enormous velocity which a broad general current would derive from that mode of paroxysmal action, *earthquake undulation*, which constitutes, as my brother and myself have endeavored to show, an essential feature in all movements of elevation. Regarding such disturbances as a true billowy pulsation of the flexible crust of the globe, we

have deduced from data connected with some of the best authenticated earthquakes, the extraordinary progressive velocity of the undulations of the ground, and have shown that when the pulsation has been imparted to the sea, the vast waves engendered have moved at the amazing speed of one mile or more per minute. Making every abatement for resistance from the comparative shallowness of a continental inundation, the phenomena of earthquakes fully justify us in the belief that the broad and rapid onward undulations of the ground would be propagated to an uplifted sea above, and the gigantic billows be propelled across the surface of the heaving land, with a velocity and a propulsive energy approached by no other possible terrestrial current.

If we will conceive, then, a wide expanse of waters, less perhaps than one thousand feet in depth, dislodged from some high northern or circumpolar basin, by a general lifting of that region of perhaps a few hundred feet, and an equal subsidence of the country south, and imagine this whole mass converted by earthquake pulsations of the breadth which such undulations have, into a series of stupendous and rapid-moving waves of translation, helped on by the still more rapid flexures of the floor over which they move, and then advert to the shattering and loosening power of the tremendous jar of the earthquake, we shall have an agent adequate in every way to produce the results we see, to float the northern ice from its moorings, to rip off, assisted with its aid, the outcrops of the hardest strata, to grind up and strew wide their fragments, to scour down the whole rocky floor, and, gathering energy with resistance, to sweep up the slopes and over the highest mountains.

Perhaps I may be permitted, before quitting the class of topics connected with geological dynamics, to allude to the researches upon which this theory of earthquake action has been founded, and to refer to the phenomenon which it is conceived to explain.

At the last meeting of the Association, we deduced, from an analysis of a large mass of data connected with the recent earthquakes of the Mississippi valley and of the West Indies, and from the history of other earthquakes, a striking confirmation of some of the laws of earthquake motion long ago suggested by Mitchell. From the facts set forth, I think it can no longer be doubted that a characteristic feature of earthquake motion is a rapid progressive undulation of the ground, of the nature of a series of actual billows or waves, which are sometimes of the vast amplitude of several miles, and chase each other with an enormous velocity, equal in many instances to twenty or thirty miles per minute. This movement we are disposed to impute to an actual pulsa-

tion in the fluid lava mass, upon which the thin crust of the earth is supposed to rest, excited by a sudden rupturing and instantaneous collapsing of the crust, rent by the tension of highly elastic steam and other vapors.

In a previous year we drew the attention of the Association to the remarkable structural features of the Appalachian chain, and showed that these laws of earthquake action furnish perhaps the only solution of the origin of those grand flexures and folds into which the Appalachian strata have been bent, so extraordinary for their regularity, great length, parallelism, wave-like form, and progressive subsidence westward; and in illustration of the power of earthquakes thus to produce permanent anticlinals, we instanced among other cases the elevation in 1819 of Ullah Bund, a low, broad mound, fifty miles in length, lifted from the flat plain of the delta of the Indus by the great earthquake of Cutch.

Having now passed in review some of the more important general conclusions in relation to our geology to which recent researches have led, we may turn for a moment before closing to contemplate the magnitude and enticing interest of the field for future discovery, which these explorations have made accessible.

When we reflect on the enormous expansion of some of our great systems of strata, nothing short of the entire ancient seas in which they were deposited, and regarding their excessive thickness, permit our thoughts to dilate until they can take in the true areas which they occupy in space, and the ages of time which they reveal, and then consider to how great an extent each layer collected in those ancient seas is now exposed to view, on the flanks of our huge mountain chains and in the banks and cliffs of our mighty rivers and their unnumbered tributaries, and above all when we advert to the true *nature* of each stratum, the treasures which it contains, the secrets which lie locked within it,—we become aware of the inexhaustible variety and the grandeur of the problems connected with the geology of this continent.

Let us not think that with the completion of the explorations now so actively in progress, with the mapping in of the outcrops of the strata, and the description of their organic remains, the field for investigation will have become exhausted. It will in fact only have become opened up for more minute and critical research. The utmost perhaps that we of this generation can hope to do, is by uncovering the main parts of the buried temple to disclose its vast dimensions and some portion of its elaborate external beauty; but to penetrate its shrines and read

upon its inner walls the whole narrative of its origin and construction, is the glorious privilege which awaits a future age.

Geology grows more interesting as we penetrate into the deeper secrets of the past, as we leave the obvious and commonplace phenomena and reach the recondite and remote, in the midst of which, as in the moral and intellectual recesses of the human constitution, would seem to lie the only true and actual indexes of the great forces which sway events. It is this very power to reconstruct the past which confers on geology its most distinctive feature, and has placed it in so eminent a rank among the sciences.

I question if many minds, even among those devoted to geological research, are impressed with the wonderful extent to which this science is likely in future ages to carry the restoration of antiquity, reproducing in vivid distinctness the ancient geography, climate, and inhabitants of the globe, tracing the many successive oceans, bays, and shores, and repeopling for each epoch all the waters and the land; I question if we are at all aware how *completely* the whole history of all departed time lies indelibly recorded with the amplest minuteness of detail in the successive sediments of the globe, how effectually in other words every period of time *has written its own history*, carefully preserving every created form and every trace of action.

Each broad stratum, to the very *thinnest*, be it remembered, was once the sustaining surface of its region, supported therefore all that the earth then possessed of its teeming generations, and received in some form, either perfect or mutilated, every living or organized thing. While the waters above it were the cradle and the theatre of a multitude of races, *it* was the universal tomb, receiving them all into its soft bosom in *every stage* of their life, and thus recording the minutest particulars of their individual biography. Let us reflect too that in these successively superimposed surfaces we have sequences of continuous time of all amounts, from intervals the minutest to ages the most protracted, so that we behold the birth, the spread and the extinction of long enduring races, no less than of individual beings, and illustrated by the movements of every contemporaneous physical condition and event. The *life of races* is thus disclosed, and how magnificent and vast are its higher and profounder laws compared with those which mark the development of single and fast fleeting individuals.

The creative spirit that broods over nature and has clothed matter in the garb of time, not only confers on each special being its special features and functions, but links it in long and mysterious relationship to

others, past and to come, thus elaborating in the longest periods the highest generalizations. To discover and read the laws which have controlled the successive aspects of life upon this planet, is to recognize perhaps the very loftiest class of physical truths which human research can ever hope to unfold.

But, gentlemen, I must desist, having already exceeded my just limits. I pause because my pages are full, and not because my topics are exhausted. So extensive is the harvest which the geologists of the United States have of late been reaping, that I have not found it practicable to count over all the gathered store, or mention more than a portion of the products of some of the richest fields. This creditable accession to the scientific wealth of the country, the fruit in part of liberal legislation, owes much of its value to the intrepid zeal and the excellent spirit of mutual fellowship and coöperation enlisted in producing it. Whatever may be the scientific worth of the discoveries made in this and other paths of knowledge, or however cheering the prospect of the yet ampler developments that will surely attend future enquiry, let us not forget that to win for our labors the approval of the wise and good, they must bear the seal not only of physical but of moral truth; must show, as I trust they do, that in studying great Nature's laws, while our perceptions of the beautiful have been quickened, and our reason disciplined, the yet diviner faculties of our being have been exercised in the cultivation of a generous charity and a mutual kindness.